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Optical characteristics, growth and yield quality of cotton under different growing environments

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सार – वर्ष 2015-16 के दौरान खरीफ के दौरान हिसार में कृषि मौसम विज्ञान विभाग, सी सी एस हरियाणा कृषि विश्वविद्यालय के अनुसंधान क्षेत्र में फसल की बढ़वार कपास के बीज और गुणवत्ता प्राचल, तेल और प्रोटीन तत्व के लिए प्रकाशीय विशेषताओं को बढ़ाने के लिए खेत में प्रयोग किए गए। मुख्य तीन प्लॉटों और तीन उपजों वाले सब प्लोट (पंचम 541, SP 7121 और RCH 791) के उपचारों में बुआई की तारीख मई के दूसरे हफ्ते (D1), मई के तीसरे हफ्ते (D2) और जून के पहले हफ्ते (D3) की रखी गई। कपास की फसल स्प्लिट प्लॉट डिज़ाइन में बोई गई और तीन बार उसकी पुनरावृत्ति की गई। पहले बोई गई फसलों के बाद में बोई गई फसलों की अपेक्षा PAR अवशोषण अधिक था जबकि प्रकाश संश्लेषण में सक्रिय विकिरण (PAR) RCH 791 में सबसे कम था। पहले बोई गई फसल और RCH पकने में अधिक दिन लेती है। पहले बोई गई फसलें और RCH 791 सबसे अधिक LAI पौधे की उँचाई और परिपक्वता की सभी अवस्थाओं में शुष्कता उत्पन्न करती हैं। बुआई में देरी से शाखाओं की संख्या में काफी कमी हो जाती है। कपास की फसल की बुआई में देरी से कपास के बीज उपज, कपास लिंट, तेल का प्रतिशत प्रोटीन तत्व और बॉलस, प्रति पौधा में भी कमी आती है। मौसम प्राचल वर्धनशीलता के दौरान फसल प्राचलों से अच्छे कोरिलेट करते है। थर्मल इंडेक्स की तुलना में अवरुद्ध प्रकाश संश्लेषित सक्रिय विकिरण (IPAR) तेल तत्वों के साथ बेहतर ढंग से जुड़े है।

ABSTRACT. The field experiment was conducted to quantify the optical characteristics for growth development, seed cotton yield and quality parameters, oil and protein contents at the research area of the Department of Agricultural Meteorology, CCS Haryana Agricultural University, Hisar, during the *kharif* season of 2015-16. The main plots treatments consisted of three date of sowing 2nd week of May (D1), 3rd week of May (D2) and 1st week of June (D3) and sub-plots consisted of three cultivars (Pancham 541, SP 7121 and RCH 791). The cotton crop sown in split-plot design with three replications. The PAR absorption was higher in early sown crops as compared to late sown crops whereas transmitted Photosynthetically active radiation (PAR) was lowest in RCH 791. Early sown crop and RCH 791 took more days for physiological maturity. The early crop sown and RCH 791 produced significantly highest LAI, plant height and dry matter at all phenophases. The delay in sowing significantly reduced the number of sympodial branches. The delay in sowing of cotton crop also reduced the seed cotton yield, cotton seed yield, cotton lint, oil percentage, protein content and bolls per plant. Weather parameters were better correlated with crop parameters during vegetative phase. Intercepted photosynthetically active radiation (IPAR) was better associated with oil content as compared to thermal indices.

Key words – Cotton, Growth and yield parameters, Oil and protein content, Photo synthetically active radiation.

1. Introduction

Cotton is an important fibre crop supplying about 65% requirement of the Indian textile industry. The primary product of the cotton plant is the lint that covers the seed within the ball and provides a source of high quality fibre.

The cotton seeds are an important source of oil for human consumption and a high protein meal used as a livestock feed. The cotton waste after ginning is used for fertilizer and the cellulose from the stalk may be used for products such as paper and cardboard. In India, area under cotton crop was 11.8 million hectares with production of 26.8 m bales in 2015-2016 with an average yield 0.494 ton/hectare [As per AICRP, 2015-16 (http://aiccip.cicr. org.in/)].

It requires a minimum daily air temperature of 15 °C for germination, 21-27 °C for vegetative growth and above 15 °C for whole crop growth season (Waddle 1984). Cool nights are beneficial during the fruiting period. With high temperature, vegetative branch increases and fruiting branch decreases. Despite originating from hot climates, cotton does not necessarily yield best at excessive high temperatures and a negative correlation has been reported between yield and high temperature during flowering and early boll development.

2. Materials and method

The field experiment was conducted at the research area of the Department of Agricultural meteorology, CCS Haryana Agricultural University, Hisar situated in the semi-arid zone at an elevation of 215.2 m with a longitude of 75° 46′ E and latitude of 29°10′ N during the *kharif* season of 2015-16. The main plots treatments consisted of three date of sowing (2nd week of May (D1), 3rd week of May (D2) and 1st week of June (D3) and sub-plots consisted of three cultivars Pancham 541, SP 7121 and RCH 791. Cultivars of cotton sown were in split plot design in three replications at spacing of 67.5 × 30 cm.

Quantum sensor was used to measure photo synthecally active radiation (PAR) after 30 days of sowing at 30 days interval during noon hours at top, middle and bottom of canopy. The reflected radiation was obtained by keeping the sensor inverted at 1 m above the crop canopy and the sensor was also kept on ground across the rows diagonally at random sites to measure transmitted radiation at the ground level inside the canopy. Daily solar radiation data was measured with Pyranometer and used for computing IPAR.

2.1. *Plant observations*

Three plants were uprooted from each plot and their leaves were used for measuring leaf area per plant (cm^2) with the help of leaf area meter (LI-3000 Leaf Area Meter, LICOR Ltd., Nebraska, USA). Leaf area index (LAI) was calculated by dividing total green leaf area of per plant (cm^2) and total ground area covered by per plant (cm^2)at the intervals of 30, 60, 90, 120 and 150 days of sowing.

$$\text{LAI} = \frac{\text{Total green area per plant (cm}^2\text{)}}{\text{Total ground area covered by per plant (cm}^2\text{)}}$$

The above plant samples were first air dried and then oven dried at a temperature of 70 °C till constant weight was obtained. Dry weight was expressed per plant basis after 30, 60, 90, 120 and 150 days of sowing. Plant height and other plant observations were measured on three tagged plants in each plot at above said intervals. Number of detached bolls was counted and mean number of bolls per plant was calculated. Mean weight of bolls per plant was calculated in all the plots. The seed cotton was picked

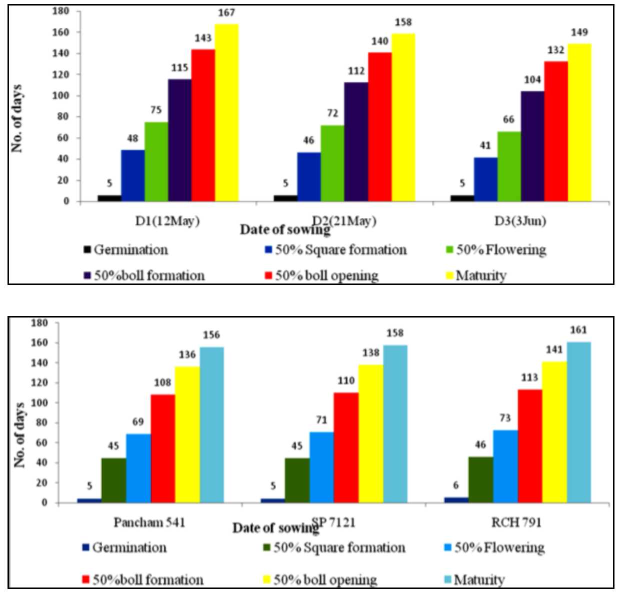

Fig. 1. Phenology of cotton cultivars under different growing environments

from three randomly selected plants from each plot. The seed cotton yield was calculated on net plot area basis. Cotton lint was removed from cotton seed by ginning and cotton lint weight was taken.

2.2. *Protein content*

Protein content was determined by the following method.

(*i*) *Digestion* : Sample (0.2 g) was taken in Kjedahl flask. Two gram digestion mixture and 10 ml conc. H_2SO_4 were added to it. The flask were placed on digestion bench and heated till the solution became clear. The flasks were removed, cooled and volume was made to 100 ml with distilled water.

(*ii*) *Distillation* : Aliquot (10 ml) was transferred to micro-Kjedahl assembly and 10 ml of 40% NaOH was added to it. 10 ml of N/100 H_2SO_4 was taken in conical flask and 2-3 drops of methyl red indicator were added to it. This conical flask was set under condenser. The distillation was carried for 10-15 minute till its volume become 50 ml. Blank was also run simultaneously.

(*iii*) *Titration* : The conical flask was removed after washing the tip of condenser with distilled water into the flask. The content of flask was titrated with N/100 NaOH till the end point (red to pink). The volume of alkali used for neutralization of H_2SO_4 was recorded. The amount of nitrogen and hence protein in the sample was calculated using following relationship.

1 ml N/100 H_2SO_4 = 0.00014 g N

$$\% \text{ crude protein} = \frac{V \times 0.00014 \times D \times 100 \times 6.25}{W \times A}$$

where,

V = Volume of N/100 H_2SO_4 taken – volume of N/100 NaOH used for titration.

D = Dilution factor (volume made involumetric flask)

W = Weight (g) of sample

A = Aliquot taken for distillation

2.3. *Oil content (%)*

The oil content was determined by Soxhelt method. For oil extraction, one gram each dried and grinded seed samples were treated with petroleum-ether for1-2 hours in Soxhlet apparatus. After oil extraction, the treated samples were dried and weighed. Percent reduction in oil content was calculated by using simple formula given below:

$$\text{Oil }(\%) = \frac{(\text{Weight of sample before extraction - Weight of sample after extraction}) \times 100}{\text{Weight of sample before extraction}}$$

3. Results and discussion

Early sown crop required more days (167) to physiological maturity than late sown crop (149) which might be because cotton is a short day crop. Also RCH 791 matured in (161) followed by SP 7121 (158) and Pancham 541 (156) (Fig. 1). The days taken for 50% flowering were less in late sown crops as compared to early sown crop. Pancham 541 matured attained 50% flowering by 2 and 4 days over SP 7121 and RCH 791 respectively.

More PAR absorption (%) and less transmission (%) were recorded in 2nd week of May (D1) sown crop as compared to 3rd week of May (D2) and 1st week of June (D3) crop which might be due to maximum leaf area index was produced by 2nd week of May sown crop. Cultivar RCH 791 absorbed maximum photosynthecally active radiation (PAR) followed by SP 7121 and Pancham 541. This might be also due to maximum value of leaf area index was observed in RCH 791. On the contrary, transmission (%) was found to be higher in 1st week of June (D3) sown crop as compared to 3rd week of May and 2nd week of May (Table 1). Monga *et al.* (2009) also reported the same radiation pattern in tomato crop under different sowing environments.

Leaf area index (LAI) observed was maximum in 2nd week of May sown crop as compared to 3rd week of May and 1st week of June sown crop (Table 2). This might be due to maximum vegetative period was observed in 2nd week of May sown crop. Among cultivars RCH 791 produced more leaf area index as compared to SP 7121 and Pancham 541.This was because of its resistance to leaf curl virus disease and there by leaf size is more in RCH 791 as compared to SP 7121 and Pancham 541. Critical difference (difference between two main

TABLE 1

Optical characteristics (Indices) of cotton cultivars under different growing environments

Growing environments	Reflection (%)	Transmission (%)	Absorption (%)
D1 sown crop	9.4	7.5	83.1
D2 sown crop	9.5	7.9	82.6
D3 sown crop	14.8	8.9	76.3
Pancham 541	19.6	8.5	71.9
SP 7121	10.3	8.0	81.7
RCH 791	3.8	7.8	88.4

TABLE 2

Leaf area index of cotton cultivars at various growth intervals under different growing environments

Growing environments	DAS (Days after sowing)				
	30	60	90	120	150
D1 sown crop	0.11	0.97	1.81	3.46	1.47
D2 sown crop	0.10	0.94	1.69	3.33	1.31
D3 sown crop	0.12	0.84	1.62	2.75	1.27
CD at 5%	N/A	N/A	N/A	0.25	N/A
Pancham 541	0.10	0.75	1.55	2.92	1.16
SP 7121	0.10	0.87	1.61	3.11	1.29
RCH 791	0.14	1.13	1.95	3.50	1.60
CD at 5%	N/A	0.15	0.32	0.33	0.22

TABLE 3

Plant height (cm) of cotton cultivars at various growth intervals under different growing environments

Growing environments	DAS (Days after sowing)				
	30	60	90	120	150
D1 sown crop	35.1	88.2	116.8	122.3	127.5
D2 sown crop	22.7	82.0	114.1	120.3	124.1
D3 sown crop	20.9	77.2	88.4	91.9	95.1
CD at 5%	2.5	7.4	16.1	10.9	5.1
Pancham 541	24.2	69.9	91.8	97.9	102.7
SP 7121	29.5	94.6	120.0	125.5	128.8
RCH 791	24.9	82.9	107.4	111.0	115.3
CD at 5%	3.1	7.6	8.1	5.7	5.8

TABLE 4

Dry matter (g/plant) of cotton cultivars at various growth intervals under different growing environments

Growing environments	DAS (Days after sowing)					
	30	60	90	120	150	Maturity
D1 sown crop	9.8	35.1	128.0	247.1	297.6	326.1
D2 sown crop	9.1	30.7	117.4	227.2	279.4	293.4
D3 sown crop	7.5	27.1	105.7	208.2	**257.1**	257.1
CD at 5%	1.4	4.0	4.2	16.0	25.8	15.0
Pancham 541	7.7	23.0	107.7	210.9	262.6	277.1
SP 7121	8.5	25.8	110.3	221.0	270.9	285.1
RCH 791	10.2	44.1	133.1	250.5	300.6	314.3
CD at 5%	1.3	1.9	4.4	13.0	15.3	9.6

treatments) in LAI at 5% was observed at 120 days after sowing under different sowing environments. Tyagi (1994) also found that RH 30 exhibited higher LAI followed by Varuna and Laxmi.

2nd week of May sown crop produced taller plants as compared to 3rd week of May and 1st week of June sown crop. This might be due to more growth period and PAR interception by 2nd week of May sown crop. Among cultivars SP 7121 attained maximum plant height compared to RCH 791 and Pancham 541 (Table 3). Maximum critical difference (CD) at 5% was observed at 90 days after sowing.

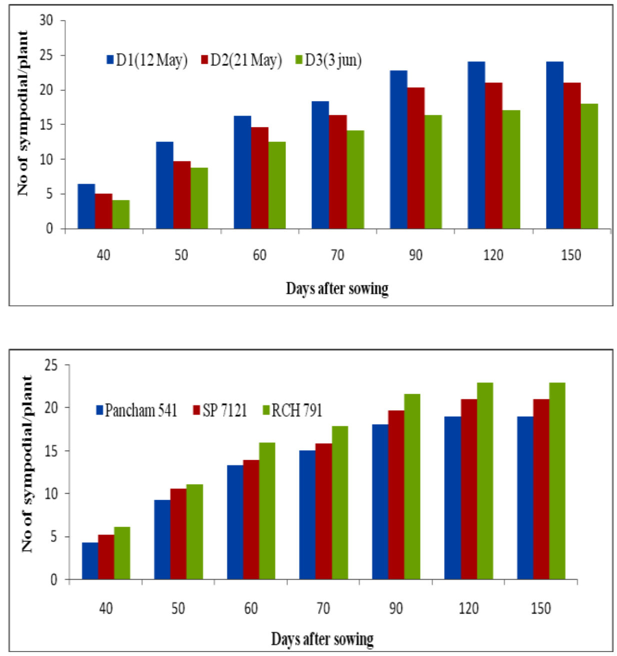

Fig. 2. Number of sympodial/plant of cottoncultivars at various growth intervals under different growing environments

Dry matter accumulation was higher in 2nd week of May sown crop as compared to 3rd week of May and 1st week of June sown crop (Table 4). This might be because of more LAI and PAR absorption by 2nd week of May sown crop. Among cultivars RCH 791 produced higher dry matter as compared to SP 7121 and Pancham 541. The highest biomass in cultivar RCH 791 might be also due to maximum LAI and PAR absorbed by this cultivar. Critical difference at 5% in dry matter production increases with increase in the dry matter and peak was observed at 150 DAS. These results are in unison with those obtained by Tyagi (1994) and Chakravarty *et al*. (2006) in *B. juncea*.

Number of sympodial/plant increased from 40 to 90 DAS and there after no more production of sympodial branches per plant in all the cultivars and growing environments (Fig. 2). Number of sympodial/plant was recoded maximum in cotton crop sown on 2nd week of May (24) followed by 3rd week of May (21) and 1st week of June (18). The cultivar RCH 791 produced maximum (23) and Pancham 541 produced minimum (19) number of sympodial/ plant. This might be also attributed to higher LAI and PAR absorption observed in this cultivar.

The maximum value of yield attributes (number of bolls plant^{-1}, bolls weight/plant, seed cotton, cotton lint, cotton seed and dry matter) was observed in 2nd week of May sown crop as compared to 3rd week of May and 1st week of June sown crop (Table 5) which might be because

TABLE 5

Effect of growing environments on bolls/plant, bolls weight/plant, seed cotton, cotton lint, cotton seed, oil and protein content of cotton cultivars

Growing environments	Seed cotton (q/ha)	Lint (q/ha)	Cotton seed (q/ha)	Oil (%)	Protein (%)	Bolls / plant	Bolls weight/ plant	Dry Matter (q/ha)
Crop sown (D1) during 2nd week of May	17.7	5.7	12.0	19.8	17.7	18.0	64.6	38.4
Crop sown (D2) during 3rd week of May	14.8	5.0	9.8	17.9	18.8	16.0	54.0	32.1
Crop sown (D3) during 1st week of June	10.1	3.5	6.6	15.9	16.5	11.0	36.8	21.9
CD at 5%	1.8	0.6	1.1	0.8	NA	1.7	6.4	3.8
Pancham 541	11.3	3.8	7.5	16.1	18.0	12.0	41.1	24.4
SP 7121	13.2	4.4	8.8	17.9	17.2	14.0	48.1	28.6
RCH 791	18.2	6.1	12.1	19.7	17.8	19.0	66.3	39.4
CD at 5%	1.3	0.4	0.9	1.1	0.66	1.5	4.8	2.8

of the better energy conversion efficiency in dry matter of cotton cultivars in first growing environment and resulted in better crop growth. Among the cultivars, yield and its attributes were more in RCH 791 as compared to SP 7121 and Pancham 541 (Table 5). It might be also attributed to more LAI, PAR absorption and dry matter in RCH 791. Among the entire yield attributes, maximum critical difference at 5% was observed in bolls weight per plant under different sowing environments. Qayyum *et al.* (1996) also expressed their views that medium and early sown cotton produced significantly higher seed cotton yield than late sowing under Tandojam climatic conditions.

Maximum oil content was observed in 2nd week of May sown crop and lowest in 1st week of June sown crop. Among the cultivars, RCH 791 yielded maximum oil followed by SP 7121and Pancham 541 (Table 5). All the growth factors are higher is RCH 791 and 2nd week of May sown crop. Maximum protein was observed in 3rd week of May sown crop and lowest in 1st week of June sown crop. This might be due to 3rd week of May sowing environment was more favorable for protein accumulation, because of moderate temperatures prevailed during this growing environment. Among the cultivars, Pancham 541 yielded maximum protein content followed by RCH 791 and SP 7121. No critical difference at 5% was observed in protein % under different sowing environments. Deho *et al.* (2014) also reported that 1st May sowing produced maximum seed oil content (20.58%) followed by 15th May sown crop (20.25%).

3.1. *Crop weather relationship*

Dry matter production was directly related with plant height (Fig. 3). The slope value of the regression line shows that growing environment of cotton sown on 2nd week of May produced more dry matter production per unit of plant height. Evangelos *et al*. (2012) also studied the radiation use efficiency of cotton in two different environmental conditions.

Plant height was directly related with LAI as shown in Fig. 4. The slope value of the regression line shows that growing environment of cotton sown on 1st week of June yielded more leaf area index per unit plant height.

Weather parameters were better associated with the crop parameters during vegetative phase. Maximum temperature, minimum temperature, relative humidity morning and evening, wind speed and rainfall showed a positive correlation with dry matter, max. LAI, seed cotton, cotton seed, lint, oil, protein, boll/plant, bolls wt., oil and protein % per plant during vegetative phase, whereas morning and evening relative humidity showed negative correlation with dry matter, max. LAI, seed cotton, cotton seed, lint, oil, protein, boll/plant, bolls wt., oil and protein % per plant during reproductive phase (Table 6). This might be due to negative effect of higher relative humidity on reproductive traits. Pouresia and Nabipour (2007) also observed a negative correlation between air temperature and sunshine hours during seed development phase with leaf area index.

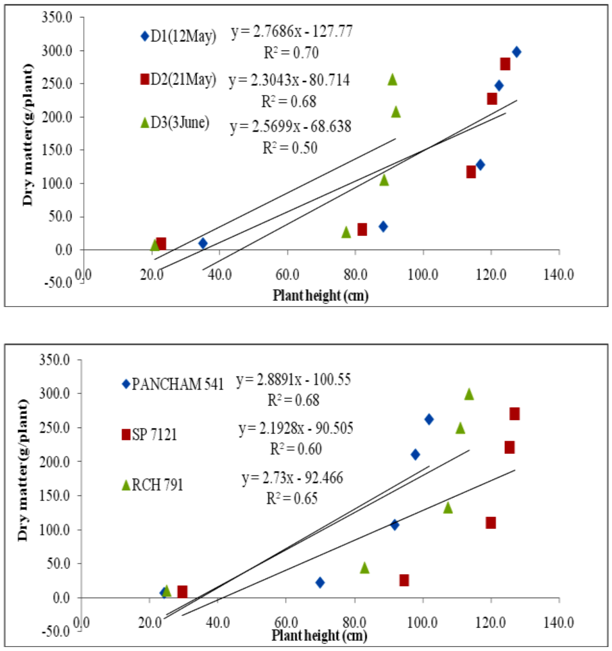

Fig. 3. Relationship of dry matter production with plant height under different growing environments

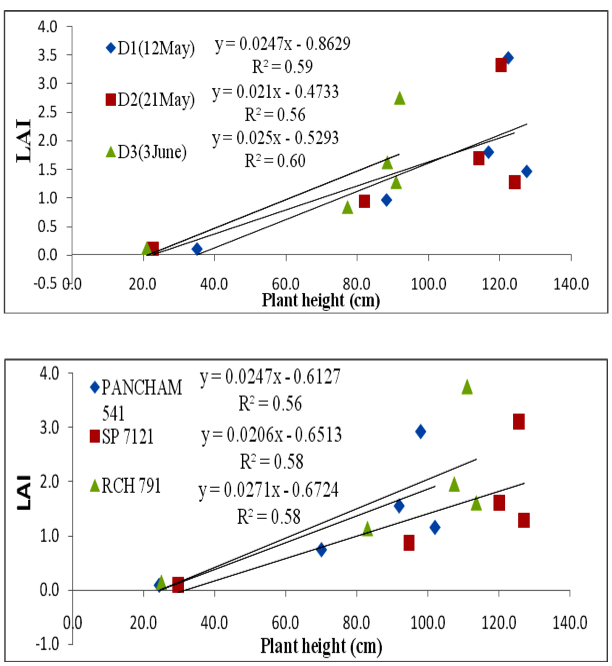

Fig. 4. Relationship of LAI with plant height under different growing environments

Relative humidity at morning and evening hours during reproductive phase had significantly negative correlations with seed and biological yields, whereas during vegetative phase, it had significantly positive correlation. Similar results were reported by Singh (1999).

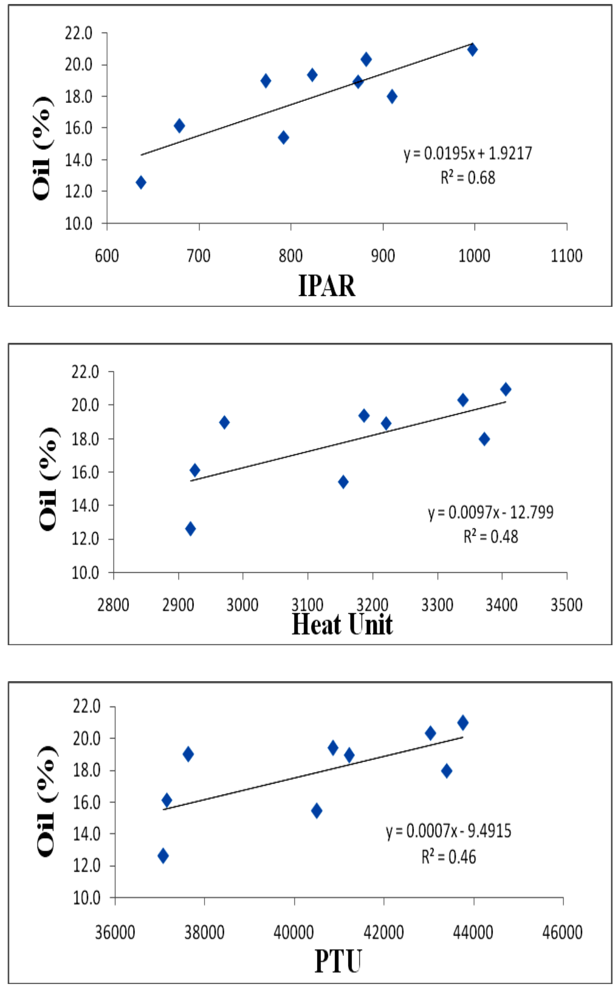

Fig. 5. Relationship of oil (%) with IPAR, heat unit and PTU

The negative correlations of temperature and sunshine hours during reproductive phase with oil content were also reported by Robertson *et al*. (2002); Omidi *et al*. (2007) and Liyong *et al*. (2007).

Energy indices: Heat unit (HU), Helio thermal unit (HTU) and Photo thermal unit (PTU) were positively and better correlated with all the yield parameters during vegetative phase than that of reproductive phase (Table 6).

3.2. *Oil and protein with energy indices*

Oil content was directly and linearly related with intercepted photosynthetically radiation, HU and PTU by the crop. Oil and PTU, PAR, HU explained 68%, 48%and 46% variability in oil content as sown in Fig. 5. R^2, value in respect of IPAR is higher with oil accumulation than HU and PTU.

TABLE 6

Correlation of weather with crop parameters at different phenophases

Weather parameters	Dry Matter	Max. LAI	Seed Cotton	Cotton lint	Cotton Seed	Oil	Protein	Boll	Boll Wt./Plant
Vegetative phase									
Tmax	0.48	0.56	0.48	0.53	0.46	0.31	0.59	0.48	0.48
Tmin	0.57	0.64	0.57	0.53	0.59	0.46	0.37	0.57	0.57
RHm	0.35	0.38	0.35	0.28	0.38	0.29	0.04	0.35	0.35
RHe	0.50	0.55	0.50	0.45	0.53	0.42	0.25	0.50	0.50
Sunshine hours	-0.41	-0.50	-0.41	-0.36	-0.43	-0.22	-0.17	-0.41	-0.41
Wind speed	0.52	0.53	0.52	0.46	0.54	0.49	0.19	0.52	0.52
Rainfall	0.50	0.61	0.50	0.45	0.52	0.46	0.10	0.50	0.50
HU	0.66	0.67	0.66	0.60	0.68	0.56	0.22	0.66	0.66
PTU	0.79	0.84	0.79	0.75	0.80	0.67	0.27	0.79	0.79
HTU	0.62	0.64	0.63	0.56	0.65	0.53	0.23	0.62	0.62
Reproductive phase									
T max	0.63	0.71	0.63	0.59	0.65	0.56	0.28	0.63	0.63
T min	-0.67	-0.70	-0.67	-0.62	-0.69	-0.58	-0.31	-0.67	-0.67
RHm	-0.65	-0.73	-0.65	-0.62	-0.67	-0.56	-0.32	-0.65	-0.65
Rhe	-0.65	-0.71	-0.65	-0.61	-0.67	-0.57	-0.29	-0.65	-0.65
Sunshine hours	0.62	0.71	0.62	0.58	0.63	0.47	0.27	0.62	0.62
Wind speed	-0.35	-0.27	-0.35	-0.28	-0.38	-0.41	0.04	-0.35	-0.35
Rainfall	-0.50	-0.61	-0.50	-0.45	-0.52	-0.46	-0.10	-0.50	-0.50
HU	0.88	0.93	0.88	0.85	0.87	0.77	0.26	0.88	0.88
PTU	0.87	0.92	0.87	0.84	0.88	0.76	0.26	0.88	0.87
HTU	0.79	0.86	0.79	0.76	0.80	0.65	0.27	0.79	0.79

"r" value at 5% level of significance = 0.67

4. Conclusion

Based on the above result it is concluded that early sown crop and RCH 791 took more days to physiological maturity. Variability in oil content was better explained by intercepted PAR as compared to other agrometeorological indices. Early sown crop produce maximum seed cotton yield, cotton seed yield, cotton lint, oil percentage and bolls per plant as compared to late sown crop.

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