Original Research Article

Evaluation of the agromet indices impact on Cowpea crop at Khurdha District of Odisha, India

Abstract

At the ICAR-IIWM research farm in Odisha, a study was carried out during the rabi season to assess the effects of agromet indices on the cowpea variety Kashi uttam during the two growth seasons of 2018–19 and 2019–20. Different growing seasons and a delay in sowing had a significant impact on the length of phenological stages and accumulation of agro-climatic indices (Growing Degree Days, Photothermal Units, and Heliothermal Units). The findings showed that distinct growth phases at the second growing season were responsible for the greater GDD and PTU. However, the decrease in HTU during the second growing season showed that the crop required fewer heat units as a result of the second growth season's considerably lower number of sunshine hours. Among the seasons and sowing dates, the meteorological indices accretion was perceived in 2nd growing season as compared to 1st growing season crop. Second season crop had sown earlier and get highest heat use efficiency.

Keywords: meteorological indices, cowpea, productivity, growing season.

Introduction

The productivity of agriculture in all hemispheres is significantly impacted by weather variability and climate change. Every crop has specific requirements for a certain weather condition in order for it to grow, develop, and produce at its highest potential (Razzaq et. al., 1986; Zinn et. al., 2010). One of the most crucial climatic factors for regulating and managing crop growth and development is temperature, which is also well known for its role in disease and insect infestation. The concept driving heat units is that the amount of actual time needed to reach a phenological stage is linearly related to temperature between base temperature and ideal temperature. The basic units for analysing the phenology of crops under climatic fluctuation are thought to be heat units (Leith,1974; Sreenivas et. al., 2010). Efficiency, the use of heat in terms of dry matter accretion, is dependent on the type of crop, genetic characteristics, and the timing of the sowing, and it has a significant practical impact on crop productivity (Rao et. al.,1999). Due to the daily fluctuations in weather, growth and yield performance varied with each growing season. The association between two or more weather factors and grain yield of crops can be used for yield prediction well in advance of the actual crop harvest (Sastri et al., 1996). The accumulated heat unit system can be used to study the effects of temperature and weather conditions on the phenology and yield of crop plants over the course of two growing seasons (Shankar et. al., 1996). From emergence through physiological maturity, a varied growing season could produce different environmental conditions. Growing degree days (GDD) or the thermal unit are the most used temperature indices used to predict plant development. The current study's objective was to evaluate the effects of agrometeorological variables on the cowpea crop in the tropical Khurdha district of Odisha.

Materials and method

Study area

The agricultural experiment took place from December to March in the years 2018–19 and 2019–20 at the Indian Institute of Water Management (IIWM), in the districts of Deras, Mendhasal, Khurdha, Odisha. It is 23 metres above sea level and located between Latitude 20°17' N and Longitude 85°41' E. The research area's average yearly rainfall is 1428 mm (Odisha Agriculture Statistics, 2017-18). The south-west monsoon, which begins at the end of June and lasts until October, is the main source of rainfall. From November through June, the weather is relatively dry. Winter is cold and dry, while summer is hot and humid, with temperatures occasionally feeling as high as 45.50C in May and June. In light of this, the highest average temperature is 31.30°C and the lowest is 21.80°C (Odisha Agriculture Statistics, 2017-18).

Observations

The cowpea crop (cv. Kashi uttam) was sown on 40 cm-spaced ridges with a plant-to-plant distance of 15 cm in December 2018–19 and 2019–20, respectively. The seed rate was 12 kg ha-1, and the N:P:K fertiliser dose was 25:50:25. The experimental plots were used to record the dates of the major phenological stages, including emergence, branching, commencing bloom, full flowering, early pod development, complete pod development stage, full seed development, and full maturity stages. Weather information was gathered daily during the growing seasons of 2018-19 and 2019-20 from the Agro-Meteorological Observatory, which is close to the experimental farm. Weather variables included maximum temperature, minimum temperature, bright sun shine hours, wind speed (km/hrs), rainfall, and relative humidity (%).

Agro-meteorological Indices

Using the method outlined by Singh et al. (2015), the various agro-meteorological indices, including growth degree days (GDD), helio-thermal units (HTU), photo-thermal units (PTU), pheno-thermal index (PTI), radiation use efficiency (RUE), and heat use efficiency (HUE), were calculated.

Growing degree days (GDD)

The following formula was used to calculate the sum of degree days required to complete each phenophase:

$$\mathbf{GDD=\Sigma\ [(Tx + Tn)/2 - T_{base}]}$$

Where,

Tmax= Daily maximum temperature (^{o}C)

Tmin= Daily minimum temperature (^{o}C)

Tbase= Minimum threshold/Base temperature (^{o}C)

In order to calculate the rising degree days, the base temperature of 10^{0}C was used.

Photo-thermal Unit (PTU)

One of the fundamental elements influencing the duration of vegetative growth for photosensitive cultivars is the time of day and night. The length of the night is essential in deciding whether or not long-day plants will go into reproductive phase. Photo-thermal units are the cumulative value of rising degree days, multiplied by bright sunshine hours. The following formula can be used to numerically express this:

$$\text{PTU (day °C hour)} = \text{GDD} * n$$

Where,

n = maximum possible sunshine hours

Helio-thermal Unit (HTU)

The sum of GDD and the number of hours of strong sunshine for a given day is represented by the helio-thermal units for that day. For specific phenophases of interest, the sum of HTU was calculated using the following equation:

$$\text{HTU (day °C hour)} = \text{GDD} * n$$

Where, n = actual bright sunshine hours

Phenothermal index (PTI)

Phenothermal index according to the following equation, the ratio of degree days to the number of days between two phonological phases was calculated:

PTI (°C) =GDD/Number of days between two phenological stages.

Radiation use efficiency (RUE)

The biological yield to radiation intercepted ratio is known as the radiation use efficiency. The following formula can be used to represent it:

$$\text{RUE } (\text{gMJ}^{-1}) = \text{Biomass } (\text{g}/\text{m}^2) / \text{PAR } (\text{MJ}/\text{m}^2/\text{day})$$

Where, PAR is cumulative intercepted photo synthetically active radiation.

The amount of intercepted radiant radiation (PAR in the range of 380-700 nm) above the crop surface and ground surface was measured using a line quantum sensor, which was kept 5 cm above the surface. The observations were made at various phases of growth. The intercepted PAR (IPAR) was quantified as follows:

$$I_i = I_0 - I_{re} - I_t + I_{rg}$$

$$I_i\,(\%) \text{ by the canopy} = (I_i/I_0)*100$$

where,

I_i = Intercepted photosynthetic active radiation (PAR) by the canopy
I0 = Incident PAR on the canopy
Ire = Reflected PAR by the canopy
It = Transmitted PAR through the canopy
Irg = Reflected PAR from the ground.

Heat use efficiency (HUE)

Thermal time use efficiency (TTUE), which measures the amount of dry matter generated per unit of growing degree days or thermal time, is another way to express heat use efficiency. This was calculated using the formula below:

$$\text{HUE } (\text{g/m}^2\ {}^0\text{C day}^{-1}) = \frac{\text{Biomass } (\text{g/m}^2)}{\text{GDD } ({}^0\text{C days})}$$

Where, GDD is growing degree days.

Results

Accumulated Growing Degree Days (AGDD)

In comparison to the first growing season, cowpea in the second season crop gained more growing degree days to different phenophases (1097^{0}C day) (1037^{0}C day). Calculations yielded a mean accumulated GDD of 1067^{0}C day. The availability of a prolonged growth period and temperature fluctuation for the crop growing season were the causes of these outcomes. The favourable photoperiodic conditions that high degree days created during crop reproductive phases and maturity duration in second season sown crops (Table 1).

Table 1: AGDD, AHTU, APTU and PTI to attain different growth stages in cowpea crop under two growing seasons.

Seasons	**Different crop growth stages**								
	Sowing	**Emergence**	**Branching**	**Beginning bloom/Early bloom**	**Full flowering**	**Early pod formation stage**	**Full Pod development stage**	**Full seed development stage**	**Full Maturity stage**
AGDD (^{0}C day)									
2018	11	66	191	431	711	783	885	954	1037
2019	13	83	272	517	761	820	917	1005	1097
Mean	12	75	232	474	736	802	901	980	1067
AHTU (^{0}C day hrs)									
2018	66	471	859	3789	5900	5480	5400	6965	8089
2019	55	753	585	2763	4147	6933	8573	6434	8010
Mean	61	612	722	3276	5024	6207	6987	6700	8050
APTU (^{0}C day hrs)									
2018	120	664	1908	4952	8174	9003	10622	11449	12445
2019	137	907	2723	5165	8750	9435	10545	12063	13167
Mean	129	786	2316	5059	8462	9219	10584	11756	12806
PTI (^{0}C day day^{-1})									
2018	0	8	10	11	12	12	13	13	13
2019	0	12	12	12	12	13	13	13	14
Mean	0	10	11	12	12	13	13	13	14

Accumulated Helio-thermal Units (AHTU)

The cumulative HTU need for various phenophases was noted. First seasons displayed greater worth than second seasons. Sowing (66^0C day), branching (859^0C day), beginning bloom (3789^0C day), full flowering (5900^0C day), full seed development stage (6965^0C day), and maturity stage (8089^0C day) were higher values in the first season, while emergence (753^0C day), early pod formation stage (6933^0C day), and full pod development stage (753^0C day), were higher values in the second season (8573^0C day).

Accumulated Photo-thermal Units (APTU)

The second growing season crop of cowpea accumulated the most APTU (13167^0C day), while the first growing season crop accumulated less (12445^0C day). And 12806^0C day of the crop growth season was used to determine the mean accumulated PTU. In contrast to the first season, the results showed that the second season had the greatest PTU for cowpea crop growth seasons.

Pheno-thermal Index (PTI)

The pheno-thermal index (PTI) revealed significant variance over the course of two growing seasons, with the crop index for the second growing season being the greatest at (14) and the crop index for the first growing season being the lowest at (13). The mean PTI for both crops' growth seasons was computed using the 14 Index.

Table 2: Radiation use efficiency (RUE) and Heat use efficiency (HUE) to obtained various growth interval in cowpea under two growing seasons.

Crop season	**30 DAS**	**45 DAS**	**60 DAS**	**Maturity days**	**Mean**
RUE (g/MJ)					
2018	0.25	0.21	0.24	0.29	0.25
2019	0.23	0.25	0.32	0.30	0.28
Mean	0.24	0.23	0.28	0.30	0.26
HUE ($g/m^2/^0C$ day)					
2018	0.15	0.13	0.13	0.10	0.13
2019	0.15	0.13	0.14	0.12	0.14
Mean	0.15	0.13	0.14	0.11	0.13

Radiation Use Efficiency (RUE)

The development of the leaf canopy and its impact on the effectiveness of radiation interception are key factors in crop development that have an impact on dry matter output. Significant variance in cowpea across two growing seasons is shown in Table 2. While the first growing season had the lowest mean RUE (0.25 $g/m^2/^0C$ day) and the second had the highest mean RUE (0.28 g/MJ). The highest RUE for cowpea was attained in the second growing season.

Heat Use Efficiency (HUE)

HUE of the cowpea crop was determined, it was lowest in the first growing season (0.13g/m2/0C day) and relatively greatest (0.14g/m2/0C day) in the second growing season. This indicates that early-sown crops used more heat and had more deficiencies than late-sown crops. The early planted crop has highest heat usage efficiency and it reduced with delay in planting (Keerthi et al., 2016). (Keerthi et al., 2016).

Discussion

It may be because that more days needed for the crop to reach maturity in the second season that the accumulated GDDs and APTUs were higher during both crop growth periods. Additionally, according to Kar *et al.* (2018), the first month after sowing was accompanied by an average low temperature. As a result, less GDD was accumulated overall in the first season than in the second. According to Singh et al. (1998), the timing of sowing and the availability of moisture during the crop growth season had an impact on the amount of thermal time needed for various developmental phases. Due to the second growing season's relatively lower number of recorded sunshine hours, the crop needed fewer heat units, as evidenced by the decrease in HTUs. This variance developed as a result of temperature changes as well as shifts in the number of bright sunshiny hours throughout two distinct growing seasons. Additionally, it was discovered by Solanki and Mundar (2015) and Kar et al. (2018) that HTUs are reliant on bright sunshine hours, which were impacted by the frequent occurrence of rainfall throughout the appropriate season.

While intercepting a varied amount of radiation due to variations in the canopy surface and the LAI, RUE arose variable due to the difference in dry matter production in two seasons. according to O'Connell *et al.* (2004) the RUE levels vary with plant species, climatic conditions, measuring technique, and plant characteristics. RUE is primarily influenced by three variables: the angle of radiation interception, the plant canopy's ability to employ the intercepted radiation for photosynthesis, and the loss of dry matter via physiological processes like respiration (Sinclair and Horie, 1989 and Collino et al., 2001).

Conclusion

The results of the current study highlighted that the arrival of various phenological stages and grain production were significantly influenced by the timely sowing. When compared to delayed planting, timely seeding of crops required longer heating durations. It is clear that there is seasonal meteorological parameter fluctuation, which has an impact on agricultural yield, production, and vegetative development.

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