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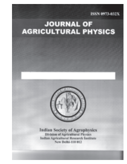

Research Article

Impact of Weather Parameters on Simulated Biophysical Parameters of Chickpea

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ABSTRACT

The study proposes the impact of weather parameters on simulated leaf area index and biomass of chickpea. The CROPGRO-chickpea model was calibrated using field experimental data of year 2017-18 and the calibrated model output was utilized to assess the impact of weather variables on biophysical parameters of chickpea. Correlation study was done between the relative growth rate of simulated leaf area index and biomass values with the observed weather variables. Our results indicate that relative growth rate of both leaf area index and biomass of chickpea are positively correlated with mean temperature and bright sunshine hours while, both are negatively correlated with relative humidity. On the other hand, rainfall, due to its uneven distribution, showed no correlation with relative growth rate of leaf area index and biomass of the crop. The study explains the crucial relationship between the weather variables and simulated biophysical parameters of CROPGRO- Chickpea model.

Key words: Chickpea, CROPGRO, Relative growth rate, Leaf area index, Biomass, Weather

Introduction

Chickpea is one of the most important pulse crop of the world belonging to the family *Leguminosae*. India being the largest producer contributes 75% of world chickpea production. In India, it covers maximum area among all the pulse crop grown in the country and is grown over 10.56 million hectare of area. Its production steadily rose over the years and at present, registers about 11.23 million tones with productivity accounting about 1063 kg/ha (DAC&FW, 2018). Nonetheless, global demand of chickpea has been projected to be 18.3 million tones compared to the current production of 11.23 million tones, and developing countries with low-income are expected to hit the widest supply-demand gap (Nedumaran and Bantilan, 2013). This emphasizes up on an urgent need to study the growth parameters of chickpea crucial for its productivity.

Weather is one of the key variable to affect growth parameters of any crop and imparts significant influence on its production (Kingra and Kaur, 2017). Rainfall, temperature, solar radiation are the key weather variables that impart maximal effect on growth parameters of a crop and ultimately affecting the crop productivity (Fiscus *et al.,* 1997; Izaurralde *et al.,* 2003 Gholipoor, 2007) Therefore, analyzing the impact of weather variables on the growth and development of crops has been of worldwide interest. A number of approaches have been developed in this regard. One of them is the use of statistical approach to obtain correlation between weather variables and growth parameters of the crop (Baier and Robertson, 1968).

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The current study focusses deriving the statistical relationship between weather variables on growth parameters of chickpea crop. An experiment was laid in GBPUA&T, Uttarakhand in *rabi* 2017-18 with chickpea crop. The study utilized CROPGRO-Chickpea model of Decision Support for Agrotechnology Transfer (DSSAT) to derive the values of crop biophysical parameters. DSSAT is a software application program comprising crop simulation models for over 42 crops (as of v.4.7) as well as, tools to aid effective use of the models (IBSNAT, 1993). DSSAT is used to simulate growth, development, and yield of a crop being grown on a uniform area of land, as well as the changes in soil water, nitrogen & carbon, occurring under the cropping system over the period of time (Jones *et al*., 2003). It comprises physiologically based simulation models which take into consideration phenologic development, growth, senescence, photosynthesis, respiration, infiltration, drainage and evaporation on a daily basis and respond dynamically to weather inputs (Kaur *et al.,* 2018). CROPGRO is a physiological process-oriented legume crop model that permits the simulation of carbon, water and nitrogen balances for the, plant and soil (Hoogenboom *et al*., 1994; Boote, 1998). At a daily time step, growth is integrated, ultimately predicting biophysical parameters such as leaf area, biomass and yield of the crop.

More specifically, the objective of this study was to investigate the effect of weather variables on relative growth rate of CROPGRO-Chickpea model-derived biophysical parameters of the crop. The weather variables considered for the study were bright sunshine hour, mean temperature, relative humidity and rainfall while, biophysical parameters were leaf area index and biomass of the crop.

Crop biomass is an indicator of production and productivity of the crop. A dense lush green healthy crop intercepts more solar radiation and thus, more efficient in photosynthesis than a thin, dull vegetation. Therefore, higher biomass is linked with higher crop production and yield.

Leaf area index (LAI) is another important factor affecting crop growth rate as it interprets the dry matter production capacity of the crop in response to availability of solar radiation and amount of photosynthesis (Stern and Donald, 1961; Roy *et al.,* 2018). It is the ratio of one sided green leaf area to ground area. Indirectly, it indicates green leaf biomass, and thereby acting as one of the important variables in estimation of growth and production of the crop. The amount of solar radiation interception and thus photosynthesis by a plant canopy depends on its leaf area index. There are evidence from researches that the rate of dry matter production by the crop increases with increase in leaf area index of the crop until a maximum value (Watson, 1958; Davidson and Donald, 1958).

Material and Methods

Details of the experimental site

The experiment was laid out in the field C5 of Norman E. Borlaug Crop Research Centre of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar (Uttarakhand). The topography of the experimental site is fairly uniform. Pantnagar lies in the Tarai belt at the foothills of the Western Himalayas at 29.03° N latitude, 79.48° E longitude and at an altitude of 231 m above the mean sea level.

Climate

The experimental site is characterized as humid subtropical, with high temperatures during summers (March to June). Generally there is intense rainfall during monsoons (July to September) and severe cold in winters, (December to February). Minimum temperature of the study area is usually recorded in the month of January and can be as low as 1.5±1.0°C. However, maximum temperature may rise up to 45.5±1.5°C during the month of May. Annual average rainfall of the area usually ranges between 1300-1500 mm, 80% of which is received during the south-west monsoon during July-September. Remaining amount of rainfall is received during winter season (December to February) from "Western Disturbances". Maximum relative humidity ranges between 90-95% during monsoon as well as in winter season.

Soil

The soil of the experimental field was developed in loamy alluvial sediments. Soil was silty loam in texture with 28.7% sand, 54.5% silt and 16.8% clay in the upper 15 cm layer of the soil with 1.3% organic carbon as obtained after soil analysis.

Weather data

Weather data parameters for the years 2017-18 including maximum and minimum temperatures, bright sunshine hours (BSS), relative humidity and rainfall, were collected from the agro-meteorological observatory located near the experimental site at Norman E. Borlaug Crop Research Centre, GBPUA&T, Pantnagar.

Field experiment details

The experiment was conducted using the cultivar Pusa-362 during *rabi* 2017-18. There were 6 treatment combinations which comprised of three dates of sowing and two irrigation levels. The three dates of sowing were 29th November, 10th December and 24th December, respectively, while the two irrigation level comprised of one and two irrigations (70 mm each). The data collection was done at 10 days interval and a total of 9 sets of data for each treatment combination were collected in the entire growing season. Therefore, at the end of the season 54 data points were obtained for each of the parameter under study.

Use of model

The CROPGRO-Chickpea model was employed in the study as the crop growth simulation model to assess the impact of weather variables on biophysical parameters of chickpea. The model was calibrated and validated using field experimental data prior to incorporating it in the proposed analysis. Out of 54 data points, 36 data points were used for calibration of the model, whereas 18 data points were used for validation of the model.

Calibration and Validation of model

In order to acquire the genetic coefficient for the cultivar, the CROPGRO-Chickpea model was calibrated using 36 data points for each of the 'days to phenological stages' and 'biophysical parameters (LAI, biomass)', acquired from the field experiment laid out during *rabi* (2017-18). These data points were utilized to construct all the input files of the model. The model was then run to simulate the output. The observed values and simulated values were compared subsequently and to minimize the difference between them "hit and trial method" was opted. Adjustments were made in the parameters and the model was run several times until observed and simulated values were sufficiently close to each other.

After calibration was achieved, the model was validated using the same year dataset that was used in calibration i.e., 2017-18. For this, the remaining 18 data points for each of the 'days to phenological stages' and 'biophysical parameters (LAI, biomass)' were utilized. Wilmott index of agreement (d) was found to be 0.92 in the study. Once the model was successfully calibrated and validated, the effect of weather variables on LAI and biomass were scrutinized using the values simulated by the model.

Effect of weather on simulated biophysical parameters

CROPGRO simulates daily values of several growth parameters in PlantGro.Out file from which daily LAI and biomass values were obtained. These values of LAI and biomass were averaged to weekly values separately for all the six treatments. Then, the relative growth rate (per week) of both these biophysical parameters were determined. The daily values of weather variables viz. bright sunshine hours, mean temperature, relative humidity and rainfall as obtained from agrometeorological observatory were also converted into respective weekly values. Afterwards the impacts of each weather variable on relative growth rate of each of the biophysical parameters were assessed and a relationship was established between them.

Results and Discussions

Results

LAI and weather variables

Weekly bright sunshine hours and weekly mean temperature has imparted a positive correlation with relative growth rate of LAI per week with R^2 = 0.45 (Fig. 1) and R^2 = 0.53 (Fig. 2), respectively. Weekly relative humidity, on the other hand, imparted a negative correlation with relative growth rate of LAI having R^2 = 0.52 (Fig. 3). Weekly rainfall, however, exhibited no correlation (R^2=0.03) with relative growth of LAI (Fig. 4).

Biomass and weather variables

A positive correlation has been obtained between relative growth rate of biomass per week and weekly bright sunshine hours with R^2 = 0.58 (Fig. 5). Weekly temperature (mean), also, has

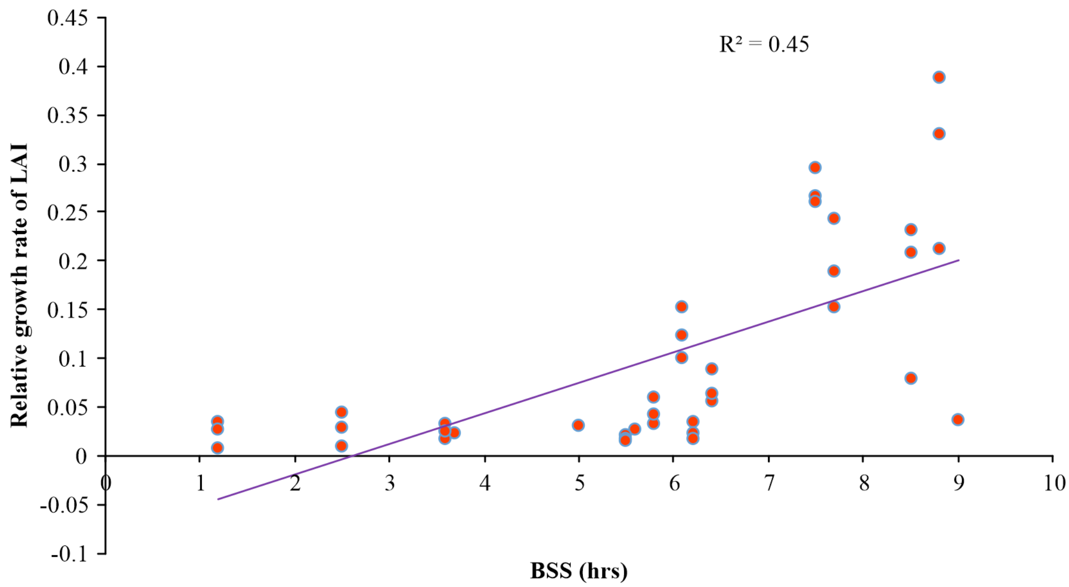

Fig. 1. Effect of bright sunshine hours (hrs) on relative growth rate of LAI per week

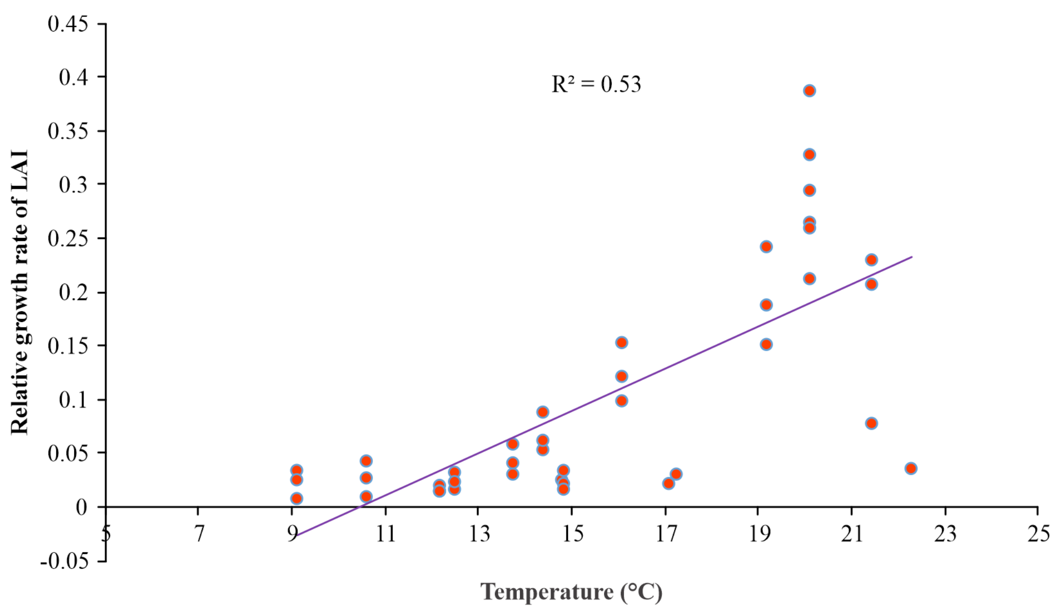

Fig. 2. Effect of mean temperature (°C) on relative growth rate of LAI per week

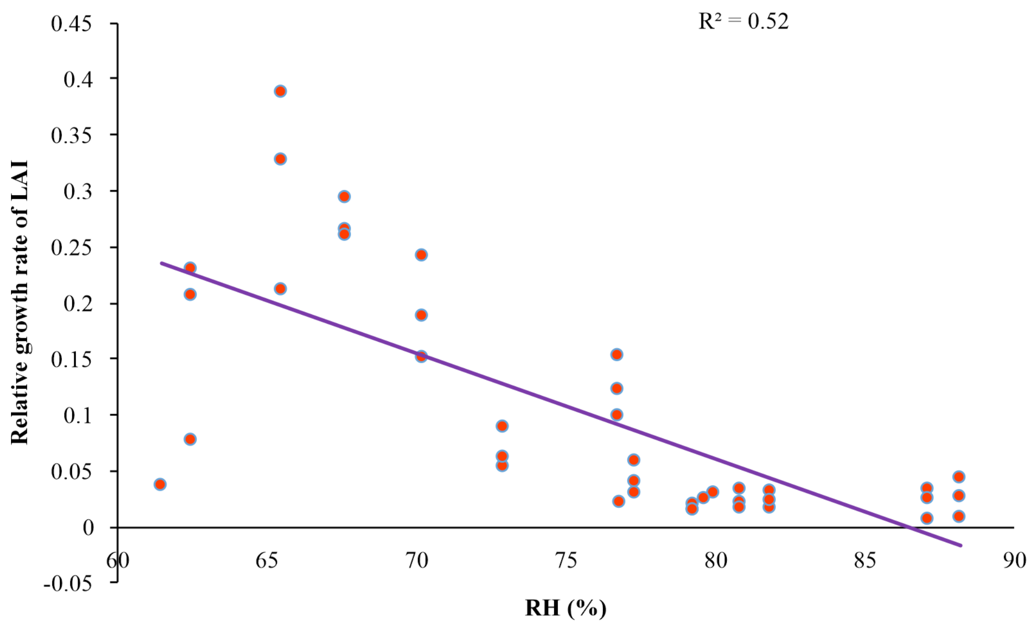

Fig. 3. Effect of relative humidity (%) on relative growth rate of LAI per week

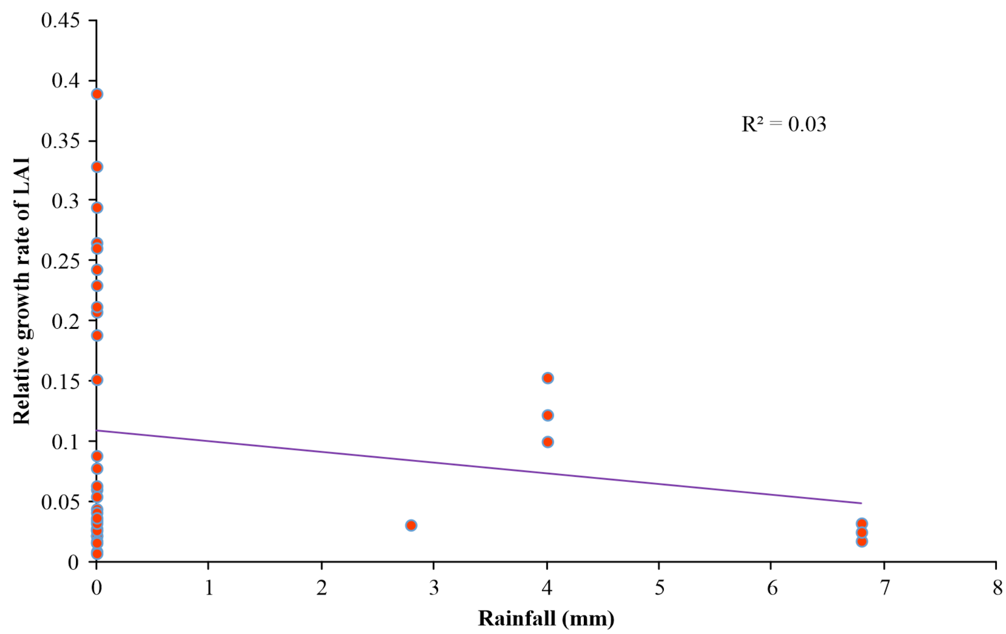

Fig. 4. Effect of rainfall (mm) on relative growth rate of LAI per week

imparted a strong positive correlation ($R^2 = 0.82$) with relative growth of biomass per week as presented in Fig. 6.

Weekly relative humidity, however, imparted a strong negative correlation with relative growth rate of biomass with $R^2 = 0.83$ (Fig. 7). Weekly rainfall, on the other hand, was found to have no correlation with relative growth of biomass (Fig. 8).

Discussion

LAI and weather variables

Positive correlation ($R^2 = 0.45$) between bright sunshine hours and relative growth rate of LAI (Fig. 1) can be attributed to the fact that due to increase in bright sunshine hours, light interception by the plant canopy increases thereby increasing photosynthesis. Higher photosynthesis

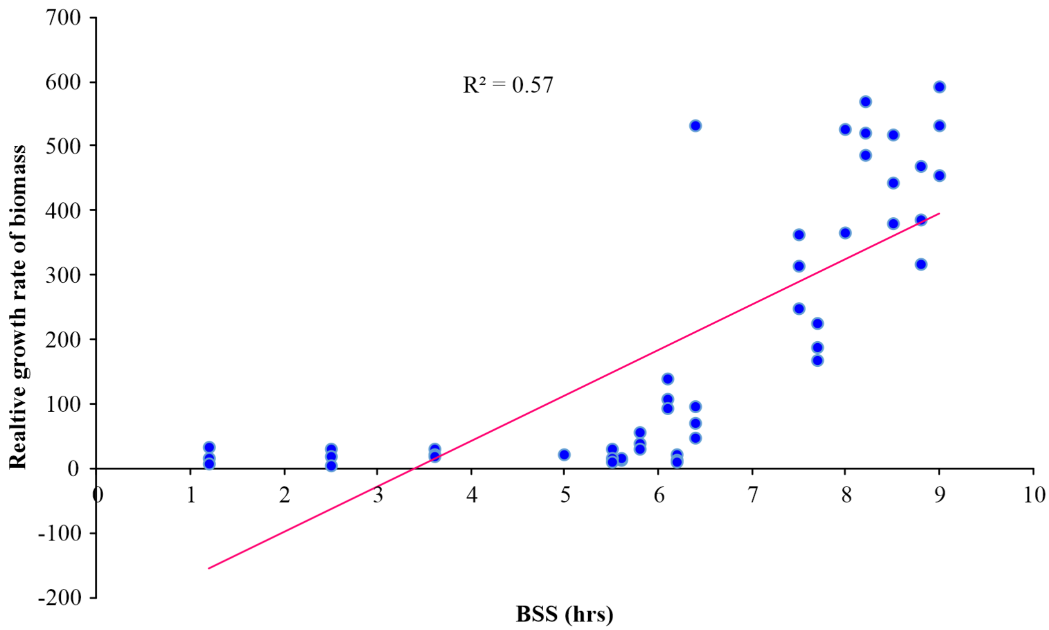

Fig. 5. Effect of bright sunshine hours (hrs) on relative growth rate of biomass per week

leads to increased assimilation of photosynthates, ultimately augmenting leaf expansion and thus, higher LAI values. Therefore, higher values of LAI were obtained as a result of increasing bright sunshine hours. Also, increment in bright sunshine hours results into increase in temperature which shoot up metabolism in plants. Raised metabolism facilitates vigorous translocation of photo-synthetic assimilates among different plant organs including leaves, hence, leaves expand more thereby registering an increase in LAI of the crop. Therefore, a positive correlation (R^2 = 0.53) of relative growth of LAI with mean temperature as presented in Fig. 2 is justified. Tesfaye *et al*. (2006) also reported that attainment of high LAI that reduces soil water evaporation intercepts and converts radiation into dry matter and its partitioning to the seed more efficiently which is the major requirement of a high seed yield in grain legumes .

Relative humidity imparted a negative correlation (R^2 = 0.52) with relative growth rate of LAI (Fig. 3) on the account of reduced transpiration with increase in relative humidity. Rate of transpiration is directly related to ascent of sap and translocation of nutrients among different plant organs. Higher relative humidity leads to decline in transpiration rate thereby slowing down the ascent of sap and translocation of nutrients. Also, in order to reduce translocation, plants fold their leaves to reduce the surface area of transpiring surface. Consequently, leaf expansion is hindered and LAI decreases with increase in relative humidity of ambient environment.

Rainfall, however, exhibited no correlation with relative growth of LAI (Fig. 4). This can be attributed to the uneven distribution of rainfall, the major part of which occurred during harvestable maturity of the crop, keeping crop growth period rain deficient. If rainfall would have occurred during the critical growth period of the crop with even distribution, the scenario would have been different with positive correlation between rainfall and relative growth rate of LAI.

Biomass and weather variables

As discussed for LAI, higher radiation interception by the plant canopy with increase in bright sunshine hours intensifies photosynthesis. This leads to higher accumulation of dry matter by the crop thereby increasing its weight. Hence, bright sunshine hours was fond to be positively

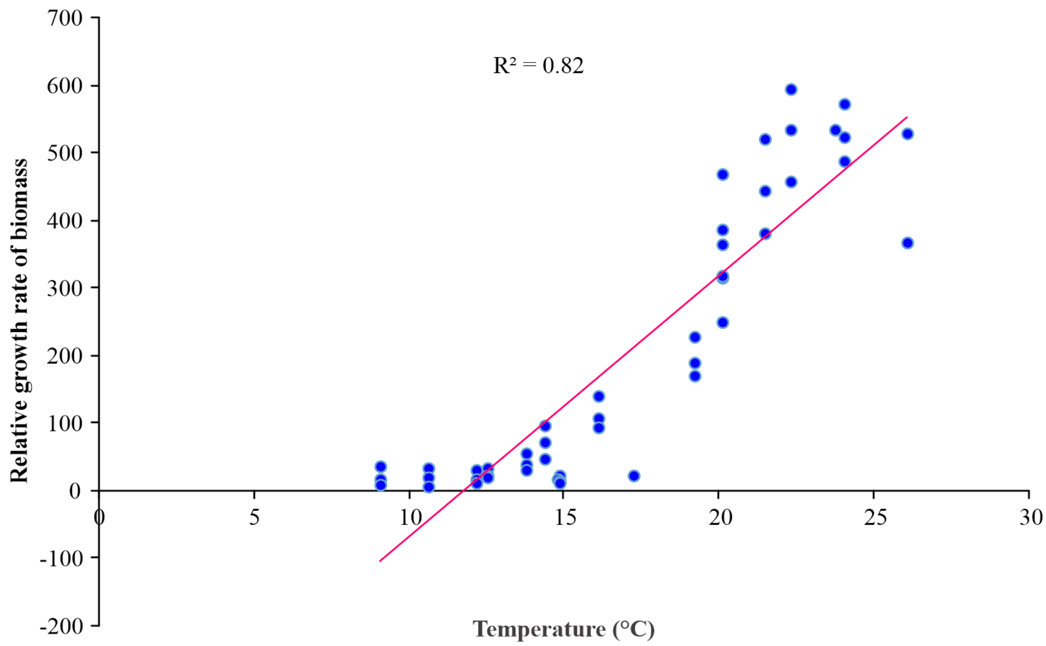

Fig. 6. Effect of mean temperature (°C) on relative growth rate of biomass per week

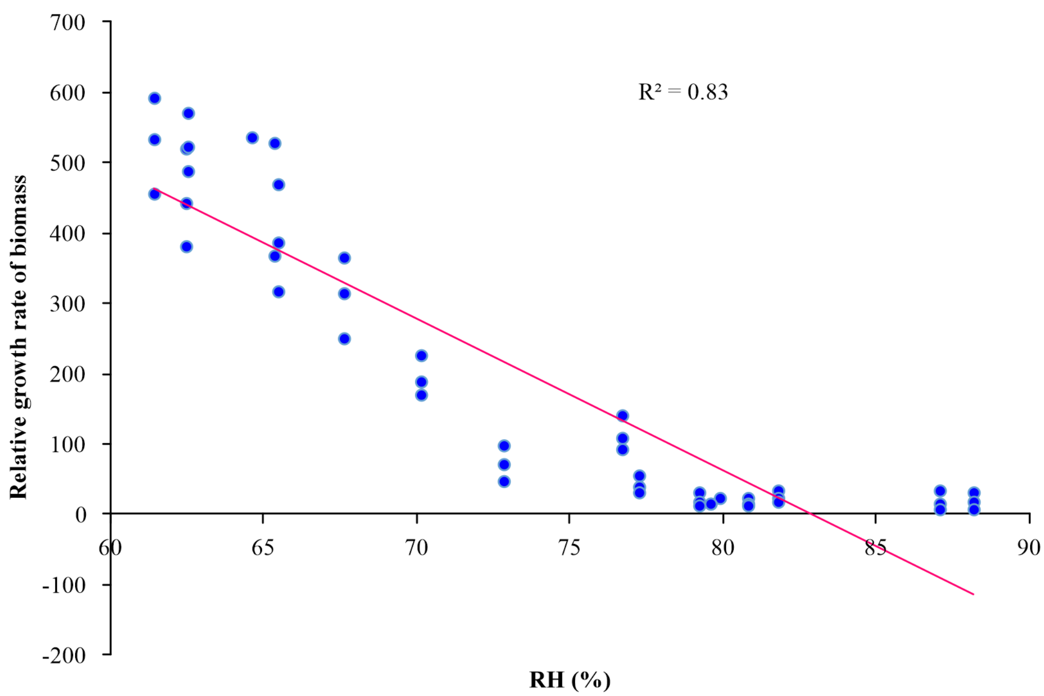

Fig. 7. Effect of relative humidity (%) on relative growth rate of biomass per week

correlated (R^2 = 0.58) with relative growth rate of biomass of the plant (Fig. 5). Soltani *et al.*, (1999) also found that daily increase in crop biomass is a function of intercepted solar radiation and the fraction of intercepted radiation is determined from crop leaf area index (Hammer *et al.*, 2010). On the other hand, increase in temperature enhances metabolism in plants, resulting into vigorous canopy growth with higher biomass accumulation and thus, strong positive correlation of relative growth of biomass with mean temperature (R^2 = 0.82) is justified as

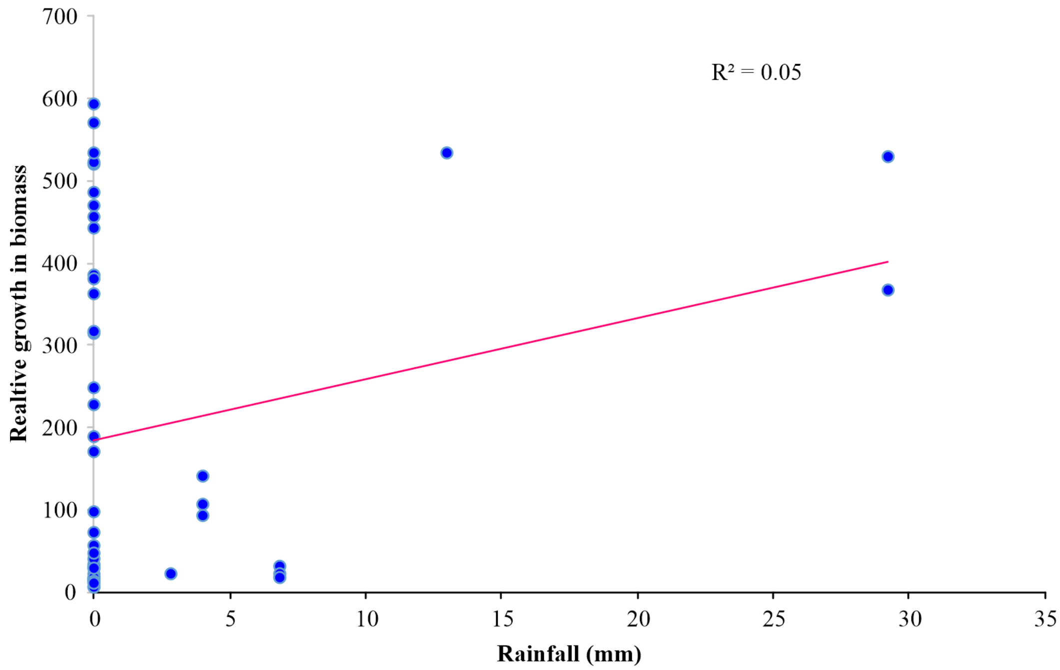

Fig. 8. Effect of rainfall (mm) on relative growth rate of biomass per week

presented in Fig. 6. The results fall in line with those of Gholipoor (2007) who also reasoned that higher temperatures may increase plant carboxilation and stimulate higher photosynthesis, respiration, and transpiration rates. Mera *et al.* (2006) found that flowering may also be partially triggered by higher temperatures, while low temperatures may reduce energy use and increased sugar storage.

A strong negative correlation(R^2 = 0.83) between relative humidity and the relative growth rate of biomass (Fig. 7) can also be ascribed to reduced transpiration and translocation of nutrient which hampered potential proliferation and gain in weight of the canopy, consequently, reduced biomass of the crop. Whereas, uneven distribution of rainfall exacerbated by its deficiency during critical growth period of the crop resulted into no correlation between weekly rainfall and relative growth of biomass of the crop (Fig. 8).

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