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Crop-Weather Relations in Groundnut and Yield Forecasting With Growing Degree Days in the Southern Region of Andhra Pradesh

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ABSTRACT

The potential productivity of groundnut depends on the weather relations of the crop during the growing season. The study of crop weather relations in rapidly changing climate situations is essential in order to understand the behavior of the crop in response to these changes. A field experiment was conducted between 2011 and 2018 at RARS, Tirupati, to study groundnut crop weather relationships in the Southern Zone of Andhra Pradesh. The experiment was laid in split plot design with three replications. The main plot treatments comprised of three dates of sowing viz., sowing during 2nd fortnight of June, 1st fortnight of July and 2nd fortnight of July and sub treatments consisted of six varieties. The study showed that during seedling emergence, maximum temperature prevailed from pod growth until maturity had a major positive impact on groundnut output. Maximum temperature and after noon relative humidity during flowering had a strong positive correlation with pod yield, while during the initiation stage of the pod wind velocity showed a negative correlation. Night temperatures ranged from 22.4 to 25.3 °C and maximum temperatures ranged from 32.7 to 34.5 °C during the reproductive period and even distribution of 294 mm rainfall during pod growth until maturity is optimal for groundnut to ensure an optimum yield of 1450 kg per hectare under rainfed conditions. For prediction of distinct phenophases and maturity, regression equations were developed and validated. The findings are within the +/- 10% error and are better suited to Andhra Pradesh's Southern Region. It was concluded from the experimental studies that Spanish groundnut varieties need accumulation of 2010 to 2085 growing degree days (GDD) to achieve maturity.

Keywords Crop weather relations, Growing degree days (GDD), Groundnut, Phenology, Yield forecast.

INTRODUCTION

Growth and yield of a crop depend on a number of factors like management, cultivars however, climate plays the most important role. Among the climatic parameters solar radiation, temperature, humidity and rainfall are very important. Oil seed crops, particularly peanut are very sensitive to climatic parameters such as radiation and temperature (Banik *et al.* 2009). Crop management practices such as sowing time and the selection of appropriate cultivars are essential for exploring the benefits of a favorable environment in

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Table 1. Optimum weather for different phenophases of *kharif* groundnut.

Phenophase	Sowing - emergence		Emergence - 50% flowering		50% Flowering - pegging		Pegging - Pod initiation		Pod initiation - Pod maturity	
T_{max}	34.6	36.1	34.2	35.6	33.6	34.9	33.2	34.5	32.7	33.6
T_{mini}	25.2	26.0	25.0	25.7	24.4	25.3	23.8	25.1	22.4	23.8
T mean	29.9	31.0	29.7	30.6	29.1	30.0	27.1	34.2	27.6	28.6
DV	9.2	10.3	9.0	10.1	8.7	10.1	8.7	10.2	9.5	10.6
RH1	66.7	75.4	70.2	76.5	72.3	79.0	73.6	79.8	79.4	83.5
RH2	40.7	47.8	43.4	49.3	45.7	52.1	47.3	53.5	50.4	55.1
RH mean	54.0	61.3	57.1	62.6	59.3	65.2	60.7	66.4	65.2	69.1
WV	7.8	9.7	7.2	8.7	6.1	7.9	5.4	7.2	4.4	4.9
SSH	3.2	4.6	3.1	4.7	3.2	4.8	3.5	4.9	4.6	5.2
RF (mm)		31.3		70.6		54.3		61.6		294.5
Evaporation	5.4	6.9	5.2	6.2	4.8	5.8	4.6	5.6	4.2	4.9
GDD	145.9	159.1	318.1	349.8	234.2	274.2	226.3	262.7	1014.4	1109.7
HTU	488.1	716.2	1046.4	1623.4	820.4	1261.0	849.5	1226.1	4887.9	5728.7
AGDD	145.9	159.1	468.0	504.8	723.4	757.8	962.3	1007.9	2008.0	2086.2
AHTU	488.1	716.2	1643.2	2230.8	2590.7	3364.7	3594.9	4436.1	8633.7	10013.9

order to maximize pod yield, improve yield parameters and improve peanut quality. Seed maturity depends on genotype x climate interactions. Variations in weather patterns affect the length of the growing season as well as the date of flowering and pod development and declining minimum temperatures in later sowings could slow down the pod development. High temperatures could potentially damage depending on the additional temperature increase resulting from partial stomata closure (Pradhan *et al.* 2018). The potential productivity of groundnuts depends on the weather relations of the crop during the growing season, which in turn depends on the time of sowing. Optimum sowing time is determined for each crop to adjust the duration of the crop growth phases to match the weather conditions. According to Patel *et al.* (2013) 19-31% yield reduction will be there in groundnut which was sown at the onset of monsoon and 21-38% yield reduction may be there in the case of groundnut which sown 15 days later, due to change in weather.

The phenology of the crop until its maturity and yield is mainly influenced by temperature. Crop growth and physical development are determined by heat units. Each stage of plant development requires accumulation of degree-days, which is relatively constant and independent of the date, crop and variety of sowing. The duration of each growth phase determines the accumulation and partitioning of the dry matter in the various organs. The concept of heat units is based on the cumulative effect of temperature and crop phenology used to describe the relationship between crop temperatures. Optimum time of sowing is one of the important aspects that gives an opportunity for better utilization of natural resources by the crop. It helps in identification of critical phenological phases of crops for achieving optimum production

Table 2. Correlation coefficients between weather parameters and groundnut pod yield during different phenophases.

	Sowing emergence	Emergence - 50% flowering	50% Flowering - pegging	Pegging pod initiation	Pod initiation pod maturity
T_{max}	0.51*	0.44*	0.21	0.35	0.33
T_{min}	0.21	0.34	-0.05	-0.07	0.10
T mean	0.43*	0.45*	0.13	0.42	0.21
DV	0.52*	0.35	0.25	0.36	0.13
RH1	-0.12	-0.36	-0.27	-0.08	-0.18
RH2	-0.40	-0.51*	-0.27	-0.32	-0.08
RH mean	-0.27	-0.48*	-0.30	-0.21	-0.14
WV	0.21	0.44*	0.47*	0.50*	0.28
SSH	0.38	-0.16	-0.24	0.20	-0.09
Rainfall	0.22	0.00	-0.13	-0.22	0.24
Evaporation	0.42	0.40	0.13	0.40	0.04

Table 3. Regression equations for crop weather relationship in groundnut during different phenophases.

Phenophase	Regression equation	R^2 value
Sowing - emergence	$Y = -2636.234+114.749T_{max}$	0.255
Emergence - 50% flowering	$Y = -4210.106+173.590\ T_{max}$-109.577 sunshine	0.394
	(or)	or
	$Y = 2791.348-29.687\ RH_2$	0.262
Flowering - pegging	$Y = 799.69+88.250$ WV	0.224
Pegging - pod initiation	$Y = 834.329+92.377$ WV	0.248
Pod development	$Y = -21432+641.397\ T_{max}$-123.453 Tmin+84.325 RH_2	0.384
Sowing - harvest	$Y = -9388.942 + 309.552\ T_{max} + 0.685$ RF	0.426

with less cost of cultivation. The growing degree days (GDD) or heat units helps in identification of optimum sowing window under rapidly changing climatic conditions. (Sahu 2012, Guled *et al.* 2013, Bhaskaran *et al.* 2020) given the effect of growing degree days on yield and sowing date of groundnut and weather relations. The duration of the particular stage of growth was directly related to temperature, so that crop phenophases could be predicted by growing degree days. Climate change is a major problem affecting agriculture in many ways which is varying the weather and affecting the crop yields. The study of crop weather relations in rapidly changing climate situations is essential in order to understand the behavior of the crop in response to these changes.

MATERIALS AND METHODS

A field experiment was conducted at Regional Agricultural Research Station, Tirupati to study crop weather relationship in groundnut in Southern Zone of Andhra Pradesh during 2011 to 2018. The experiment was laid in split plot design with three replications. The main treatments comprised of three dates of sowing viz., sowing during 2nd fortnight of June, 1st fortnight of July and 2nd fortnight of July and sub treatments consisted of six varieties. The gross plot size was 4.5 m × 5 m. The crop was planted with inter row spacing of 30 cm and intra-row spacing of 10 cm. A uniform recommended dose of 20:40:50 kg of N_2, P_2O_5 and K_2O fertilizers were applied at the time of sowing. All other management practices were uniformly adopted in all treatments. The interference of biotic and abiotic factors was effectively checked during the crop growth period.

Data pertaining to all weather parameters were collected from the Class B meteorological observatory located at Regional Agricultural Research Station, Tirupati. Mean weather parameters were worked out for all phenological events and simple statistical methods were used to derive the optimum range of weather parameters for groundnut crop during different phenophases at Southern zone of Andhra Pradesh. Correlation coefficients between weather parameters and yield and yield components were worked out for ascertaining crop weather relationships. Regression equations were also established to validate prediction

Table 4. Regression equations for prediction of different phenological events of groundnut.

Sl. No.	Phenological event	Regression equation	R^2 value
1	Sowing to emergence	1.743+ 0.031 GDD	0.643
2	Sowing to 50% Flowering (0-3d)	8.112 + 0.031 GDD	0.713
3	Sowing to Pegging (1-3d)	15.017+ 0.028 GDD	0.466
4	Sowing to Pod Initiation (0-3 d)	4.523 + 0.045 GDD	0.651
5	Sowing to physiological maturity (0-4d)	22.274 + 0.042 GDD	0.439

model. Accumulation of heat units was calculated using the formula

$$AGDD = \sum_{1}^{N} \{(T_{max} + T_{min})/2\} - Tb$$

Where,

T_{max}, T_{min} are daily maximum and minimum temperature (°C) and Tb is base temperature (°C) of sowing or start of phenophases and N is date of harvest or end of phenophases.

The information on crop weather relationships in groundnut in Southern Zone of Andhra Pradesh is meager and hence the experiment has been taken up with an objective to study the influence of weather on growth and performance of groundnut.

RESULTS AND DISCUSSION

Optimum weather during different phenophases

Groundnut is a tropical plant and requires a long and warm growing season. Groundnut needs well-distributed rainfall of at least 500 mm during the crop-growing season, accompanied by an abundance of sunshine and relatively warm temperature (Pandey *et al*. 2016).

The optimum weather for groundnut crop during different phenophases presented in Table 1 revealed that maximum temperature of 34.6 to 36.1°C and 29.9 to 31°C mean temperature with receipt of 31.3 mm of rainfall is congenial for germination and seedling emergence. During vegetative period afternoon relative humidity in the range of 43.4 to 49.3% and 57.1 to 62.6% mean relative humidity and maximum temperature within the range of 34.2 to 35.6 is essential for better yields. The results also revealed that optimum range of sunshine is 3.1 to 4.7 h during this corresponding stage. During the subsequent stages of pegging and pod initiation wind velocity had shown remarkable influence on the growth and performance of the crop and found optimum in the range of 7.2 to 8.7 km ph and 6.1 to 7.9 respectively. Initiation of flowering and the start of pod development stages were the most sensitive to variation in temperature and photoperiod. Physiological and morphological developments of plants are markedly influenced by temperature and day length. The experimental results also showed that night temperatures ranging from 22.4 to 25.3°C and maximum temperature ranging from 32.7 to 34.5°C during reproductive phase and even distribution of rainfall of 294 mm during pod development until maturity are optimum for groundnut for securing optimum yields of 1450 kg per hectare under rainfed situation.

Table 5. Validation of *kharif* 2018 data with regression equation (yield forecasting).

$Y = -9388.942 + 309.562\ T_{max} + 0.685\ RF$ $R^2 = 0.426$				
	Predicted	observed	Difference	Error (%)
D_1	1685	1626	59	3.6
D_2	1613	1886	-273	-14.47
D_3	1406	1540	-134	-8.70
Mean	1568	1684	-116	-6.52

The data on correlation coefficients between weather parameters and pod yield during different phenophases presented in Tables 1-2 revealed that maximum and mean temperatures have significant positive correlation from emergence to 50% flowering. Diurnal variation temperature also has similar influence during emergence of seedlings. It is also observed that afternoon relative humidity and mean relative humidity during the period from emergence to 50% flowering exhibited negative correlation with pod yield. Wind velocity has exerted significant positive influence on pod yield from emergence to pod initiation.

The regression equations to depict crop weather relationships during different phenophases are presented in Table 3. Step down procedure was followed to find most influencing weather parameter during particular phenophases that limits the growth and yield of the crop. The analysis revealed that maximum temperature prevailed during seedling emergence and pod development until maturity had significant positive influence on the performance of groundnut. Both

maximum temperature and after noon relative humidity during flowering stage had significant positive relation with pod yield while, Wind velocity showed negative influence during pod initiation stage.

Accumulation of heat units

The data on accumulation of heat units during different phenophases which remarkably influenced the advancement of crop until maturity is presented in Table 1. The data revealed that groundnut required accumulation of 145 to 159 heat units for seedling emergence. The crop has accumulated 468 to 504.8 heat units to attain 50% flowering from the date of sowing. The crop required accumulation of 723.4 to 757.8 growing degree days to reach pegging stage. Pod was initiated when 962.3 to 1007.9 heat units were accumulated. It is also evident from the table that groundnut crop requires accumulation of 2008 to 2086.2 heat units to attain maturity. Ong (1986) reported a maturity index or thermal units of 2000°Cd for the cultivars in warm regions of India at a base temperature of 10°C. The varieties TMV-2 and Robut 33-1 grown in semi-arid Anantapur region of India required 1732°Cd of growing degree days, respectively (Anonymus 2011).

Results presented in Tables 4 and 5 showed that phenological events can be predicted using the equations within the error of +/- 10 % and that the evolved regression equations are better suited to the southern zone of Andhra Pradesh.

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