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PHENOTYPIC VARIATION AND CROP-WEATHER RELATIONSHIPS AMONG GROUNDNUT (*ARACHIS HYPOGAEA* L.) VARIETIES IN SOUTHERN TELANGANA, INDIA

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ABSTRACT
Field experiment was conducted at Krishi Vigyan Kendra, Palem, Nagarkurnool District, Telangana. The influence of weather parameters on the growth and productivity of two groundnut cultivars, Kadiri-6 and Visishta (TCGS-1694), was evaluated using correlation and regression analyses. In Kadiri-6, correlation analysis revealed a favourable association of higher temperatures during the early growth period with crop establishment and dry matter production. However, relatively cooler conditions and lower relative humidity during the reproductive and maturity stages were associated with improved pod development and yield. In contrast, Visishta showed a positive response to suitable temperature conditions during early crop growth, followed by humid and relatively cooler weather during the reproductive period, which favoured dry matter accumulation, pod yield and haulm production. Regression analysis further indicated that increased temperatures from pod development to maturity and higher morning relative humidity between flowering and pod development adversely influenced pod yield in Kadiri-6, whereas higher night temperatures showed a favourable association. In Visishta, elevated maximum temperatures during physiological maturity to harvest adversely affected pod yield, while moderate temperatures during emergence to pod initiation and greater sunshine hours during pod development favoured yield formation. Dry matter accumulation was negatively associated with increased temperature and rainfall during pod and seed development. The developed regression models accounted for 97.6 and 94.4 per cent of the variation in pod yield and dry matter production, respectively, in Kadiri-6, while the corresponding values for Visishta were 99.5 and 95.4 per cent. The results establish that the response of groundnut cultivars to weather variability differs across crop growth stages, emphasizing the importance of favourable weather conditions during critical developmental periods for improving crop growth and yield.

KEYWORDS: Groundnut, weather variability, Kadiri-6, Visishta, correlation, regression

INTRODUCTION
Groundnut is the major oil seed crop in India and it plays a major role in bridging the vegetable oil deficit in the country. Groundnuts in India are available throughout the year due to a two-crop cycle. Ground Nuts are important protein crops in India grown mostly under rain-fed conditions. They have a rich nutty flavour, sweet taste, crunchy texture and over and above a relatively long shelf life. Soil conditions in some producing regions are ideally suited for dry, clean and spotless Groundnuts in shell. It is an annual herbaceous plant growing 30 to 50 cm (1.0 to 1.6 ft) tall. The leaves are opposite, pinnate with four leaflets (two opposite pairs; no terminal leaflet), each leaflet 1 to 7 cm long and 1 to 3 cm broad (Anon., 2023a). According to the USDA Trusted Source database, every 100 g of peanuts contains 560 calories and the following nutrient quantities: Protein: 20.16 g, fat: 45.32 g, carbohydrate: 27.17 g, fibre 10.60 g, sugar: 7.66 g. Healthful mono unsaturated fatty acids and PUFAs make up most of the fat content in pistachios. While pistachios offer fewer minerals than some other nuts, they contain a substantial 1,025 mg of potassium per 100 g. Other notable vitamins and minerals in pistachios include Calcium: 105 mg, Iron: 3.92 mg, Magnesium: 121 mg, Phosphorous: 490 mg (Anon., 2023b). Groundnut (*Arachis hypogaea* L.) is one of the major oilseed crops grown in subtropical and tropical regions of India occupied the first position in terms of area and second position in terms of production in the world. Presently, it occupies an area of 5705 thousand hectares, producing 10135 thousand tonnes with a productivity 1777 kg ha^{-1} (Anon., 2022). Among the states, Telangana (1.55 lakh ha) stands first with respect to area followed by Karnataka (1.01 lakh hectares), Andhra Pradesh (0.23 lakh hectares), Odisha (0.16 lakh hectares) and Tamil Nadu (0.15 lakh hectares). Telangana, groundnut is occupying with an area of 155 thousand hectares, producing 349.84 thousand tonnes with the

productivity of 2257 kg ha^{-1} during 2021-22. Within the Telangana state, Nagarkurnool district is occupying the largest area (30420.99 hectares) when compared to rest of the districts (Anon., 2022).

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 is 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 favourable environment in 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 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 Krishi Vigyan Kendra, Palem, Nagarkurnool District which is geographically situated at 16° 314' N latitude and 78° 15'3" E longitude and at an altitude of 480 m above mean sea level, covered under Southern Telangana Agro climatic zone. During the crop grown period *rabi* 2023-24 (1st Oct 2023 to 15th April, 2024), weekly mean maximum temperature in crop growth period ranged between 30.7 ºC to 41.9 ºC with an average of 35.2 ^{0}C and weekly mean minimum temperature ranged from 15.1 ºC to 24.6 °C with an average of 19.6 °C. The weekly mean pan evaporation during the cropping period ranged from 3.5 to 9 mm day^{-1} with an average of 5.5 mm day^{-1}. Rainfall 1.8 mm was received and 2 rainy days were recorded in season. The weekly mean morning relative humidity (R.H-I) ranged from 62.2 to 100 per cent with an average of 91.7 per cent and while weekly mean afternoon relative humidity (R.H-II) ranged from 54.6 to 15 per cent with an average of 33.3 per cent. The weekly mean sunshine hours ranged from 3.1 hour to 9.1 hours with an average of 6.5 hours. Standard weeks, weekly mean wind velocity ranged from 0 to 6.2 km h^{-1} with an average of 4.5 km h^{-1} during the study from 40th to 52nd weeks in 2023 and 1st to 15th weeks in 2024. During the crop grown period *rabi* 2024-25 (1st Oct 2024 to 15th April, 2025), weekly mean maximum temperature during the crop growth period during rabi 2023-24 r*abi* (1st Oct 2024 to 14th April, 2025) ranged between 30.6 ºC to 39.6 ºC with an average of 34.9 ^{0}C and the weekly mean minimum temperature ranged from 14.6 ºC to 23.0 °C with an average of 18.7 °C. The weekly mean pan evaporation during the cropping period ranged from 4.7 to 9.7 mm day^{-1} with an average of 7.1 mm day^{-1} and 18 mm rainfall was received during the crop growing season with 7 rainy days. The weekly mean morning relative humidity (R.H-I) ranged from 84.0 to 100 per cent with an average of 96.6 per cent and afternoon relative humidity (R.H-II) during the crop season ranged from 21.6 to 69.8 per cent with an average of 39.20 per cent. The weekly mean sunshine hours ranged 3.1 hour to 9.1 hours with an average of 6.9 hours. Weekly mean wind velocity ranged from 2.6 to 4.2 km h^{-1} with an average of 3.5 km h^{-1} during the study during the study from 40th to 52nd weeks in 2024 and 1st to 15th weeks in 2025. Soil samples were collected by excavating a vertical soil profile pit of 1 m × 1 m × 1 m at the experimental site. Samples were taken from different soil layers of the profile for analysis in order to generate physical, physico chemical and soil profile data on the following parameters. Soil was sandy loam in texture with pH of 8.03 (moderately alkaline and very low in salt content 0.42 dS m^{-1}). The soil was very low in organic carbon (0.31 %), low in available nitrogen (164.3 kg ha^{-1}), high in available phosphorus (42.3 kg ha^{-1}) and medium to high in available potassium (182.4 kg ha^{-1}), medium in sulphur (10.6 ppm) and low in calcium (13.1 c mol (p^{+}) kg^{-1} soil) bulk density of 1.42 g c^{-3} and hydraulic conductivity was

44.6 mm hr^{-1}. Varieties were procured from RARS, Palem *viz.,* K6 Groundnut variety was nationally released in 2005 and was originally developed at the Rekulakunta Research Station in Andhra Pradesh. It is having duration 110-115 days, Yield potential 40-45 q ha^{-1}, Oil % 48, shelling % 74, 100 kernel weight 35-40 g, Early, high yielding, Spanish bunch, attractive kernel and synchronous maturity. Groundnut variety TCGS 1694 was released in 2023 by Professor Jayashankar Telangana Agricultural University. It is having 105-110 days duration, Yield Potential 40-45q ha^{-1} with 73-75% shelling percentage, 100 seed weight 40-42g, oil content 50 %, Short stature, pink testa, Rust and Drought tolerant. The experiment was titled with "Calibration and Validation of CSM-CROPGRO- Peanut model to simulate optimum sowing time and phosphorus level for Groundnut varieties in alfisols of Southern Telangana Zone" was conducted during *Rabi* 2023-24 and 2024-25 to find out suitable optimum time of sowing and phosphorus level for groundnut varieties viz., Kadiri-6 (K-6) and TCGS-1694 (Visishta) to realise higher pod yield of Groundnut. The treatment was laid out in a spilt plot design with four replications. The gross and net plot size was 5.4 m × 3.8 m and 4.5 m x 3.4 m respectively. Spacing of 22.5 × 10 cm was followed with seed rate of 150 kg ha^{-1}. Five dates of sowings taken under main plots viz., D_1: 1st Fortnight of October, D_2: 2nd Fortnight of October, D_3: 1st Fortnight of November, D_4: 2nd Fortnight of November, D_5: 1st Fortnight of December and D_6: 15th of December, two varieties were taken under sub plots viz., Kadiri-6 (K-6) and Visishta, (TCGS-1694). Four phosphorus levels were taken under sub-sub plots viz., P_1: 0 kg P_2O_5 ha^{-1} (No Phosphorus), P_2: 20 kg P_2O_5 ha^{-1}, P_3: 40 kg P_2O_5 ha^{-1} and P_4: 60 kg P_2O_5 ha^{-1}. Two varieties were taken under sub plots viz., Kadiri-6 (K-6) and Visishta (TCGS-1694). Groundnut varieties for seed purpose were brought from Regional Agricultural Research Station, Palem. Land was prepared by ploughing once with mould board plough and twice with a tractor drawn cultivator followed by harrowing with disk harrow and levelled with a tractor drawn leveller. The uprooted weeds and stubbles were removed. The plot was laid out as per the layout plan and bunds were formed with bund former. Levelling within the plots was done manually. Healthy and matured seed with a germination per cent more than 90 for both the varieties Kadiri-6 (K-6) and Visishta (TCGS-1694) was taken and sowing was done as per the dates of sowing treatments of the experiments from 1st October to 15th December for both the experiments during *Rabi* 2023-24 and 2024-25 by dibbling method using one seed per spot with a recommended spacing of 22.5 cm x 10 cm at a depth of 4 to 5 cm. Thinning and gap filling was done simultaneously at 10 days after sowing to obtain uniform plant stand. Recommended dose of fertilizers 40:40:50 N: P_2O_5: K_2O kg ha^{-1} (Gypsum @ 500 kg ha^{-1} for Ca and S). Nitrogen fertilizer was applied in two splits i.e., 50 per cent as basal and remaining 50 per cent at 30 DAS in the form of urea and both Phosphorus, Potassium fertilizers were applied 100 per cent in the form of single super phosphate and muriate of potash as basal but gypsum @ 500 kg ha^{-1} was applied at flower initiation stage. First irrigation was given one day after sowing to ensure uniform germination. Eight to nine irrigations were given throughout the crop growth period as and when the crop was in need. Final irrigation was given three days before harvesting of crop. Hand weeding was done twice at 20 and 35 days after sowing. Seed treatment done with imidacloprid 2 ml kg^{-1} seed to control white grubs, Tebuconazole 1g kg^{-1} and Trichoderma viride 10 g kg^{-1} to manage fungal diseases like collar, stem, and root rot. Light incidence of leaf eating caterpillars was observed for which neem oil 1500 ppm @ 3 ml L^{-1} was spraying at 30 DAS and at pod initiation stage. Fipronil 40% + Imidacloprid 40% WG @ 0.5 ml L^{-1} spraying against sucking pests Aphids and Jassids. At pod initiation and development stage, wilt and leaf spot incidence was observed and spraying of Tebuconazole 50% + Trifloxystrobin 25% WG 0.4 g L^{-1} was done to control above diseases. The crop was harvested was done as per the dates of sowing treatments of the experiments from 1st February to 15th April during 2023-24 and 2024-25 for both the experiments by manual harvesting method when more than 90 per cent of the pods matured and randomly selected plants showed black streaks on the inner wall of the shell. In each plot, four rows of the crop (two rows on either side) were left as border rows in each plot. On either side, along breadth of the plot, five plants were left as border. The border rows of the plot were first harvested followed by the plants in the net plot. The pods were hand stripped and sundried to reach to constant weight. The pod yield was recorded in q ha^{-1}. After stripping the pods, the haulm yield was also recorded after sun drying and expressed in q ha^{-1}. Observations taken from ten plants in each net plot were selected at random and tagged for taking observations on growth parameters at flower appearance, first pod formation, first seed formation, and physiological maturity stages and yield attributes and yield at each stage. Destructive sampling (dry matter production) was done in gross plots by taking five plants each time from the border rows leaving the extreme row of the plot. Composite soil samples were collected before sowing and after harvest of crop to estimate the soil pH, EC, organic carbon, initial and final available nutrient status of available nitrogen, phosphorus and potassium in soil and expressed in kg ha^{-1}. The price in rupees for the inputs at the time of their use and price for produce obtained that were prevailing at the time of sale was considered for working out the cost of cultivation, returns and B: C ratio as below. Data on different characters *viz.,* growth and yield components and yield, were subjected to analysis of variance procedures as outlined for Split plot design (Gomez and Gomez, 1984). Statistical significance was tested by F value at 0.05 level of probability and critical difference was worked out wherever the effects were significant. The influence of weather parameters was studied by comparing each date of sowing at two varieties and four phosphorus levels thus constituting ten and six teen treatmental combinations.

RESULTS AND DISCUSSION

Correlation Coefficients of Cultivar Kadiri-6:

Warmer temperatures during the initial growth stages favoured plant establishment and dry matter accumulation, whereas lower temperatures and relative humidity during the reproductive and maturity stages supported pod development and yield. Temperature and evening relative humidity (RH-II) were the most influential weather parameters affecting biomass accumulation and pod yield in Kadiri-6, the results were presented in (Table No. 1).

Table 1. Correlation coefficients between weather parameters during different phenophases and drymatter production, haulm yield and pod yield of Kadiri-6.

Phenophases	T max	T min	T mean	RH-I	RH-II	BSSH	E vap
Drymatter production at first flower							
P_1	.891**	.709**	.891**	.349	.119	.359	.284
P_2	.778**	.874**	.921**	-.247	.359	-.514	.110
Drymatter production at first pod							
P_1	.855**	.716**	.880**	.391	.138	.408	.331
P_2	.844**	.825**	.913**	-.146	.264	-.415	.173
P_3	-.523	.663**	.093	.112	.840**	-.768**	-.484
Drymatter production at first seed							
P_1	.865**	.719**	.887**	.391	.135	.404	.332
P_2	.841**	.833**	.917**	-.162	.272	-.430	.165
P_3	-.544*	.656*	.072	.125	.852**	-.774**	-.496
P_4	-.941**	-.227	-.793**	.530	.906**	-.337	-.648*
Drymatter production at physiological maturity							
P_1	.892**	.681**	.873**	.380	.098	.425	.304
P_2	.805**	.902**	.951**	-.246	.368	-.517	.129
P_3	-.581*	.639*	.034	.242	.860**	-.710**	-.528
P_4	-.926**	-.195	-.767**	.581*	.901**	-.449	-.663**
P_5	-.941**	-.835**	-.927**	.704**	.794**	.134	-.441
Haulm yield							
P_1	.765**	.254	.524	.327	-.253	.583*	.546*
P_2	.670**	.418	.558*	-.591*	-.021	-.306	.268
P_3	-.636*	.378	-.193	.288	.826**	-.538*	-.330
P_4	-.773**	-.524	-.815**	.632*	.657*	.188	-.265
P_5	-.593*	-.763**	-.702**	.700**	.397	.136	-.047
Pod yield							
P_1	.878**	.589*	.804**	.453	-.061	.462	.319
P_2	.761**	.827**	.881**	-.464	.243	-.572*	.048
P_3	-.765**	.517	-.187	.190	.899**	-.745**	-.617*
P_4	-.967**	-.381	-.886**	.712**	.831**	-.284	-.687**
P_5	-.837**	-.850**	-.878**	.691**	.578*	.140	-.354

P_1- Sowing to emergence, P_2-Emergence-first flower appearance, P_3-First flower appearance- first pod, P_4- First pod- first seed, P_5- First seed- physiological maturity; T max- maximum temperature, T min- minimum temperature, T mean- mean temperature, RH-I- Morning relative humidity, RH-II- Afternoon relative humidity, BSSH- Bright sunshine hours, Evap - Evaporation

Maximum temperature (T_{max}):

Shown strong positive correlation to pod yield, dry matter and haulm yield production at early stages of the crop growth (P_1 and P_2) and indicates that warmer temperatures promote crop establishment as well as vegetative growth. Similar results were also found by Meena *et al.* (2005). This might be due to warmer temperatures that

improve the germination, root growth, uptake of nutrients and efficiency of photosynthesis leads ultimately to better dry matter production. Maximum temperature in case of (P_3, P_4 and P_5 stages) observed negative correlations significantly with regards to yield and dry matter production. Similar results were also found by Ashwini *et al.* (2024). Higher temperature at pod and seed development respiration rate increases that leads to reduced translocation of assimilates.

Minimum temperature (T_{min}):

Minimum temperature showed a positive correlation with pod yield and dry matter production during the vegetative and flowering stages (P_2 and P_3). This may be attributed to the favourable effects of optimum night temperatures on cell division, enzyme activity and the accumulation of assimilates, thereby ensuring adequate food reserves for crop growth and development. In contrast, negative correlations were observed during the seed filling and maturity stages, possibly due to increased maintenance respiration under higher night temperatures, which accelerates the depletion of stored carbohydrates and reduces assimilate availability for seed development. Similar findings were reported by Mote *et al.* (2024).

Mean temperature (T_{mean}):

A strong positive correlation was observed between mean temperature and pod yield and dry matter production during the early growth stages (P_1 and P_2), possibly due to favourable temperatures promoting leaf area development, photosynthetic activity and crop growth. Similar findings were reported by Yadav (2023). However, the mean temperature showed a negative correlation with yield attributes during the pod development and crop maturity stages (P_4 and P_5), suggesting that elevated temperatures during the reproductive phase may shorten the seed filling duration and limit assimilate partitioning towards developing pods, ultimately reducing yield.

Morning relative humidity (RH-1):

During the early growth stages (P_1, P_2 and P_3), morning relative humidity showed weak correlations with pod yield, dry matter production and haulm yield, whereas positive correlations were observed during the later growth stages. Similar findings were reported by Vinu *et al.* (2020). Adequate morning relative humidity may help to maintain plant water status, support photosynthetic activity and facilitate assimilate production and translocation to developing pods, thereby contributing to higher yields.

Afternoon relative humidity (RH-II):

Pod yield, dry matter production and haulm yield showed strong positive correlations with evening relative humidity (RH-II) during the later growth stages (P_3, P_4 and P_5). Similar findings were reported by Vinu *et al.* (2020). Higher evening relative humidity may help to maintain favourable crop water relations during the reproductive phase by reducing moisture loss through transpiration and supporting plant physiological activities. These conditions may promote flowering, pegging, pod development and assimilate accumulation, thereby contributing to higher pod yield and biomass production.

Bright sunshine hours (BSSH):

Bright sunshine hours showed a positive correlation with dry matter production during the initial growth stage (P_1), possibly due to increased solar radiation availability, which enhances photosynthetic activity and biomass accumulation. Similar findings were reported by Yadav (2023). In contrast, negative correlations were observed between bright sunshine hours and pod yield and dry matter production during the flowering and pod development stages (P_2 and P_3). This may be attributed to increased evapotranspiration and canopy temperature under prolonged sunshine, which can intensify moisture stress, impair reproductive development and ultimately reduce crop productivity. Similar findings were reported by Vinu *et al.* (2020).

Evaporation (Evap):

Negative correlations were observed between evaporation rate and pod yield and dry matter production during the reproductive stages. Similar findings were reported by Mote *et al.* (2024). Higher evaporation rates increase atmospheric water demand, accelerate soil moisture depletion and intensify crop water stress. During the seed filling and maturity stages, excessive evaporative demand may impair assimilate accumulation and translocation to developing pods, ultimately reducing pod yield in groundnut.

Correlation coefficients of cultivar Visishta (TCGS-1694)

Positive correlations were observed between optimum temperatures during the early growth stages and crop productivity. During the reproductive phase, humid and relatively cooler conditions favoured dry matter accumulation, pod yield and haulm yield in groundnut variety Visishta (TCGS-1694). These favourable weather conditions may have supported photosynthetic activity, maintained crop water status and enhanced assimilate partitioning towards developing pods, thereby contributing to improved crop productivity, the results were presented in (Table No. 2).

Table 2. Correlation coefficients between weather parameters during different phenophases and drymatter production, haulm yield and pod yield of Visishta.

Phenophases	T max	T min	T mean	RH-I	RH-II	BSSH	E vap
Drymatter production at first flower							
P_1	.889**	.675**	.861**	.386	.031	.419	.280
P_2	.807**	.882**	.932**	-.257	.269	-.540*	-.001

Drymatter production at first pod							
P_1	.840**	.718**	.868**	.510	.189	.424	.373
P_2	.862**	.832**	.919**	-.188	.250	-.436	.212
P_3	-.615*	.631*	-.011	.064	.905**	-.779**	-.485
Drymatter production at first seed							
P_1	.841**	.711**	.864**	.517	.177	.442	.380
P_2	.855**	.838**	.921**	-.210	.261	-.459	.205
P_3	-.633*	.623*	-.030	.071	.913**	-.764**	-.490
P_4	-.955**	-.385	-.856**	.616*	.906**	-.246	-.625*
Drymatter production at physiological maturity							
P_1	.817**	.636*	.802**	.551*	.073	.396	.373
P_2	.740**	.749**	.813**	-.322	.211	-.507	.119
P_3	-.769**	.457	-.256	.050	.916**	-.766**	-.529
P_4	-.959**	-.561*	-.939**	.704**	.805**	-.079	-.601*
P_5	-.805**	-.870**	-.871**	.765**	.561*	.213	-.247
Haulm yield							
P_1	.528	.373	.492	.545*	-.068	.112	.164
P_2	.305	.427	.417	-.376	.137	-.510	-.127
P_3	-.814**	.012	-.614*	.009	.681**	-.573*	-.463
P_4	-.729**	-.613*	-.798**	.647*	.462	.239	-.421
P_5	-.364	-.601*	-.498	.483	.061	.247	.013
Pod yield							
P_1	.856**	.669**	.843**	.411	.144	.502	.398
P_2	.904**	.847**	.946**	-.227	.237	-.409	.243
P_3	-.541*	.723**	.112	.115	.879**	-.727**	-.474
P_4	-.919**	-.299	-.791**	.567*	.910**	-.353	-.622*
P_5	-.972**	-.881**	-.967**	.787**	.834**	.138	-.419

P_1- Sowing to emergence, P_2-Emergence-first flower appearance, P_3-First flower appearance- first pod, P_4- First pod- first seed, P_5- First seed- physiological maturity; T max- maximum temperature, T min- minimum temperature, T mean- mean temperature, RH-I- Morning relative humidity, RH-II- Afternoon relative humidity, BSSH- Bright sunshine hours, Evap - Evaporation

Maximum temperature (Tmax):

Pod yield and dry matter production showed strong positive correlations with maximum temperature during the early growth stages (P_1 and P_2). Similar findings were reported by Meena *et al.* (2005). This relationship may be attributed to optimum temperatures favouring leaf area development, photosynthetic activity and nutrient uptake, thereby promoting crop growth and biomass accumulation. In contrast, maximum temperature exhibited negative correlations with dry matter production, pod yield and haulm yield during the reproductive stages (P_3 and P_4). Elevated temperatures during flowering and pod development may impair flower formation, increase flower and pod abortion and reduce assimilate accumulation and partitioning, ultimately resulting in lower crop productivity. Similar findings were reported by Ashwini *et al.* (2024).

Minimum temperature (T min):

Minimum temperature showed positive correlations with pod yield and dry matter production during the early growth stages (P_1 and P_2), possibly because optimum night temperatures supported metabolic activities and biomass accumulation. A positive correlation was also observed during the reproductive stage (P_3). In contrast, negative correlations were observed during pod development and crop maturity, suggesting that higher minimum temperatures may increase nocturnal respiration and accelerate the depletion of stored carbohydrates, thereby reducing assimilate availability for pod development and ultimately lowering crop yield. Similar findings were reported by Mote *et al.* (2024).

Mean temperature (T mean):

Mean temperature showed a positive correlation with pod yield and dry matter production during the early growth stages (P_1 and P_2). Similar findings were reported by Yadav (2023). This positive relationship may be attributed

to optimum temperatures that promote photosynthesis, crop growth and dry matter accumulation. In contrast, negative correlations were observed during the later stages (P_4 and P_5), corresponding to pod development and seed filling. Higher mean temperatures during these reproductive stages may accelerate crop maturity and shorten the duration of assimilate production and translocation to developing pods, thereby observed yield reduction.

Morning relative humidity (RH-1):

Morning relative humidity showed a positive correlation with pod yield, haulm yield and dry matter accumulation, particularly during the reproductive phase. Similar findings were reported by Vinu *et al.* (2020). Higher morning relative humidity may help maintain plant water balance by reducing transpiration losses, thereby supporting physiological processes and nutrient uptake. Adequate humidity may also favour photosynthetic activity and the production and translocation of assimilates towards developing pods, ultimately contributing to improved crop growth and yield.

Afternoon relative humidity (RH-II):

Afternoon relative humidity (RH-II) showed positive correlations with crop yield and dry matter production during the flowering, pegging and pod development stages (P_1, P_2 and P_3). Similar findings were reported by Vinu *et al.* (2020). Higher afternoon relative humidity may help alleviate crop water stress by reducing evaporative demand and maintaining favourable plant water status. These conditions may support flowering, pegging and pod development, thereby enhancing assimilate accumulation and partitioning towards reproductive organs and ultimately improving groundnut yield.

Bright sunshine hours (BSSH):

Bright sunshine hours showed a positive correlation with crop growth during the initial stages, possibly due to increased solar radiation availability, which enhances photosynthetic activity and dry matter accumulation. Similar findings were reported by Yadav (2023). In contrast, negative correlations were observed during the reproductive phase, indicating a decline in pod yield and dry matter production under prolonged sunshine conditions. Increased sunshine hours may intensify evapotranspiration, accelerate soil moisture depletion and induce crop water stress, thereby impairing reproductive development and reducing yield. Similar findings were reported by Vinu *et al.* (2020).

Evaporation (Evap):

Evaporation rate showed negative correlations with pod yield, haulm yield and dry matter accumulation during the reproductive phase. Similar findings were reported by Mote *et al.* (2024). Higher evaporation rates increase water losses from the soil and crop, leading to soil moisture depletion and intensified crop water stress. These conditions may impair seed filling, restrict biomass accumulation and reduce assimilate partitioning towards developing pods, ultimately decreasing yield in groundnut.

Regression analysis

Regression equation describes that how weather elements were affected the dry matter and pod yield production of cultivars in groundnut crop. Coefficient signs (- or +) explains that negative or positive relation to the weather elements whereas (R^2) indicates coefficient of determination which quantify the variation in dry matter and pod yield.

Regression equations for variety Kadiri-6

Pod yield(Y) = 12596 – 151.4 * P_4 T Maximum – 63.4 P_2 RH-I + 55.4 P_2 T Minimum

$r^2 = 0.976$

During the pod development to physiological maturity phase (P_4), maximum temperature exhibited a negative coefficient, indicating that raised temperatures during pod development may reduce crop yield by increasing respiratory losses, accelerating leaf senescence and disrupting the source sink relationship, thereby limiting the translocation of photosynthates to developing pods. Similar findings were reported by Ashwini *et al.* (2024). During the flowering to pod development phase (P_2), morning relative humidity also showed a negative coefficient, possibly due to its association with reduced light interception and favourable conditions for pest and disease incidence. Similar findings were reported by Vinu *et al.* (2020). In contrast, a positive coefficient was observed for minimum temperature during P_2, suggesting that favourable night temperatures may enhance metabolic activity and nutrient uptake, promote leaf area expansion and dry matter accumulation, and ultimately improve pod yield. Finally, coefficient of determination R^2 (97.6 %) describes that influence of weather elements were most responsible for yield variation in K-6.

Dry matter production at physiological maturity (Y) = 1317 + 331.5 * P_2 T Mean - 131.8* P_4 T Maximum

$r^2 = 0.942$

During the flowering to pod development stage (P_2), a positive coefficient was observed for dry matter accumulation, indicating that favourable temperatures may promote photosynthetic activity, leaf area development and biomass production. Moderate temperatures generally favour dry matter accumulation in groundnut, as reported by Yadav (2023). In contrast, a negative coefficient was observed during the pod development stage (P_4), possibly due to increased photorespiration and reduced assimilate availability under raised temperatures. Heat stress may also shorten the seed filling period, thereby limiting dry matter accumulation. Similar findings were reported by Mote *et al.* (2024). These results indicate that dry matter production in groundnut variety Kadiri-6 was influenced by temperature conditions during both the vegetative and pod development stages. Overall R^2

(94.4 %) describes that influence of weather elements were most responsible towards dry matter accumulation at different growth stages in K-6.

Regression equations for variety Visishta (TCGS-1694)

Pod yield (Y) = 2703.7 – 127.9 * P_5 T Maximum + 28.5 * P_4 BSSH + 178 * P_2 T Maximum + 108.7 * P_1 T Maximum

$r^2 = 0.995$

During physiological maturity to harvest stage (P_5), maximum temperature exhibited a negative coefficient for pod yield, possibly due to increased moisture stress and accelerated crop senescence, which may adversely affect pod development and final yield. Similar findings were reported by Mote *et al.* (2024). In contrast, positive coefficients were observed during the emergence to flowering (P_1) and flowering to pod initiation (P_2) stages, indicating that favourable maximum temperatures may promote crop establishment, root growth and nodulation, thereby supporting overall crop growth and development. Similar findings were reported by Meena *et al.* (2005). Additionally, bright sunshine hours showed a positive coefficient for pod yield during the pod development to seed development stage (P_4), possibly due to improved solar radiation availability, which enhances photosynthetic activity and dry matter accumulation, ultimately contributing to higher pod yield. Similar findings were reported by Yadav (2023). Coefficient of determination R^2 (99.5 %) denotes that pod yield was highly influenced by the weather elements in variety Visishta.

Dry matter production at physiological maturity(Y) = 16726–324.4 * P_4 T Max – 7.3* P_2RF

$r^2 = 0.954$

Pod to seed development stage (P_4), elevated temperatures showed a negative association with dry matter production, possibly due to increased respiratory losses and reduced photosynthetic efficiency, which limit assimilate accumulation and biomass production. Similar findings were reported by Ashwini *et al.* (2024). Negative associations were also observed between rainfall and dry matter production during the flowering and pod initiation stages (P_2 and P_3), potentially due to excessive soil moisture, poor drainage and inadequate soil aeration, which may impair root respiration and nutrient uptake. Overall, moderate temperatures and favourable soil moisture conditions appeared to support greater dry matter accumulation in groundnut variety Visishta (TCGS-1694) than conditions associated with moisture stress. Similar findings were reported by Yadav (2023). R^2(95.4 %) shows that weather elements were highly responsible for dry matter accumulation.

We may conclude that with the regression analysis, both the varieties were highly influenced by the temperature, whereas moderate temperatures improved germination and vegetative growth and yield. Higher maximum temperature negatively effects the dry matter accumulation and pod development at reproductive phase by reducing the time span for seed filling. Higher coefficient of determination value explains most of the variations in dry matter and pod yield was because of specific weather elements.

CONCLUSION

Correlation analysis revealed that weather parameters significantly influenced the growth and yield attributes of groundnut cultivars. Optimal temperatures during the early growth stages and favorable cooler, humid conditions during the reproductive stages supported greater biomass accumulation and yield development. Thus, stage specific weather conditions played a crucial role in enhancing the productivity of Kadiri-6 and Visishta (TCGS-1694). Regression analysis stated that weather parameters strongly influenced the productivity of both groundnut cultivars, with higher coefficients of determination (R^2) indicating excellent model fit. Higher temperatures during the reproductive and physiological maturity stages adversely affected yield and dry matter accumulation, whereas favorable temperatures during early growth and increased sunshine hours during pod development enhanced crop performance. Visishta (TCGS-1694) exhibited a slightly stronger relationship between weather parameters and yield than Kadiri-6 under the existing weather conditions.

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Conflict of interest

The authors declare no conflict of interest.

Authors' contributions

K.R.K.: Conceptualization, methodology, Experimentation, formal analysis and writing - original draft; P.S.R, S.G.M, B.M.D, D.H.P, T.P.R and R.G.T.: writing - review, editing, supervision, and critical review.

Ethics and field permissions

The study involved field experiment conducted during *Rabi* 2023-24 and 2024-25 at KVK farm, Palem in Nagarkurnool district, Telangana, India, under the supervision of KVK, Palem. The experiments did not involve animals as research subjects. Permission to conduct the field experiment was obtained from the PJTAU before the

initiation of the experiments. The study was conducted in accordance with applicable institutional guidelines for on-farm agricultural research.

Data availability statement

The field-level experimental data supporting the findings of this study, including crop growth, yield attributes, pod yield observations are provided to accompanying this article. Additional information regarding the experimental methods and data analysis may be obtained from the corresponding author upon reasonable request.

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