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# Growth and yield responses of selected cowpea (V*igna unguiculata* L. Walp) cultivars to weather and soil factors of the sowing seasons

S.O.Agele*, O.M.Agbi

Department of Crop, Soil & Pest Management, Federal University of Technology, PMB 704, Akure, (NIGERIA)

E-mail: ohiagele@yahoo.com

## ABSTRACT

Experiments were conducted at the Teaching and Research Farm of the Federal University of Technology, Akure, a humid rainforest zone of southern Nigeria to examine the effects of the prevailing weather conditions of the rainy and late sowing seasons on growth and yield of three cultivars of cowpea (*Vigna unguiculata* L. Walp). The cultivars (Ife brown, IT93K-U52-1 and IT89KD-341) were chosen on the basis of contrasting maturity and seed yield, and were sown during the rainy and late seasons of 2008 and 2009. The sowing seasons were characterized by varying amounts of rainfall, solar radiation, open water evaporation (Eo), humidity (vapour pressure deficits – vpd) and temperatures. Seasonal effects were significant ($P>0.05$) on cowpea growth and seed yield. However, within a sowing season, the cultivars differed in their responses in terms of growth duration, dry matter production and seed yield. In both seasons, shoot biomass is greater in Ife brown while IT89KD-341 had significantly ($P>0.05$) higher seed yield than cultivar IT93K-U52-1, Higher shoot dry weights were produced by late maturing cultivars IT93K-U52-1 and Ife brown which also produced lesser weights of seeds. Late season cowpea out-yielded the rainy season crop in terms of total weight of pods and seeds produced per plant. Functional relationships between some weather variables and growth and yield characteristics of cowpea were established. These relationships gave a regression coefficient ($R^2$) which shows that, about 40% of shoot biomass and seed yield can be explained by a combination of weather parameters such as cumulative rainfall, minimum temperatures, open water evaporation, vapour pressure deficit (humidity) and thermal time requirements during the respective rainy (April - July) and late (September – December) seasons of sowing. It is concluded that the soil and weather conditions of cropping seasons are critical factors in the processes of determination of growth and yield of cowpea.



## INTRODUCTION

Cowpea (*Vigna unguiculata* L Walp), is a food legume which plays a major role in human nutrition in the tropics. Its edible seeds provide a cheap alternative source of protein compared to animal protein. In the humid tropics, cowpea is grown as an early and late season crop. The early season crop is planted at the onset of the rainy season while the late season crop is planted during the short second cycle of rains, a sowing season which terminates in dry season. There are sharp variations in soil water and thermal regimes in the early part of the rainy season (early vegetative phase of growth) and in the later part of the late cropping season (terminal drought situation).

Cowpea is a major grain legume crop in tropical and subtropical regions. This region is characterized by large seasonal variations in soil moisture regimes, soil and air temperatures[24]. The humid rainforest zone of Nigeria has a growing season length that is longer than 200 days with more variability of the average date of onset of the rains than its cessation[19]. Mean daily tem-

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peratures during the growing seasons varies by only a few degrees from 27-29$^0$C[14] and day length on 21 June varies from 13.37 to 13.68h/day at 8 and 13$^o$ N[8]

A cropping opportunity is provided by the earlier part of the rainy (first sowing) season before the rainfall is fully established. According to IAR&T[11], the optimal sowing date of cowpea in the rainforest zone of Nigeria (which is characterised by a bimodal pattern of rainfall distribution) is at the beginning of the rains and not when rainfall has fully established while the crop's reproductive growth phase particularly seed maturity falls into the short dry spell which marks the end of the first modal rainfall. The dry spell is characetrised by abundant sunshine and negligible cloud overcast sky.

The late sowing season falls within the second mode of rainfall distribution. However, the late season (late August/early September to December), is occasioned by limiting soil moisture status, extreme high soil temperatures, high irradiance and atmospheric vapour deficits. These environmental events have profound influence on growth and yield of crops[1,3,11]. There is therefore great need to test phenological adaptation among cowpea cultivars to environmental conditions of the seasons of sowing in a year. For example, the environmental effects on phenology with respect to time taken to attain a particular event or the rate of progression towards key events[5].

The inclusion of timing of dry spells to growth stages of crops especially rainfall based analyses of dry spell occurrence makes dry spell analyses very relevant to farm management. Barron et al.[4] termed agricultural dry spell. It is a period of consecutive dry days resulting in a soil water deficit causing crop water stress. Farmers are more concerned with the occurrence and timing of actual crop water stress as they affect growth stages most likely to suffer from water stress.

In crops, the duration of the phenophases is an important trait which determines adaptation to weather factors. The duration from sowing to flower initiation, flowering, pod and seed set as well as seed maturity in crop species is modulated by photoperiod and temperature[4]. The mechanisms underlying attainment of a growth phase such as flowering date and resultant adaptation to contrasting environments is poorly understood in most crops[8] and under varying agroecologies[2].

In plants, hydrothermal sensitivity of physiological processes has been reported[20,23,30]. It is necessary to examine the magnitudes of soil moisture stress, atmospheric water demand (Eo), humidity, irradiance and temperature and their effects on crop growth duration[5]. Phenology also determines the rate of leaf growth and the enlargement of canopy during early stage of crop cycle[6]. In crops, unfavourable growing environment imposes assimilate limitation, restricts pollination and decreases kernel set[29]. Subsequent environmental conditions after the initiation of reproductive growth can change floral development, alter pollination, or prevent fruit growth/seed filling and ultimately seed/fruit yield in crops[20,23]. In addition to the prevention of pollination, low water potentials during grain filling can arrest ovary growth and cause embryo abortion[20]. Traits such as biomass accumulation, leaf area development (duration of canopy), capacity for assimilate reserve and mobilisation to reproductive structures (grain) are important to crop yield under variable soil water and thermal regimes of the sowing seasons[10,22,28]. Plants possess traits which are important to the survival, physiological functions and are also are involved in setting tolerance limit to and confer increased productivity under variable weather conditions of the growing seasons[10,22,28]. The identification and understanding of the values of these traits is of utmost importance in the strategies to improve genotypic adaptation of crops in areas and seasons that are characterized by varying degrees of soil moisture deficits and temperature extremes encountered at some stages of crop growth cycle.

Studies of crop-weather relationships are necessary to define probabilities of occurrence of extreme weather events and the effects on crops. In addition, these relationships are useful in the assessment of the fitness/suitability of major staple crops to different localities and for projections on their productivity potentials. Such studies constitute important inputs in strategies to mitigate negative impacts of extreme weather scenario on agriculture, food supply and livelihoods in the present situation and under worse climatic conditions.

The monsoon-dependent tropics of which Nigeria is a part, experiences variability in climate/weather events characterised by the southward shift in isohyetal values of rainfall denoted by declining amount of rainfall and humidity, variable onset and cessation dates of rainfall, and increasing dust cover during harmattan and gradual rise in the surface air temperatures[16,19,31]. Onset of rainfall is associated with the length of the growing season, soil moisture recharge and possible rapid rise in water level. Since water is the most important climatic factor for rain fed agriculture in the tropics, the uncertainties about the time of onset and cessation of rains is a crucial factor for growth and yield performance (productivity) of rain fed crops.

In order to assess cultivars that are well adapted to the diverse growing ecologies/environments and seasons of planting, it is necessary to identify traits that are needed in cultivars for adaptation and performance under the prevailing weather and soil conditions of the growing season. This study appraised the effects of extreme weather events of the early part of the rainy season and the late cropping seasons (terminal drought situation) on the performance of selected cowpea lines/ genotypes.

The objectives were to examine shoot biomass and seed yield in cowpea cultivars grown under contrasting growing seasons characterised by occurrence of variable soil and air temperatures, vapor pressure deficits (atmospheric humidity), evaporative demand and soil moisture regimes in the pre- and post-flowering growth phases on the field.

## MATERIALS AND METHODS

### Experimental site and conditions

Growth, development and yield response of three cowpea cultivars to weather conditions of the rainy and late sowing seasons were studied in 2008 and 2009. The study was carried out at the Teaching and Research Farm of the Federal University of Technology, Akure, Ondo state, Nigeria. The site was manually weeded and pulverized with hoe while the seeds of selected cowpea lines (1T93K-U52-1, IT89KD-341 and Ife brown) were sown on 7$^{th}$ October, 2008 for the late season and 18$^{th}$ March, 2009 for the raining season. Seeds were sown at a spacing of 60 cm between the rows and 30 cm within the rows in field plot of 20m x 16m separated into plots of 5m x 4m each with 2m guard rows between one variety and the other in a Randomized Complete Block Experimental design (RCB). The cowpea cultivars were randomly allocated to field plots and each treatment was replicated three times. Three varieties were tested, they are: 1T89KD-341 (60days duration) white seeded obtained from Kaduna ADP (Treatment i). - 1T93K-U52-1 (75days duration) brown seeded obtained from Kaduna ADP Ife brown which was collected from the Seed Processing Unit of the Agricultural Development project (ADP) Akure, (85days duration) brown seeded. The three varieties were chosen on the basis of contrasting maturity period (days to flowering/anthesis) and seed yield. The growth and yield performance of the varieties were evaluated on the field in the respective rainy and late sowing seasons of 2008 and 2009.

## DATA COLLECTION

Collection of data started two weeks after planting, ten sample plants on which the growth parameters were taken were randomly chosen and tagged on each plot and these plants were sampled from 2m$^2$ at the centre row of the plots. The number of leaves, number of branches and plants height were observed from the ten sampled plants beginning from two weeks after planting (WAP). At physiological maturity, data were collected on plot basis for agronomic characters of root and shoot biomass. From the ten plants harvested from each plot, the number and weight of pods, number of seeds per pod was counted and seed weight was computed from average of ten sample weight of seeds/plant.

Soil temperatures were measured at weekly interval as from two weeks after planting using soil thermometers inserted into the soil to a depth of 5 cm. The duration (days) of vegetative growth, onset of flowering , 50% flowering date and onset of podding to physiological maturity was determined while the duration of reproductive growth phase was determined as the period between days of first flowering to physiological maturity.

Data on meteorological variables such as rainfall and number of rainy days, minimum and maximum temperature, solar radiation, open water evaporation and relative humidity were obtained from the Department of Meteorology, FUT, Akure. These weather factors were regressed against plant attributes (shoot biomass, duration of the critical period of seed number determination, mean seed weight and seed yield/plant).

Accumulated heat units (thermal time) was calculated from temperature coefficient for individual crops.

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Thermal time (TT°Cd) for the phenological phases were therefore calculated from the daily maximum (Tmax) and minimum (Tmin) temperatures measured at the Meteorological Observatory of the Department of Meteorology, FUT, Akure. Cardinal temperatures of Tb 8 °C, $T_{opt}$ 32 °C , Tmax 42°C[7,13,21] were assumed in the calculation of heat unit accumulation measured as growing degree days (GDD) using equation of McMaster and Wilhelm[15].

$$\mathbf{GDD} = \frac{\mathbf{Tmax + Tmin}}{\mathbf{2}} - \mathbf{Tbase} \qquad (1)$$

$$\mathbf{Tharmal\ Time} = \frac{(\mathbf{Tmax}_{1-x} - \mathbf{To})}{\mathbf{2 - Tb}} \qquad (2)$$

Tmax is the maximum temperature, To is optimum temperature and Tb is the base temperature, 1-x represents the time interval during which measurements were made (day one to the last day). The calculated degree days summed over days give the thermal time requirements (TT°Cd) for the different growth phases.

## DATA ANALYSIS

Data collected were subjected to analysis of variance (ANOVA) test and treatment means were separated using (DMRT) at 5% level of probability with the appropriate statistical method[27].

## RESULTS

Data on some meteorological variables at site of the experiment are shown in TABLE 1 and Figure 1. The study site is characterized by bi-modal rainfall pattern with the peak in August and relatively high and stable air temperatures and solar radiation. During the crop cycle at each sowing season, there were variations in temperature, intensities of radiation, atmospheric humidity and rainfall (TABLE 1). In the course of cowpea growth in the respective seasons, the variations in rainfall amounts, temperature and humidity regimes (vapour pressure deficits) imposed different degrees of extreme weather events at different stages of growth of the crop. Rainfall in the late-season period was accompanied by low humidity, high open-water evaporation, radiation intensities and temperatures (Figure 1).

Figures 2 and 3 show weather conditions during the vegetative and reproductive growth phases of cowpea in the rainy and late sowing seasons. The rainy season is characterized by increasing trends in rainfall amounts and vapour pressure deficits and open water evaporation (Eo - atmospheric demand) during cowpea vegetative and the reproductive growth phases (Figure 2). However, in the late sowing season, the growing environmental conditions was the opposite of the rainy season of sowing; decreasing trends in rainfall amounts and vapour pressure deficits and increasing open water evaporation (Figure 3). The earlier part of the rainy and later part of the late season were characterized by concurrent stresses of high intensities of soil moisture and vapour pressure deficits (atmospheric demand). Figures 4 and 5 show the pattern of soil temperatures under cowpea crop for the rainy and late sowing seasons. During the rainy season, Ife brown plots had significantly lower soil temperatures particularly during the reproductive growth phase (Figure 4) while in the late season, plots of this variety had higher soil temperatures (Figure 5).

The results indicate that increased intensities of drought and temperatures during the reproductive phase (anthesis and pod/seed filling periods) in the late season could have affected biomass accumulation and reduced seed yield in the tested cowpea cultivars. Sowing cowpea in the rainy and late cropping seasons subjected the crop's pre and post-flowering development phases to contrasting weather (environmental) conditions. The intermittent and terminal drought situations of the early rainy and late seasons appeared to have affected plant biomass, number of branches, flowering, pod and seed yield production in the cowpea cultivars evaluated. The effects of the time of sowing were significant on cowpea growth and seed yield. However, within a growing season, cultivars differed in their responses in terms of growth duration, dry matter production and seed yield (TABLES 2 and 3). In both seasons, there were differences in dry matter production among the late maturing cultivars over cultivar IT89KD-341 (early maturing), higher shoot dry weights were produced by the late maturing cultivars (Ife brown and IT93-U52-1). In the late season, cultivars IT89KD-341 and IT93-U52-1 had the least sensitivity to growing weather conditions in term of growth duration and seed yield (TABLE 3). In general, values of shoot biomass is greater in Ife brown while IT89KD-341 and IT93-U52-1 had higher seed yield (TABLES 2 and 3).

The cultivars expressed differences in their sensi-

**TABLE 1 : Meteorological conditions at the site of the experiment (2008 and 2009)**

**2008**

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rainfall (mm) | 0 | 5 | 19 | 39 | 189 | 257 | 288 | 327 | 271 | 193 | 68 | 23 |
| Min.Temp.(°C) | 17.9 | 20.6 | 22.3 | 22.9 | 21.3 | 20.8 | 21.2 | 20.8 | 21.5 | 21.8 | 20.9 | 19.5 |
| Max.Temp.(°C) | 31.8 | 32.6 | 33.3 | 32.9 | 31.6 | 30.3 | 29.6 | 28.7 | 29.6 | 30.3 | 31.7 | 30.6 |
| Rel.Humidity (%) | 47 | 41 | 48 | 55 | 63 | 67 | 73 | 81 | 72 | 63 | 52 | 48 |
| VPD (kPa) | 2.8 | 3.0 | 3.2 | 3.5 | 3.1 | 3.1 | 2.9 | 2.5 | 2.4 | 2.8 | 3.0 | 2.7 |
| Total sunshine (hours) | 191 | 219 | 238 | 206 | 183 | 177 | 128 | 93 | 138 | 219 | 235 | 193 |
| Solar radiation ($MJ/m^2/day$) | 12.3 | 16.1 | 17.8 | 17.1 | 17.2 | 15.9 | 12.9 | 9.8 | 12.4 | 13.8 | 15.8 | 14.1 |
| Open water evap. (mm) | 209 | 185 | 238 | 132 | 108 | 98 | 91 | 86 | 97 | 102 | 130 | 148 |

**2009**

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rainfall (mm) | 0 | 5.2 | 19.6 | 39.3 | 189.7 | 257.1 | 288.8 | 307.2 | 227.1 | 133.7 | 43.9 | 17.3 |
| Min. Temp (°C) | 17.9 | 20.6 | 22.3 | 22.9 | 21.3 | 20.8 | 21.2 | 20.8 | 21.5 | 21.8 | 20.9 | 19.5 |
| Max. Temp.(°C) | 31.8 | 32.6 | 33.3 | 32.9 | 31.6 | 30.3 | 29.6 | 28.7 | 29.6 | 30.3 | 31.7 | 30.6 |
| VPD (kPa) | 3.0 | 3.2 | 3.3 | 3.4 | 3.2 | 3.0 | 2.8 | 2.3 | 2.6 | 2.9 | 3.1 | 2.8 |
| Total sunshine (hours) | 191 | 219 | 238 | 206 | 183 | 177 | 128 | 93 | 138 | 219 | 235 | 193 |
| Solar radiation ($MJ/m^2/day$) | 12.3 | 16.1 | 17.8 | 17.1 | 17.2 | 15.9 | 12.9 | 9.8 | 12.4 | 13.8 | 15.8 | 14.1 |
| Open water evap. (mm) | 212 | 193 | 243 | 167 | 113 | 101 | 86 | 82 | 93 | 110 | 125 | 155 |

**Source: Meteorological observatory station of the federal university of technology, akure**

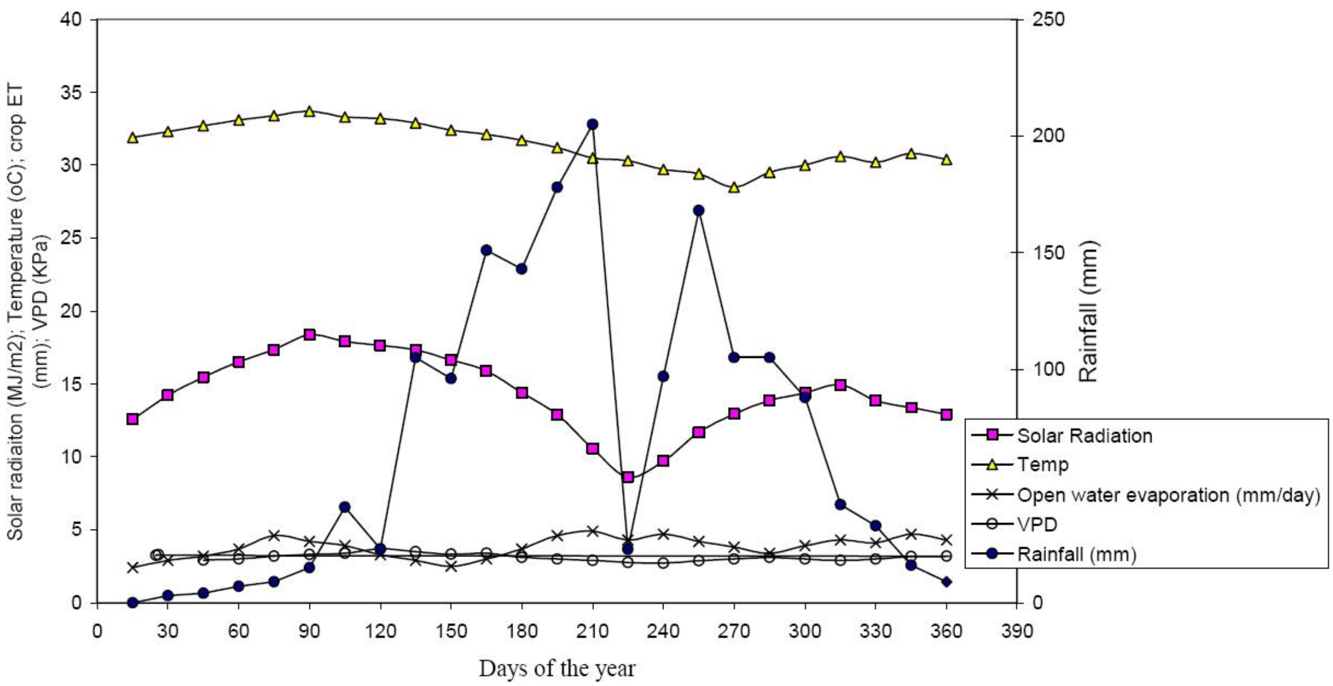


**Figure 1: Weather variables at the site of the experiment during cowpea growth (mean of 2008 &2009 experiments)**

tivity to environmental conditions, greatest sensitivity were obtained for the early maturing cultivars (IT89KD-341 and IT93-U52-1) which had their reproductive growth phase exposed for a shorter time to prevailing growing environmental weather condition. The rainy season cowpea took more time to commence flowering and complete the reproductive process (TABLE 2). The time from emergence to 50% flowering and from onset of flowering to physiological maturity were shorter in rainy season cowpea crop. In late season, the cultivar IT89KD-341 commenced flowering (especially 50% flowering dates) earlier and had a particularly shorter duration of pod and seed formation and physiological maturity.

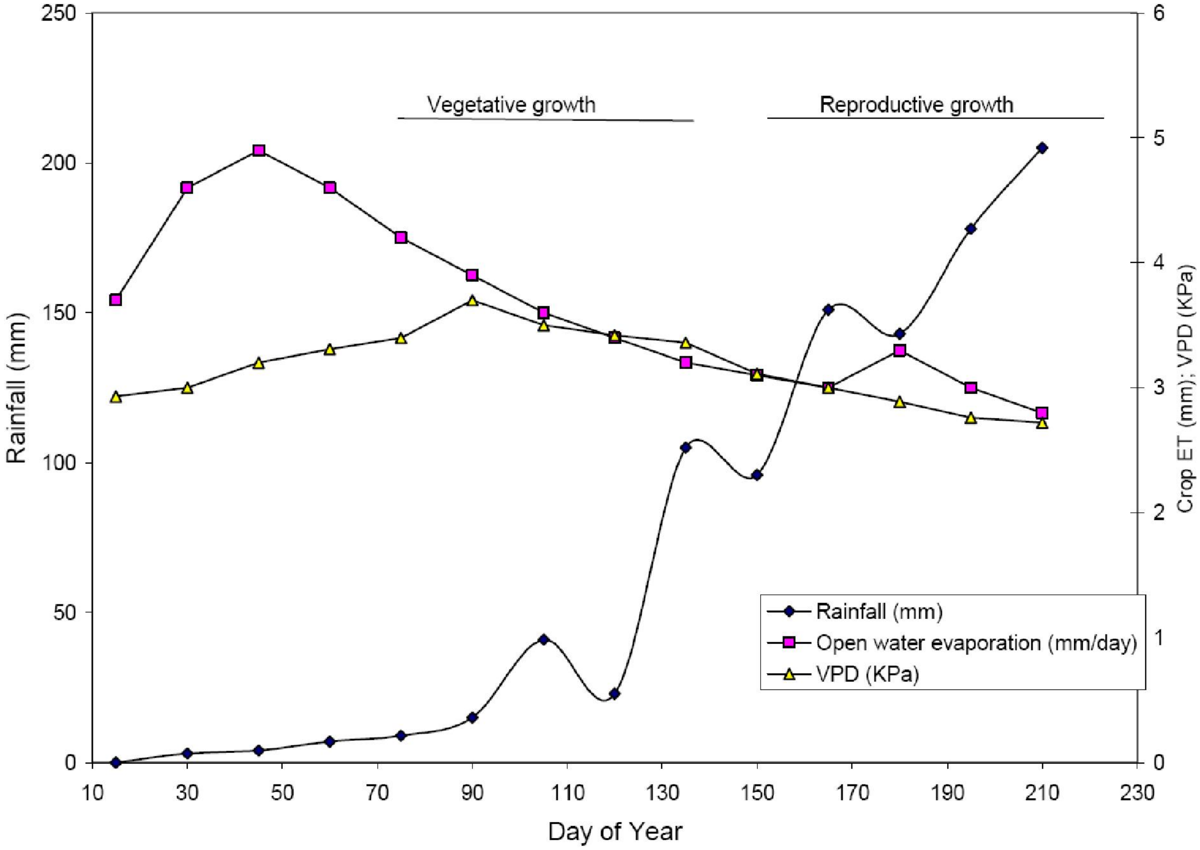


**Figure 2 : Weather condition during the growth phases in rainy season cowpea**

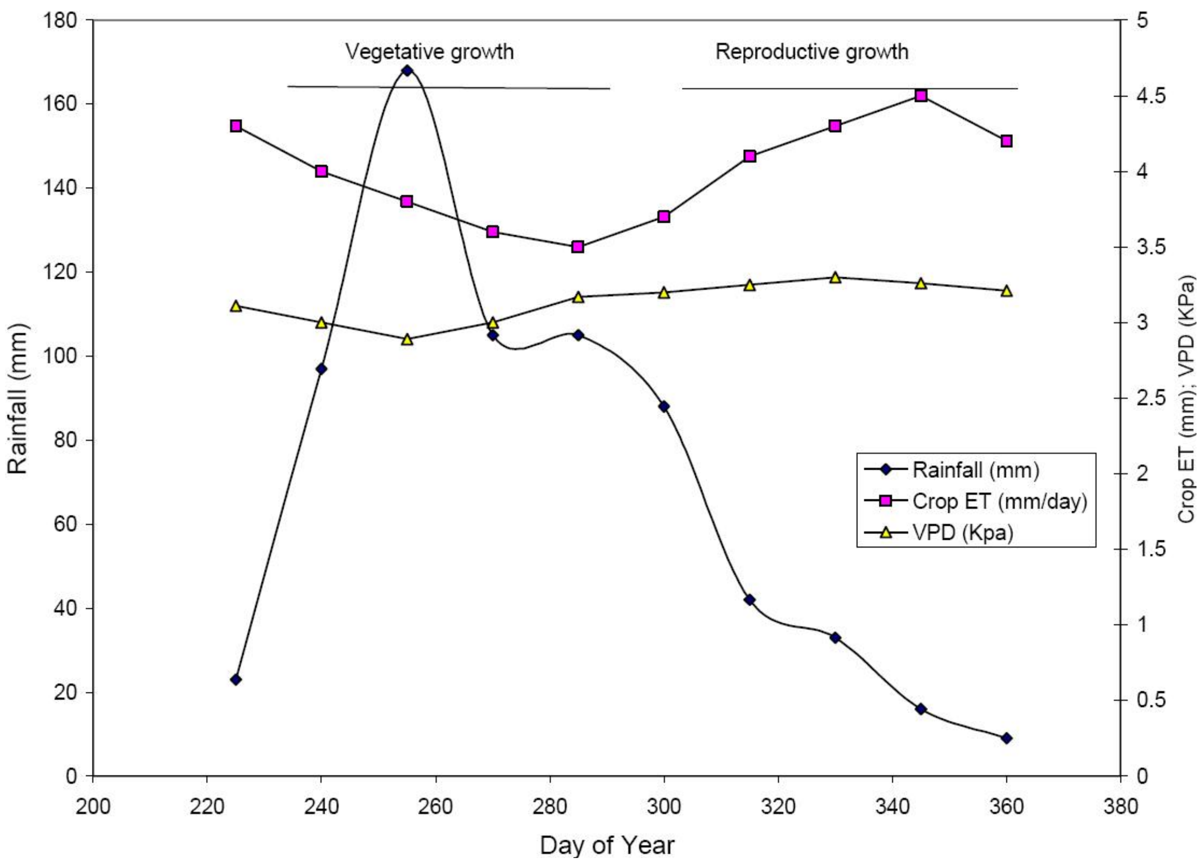


**Figure 3 : Weather condition during the growth phases in late season cowpea**

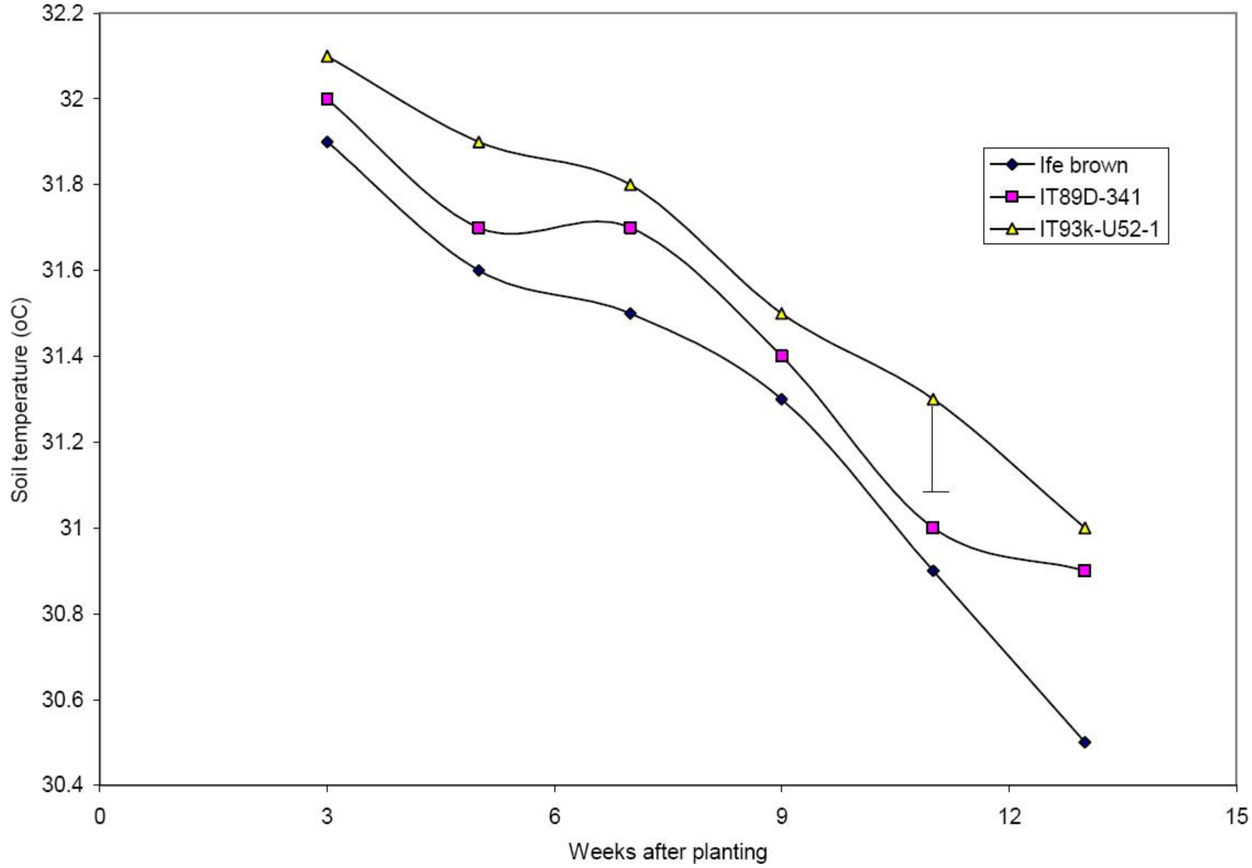


**Figure 4: Changes in soil temperatures during cowpea growth (rainy season crop)**

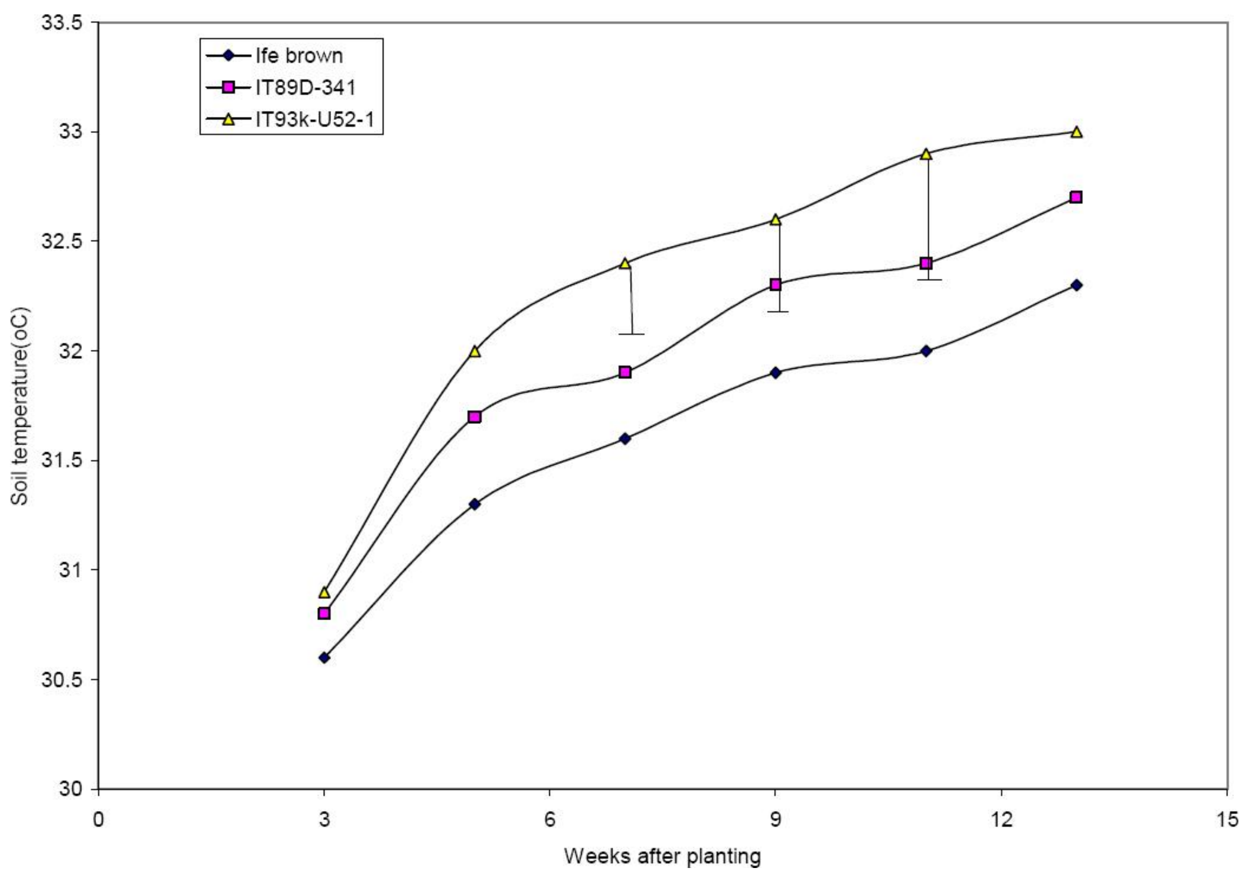


**Figure 5 : Changes in soil temperatures during cowpea growth (late season crop)**

**TABLE 2 : Growth and yield of three varieties of cowpea during the rainy season (2008)**

| Cowpea Varieties | Root dry weight (g) | Shoot dry weight (g) | Total Plant weight (g) | Number of leaves per plant | Number of branches per plant | Days to Onset of flowering | Days to 50% flowering | Emergence to peak Vegetative (days) | Flowering onset to Physiolo-ogical Maturity (days) | Number of pods per plant | Pod length (cm) | Seed yield (t/ha) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ife brown | 10.29 | 126.98 | 137.27 | 28.20 | 3.50 | 44 | 51 | 41 | 29 | 20.20 | 13.62 | 0.088 |
| IT89KD – 341 | 5.07 | 76.60 | 81.67 | 44.40 | 4.70 | 41 | 47 | 36 | 24 | 35.80 | 17.70 | 0.222 |
| IT93K – U52 – 1 | 7.58 | 108.80 | 116.38 | 35.40 | 4.70 | 44 | 49 | 37 | 26 | 13.00 | 15.10 | 0.133 |
| LSD(0.05) | 2.13 | 3.19 | 3.27 | 2.50 | 0.25 | 0.43 | 1.19 | 1.21 | 1.09 | 2.09 | 0.29 | 0.14 |
| Mean | 7.65 | 97.46 | 105.11 | 36.0 | 4.30 | 43 | 46 | 38 | 26 | 23.00 | 15.47 | 0.147 |

**TABLE 3 : Growth and yield of three varieties of cowpea during the late season (2009)**

| Cowpea Varieties | Root dry Weight (g) | Shoot dry weight (g) | Total Plant weight (g) | Number of leaves per plant | Number of branches per plant | Days to Onset of flowering | Days to 50% flowering | Emergence to peak Vegetative (days) | Flowering onset to – Physiological maturity (days) | Number of pods per plant | Pod length per plant (cm) | Seed yield (t/ha) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ife brown | 12.30 | 132.68 | 144.98 | 47.50 | 5.20 | 50 | 64 | 53 | 33 | 25.20 | 14.16 | 0.199 |
| IT89KD – 341 | 7.90 | 77.80 | 85.70 | 53.10 | 5.90 | 45 | 58 | 47 | 28 | 30.20 | 16.81 | 0.588 |
| IT93K – U52 – 1 | 10.55 | 121.40 | 131.95 | 56.20 | 5.90 | 48 | 61 | 50 | 30 | 28.10 | 15.60 | 0.311 |
| LSD(0.05) | 2.35 | 3.12 | 3.71 | 2.55 | 0.25 | 0.43 | 1.19 | 1.23 | 1.08 | 2.10 | 0.30 | 0.15 |
| Mean | 10.25 | 110.63 | 120.88 | 52.27 | 5.67 | 47 | 61 | 50 | 30 | 27.83 | 15.52 | 0.366 |

**TABLE 4 : Growth and yield of three cowpea varieties across growing seasons**

| Cowpea Varieties | No of leaves per plant | No of Branches per plant | Plant height (cm) | Leaf length (cm) | Days to onset of flowering | Days to 50% flowering | No of pods per plant | Pod length (cm) | Seed yield (t/ha) |
|---|---|---|---|---|---|---|---|---|---|
| Ife brown | 37.85a | 4.35a | 33.50b | 9.81a | 47b | 57b | 22.70a | 13.89a | 0.287a |
| IT89KD-341 | 48.75b | 5.30b | 30.95a | 11.15b | 46b | 53a | 33.00b | 17.26b | 0.810 |
| IT93K-U52-1 | 45.80b | 5.30b | 31.36a | 9.96a | 48a | 55b | 12.55a | 15.36b | 0.444b |

**Means along same column having different letters differ significantly at 5% level(DMRT)**

**TABLE 5 : Relationship between shoot biomass of cowpea and weather factors of the sowing season**

| Parameters | Regression equations | $R^2$ |
|---|---|---|
| Shoot biomass and | Rainy $y = -1.246x^2 + 348.3x - 2.37$ | 0.2 |
| Eo: | Late $y = -78x+1226.5$ | 0.5 |
| Shoot biomass and | Rainy $y = 0.743x^2-207.1x+1472$ | 0.4 |
| Rainfall: | Late $y = 0.232x^2-54.96+3444.5$ | 0.4 |
| Shoot biomass and rainy days: | Late $y = 26.45Ln(x)-104.93$ | 0.3 |
| Shoot biomass and | Rainy $y = 0.103x^2-29.14x+1472$ | 0.3 |
| T minimum: | Late $y = 0.01x^2-2.23x+150.7$ | 0.4 |
| Shoot biomass and vpd: | Late $y = 0.01x^2-2.12x+138.2$ | 0.4 |

The contrasting growing environment of the sowing seasons (rainy and late) enhanced differences in branching and in pod and seed yield. Pods and seed yield of the cultivars showed sensitivity to the length of reproductive growth phase and post flowering weather events. The different cultivars exhibited differences in their sensitivity to environmental conditions. The greatest sensitivity occurred in early maturing cultivars. Among cowpea varieties evaluated, the early maturing cultivars produced higher number of pods and weight of seeds (TABLES 2 and 3). Pods and seed yield differed significantly among cowpea varieties studied. The variety IT89KD-341 produced the highest seed yield (810 kg $ha^{-1}$ which was similar to IT93K-U52-1 (444 kg $ha^{-1}$). On the other hand the lowest yield of (287 kg ha-1) was recorded for Ife brown (TABLE 4).

Biomass production, the duration of reproductive growth phases and seed yield of cowpea were related to the prevailing weather variables of the respective seasons of growth. The regression coefficients of the

**TABLE 6 : Relationship between seed yield in cowpea and weather factors of the sowing season**

| Parameters | Regression equations | $R^2$ |
|---|---|---|
| Seed yield and Eo: | Late y = -78x +1226.5 | 0.5 |
| Seed yield and Rainfall: | Rainy y = -504.9x+411.7 | 0.1 |
| | Late y = $0.232x^2$-54.96 +3444.5 | 0.4 |
| Seed yield and Rainy days: | Late y = 26.45Ln(x)-104.93 | 0.3 |
| Seed yield and T minimum: | Rainy y = 51.2x+89.6 | 0.1 |
| | Late y = $0.01x^2$-2.23x+150.7 | 0.4 |
| Seed yield and vpd: | Rainy y = $1270x^2$-551.62x+75.4 | 0.5 |
| | Late y = $0.01x^2$-2.12x+138.2 | 0.4 |

**TABLE 7: Relationship between duration of the reproductive phase in cowpea and weather factors in the sowing season**

| Parameters | Regression equations | $R^2$ |
|---|---|---|
| Reproductive phase and Eo: | Rainy y = $1403.5e^{-0.02x}$ | 0.9 |
| | Late y = -78x +1226.5 | 0.5 |
| Reproductive phase and Rainfall: | Rainy y = -$0.85x^2$+52.8x-507.8 | 0.3 |
| | Late y = $0.232x^2$-54.96 +3444.5 | 0.4 |
| Reproductive phase and Rainy days: | Late y = 26.45Ln(x)-104.93 | 0.3 |
| Reproductive phase and T minimum : | Rainy y = -$0.106x^2$+6.5x-0.214 | 0.2 |
| | Late y = $0.01x^2$-2.23x+150.7 | 0.4 |
| Reproductive phase and vpd: | Rainy y = -0.04x2+6.56x-0.21 | 0.2 |
| | Late y = $0.01x^2$-2.12x+138.2 | 0.4 |

**TABLE 8 : Association of thermal time requirements and cowpea growth and seed yield characters of the rainy and late sowing seasons.**

| Parameters | Regression equations | $R^2$ |
|---|---|---|
| Thermal time (TT°Cd) and shoot: | Rainy y = 0.06x-0.68 | 0.9 |
| | Late y = -$0.005x^2$+2.8x-2244 | 0.4 |
| Thermal time (TT°Cd) and seed yield: | Rainy y = 0.116x-151.32 | 0.7 |
| | Late y = 8E-$05x^2$-0.33x+361.8 | 0.3 |
| Thermal time (TT°Cd) and reproductive: | Rainy y = 0.033x-49.9 | 0.7 |
| | Late y = 0.06x-102.78 | 0.4 |
| Thermal time (TT°Cd) and TPLA: | Rainy y = 0.1602x-112.1 | 0.9 |
| | Late y = -0.04x+90.36 | 0.9 |

relationships of weather factors and the duration of reproductive growth phase , shoot and seed yield of the sowing seasons differed (TABLES 6 and 7). In the rainy season, shoot biomass correlated with accumulated heat units/thermal time and evaporative demand, but had a weak negative correlation with accumulated rainfall. Seed yield were positively and highly associated with evaporative demand and thermal time but negatively with cumulated rainfall. In late season cowpea, shoot biomass negatively correlated with cumulated rainfall and evaporative demand. Similar trends were observed between the regression of seed yield with cumulated rainfall, evaporative demand and thermal time (TABLE 8).

## DISCUSSION

Despite rapid increases in crop growth which were initially obtained, final shoot dry weights reduced compared to the rainy season crop dry weights. The observed decline in maximum crop growth with thermal time may denote that the apparent optimum temperature for plant growth varies with stages of growth during its ontogeny. High temperatures decrease shoot biomass and seed yield under the supra optimal temperature regimes of the late season. In the late season, cowpea developed and matured during periods of high soil and air temperatures and atmospheric demand (range of 29.6 to 31.8°C and 2.6 to 3.0KPa). These weather factors possibly promoted rapid soil water depletion and hence the inability of soil profile water to meet crop demand. The length of the seed filling period (50% flowering to physiological maturity), was short relatively to other periods and could have contributed to the lower seed yield in late season cowpea. Seed/plant is the yield component most sensitive to soil moisture deficit, lower seed yield in late season crop may be attributed to lower assimilation efficiency and to post-anthesis soil and atmospheric moisture deficits induced embryo abortion and low assimilate enhanced poor seed filling. Pressman et al (2002) attributed low crop yield to extreme weather condition enhanced dehydration of pollen and poor pollination and embryo abortion. Low soil water availability restricted cowpea yields in the late sowing season following from the negative correlation obtained between the amount of precipitation received and the number of rainy days during the growing season. Seed yield variation is related to the amount of moisture available to the crop; in the late season cropping period, declining status of stored soil water from rainfall and increasing intensities of stressful situations had profound effect on cowpea biomass and seed yield. Nevertheless, yield reduction was low in the late season cowpea; the improved seed yield in late season cowpea may be related to the exploitation of substantial soil water prior to grain filling and presumably from the dry weather (air) during seed maturity. Increasing intensities of soil moisture deficits and supra-optimal soil temperatures which characterized late sowing season in the tropical rainforest environments elicit responses in the growth and yield of crops such as soybean[2]. It is important if the environmental parameters of rainfall, number of rain days, onset and cessation of the rainy season as well as the maximum and minimum temperatures could be reliably predicted early in the year to ascertain climate driven production risks associated with the sowing seasons. Such information will be useful to ameliorate the effects of the weather conditions of the growing seasons for improved yield of this very important protein rich plant. However, the problem associated with the prediction of rainy season onset and cessation dates as well as annual rainfall amount and distribution has been addressed by Omotosho et al, (2000). The need for methods for forecasting the number of rain days and extreme temperatures so that Omotosho's model could become fully operational cannot be over emphasized. The regulation of plant biomass especially the size of leaf area/plant by drought in order to maintain transpiration per unit area of leaf is reported for droughted cowpea[18]. Soil moisture status continued to decline even after the attainment of maximum leaf area which was large enough to shade the soil and reduce soil moisture evaporation. The relative short cycle in short duration varieties of cowpea in this study would have minimized crop water use. These cultivars appeared to have escaped soil and air drought and temperature stresses. Early maturing varieties may therefore be advantageous under drought going by their ability to complete life cycle before higher degree of moisture deficit stress and high temperatures occurred. The physiological advantage of early maturity in crops over a wide range of environmental conditions is known[22]. Craufurd and Qi[8] reported that the number of seeds could decrease through promotion of embryo abortion and pod shedding due to extreme environmental events in droughted soybean. The yields of pods and seeds differed significantly among cowpea varieties studied. The variety IT89KD-341 (TABLE 4) produced the highest seed yield (810 kg $ha^{-1}$) which was at similar to that produced by IT93K-U52-1 (444 kg $ha^{-1}$). On the other hand the lowest seed yield of (287 kg $ha^{-1}$) was recorded for Ife brown. Similar results were reported by Jaiswai (1995), who observed differences in grain yield among cultivars of mungbean. The results were also consistent with the findings of Singh et al.[26]. The highest seed yield recorded for IT89KD-341 was due to its characteristic ability to mature within 60 days of sowing before the occurrence of severe hydrothermal stresses of the late season. The least seed yield recorded for Ife brown may be due to flower shedding and embryo abortion as a result of extreme environmental events of the late season[20]. The results show that at least 82% of the yield of cowpea can be attributed to environmental parameters of rainfall and temperature trends of the sowing seasons. The sensitivity of the productive phases of growth and seed filling to environmental stresses has implications on yield performance in cowpea. Plant canopy and environmental factors had been reported to control crop water use (evapotranspiration) and the partitioning /fluxes of energy and water in cowpea[3]. High degree of association between cowpea cultivars and the weather conditions obtained in this study appears to be important to the cowpea survival and productivity under variable soil water and thermal regimes of the sowing seasons.

## CONCLUSION

The weather conditions of the growing seasons affected growth and seed yield in the three cultivars of cowpea investigated under field condition. In the site of the experiment, the sowing seasons (rainy and late/dry seasons) were characterised by varying intensities of soil moisture deficits and solar radiation and variable degrees of vapour pressure deficits (humidity) and temperatures. The intermittent and terminal drought situations of the early rainy and late seasons affected plant biomass, leaf production, flowering, pod and seed yield characters in the cowpea cultivars evaluated. Sowing cowpea in the pre (early in the rainy season) and post (dry/late cropping season) optimal planting dates subjected their pre and post-flowering development phases to contrasting environmental conditions. The magnitudes of cumulative rainfall received (and hence soil moisture content), minimum temperatures, open water evaporation (atmospheric/evaporative demand), atmospheric dryness (vapour pressure deficit) and accumulated thermal time during a specific growing season determine shoot biomass and seed yield and the duration of the reproductive growth phase. The tested varieties exhibited differences in their sensitivity to the growing season weather/environmental conditions. The greatest sensitivity occurred in early maturing cultivars. Regression equations were worked out between some growth parameters of cowpea and some weather variables. These relationships were characterized by variable regression coefficients ($R^2$) in the different sowing seasons. The regression coefficients ($R^2$) show that on the average, about 40% of shoot biomass and seed yield production in cowpea can be associated with accumulated rainfall, minimum temperatures or open water evaporation and atmospheric dryness (vapour pressure deficit) and accumulated thermal time requirements during a specific growing season. In the late season, the cowpea cultivars exhibited more sensitivity to thermal time (growing degree days) in term of growth duration and seed yield. Among cowpea varieties evaluated, the early maturing varieties produced higher number and weight of seeds. The IT89KD-341 gave the highest yield in both experiment because of its shorter gestation period which is 60 days compared with the other two varieties with the duration period of 75 and 90 days respectively. Therefore, IT89KD-341 variety is recommended for sowing in the study area because of its combined ability to resist drought and has high seed yield production. Functional relationships between some weather variables and growth and yield characteristics of cowpea were established. These relationships gave a regression coefficient ($R^2$) which shows that, about 40% of shoot biomass and seed yield can be explained by a combination of weather parameters such as cumulative rainfall, minimum temperatures, open water evaporation, vapour pressure deficit (humidity) and thermal time requirements during the respective rainy (April - July) and late (September – December) seasons of sowing. In the late season crop, the relationships which improved (higher regression coefficient: $R^2$) and were mostly positive. However, shoot biomass, seed yield and the duration of reproductive growth correlated negatively with evaporative demand (open water evaporation- Eo). It is concluded that the soil and weather conditions of cropping seasons are critical factors in the processes of determination of growth and yield of cowpea.

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