EVALUATION OF COWPEA (*Vigna unguiculata* (L.) Walp) GENOTYPES UNDER WATER STRESS CONDITION IN KONKAN REGION

THESIS

Submitted in partial fulfilment of the requirements for the Degree of

MASTER OF SCIENCE
IN
AGRICULTURE
(PLANT PHYSIOLOGY)

By
MISS. JADHAV POOJA CHANGDEO
(ADPM/21/2817)

DEPARTMENT OF AGRICULTURAL BOTANY
COLLEGE OF AGRICULTURE, DAPOLI

DR. BALASAHEB SAWANT KONKAN KRISHI VIDYAPEETH, DAPOLI, RATNAGIRI (M.S.) 415712

NOVEMBER, 2023

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Under the Guidance of

Dr. J. S. Tumdam
Assistant Professor,
College of Horticulture, Mulde
Dr. B. S. K. K. V. Dapoli

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DR. BALASAHEB SAWANT KONKAN KRISHI
VIDYAPEETH, DAPOLI, RATNAGIRI (M.S.) 415712

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DECLARATION OF STUDENT

I hereby declare that the experimental work and its interpretation of the Thesis entitled **"EVALUATION OF COWPEA (*Vigna unguicul*ata (L.) Walp) GENOTYPES UNDER WATER STRESS CONDITION IN KONKAN REGION"** or part thereof has neither been submitted for any other degree or diploma of any University, nor the data have been derived from any thesis/publication of any University or scientific organization. The source of materials used and all assistance received during the course of investigation have been duly acknowledged and that no part of the thesis has been submitted for any other degree or diploma.

Place: Dapoli **(Miss. Jadhav Pooja Changdeo)**

Date : 11/03/ 2024 Enrollment No. ADPM/21/2817

Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth
College of Agriculture, Dapoli
Dist. Ratnagiri, Maharashtra, 415712
Cell: +918010628581 Email: jsmjaya10@gmail.com

Dr. J. S. Tumdam
Assistant Professor,
College of Horticulture, Mulde
Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth,
Dapoli, 415 712, Dist. Ratnagiri (M.S.)

Date: 11/03/2024

CERTIFICATE

This is to certify that the thesis entitled, **"Evaluation of Cowpea (*Vigna unguiculata* (L.) Walp) Genotypes under Water Stress Condition in Konkan Region"** submitted for the degree of M. Sc. (Agri.) in Plant Physiology, of the College of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, is a bonafide research work carried out by **Miss. Jadhav Pooja Changdeo (ADPM/21/2817)** under my supervision and that no part of this thesis has been submitted for any other degree. The student had completed all the Course and Research requirement as per the norms in regular mode and has submitted one research paper from her M. Sc. Work.

The assistance and help received during the course of investigation have been fully acknowledged.

Place: Dapoli
Date: 11/03/2024

Chairman
Student Advisory Committee

Countersigned

Head
Department of Agricultural Botany
College of Agriculture, Dapoli

THESIS APPROVAL BY THE STUDENT'S ADVISORY COMMITTEE INCLUDING EXTERNAL EXAMINER

This is to certify that the thesis entitled, **"Evaluation of cowpea (*Vigna unguiculata* (L.) Walp) genotypes under water stress condition in konkan region"** submitted by **Miss. Jadhav Pooja Changdeo (ADPM/21/2817)** to the College of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, in partial fulfillment of the requirements for the degree of M.Sc. (Plant Physiology) in the subject having Cell biology and molecular genetics, Agrometerology and crop weather forecasting and Basic Biochemistry as Minor subjects of Department Agricultural Botany, Department of Agronomy and Department of Soil Science and Agril. Chemistry respectively has been approved by Student's Advisory Committee, Board of Studies of the Department and Evaluated by One External Examiner after an open Viva Voice examination in the presence of External Examiner on the same held on dated 11 / 03 / 2024.

1.	**Chairman, SAC**	**Dr. J. S. Tumdam** Assistant Professor, College of Horticulture, Mulde Dr. B. S. K. K. V. Dapoli.	
2.	**Member**	**Dr. A. V. Mane** Deputy Director of Research (Seed), Dr. B. S. K. K. V. Dapoli.	
3.	**Member**	**Dr. U. B. Pethe** Associate Professor (CAS), Department of Agril. Botany, College of Agriculture, Dapoli.	
4.	**Member**	**Dr. R. V. Dhopavkar** Deputy Director of Research (Agri), Dr. B. S. K. K. V. Dapoli.	
5.	**External Examiner**	**Dr. S. V. Sawardekar** Professor and In-charge Plant Biotechnology Centre College of Agriculture, Dapoli.	

Countersigned by

Head
Department of Agricultural Botany

Associate Dean
College of Agriculture, Dapoli
Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli

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Place: Dapoli
Date: 11/03/2024

(Jadhav Pooja Changdeo)

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Abbreviations

AGR	:	Absolute growth rate
C.D. @ 5 %	:	Critical difference at 5 per cent level of significance
CGR	:	Crop growth rate
cm	:	Centimeter
DAS	:	Days after sowing
et al.	:	And co-workers
Fig.	:	Figure
g	:	Gram
i.e	:	That is
kharif	:	Rainy season
LA	:	Leaf area
LAI	:	Leaf area index
LAR	:	Leaf area ratio
m	:	Meter
Max	:	Maximum
Min	:	Minimum
ml	:	Millimeter
µ	:	Micro
NAR	:	Net assimilation rate
No.	:	Number
Rabi	:	Rabi season
RGR	:	Relative growth rate
RWC	:	Relative water content
SLW	:	Specific leaf weight
S.E	:	Standard error
T	:	Treatment
V	:	Variety
%	:	Percentage
/	:	Per

INTRODUCTION

CHAPTER I : INTRODUCTION

1.1 Background information:

Pulses have been considered a major source of vegetable protein containing different minerals and vitamins. They play important role in fixing atmospheric nitrogen which helps in maintaining soil fertility. India is the largest producer of pulses in the world with 25 % share in global producer. The total production of pulses in the country 2020-21 is estimated at 25.72 million tonnes (as per Fourth Advance Estimates). Total pulses production during 2021-22 is estimated at 26.96 million tonnes which is higher by 3.14 million tonnes than the last five years' average production of 23.82 million tonnes. During 2021 the area under pulses cultivation in India was about 29 million hectares with production and productivity of 25 million MT and 764 kg/ha. India is the largest producer (25% of global production) as well as the largest consumer (27% of global consumption) of pulses in the world. The area under pulses in Maharashtra during 2021 is 20 lakh hectares and the production is about 4.22 million MT. In Konkan region the area under pulses in 2020-21 is 374.56 hundred ha and the production is 203.85 hundred tonnes.

Cowpea (*Vigna unguiculata* (L.) Walp) is one of the most important legume crop in Asia, Africa, Australia and U.S.A. and grown throughout the region of semiarid tropics of Asia, Africa, Southern Europe, Southern United States and Central South America (Timko *et al.*, 2007). The origin of cowpea is west and central region of Africa. The other names of cowpea are *chawali, southern pea, black eyed pea,* belonging to family *leguminaceae* (Mackie and Smith, 1935) and subfamily *fabaceae* with chromosome number 2n=22 (Darlington and Wylie, 1955). As per the Verdcourt (1970) *Vigna unguiculata* has five sub-species. Out of which two sub-species are wild *i.e.* sub sp. *Dekinditiana* and sub sp. *Mensensis* remaining three sub-species are cultivated and widely distributed in India and far east (Steele, 1976) are sub species *unguiculata* syn. *Vigna sinensis* recognized as common cowpea; sub sp. *Sesquipedalis* (L.) vedcourt, syn. *Vigna sesquipedalis; Vigna sinensis* var. *Sesquipedalis* which is also called as asparagus bean as well as yard long bean.

The most important cowpea growing states are Uttar Pradesh, Punjab, Haryana, Rajsthan, Madhya Pradesh and Maharashtra. It is also called as Poor man's meat. The green tender pod has 84.9 % moisture, 4.3% protein, 8.0% carbohydrates, 2% fats (Aykroyd, 1963). Cowpea seed contain nutrient in mg per 100 g seed, 6.8 iron, 4.1 zinc, 1.5 manganese, 510.0 phosphorous and 1430.0 potassium (Frota *et.al.* 2008). Cowpea seeds contain on an average 21.0-26.7 % of protein (Weng *et. al.* 2017) and 2.2 % lipid (Frota *et.al.* 2008). It is used for human consumption as well as concentrated feed for cattle.

Cowpea is one of the most important warm seasonal, annual herbaceous legume. Growth habit of cowpea ranges from erect, determinate as well as non branching types. It bears strong tap root system. Stem can be green or pigmented, leaves of cowpea are alternate trifoliate, shape of leaves are linear lanceolate to ovate. The arrangement of flowers racemose or intermediate inflorescence at the distal end 5-6 cm long peduncles. Flower arrangement is in alternate pairs having only two to few flowers per inflorescence. Flowers are self pollinating and corollas may be white, pink, pale blue or purple in colour. The stamens are diadelphous and ovary is sessile with many ovules.

Cowpea is grown in different types of climatic conditions. It is considered as early, multi seasonal and multipurpose crop. It is thrive in a 750 to 1100 mm rainfall ranges, grow well in low rainfall and diseases and pests attack increase due to high rainfall. The temperature requirement of cowpea lies between 21-35°C. It work as a medium for soil and water conservation because it is fast growing and also cover the soil surface quickly. Through the symbiotic bacteria, cowpea fixes atmospheric nitrogen to the extent of 563 kg ha^{-1}. Cowpea is also used for fodder purpose makes an important contribution to feed supplies for animals to maintain their health in dry season. (Quin,1997)

Cowpea is an annual crop that is adapted to warm conditions and sensitive to chilling. Cowpea is a broadly adapted and highly variable crop, cultivated around the world primarily as a pulse, but also as a vegetable (both for the greens and the green peas), a cover crop, and for fodder. Pulses are considered to be an important group of crops in conserving natural resources such as soil, water and nutrients. Water requirement of pulses are lower than cereals. Global water consumption of cereals is reported to be about 60% as against 4% in pulses.

In the Konkan region, the common pulses such as pigeon pea, horse gram, wal, cowpea and moth bean are sown during late *kharif* or immediately after the end of monsoon. The cultivation of cowpea in rice follows is reported to be more profitable than horse gram and mustard. In Konkan region, the area under pulses is 374.56 hundred ha having total production of 203.85 hundred tonnes and the productivity is found to be 544.23kg (Anonymous, 2021).

Water is most important factor which helps in determining the distribution of species around the globe (Bradford and Hsiao, 1982). Water stress is defined as the condition where a plant's water potential and turgor are decreased enough to inhibit normal plant functions. (Loka *et al.* 2011). Water stress is considered as a limited water supply to plant roots, which reduces the rate of transpiration in plants. Water stress is one of the major abiotic factor limiting plant growth and crop productivity in South Africa, Semi and Arid countries (Kramer, 1983). At any stage of plant growth and development, its effects can be observed. Due to water stress, yield of cowpea is reduced. Water stress was found by (Gomesda *et al.* 2001) to have a 38 significant effect on cowpea biological nitrogen fixation and consequently caused reduction in leaf chlorophyll content (Sanchez *et al.* 1983). Other reports stated that the cowpea is sensitive to water deficit during the flowering stage and pod filling stages (Akyeampong 1986; Figueiredo 1999). The effects of water stress on cowpea production have been studied, little is known about the effects of water stress on physiological mechanisms, growth and yield components. The water deficit is one of the major causes of reduction in agricultural productivity, primarily by affecting all aspects related to the plant development, including anatomical, morphological, physiological and biochemical modifications, being the losses directly related to its duration, severity and stage of crop development.

Water deficit is known as one of the major factors decreasing crop yield in different region. Water stress has long been recognized as adverse situation which influences the production of agricultural crops all over the world. In Maharashtra, the konkan region shows particular contrasting situation of enough availability of water through assured and heavy monsoon rainfall (average 3500 mm) occurring rigidly only period June to October on one way and ever-increasing terminal water stress caused by a high infiltration rate (4.4 cm/hr), poor water holding capacity (27.15 to 30.30 %) at field capacity and 16.60, 18.1% at P.W.P. (Dongale *et al.* 1987) on the another way. Generally observed that there is no rainfall from October to May emphasizes the strength of water stress which affect the yield of field crops, typically the grain legumes *viz.,* cowpea, horse gram, lablab bean, etc. which are cultivate on stored soil moisture in rice fallows during post monsoon season.

In *rabi* as well as summer season, there exist a great gap between potential yield and realized of cowpea, despite of recommended agronomic practices for various seasons in konkan region. The abiotic stress in cowpea crop induces soil moisture levels which progressing with season. Generally, water stress occurred to the *rabi* cowpea which shows the reduction in grain yield at the range of 24-89 % under mild to severe stress (Patil 1989). By altering cellular metabolism and evoking various defenses mechanisms cowpea can respond and adapt to water stress (Bohnert *et al.* 1995).

In cowpea, water stress basically affect the plant growth and development and recognized as one of the most important factor influencing crop yield (Kramer and Boyer 1995). This shows that the physiological responses to water stress and their relative influences for crop productivity differs according to genotypes, soil type, nutrient, climate sand irrigation stages. Generally, most of pulses crop are inherently adapted to stress condition by retention of several factors like indeterminate growth habit, long maturity period, deep root system, etc.

The present study is aimed at to reveal that mechanism of yield levels in water deficient condition in different genotypes including observation such as morphological, biochemical, physiological, growth parameters, phenological characters, dry matter studies, moisture content of soil and yield attributes. It is necessary to evaluate above parameters. Under water stress condition, out of the five irrigated and water stress treatment condition, the water stress was enforced in four different water stress treatment conditions. In the first treatment condition (T_1), crop was grown on regular irrigation on the basis from sowing to harvesting. In second treatment condition (T_2), water stress was given from germination to harvesting means no irrigation for crop from germination to harvesting, *i.e.* Severe stress. In third treatment condition (T_3), irrigation is given at only branching stage. In fourth treatment condition (T_4), irrigation is given only at flowering stage. In fifth treatment condition (T_5), irrigation is given only at pod filling stage. Keeping in view, the above important aspects, the present investigation entitled "Evaluation of Cowpea (*Vigna unguiculata* (L.) Walp) genotypes under water stress condition in Konkan region" will carried out with following objective –

1.2 Objectives of the study:

1. To study the morphological, physiological and biochemical changes occurring under water stress condition.
2. To study the yield response of different cowpea genotypes under water stress condition.

1.3 Hypothesis or Assumptions:

The cowpea is most important *rabi* crop in Konkan region, which is grown on residual moisture. Typically, the laterite soil type, does not contain the greatest water holding capacity, causing moisture to be reduced from the soil and causes various degrees of moisture stress on the plant. This research will be helpful to find out the performance of cowpea genotypes and their responses under water stress condition, by studying all physiological, morphological and biochemical parameters. Also helps to find out the genotype which survive better, under stress condition with high yield.

1.4 Scope & Importance of the study:

Recently, as climatic conditions varies in each growing season, it is very important to study the genotypes which shows better performance in changing environmental conditions specially in moisture stress. The reason for the low yield in cowpea may be many but the important one is moisture stress. To increase food grain production substantially to meet the demand of ever increasing population it is important to find out the variety gives suitable for moisture stress condition.

REVIEW OF LITERATURE

CHAPTER II : REVIEW OF LITERATURE

Cowpea production like most other crop is limited by factors such as poor yielding varieties, nutrition and moisture stress among other factors of production (Chiezey *et al.*1990). Cowpea is also valued for their ability to fix atmospheric nitrogen into the soil and play an important role as a rotation crop with cereals and vegetable crops (Biswas and Gresshoff, 2014).

Water stress is a significant hazard to successful crop production worldwide, limiting pulse productivity in rainfed production systems in semiarid tropics (SAT). Food legumes are more sensitive to water stress during reproductive growth, where pod number determines the number of pods. Compensation opportunities decrease beyond this stage through seeds per pod and seed size. (Bhattacharya *et al.* 2009). Grain legumes are typically grown in tropical countries during the rabbi season (Wein *et al.* 1979). This is characterized by moisture stress due to rain uncertainty. This stress results in receding soil moisture and rising temperatures. To overcome stress, researchers are exploring methods to expand irrigation areas and improve irrigation scheduling for higher grain legume production in stress conditions. Consequently, the crop is subjected to moisture stress, due to receding soil moisture and raising temperature (Kumar and Sinha, 1988). Water stress is the most prevalent abiotic stress limiting global plant growth and productivity. Water deficits occur when water availability is insufficient for growth, photosynthesis, and transpiration, causing stunting, flower abortion, and leaf senescence (Blum 2005).

The present investigation entitled **"Evaluation of Cowpea *(Vigna unguiculata* (L.) Walp) genotypes under water stress condition in Konkan region." This chapter presents relevant literature for the investigation, categorized under sub-headings:**

2.1 Morphological character

2.2 Biochemical parameter

2.3 Physiological behaviour

2.4 Growth parameters

2.5 Yield and yield attributes

2.1. Morphological characters

Tarun (1987) studied the physiological basis of field variation in lablab bean, evaluating sixteen genotypes for branching plant height, dry matter distribution, and growth parameter. Results showed variation among growth parameters, with EC 10184 showing the highest daily dry matter production rate.

Naik (1990) studied the physiological basis for varietal differences in growth and yield of cowpea *(Vigna unguiculata* L. Walp.). He evaluated eight genotypes for leaf number, plant height, seed yield, and dry matter accumulation. He found significant variation among genotypes, with ACCC-224 having the highest was recorded.

Shinde (1998) assessed water stress evaluation using potassium and growth regulator in five green legumes, including lablab bean which showed maximum plant height, leaf number, and leaf area under no stress conditions.

Nasreen *et al.* (2000) studied morphological and physiological variation in lablab bean. For major morphological character 107 lablab genotype were evaluated from 20 different countries. Variation was studied among the genotypes.

Nkouannessi (2005) studied the genetic, morphological and physiological evaluation of African cowpea genotype. The result revealed a relative high level of dis-similarity among the accession for most of the morphological traits analysed.

Naim *et al.* (2007) examined the effect of four different number of plants per stand on the performance of three cowpea varieties in rainfed conditions. The results showed that increasing plant per stand decreased plant height. The local variety (Beldi) had significantly taller plants as compared to other varieties. Grain yield per unit area increased significantly due to increased plants or stand and reduced the number of pods per plant, 100 grain weight, grain per plant and harvest index.

Kamai *et al.* (2010) performed a varietal trials and physiological component determining yield differences among cowpea varieties in the semiarid zones of Nigeria. The result showed that cowpea grain yield per hectare was positively correlated with harvest index, shell weight, soil moisture suction measurement, shelling percentage and grain yield per plant which observed significant negative corelation between cowpea grain yield per hectare and number of days to first and 50 per cent flowering, 100 grain weight, the number of days to physiological maturity and pod development period.

Borkar *et al.* (2011) conducted morpho-physiological analysis for growth and yield variation in 22 genotypes of groundnut. They observed different characters such as plant height, days to 50 per cent flowering, days to physiological maturity as well as yield parameter. All genotypes significantly differed for different parameters.

Ranawake and Dahanayaka (2012) observed that number of leaves was significantly affected when the drought applied at 8 WAP. Further, all the measured parameters other than length of tap root and number of nodules per plant were significantly affected by drought stress at 3 WAP.

Groteluschen (2014) carried out experiment with the promising multipurpose legume *Lablab purpureus* (L.) in small-holder farming system of Eastern. He recorded maximum plant height in genotypes CPI 52535.

Kataria and Singh (2014) examined the effect of applied potassium in selected mung bean genotype SML-668 and MH-318 under water stress conditions. The results revealed that stress condition in both the genotype of mug bean showed an increasing trend for leaf area from vegetative to the flowering stage, whereas there was a sharp decline in leaf area from flowering to pod formation stage. Genotype SML-668 showed maximum leaf area (80.2, 126.0 and 61.1 cm^2) than MH-318 (61.5, 91.9 and 49.6 cm^2) respectively at vegetative, flowering and pod formation stage.

Mustapha *et al.* (2014) studied the effect of moisture stress on the growth parameter of different soybean genotype. The result revealed that at stress condition in all the genotypes of soybean showed an increasing trend for plant height from stress at vegetative stage (36.82 cm) to stress at post-flowering stage (51.24 cm).

Shirodkar (2016) recorded the morphological parameter in Wal (*Lablab purpureus* L.) under moisture stress condition such as plant height, number of leaves, leaf area per plant and number of branches per plant. The result showed that maximum plant height, number of leaves, leaf area per plant and number of branches per plant in I_7 treatment (seven irrigation at 10 days intervals).

Kurhe (2020) studied the morphological traits associated with growth and yield of promising cultures of Wal (*Lablab purpureus* L. Sweet) under irrigated and residual moisture conditions. This experiment consisted of two irrigation levels such as I_1 residual moisture condition (no irrigation) and I_2 irrigation condition (irrigation at critical stages) and eleven genotypes namely V_1, V_2, V_3, V_4, V_5, V_6, V_7, V_8, V_9, V_{10}, V_{11} Konkan Wal-2 (check). Among them, lablab with two irrigation level I_2 (irrigation at critical stage) recorded maximum plant height, number of leaves, number of branches.

Tetteh Rashied *et al.* (2020) studied the effect of water stress on growth of two cowpea accessories (UCC 321 and GH 4769). The result indicated that under water stress condition, there was reduction in plant height, number of leaves and plant dry mass than the watered cowpea plant.

Omolayo *et al.* (2021) studied morpho-physiological changes in cowpea genotypes under drought stress. A total three genotypes were subjected to 28 days of three volumetric water content treatment. The result indicated that drought stressed condition in all the genotypes of cowpea showed that plant height, leaf area, number of leaves and total dry mass were significantly decreased. compared to well water and intermediate drought conditions.

2.2 Biochemical parameter

Purushottam *et al.* (1998) observed that there was increase in proline content in groundnut leaves when crop was subjected to moisture stress.

Mafakheri *et al.* (2010) studied proline content of the leaves increased at both stages like vegetative and flowering stages of chickpea in all varieties response to drought.

Kumar *et al.* (2011) noticed the effect of polyethylene glycol induced water stress (-0.45 MPa and -1.22 MPa) on physiological and by biochemical responses of pigeon pea (*Cajanus Cajan* L. Millsp.). The results indicated that under progressive mild stress free proline content increased up to 12.17µMgm^{-1} and 54.47 µMgm^{-1} accumulation of proline observed under progressive severe stress condition. There was an increasing trend in the total chlorophyll content from progressing moderate stress to progressive severe stress condition.

Salekjalali *et al.* (2012) showed the effect of soil water shortages on the activity of antioxidant enzymes as well as the content of chlorophylls and protein in Barley. They revealed that RWC of barley leaves decreased under drought stress when compared to unstressed conditions and it was noticed that 25% and 57 % in moderate stress and in severe stress condition respectively.

Maritim *et al.* (2013) examined the effect of water stress (soil moisture level at 34%, 24% and 16%) on accumulation of proline and glycine betaine in tea at Kenya. Imposition of water deficit conditions on tea seedlings caused significant increases in proline leaves in treatments and eight cultivars used for study purpose.

Panda *et al*. (2015) observed that moisture at branching and flowering in sesame reduced chlorophyll stability index, which in turn effected the seed yield while sesame seeds treated with salicylic acid (1000 ppm) observed highest chlorophyll stability index.

Sun *et al*. (2015) examined the proline, sugars and antioxidant enzymes response to drought stress in the leaves of strawberry plant at China and stated that the proline levels were higher in leaves subjected to drought stress treatment used (control 70-85% WHC, mild stress 50-60% WHC, moderate 40-50% WHC and severe stress 30-40% WHC) the proline contents of leaves subjected to mild, moderate and severe drought stress where 1.34 fold, 1.9 fold and 2.3 fold higher than that of control leaves, respectively .The leaves water potential decreases from the mild, moderate and stressed plants. The leaf water potential of mild, moderate -1.93, - 2.73 and 3.25 MPa at 10 days after stressing treatment, respectively.

Shirodkar (2016) studied the biochemical parameter in Wal (*Lablab purpureus* L) under moisture stress condition. The result showed that total chlorophyll is increased in I_7 treatment (seven irrigation at 10 days intervals), whereas there was accumulation of maximum proline at I_0 (no irrigation after 30 DAS).

Kardile *et al.* (2018). Examined the chlorophyll content and proline content at different stages of growth in cowpea (*Vigna unguiculata* L. Walp.) genotypes under moisture stress condition. The result showed that the less reduction in chlorophyll content under severe stressed and high proline accumulation was higher under water stressed condition than irrigated condition.

Nkoana K D *et al.* (2019) studied 28 cowpea germplasm accessions including two controls viz. IT96D-602 (drought tolerant) and TVU7778 (susceptible to drought) in the drought screening house using plastic box evaluation method. Stem greenness and recovery appeared to be a reliable indicator of drought tolerant genotypes which was readily observed in Acc1257, Acc1168, Acc2355, IT96D-602 and Acc5352 which also correlated significantly and positively with proline content.

Kurhe (2020) studied the biochemical traits associated with growth and yield of promising cultures of Wal (*Lablab purpureus* L. sweet) under irrigated and residual moisture conditions. The lablab crop showed increase in the accumulation of maximum proline at I_1 residual moisture condition (no irrigation).

Mahmud *et al*. (2021) found that CIP-396244.12 and CIP-393371 these two genotypes also accumulated more proline and total soluble sugar in leaves with less destruction in total chlorophyll under water stress condition than control. An increase in chlorophyll a/b ratio was found in CIP 396244.12, followed by CIP 393371.58 under water stress condition. The highest catalase activity was observed in CIP 396244.12, followed by CIP 393371.58 under water stress condition. The result revealed that CIP 393371.58 and CIP 396244.12 greater adaptability in changing environment.

Moloi M J *et al.* (2021) found that severe drought stress negatively impacts vegetable-type soybean production in Africa, affecting ascorbate peroxidase (APX), guaiacol peroxidase (GPX), and glutathione reductase (GR) activities. The study examined five cultivars, UVE8, UVE14, UVE17, AGS354, and AGS429. Drought increased proline contents at flowering and pod-filling stages. The study found that tolerance responses of vegetable-type soybean, particularly at the flowering stage. The induction of TSS at flowering and proline at pod filling is crucial for this crop's drought tolerance response.

Theophilus Kwabla Tengey *et al.* (2023) noticed the prolonged drought of cowpea at the seedling stage. 15 genotypes of cowpea were studied under water stress condition. The result revealed significantly genotypes showed that high chlorophyll content under drought stress for unfailure and trifoliate leaves.

2.3 Physiological behaviour

Hayatu and Mukhtar (2010) evaluated physiological responses of drought resistance cowpea genotype (*Vigna unguiculata* (L.) Walp.) to water stress at Nigeria. The seven genotypes of cowpea (ITOOK-835-45, ITOOK-901-5, IT96D-610, IT97K-819-118, IT98K-205-8, IT98K-555-1 and IT99K-377-1). Under moderate stress condition, the genotype ITOOK-901-5 and IT97K-819-118 noted (24.51%) and (6.64%) chlorophyll content respectively, whereas under severe water stress condition, the reduction in chlorophyll content ranged from 14.82% in ITOOK-835-45 to 38.21% in IT99K-377-1.

Makbul *et al.* (2011) evaluated the changes in anatomical and physiological parameters of soybean under drought stress at Turkey and revealed that the chlorophyll content and water potential in the leaves noticed significant decrease during the stress treatment. Among these two treatments (unstressed and stressed), the chlorophyll content showed in the leaves of unstressed plant was 2.11 mg/g, whereas the drought stress leaves recorded 1.52 mg/g. The leaf water potential seen in the leaf unstressed plant was -0.88 as well as in the drought stressed leaf recorded -1.18.

Kumar *et al.* (2011) observed that maximum relative water content (69.33%) was recorded in progressive moderate stress (-0.45 Mpa), whereas in progressive severe stress (-1.22 MPa) it recorded minimum relative water content (40%).

Chandrashekhar *et al.* (2012) carried out an experiment to find out the physiological and biochemical changes during moisture stress in banana (CV. Culcutta- 4 (AA) and Beehee Kela (BB) type) at a Banglore. The results showed that at stressed condition Culcutta-4 and Beehee Kela (BB) observed -1.824 and -1.518 water potential which was maximum than control (-1.35 and -0.913), respectively.

Zinlala V and Buncel (1998) examined that the effect of water regimes on physiological parameters of Indian bean (*Lablab purpureus* L.). Six genotypes of Indian bean were examined for four different irrigation levels. Various physiological parameters such as photosynthesis rate, stomatal conductance, leaf area, plant height, number of branches, days to 50 per cent flowering, number of pods per plant, seeds per pod were observed at different growth stages. The study revealed that the application of stress condition at different growth stages lowers the different physiological parameters. Irrigation as per recommendation observed the normal physiological parameters as compared to treatment of stress.

Kardile (2018) studied cowpea genotypes under moisture stress conditions, Konkan Sadabahar with the highest relative water content (83.54) at harvest. From 45 days to 90 days, water stress treatments significantly affected relative water content. Fodder cowpea-1 and ACP-109 showed less reduction in relative water content under stressed conditions, indicating better hydration, internal water relations, and drought tolerance capacity.

Nkoana *et al.* (2019) studied 28 cowpea germplasm accessions, including drought-tolerant and susceptible ones, in a drought screening house. They found significant differences in physiological traits, except leaf wilting index. Stem greenness and recovery were reliable indicators of drought-tolerant genotypes, correlated with relative water content.

Kurhe (2020) studied the physiological traits associated with growth and yield of promising cultures of Wal (*Lablab purpureus* L. Sweet) under irrigated and residual moisture conditions. The lablab crop showed increase in relative water content at I_2 (irrigation at critical stage).

Mekonnen (2020) carried out experiment and found that the seed filling water stress resulted greater reductions in the value of all tested parameters studied compared to optimum watering and vegetative stress except number of primary branches and harvesting index, which were significantly lower under vegetative water stress. As well, the two varieties significantly differed for all observed parameters except number of nodules per plant and nodule dry weight. Days to flowering, pod maturity, number of pods per plant, number of seeds per pod and harvest index were significantly higher for Mastewal variety while, plant height, number of primary branches, number of secondary branches, dry biomass, seed yield per plant, hundred seed weight and root dry weight were greater for Habru variety. Water stress affected the days to flowering, plant height, seed yield per plant, hundred seed weight, number of pods per plant and harvest index.

Mahmud *et al*. (2021) found that CIP396244.12 and CIP 393371.58 showed higher membrane stability index (lowest injury) after 10 and 20 days of drought treatment.

Gujrall *et al.* (2022) observed that shoot growth, root growth, leaf area, relative leaf water content (RLWC), photosynthetic pigments (chl. a, b, carotenoids) exhibited a decline with an increase in water stress treatment except the catalase activity which displayed increasing trend. Stress-induced changes in metabolism and development can be attributed to altered patterns of gene expression.

2.4 Growth parameters

Parab *et al.* (1991) communicated that, when cowpea crop was subjected to regimes of irrigation stress, leaf area ratio was found to be affected and declined rapidly under stress condition and sudden fall of leaf occurred.

Shinde (1998) studied the effect of elevation of water by potassium and growth regulators in five green legumes. Out of them, lablab bean showed maximum absolute growth rate as well as relative growth rate during the initial stage under no stress condition.

Deokar *et al.* (2009) observed the difference in growth and yield of six genotypes of soybean. Among these, the number showed the highest absolute growth rate, relative growth rate, and net assimilation rate.

Ozalkan *et al.* (2010) observed the relationship between not only the some plant growth parameters but also grain yield of chickpea during different growth stages. The relation between some plant growth parameters such as (NAR), (RGR), and (AGR) with biomass and grain yield of chickpea was showed. The mean grain yield was 1.86 t/ha^{-1} which varied between 1.4127 t/ ha^{-1} and 2.27 t/ ha^{-1} for different varieties.

Grotekuschen (2014) observed maximum relative growth rate as well as leaf area index in CPI 60795 genotype of lablab bean.

Hasaan *et al.* (2014) studied forage yield and quality of lablab intercropped in maize with a flood irrigation system. The research was conducted with two factors, the age of harvest (6, 9, 12, 15 and 18 weeks after sowing) and irrigation schedule (3, 6 and 9 days interval) 6 weeks after sowing (harvesting age) of lablab noted 5.03 t/ha dry matter. The age of harvest has not shown a significant difference in the leaf area index. The age of harvest has not shown a significant difference in leaf area index. The age of harvest 6, 9 and 12 WAS recorded 0.6, 0.5 and 0.6 leaf area index, respectively.

Menon and Savitri (2015) carried out an experiment to mitigate water stress in vegetable cowpea through seed hardening and moisture conservation practices. Different treatments used for mitigating water stress, treatment five days irrigation interval resulted maximum plant height of 0.76 cm and maximum number of leaves (10.7) at 45 days after sowing.

Shirodkar (2016) studied the different growth parameters in Wal (*Lablab purpureus* L.) under moisture stress condition. The different growth parameters are leaf area, leaf area index, absolute growth rate, relative growth rate, leaf area ratio, etc. The result showed that the above growth parameters was increased in I_7 treatment (seven irrigation at 10 days intervals).

Kurhe (2020) studied the growth parameter in Wal (*Lablab purpureus* L. Sweet) under irrigated and residual moisture condition. Among them, I_2 (irrigation at critical stage) recorded the leaf area, leaf area index, specific leaf weight, absolute growth rate, relative growth rate, leaf area ratio, etc. whereas genotype V_6 showed maximum leaf area, leaf area index, relative growth rate and leaf area ratio.

Jaymini Jayawardhane *et al.* (2021) observed the response of cowpea plants to abiotic stress applied with increasing intensity of water deficit treatments (gradually decrease in water supply). Following two weeks of treatments the fresh weight of leaves and of the whole plant weight and relative water content decreased.

2.4 Yield and Yield attributes

Rao *et al.* (2003) examined the effect of drought and temperature on plant growth and nutrient uptake of grain legumes viz. green gram, black gram and cowpea, they showed that under stressed condition yield and yield contributing characters such as number of pods, number of seeds per pod and 100 seed weight was drastically reduced.

Futuless and Bake (2009) studied the yield and yield attributes of some cowpea (*Vigna unguiculata* (L.) Walp) varieties in Northern Guinea Savanna. They observed parameters such as plant height, number of leaves per plant number of branches per plant, number of days to flowering, pod filling period, days to physiological maturity, pods per plant, pod length, number of seeds per pods number of seed per plant, 100 seed weight and yield per hectare. The flowering stage between 38.02 days to 50.12 days after planting and the maturity period did not exceed 71 days. The average grain yield ranged between 14,000.3 kg/ha to 20,000.20 kg/ha. V_2 (Brown Kananado) showed the highest yield of 20,000.20 kg/ha with V_5 (Iite-Brown) giving the least yield of 14,000.30 kg/ ha.

Ahmed *et al.* (2010) showed that, the reproductive stage of cowpea crop was more sensitive to drought which showed in reduction in yield from 40 to 50 %, depend on environmental conditions prevailing during the drought treatment. They further seen that, significant reduction in number of harvested pods per plant under water stress could be attributed to the abscission of the reproductive structures.

Ranawake and Dahanayaka (2012) observed that water stress significantly affects pod filling stage of Mung bean. Number of floral buds and number of pods were not affected by the drought stress at 8 WAP though there is no ecological value of these characters as the pod filling efficiency is low in Mung bean under drought stress.

Siahbidi *et al*. (2014) studied the responses of sunflower genotypes (Farrokh, Ghaseem and SHF 81-90) to water stress (irrigation in 25, 50 and 75% depletion of soil moisture) and super absorbent (0, 100 and 200 kg/ha). Among the genotypes Ghasem has showed 100 seed weight of 6.2, 6.6 and 6.8 gm at full stress, semi stress and full irrigation condition, respectively. The results revealed that seed yield of all the genotypes were affected in water deficit and super absorbant. Among the genotypes Farrokh has noticed seed yield of 3071, 4583 and 5524 kg/ ha at full stress, semi stress and full irrigation condition, respectively.

Panda *et al.* (2015) studied 28 genotypes of French bean for morpho-physiological characters. These characters are green pod length, plant height, internodal length, number of pods per plant, days to 50 per cent flowering and number of branches which observed high variability. The study showed that due emphasis should be given to several pods per plant, plant height, and several branches per plant during the selection process for the development of superior genotypes.

Anita and Lakshmi (2015) studied the growth characters of fodder cowpea varieties as influenced by soil moisture stress levels (pre sowing irrigation and irrigation at IW/CPE ratio 0.4, 0.6 and 0.8). The results showed that irrigation at pre sowing and irrigation at IW/CPE ratio 0.4 were at par with each number of branches. The number of branches were significantly higher when irrigation at IW/ CPE ratio 0.8 (4.22) and irrigating at IW/ CPE ratio 0.4 (3.80).

Menon and Savitri (2015) carried out an experiment to mitigate water stress in vegetable cowpea through seed hardening and moisture conservation practices. Among the different treatments used for mitigating water stress, treatment of five days irrigation interval showed maximum number of branches (2.3), maximum number of pods (4.0) and maximum number of seeds per pod (14.8).

Ndiso *et al.* (2016) studied cowpea variety, water stress and the interaction between cowpea variety and water stress significantly affected the harvest index. Water stress at vegetative stage significantly increased harvest indices of all cowpea varieties except Macho, Nyeupe and Kutambaa. Water stress at flowering enhanced cowpea harvest indices for only K80, Kaima-koko, Nyekundu, and Kutambaa varieties. Mwandato had significantly the highest harvest indices under all the stress levels. Under water stress at vegetative stage, Kutambaa and Nyeupe had significantly the highest indices than all other varieties. Harvest indices varied from 2.93% (Mwandato) to 12.8% (M66) under no stress, 2.13% (Mwandato) to 25.3% under stress at vegetative stage and 3.47% (Mwandato) to 18% (M66) at flowering.

Shirodkar (2016) studied the yield attributes in wal (*Lablab purpureus* L) under moisture stress condition. The different yield attribute was included in research was number of pods per plants, number of seeds per plants, 100 grain weight, seed yield, etc. The maximum number of pods per plants, number of seeds per plants, 100 grain weight, seed yield was recorded in I_4 treatment (four irrigation at 10 days intervals).

Kardile *et al.* (2018) investigated the component traits responsible for developmental plasticity and mechanism of sustaining yield levels in water deficit conditions with support of growth analysis biochemical physiological parameters yield and yield contributing characters study studies on yield contributing characters *viz.*, day to 50% flowering day to maturity, number of pods per plant, length of pod number of grains per pod, 100 grain weight, grain yield per plant and grain yield per hectare found to be influenced significantly by different water stress treatment in cow pea genotypes. Changes in above mentioned parameter showed that fodder cowpea-1 and konkan sadabahar both varieties are much tolerant to water stress compared to ACP-109 and PCP.

Kurhe (2020) studied the yield attributes in Wal (*Lablab purpureus* L. Sweet) under irrigated and residual moisture condition. Among the two irrigation level I_2 recorded the maximum seed yield. Among them, genotypes used for the study, genotype V_6 had recorded maximum number of pods per plants, number of seeds per plants, 100 grain weight, seed yield, etc.

Shende *et al.* (2020) found that drought stress reduced seed yield and its attributes. Mean seed yield was decreased by 20.46 % and 19.31% in Vishal during 2018 and 2019, respectively under non stress condition than irrigated condition. ICC 14778, JG 11 and ICC 4958 genotypes were detected with high seed yield under non irrigated and irrigated condition. They were also observed superior to the seed yield under irrigated condition.

Abiola Toyin Ajayi (2020) studied yield characters and drought tolerance indices (DTIs) in 24 genotypes of cowpea (*Vigna unguiculata* (L.) Walp) in the screen house in pots under two watering regimes; 500 ml/pot daily and once in 10 days for control and drought stress, respectively. Genotypes G20, G19 and G11 were considered the best in terms of yield above average (18.94 g) in control and (3.98 g) under drought stress, while G2 was more stable (13.79 g and 10.71 g) under both conditions.

Ricardo Santas *et al.* (2020) studied morphological variation in cowpea under drought stress. A total 29 cowpea genotypes were evaluated from 11 different countries for yield characters. The result showed that number of pods per plant, pod dry weight decrease under drought condition.

Vincent Ezin *et al.* (2021) examined the physiological basis for varietal difference in vegetative and reproductive stages of cowpea (*Vigna unguiculata* (L.) Walp.) under water stress condition. 20 cowpea genotypes were evaluated for various yield attributes like days to flowering, number of pods, yield per plant, the weight of 100 seed, showed significantly difference under water stress.

MATERIALS AND METHODS

CHAPTER III: MATERIAL AND METHODS

The present investigation entitled **"Evaluation of Cowpea *(Vigna unguiculata* (L.) Walp) genotypes under water stress condition in Konkan region"** was carried out at Research and Education farm, Department of Agricultural Botany, College of Agriculture, Dapoli during the year 2022-23. This chapter provides a thorough description of the materials used and the methodology employed during the entire investigation.

3.1. Experimental site:

The present investigation was carried out at Research and Education farm, Department of Agricultural Botany, College of Agriculture, Dapoli, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli during the *rabi* 2022-23.

3.2. Climatic and weather conditions:

The Research and Education farm, Department of Agricultural Botany, College of Agriculture, Dapoli comes under the Dapoli Taluka, it is situated in the sub-tropical region on the 17^{o} 45' 02" North latitude and 73^{o} 10' 55" East longitude, having elevation of 250 meters above the mean sea level. The average annual precipitation is about 3500-4000 mm. The meteorological observations during *rabi* season *i.e.* October to March 2022-23, were recorded at the meteorological observatory, Agronomy, College of Agriculture, Dapoli. The details of the meteorological data are presented in Appendix-I.

3.3 Experimental design:

The experiment was laid out in Strip Plot Design with three replications provided with 5 treatments.

3.3.1 Experimental details:

Season	:	*Rabi* 2022-23
Design	:	Strip Plot Design.
Treatments	:	05
Replication	:	03
Plot size	:	1.5 m × 1.2 m
Spacing	:	30 cm x 15 cm
Crop	:	Cowpea (*Vigna unguiculata* (L.) Walp)
Variety	:	04

Table 3.3.1. Treatment details: Number of treatments: 05

T_1	Absolute control (Regular Irrigation)
T_2	Severe Stress (No Irrigation)
T_3	Irrigation at branching stage
T_4	Irrigation at flowering stage
T_5	Irrigation at pod filling stage

T- Treatment

3.3.2. Main plot treatment details:

3.3.2.1. Absolute control / Regular Irrigation (T_1):

The crop was irrigated at about 10 days interval so as to keep the soil moisture close to field capacity.

3.3.2.2. Severe stress / No Irrigation (T_2):

Water stress was induced by giving irrigation after germination due to which moisture stress was induced till harvest.

3.3.2.3. Irrigation at branching stage (T_3):

Water stress was induced by giving only one irrigation at branching stage.

3.3.2.4. Irrigation at flowering stage (T_4):

Water stress was induced by giving only one irrigation at flowering stage.

3.3.2.5. Irrigation at pod filling stage (T_5):

Water stress was induced by giving only one irrigation at pod filling stage.

Table 3.3.2. Number of Variety: 04

V_1	Konkan Safed
V_2	Konkan Sadabahar
V_3	Phule Sonali
V_4	Phule Rukmini

V - Variety

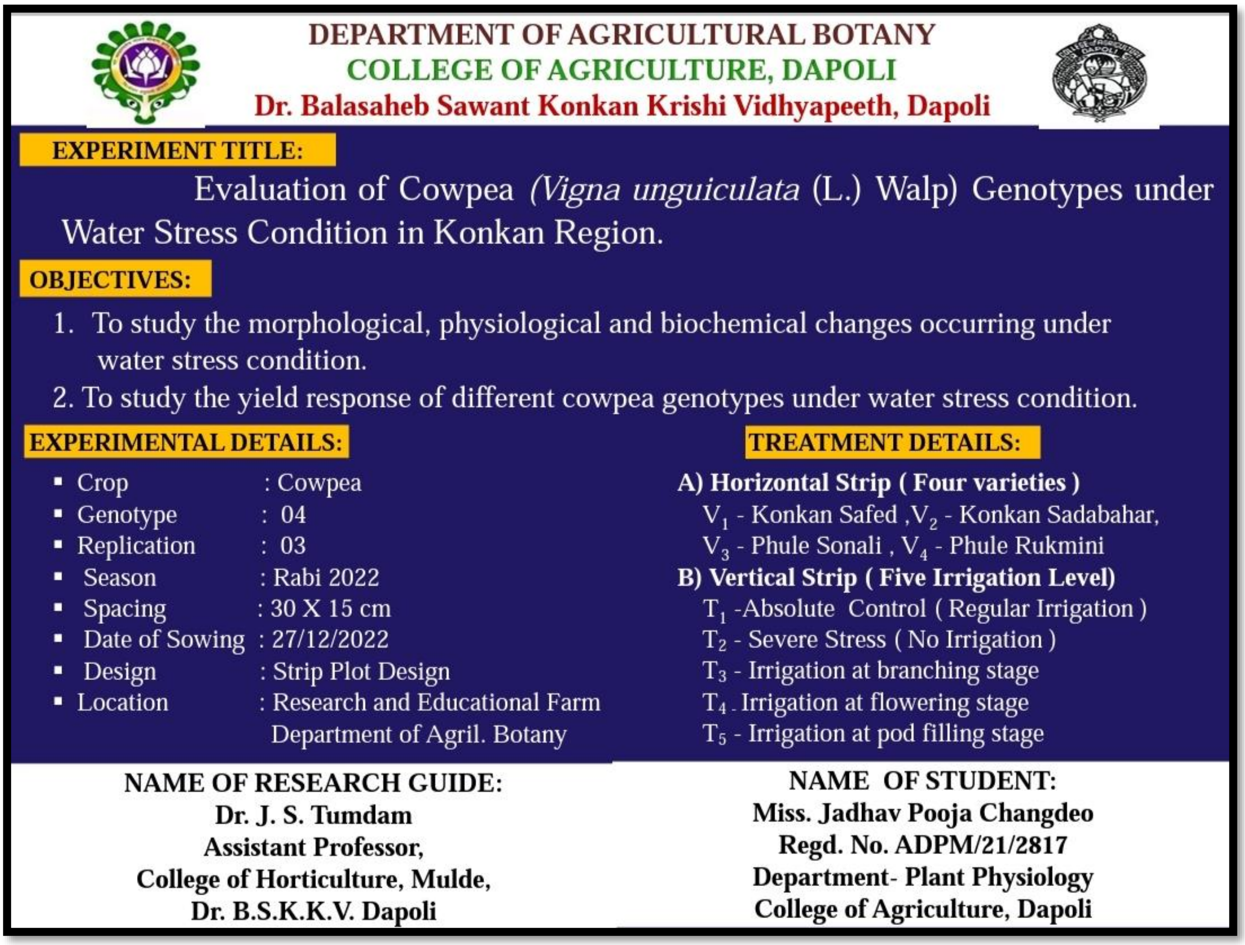


Plate 1. Field view of Experimental plot

3.4 Cultural practices:

3.4.1 Field preparation:

Immediately after the harvesting of rice, the field preparation was done. Herbicide was sprayed and a grass cutter was used to clean up the plot. Layout of the main plot and sub plots was done by taking proper measurements and marking was done by using sticks. The experiment was carried out on lateritic soil at its typical fertility and moisture level.

3.4.2 Sowing and cultural operations:

Sowing was done on 27th December 2022. Two seeds were dibbled at each hill with proper spacing to retain only one healthy seedling per hill. Fertilizers were applied @ 25 kg N, 50 kg P_2O_5 per hectare respectively at the time of sowing. Labelling of treatment plots was done by using zinc labels. Gap filling was done ten days after sowing. Two weeding's were done, one at 30 DAS with the help of weeder and one hand weeding at 60 days after sowing. Irrigation at a critical stage (*i.e*., Branching stage, flowering stage and pod filling stage) was given to the treatment plots and control treatment plot the regular irrigation was given at all critical stages still to harvest.

3.5 Observations recorded:

Five plants were selected randomly from each plot for recording the observations. Zinc labels were used to mark these five plants. Following observations were taken during the course of experimentation.

3.5.1 Moisture content in the soil:

The changes in soil moisture content were studied by taking frequent samples at 20 days interval from sowing till harvest by using gravimetric method. The soil samples were collected from each plot at a depth of 0-20cm by using a screw auger and were stored in air tight steel containers. Then the containers with soil samples were weighed (*i.e.* fresh weight) and oven dried at 105ºC for 24-48 hours until all the moisture was driven off from them. Then the containers were taken out and allowed to cool at room temperature. Now the samples were weighed again to get the oven dry weight. The difference in weights between fresh and oven-dried soil samples gave the weight of moisture in the samples and expressed as percentage.

$$\text{Soil moisture } \% = \frac{\text{Wm} - \text{Wd}}{\text{Wd}} \times 100$$

Where,

Wm - weight of moist soil sample.

Wd - weight of oven dry soil sample.

3.5.2 Morphological observations:

3.5.2.1 Plant height (cm):

The plant height was measured from ground level to the highest growing point of main stem with meter scale and expressed in centimeter (cm). The height of the plant was recorded at 20, 40, 60 days after sowing and at harvest.

3.5.2.2 Number of branches per plant:

Total number of branches produced by plant was recorded from the tagged plants by counting all the branches at 20, 40, 60 days after sowing and at harvest. Then average was worked out for statistical analysis.

3.5.2.3 Number of leaves per plant:

Total number of leaves produced by plant was recorded from the tagged plants by counting all the branches at 20, 40, 60 days after sowing and at harvest. Then average was worked out for statistical analysis.

3.5.2.4 Leaf area per plant (dm^2 /plant):

Leaf samples for each treatment were selected randomly from plot at 20 days interval till harvest. Large to small size leaf samples were collected from fully expanded green leaves (at least 5 leaves from each treatment). Immediately after the collection of samples leaves were transported to the laboratory. For appropriate measurements, damaged plants as well as abnormally grown plants were removed and leaves from healthy plants were collected. Leaf length was measured from lamina tip to the point of intersection of the lamina and the petiole, along the midrib of the lamina, while leaf breadth was measured from end-to-end between the widest lobes of the lamina perpendicular to the lamina mid-rib. Leaf area per plant was calculated with the help of formula given by, Tsunoda (1962).

Leaf area = Length of the leaf x Breadth of the leaf x Correction factor (2.325) x Number of leaves per plant

Actual leaf area was measured with leaf area meter (Licor LI-3100) by placing the sample leaves on the leaf area meter desktop and by holding flat and secure and reading was recorded.

3.5.3 Dry matter accumulation (g /plant):

For the estimation of dry matter accumulation, from each treatment plot five plants were randomly selected at each sampling and were separated into stem and leaves. These samples were properly labelled and dried in a hot air oven at 80^0C for first one hour and then at constant temperature of 60^0C. When plant parts were completely dried, the dry weight of each plant part (*i.e.* stems, roots and leaves) was recorded separately by using weighing balance. Summing up the weight of the plant parts (*i.e.* stem, leaves and roots) of the same plant gave the total dry matter per plant. Percentage distribution of dry matter in different plant parts was calculated by considering total dry matter as 100 per cent.

3.5.4 Phenological Studies:

3.5.4.1 Days to flower initiation:

The number of days were recorded from the date of sowing to the initiation of the first flower in each treatment plot.

3.5.4.2 Days to 50 per cent flowering:

The number of days were counted from the date of sowing to the date on which the 50 per cent of the plant population in a plot exhibited flowering and was recorded as days to 50 per cent flowering.

3.5.4.3 Days to physiological maturity:

Time required from date of sowing till the physiological maturity was counted in days and recorded as days to physiological maturity of the treatment plot.

3.5.5 Biochemical observations:

The following biochemical observations were recorded at 20, 40, 60 DAS and at harvest.

1. Total chlorophyll content of leaves (mg/g)
2. Proline content

3.5.5.1 Total chlorophyll content of leaves (mg/g):

The chlorophyll content of the leaves was estimated at 20, 40, 60, at harvest by using the method of Hiscox and Israelston (1979). Fully open mature leaf was taken as the experimental sample for chlorophyll estimation. In this method, 100 mg of clean leaf fresh tissue was weighed and incubated in 7.0 ml dimethyl sulfoxide (DMSO) at 65°C for 30 minutes. At the end of the incubation period, supernatant was decanted and the volume was made up to 10.0 ml with DMSO. The absorbance of the extract was recorded in spectrophotometer (HALO DB-20S UV-VIS double beam) at 645, 652 and 663 nm wavelengths, using pure DMSO as blank. The results were expressed as mg/g fresh weight.

The chlorophyll content was calculated by the formula as given below:

1. Chlorophyll `a' (mg/g) = 12.7 (OD 663) – 2.69 (OD 645) x $\frac{V}{1000 \times W}$

2. Chlorophyll `b' (mg/g) = 22.9 (OD 645) – 4.68 (OD 663) x $\frac{V}{1000 \times W}$

3. Total chlorophyll (mg/g) = Chlorophyll `a' + Chlorophyll `b'

Where,

OD = Optical density

V = Final volume of DMSO (10 ml)

W = Fresh weight of leaf sample (0.100 g)

3.5.5.2 Proline content (µmol/g):

Proline content from the leaf tissues of each treatment from each replication were estimated by following the method suggested by Bates *et al.*, (1973).

Reagents used:

1. Aqueous sulfosalicylic acid (3%)
2. Glacial acetic acid
3. Toluene
4. Acid ninhydrin: 1.25g of ninhydrin was dissolved in a warm mixture of 30 ml of glacial acetic acid and 20 ml of 6 M orthophosphoric acid.

Procedure:

The fresh leaf sample of (0.5 g) was homogenized in 10 ml of 3 per cent sulphosalicylic acid. The homogenate was filtered through a double layered filter paper. A 2 ml of the filtrate was taken in a test tube to which 2 ml of acid ninhydrin reagent (2.5 g of ninhydrin was dissolved in 40 ml of 6M orthophosphoric acid and 60 ml of glacial acetic acid), 2 ml of glacial acetic acid was added.

The test tubes containing the mixture were placed in boiling water bath for one hour. The test tubes were then cooled by keeping them in an ice bath. The contents were transferred to a separating funnel and 4 ml of toluene was added and mixed vigorously. The coloured toluene fraction was separated and measured at 520 nm in a spectrophotometer. A blank was maintained with all the reactants except the leaf extract. Proline content in leaf tissue was calculated by using the formula

$$\text{Proline } (\mu \text{ mole/g tissue}) = \frac{34.11 \text{ x OD 520 x V}}{2 \text{ x f}}$$

Where,

V= Total volume of extract

f = Grams of fresh leaf

2= Volume of extract taken

3.5.6. Physiological observations:

3.5.6.1 Relative water content (RWC) (%):

The following method was used for the assessment of relative water content. It was done at 20, 40, 60 DAS and at harvest. Fresh leaves from each treatment were collected in the plastic bag and were brought to the laboratory for recording their fresh weight. The fresh leaves were weighed on electronic weighing balance. Later these leaves were kept in water under diffused light for 4 hours at room temperature and then their turgid weight was recorded. Further these leaves were allowed to dry in hot oven at 75 ^{0}C and their dry weights were recorded. The RWC of leaves were calculated by using formula given by Barrs and Weatherly (1962).

$$\text{RWC } \% = \frac{\text{Fresh weight } - \text{ Dry weight}}{\text{Turgid weight} - \text{Dry weight}} \times 100$$

3.5.6.2 Chlorophyll stability index (%):

Estimation of Chlorophyll stability index was done by spectrophotometric method as suggested by Kaloyereas (1958). It was done at 20 days interval (20,40,60 DAS and at harvest) from sowing during the course of plant growth. Two clean glass tubes were taken and five grams of representative leaf sample was added to them with 50 ml of distilled water. One of the tube was subjected to the heat in water bath at 56 ^{0}C ± 1^{0}C for exactly 30 minutes, while the other one was kept as control. The collected leaves were then grounded in a mortar for five minutes with 100 ml of 80 % acetone. The slurry was then filtered by using the whatman No.1 filter paper. The chlorophyll extract was immediately examined under spectrophotometer at 652 nm wavelength. The difference in two readings (Reading without heating the tube and reading after heating the tube under water bath at 56 ^{0}C = ΔR) was defined as chlorophyll stability index. The following formula was used to calculate the chlorophyll stability index.

$$CSI = \frac{\text{Total Chlorophyll content in boiled sample}}{\text{Total Chlorophyll content in normal sample}}$$

3.5.7. Growth parameters:

Data obtained from dry matter studies at specific time intervals was used for computation of the following growth parameters.

1. Leaf area per plant (dm^2 /plant)
2. Leaf area index (LAR)
3. Specific leaf weight (SLW) g /dm^2
4. Absolute growth rate (AGR) g/day
5. Relative growth rate (RGR) g/g/day
6. Net assimilation rate (NAR) g/dm^2/day
7. Leaf area ratio (LAR)

3.5.7.1 Leaf area per plant (dm^2 /plant):

Leaf area per plant was calculated by leaf length was measured from lamina tip to the point of intersection of the lamina and the petiole, along the midrib of the lamina, while leaf breadth was measured from end-to-end between the widest lobes of the lamina perpendicular to the lamina mid-rib. leaf area per plant was calculated with the help of formula given by, Tsunoda (1962).

Leaf area = Length of the leaf x Breadth of the leaf x Correction factor (2.325)
x Number of leaves per plant

3.5.7.2 Leaf area index (LAI):

Leaf area index was determined by taking a statistically significant sample of foliage from a plant canopy, measuring the leaf area per sample plot and dividing it by the plot land surface area. Leaf area index (LAI) was calculated as per the formula given by Watson (1958).

$$LAI = \frac{\text{Leaf area per plant } (dm^2)}{\text{Occupied land area per plant (cm)}}$$

3.5.7.3 Specific leaf weight (SLW):

It is the ratio between leaf weight and leaf area. It signifies the thickness of the leaf was measured with the help of specific leaf weight and it was calculated by formula as suggested by Radford (1962) and expressed as g /dm^2

$$SLW = \frac{\text{Leaf dry weight}}{\text{Leaf Area}}$$

3.5.7.4 Absolute growth rate (AGR):

Absolute growth rate (AGR) was calculated from total dry matter accumulation by using formula given by Watson (1958) and expressed as g/day.

$$AGR = \frac{(W_2 - W_1)}{(t_2 - t_1)} \text{ g/day}$$

Where, W_2 and W_1 represent total dry matter per plant at t_2 and t_1 time intervals respectively.

3.5.7.5 Relative growth rate (RGR):

It is the rate of increase in dry weight per unit dry material present per unit time and expressed as g/g/day. RGR was calculated by the formula given by Briggs (1920).

$$RGR = \frac{(\text{Log}_e W_2 - \text{Log}_e W_1)}{(t_2 - t_1)} \text{ g/g/day}$$

Where, W_2 and W_1 represent total dry matter per plant at times t_2 and t_1 respectively.

3.5.7.6 Net assimilation rate (NAR):

The relationship between leaf area and dry matter accumulation was measured with the help of net assimilation rate and it was calculated by the formula as suggested by Gregory (1926) and expressed as $g/dm^2/day$.

$$NAR = \frac{(W_2 - W_1)}{(L_2 - L_1)} \times \frac{(\text{Log}_e L_2 - \text{Log}_e L_1)}{(t_2 - t_1)} \text{ g/dm}^2\text{/day}$$

Where, W_2 and W_1 represent total dry matter per plant and L_2 and L_1 denote the leaf area per plant at t_2 and t_1 times, respectively.

3.5.7.7 Leaf Area Ratio (LAR):

Leaf area ratio was worked out by formula given by Radford (1962) and expressed as $dm^2/g/$ day.

$$LAR = \frac{(RGR)}{(NAR)}$$

3.5.8. Yield and yield attributes:

Harvesting was done when plants reached to its physiological maturity. Five randomly selected plants from each treatment plot were harvested separately. Observations related to yield and yield attributes of these selected plants were recorded as follows.

1. Number of pods per plant
2. Number of seeds per plant
3. Seed yield (g/plant)
4. 100 seed weight (g)
5. Harvest index (%)

3.5.8.1 Number of pods per plant:

Number of pods per plant was counted from pods harvested from five randomly selected plants from each treatment plot at the time of harvest. Later average was worked out to record the observations.

3.5.8.2 Number of seeds per plant:

Five mature plant from each treatment were selected randomly. These plants pods were threshed separately and average number of seeds per plant was calculated.

3.5.8.3 Seed yield (g/plant):

All the pods of the individual selected plants from each treatment were harvested, threshed and dried. These seeds were separately weighed on weighing balance and then seed yield per plant was recorded in grams.

3.5.8.4 100 seed weight (g):

The weight of randomly selected hundred seeds from each treatment plot was recorded in grams.

3.5.8.5 Harvest index (%):

It is the ratio of economic yield to the biological yield and is expressed in percentage. It represents the efficiency of photosynthesis translocation to economic parts of the plant. It was estimated by using the formula proposed by Donald (1962).

$$\text{Harvest Index (\%)} = \frac{\text{Grain weight per plant}}{\text{Total dry weight per plant at harvest}} \times 100$$

3.6 Statistical analysis:

The data collected were subjected to the statistical analysis for strip plot design. The statistical analysis of the data was done by the standard method known as “Analysis of Variance” described by Panse and Sukhatme (1967). The standard error (SE) of mean and critical difference (CD) at 5 per cent level was worked out, wherever the results were significant.

RESULTS AND DISCUSSION

CHAPTER IV: RESULTS AND DISCUSSION

The present investigation entitled **"Evaluation of Cowpea (*Vigna unguiculata* (L.) Walp) Genotypes under Water Stress Condition in Konkan Region"** was carried out at Dapoli during *rabi* (2022-23) season, to study the influence of different water stress treatments with interaction of four genotypes was studied in cowpea crop at 20, 40, 60 DAS and at harvest.

The results obtained in the present investigation are given under the following heads.

4.1 Soil Moisture Content (%)

4.2 Morphological Observation

4.3 Biochemical Observation

4.4 Physiological Observation

4.5 Dry Matter Studies

4.6 Growth Parameters

4.7 Phenological Characters

4.8 Yield and Yield Attributes

4.1 Soil Moisture Content (%):

The soil moisture content of field capacity and permanent wilting point in all treatments, were investigated in the experimental plot. Data on soil moisture content is presented in Table 4.1 and Fig. 1. The soil moisture content was determined at 20 days interval from sowing (DAS) to harvest. The soil moisture content at the initial stage (at crop sowing stage) was 32.21 (%) same in all treatment, (regular irrigation, no irrigation, at branching stage, at flowering stage and at pod filling stage) under water stress condition. The soil moisture content from 20-60 DAS was changed after irrigation at vegetative and critical growth stages in treatment of stress condition. In a further course of study, under water stress condition soil moisture content went on decreasing from initial stage to harvest and remained below the permanent wilting point in treatment T_2 (no irrigation/severe stress) it was 18.42 (%). In all water stress irrigation treatment, it was changed after protective irrigation at the time of vegetative and critical stages of crop growth 28.67 (%) at branching stage, 27.83 (%) at flowering stage and 27.72 (%) at pod filling stage, whereas at harvest, it was 18.42 (%) in treatment T_2 (no irrigation/severe stress) will be reverse 20, 40,60 and 80 DAS.

Table 4.1 The per cent change in soil moisture content during crop growth period.

Soil Moisture Content (%)		
Time of Sampling	**Treatment details**	**Moisture (%)**
At Sowing	T_1 (Regular irrigation)	32.21
	T_2 (No irrigation)	32.21
	T_3 (At branching stage)	32.21
	T_4 (At flowering stage)	32.21
	T_5 (At pod filling stage)	32.21
20 DAS	T_1 (Regular irrigation)	30.47
	T_2 (No irrigation)	26.21
	T_3 (At branching stage)	28.67
	T_4 (At flowering stage)	26.43
	T_5 (At pod filling stage)	26.37
40 DAS	T_1 (Regular irrigation)	29.87
	T_2 (No irrigation)	24.24
	T_3 (At branching stage)	26.09
	T_4 (At flowering stage)	27.83
	T_5 (At pod filling stage)	25.37
60 DAS	T_1 (Regular irrigation)	29.27
	T_2 (No irrigation)	21.12
	T_3 (At branching stage)	22.26
	T_4 (At flowering stage)	23.44
	T_5 (At pod filling stage)	27.72
80 DAS	T_1 (Regular irrigation)	28.31
	T_2 (No irrigation)	18.42
	T_3 (At branching stage)	19.08
	T_4 (At flowering stage)	21.14
	T_5 (At pod filling stage)	22.05

4.2 Morphological Observation:

4.2.1 Plant height (cm)

The statistical analysis of the data on plant height shows that significant difference found among all treatments and the data was presented in the Table 4.2. and Fig. 2. The periodical data on influences of water stress on mean plant height increased progressively as the advancing age of the crop up to harvest. Plants from treatment T_1 (absolute control condition) recorded highest plant height as compared to plants from other treatment of water stress condition.

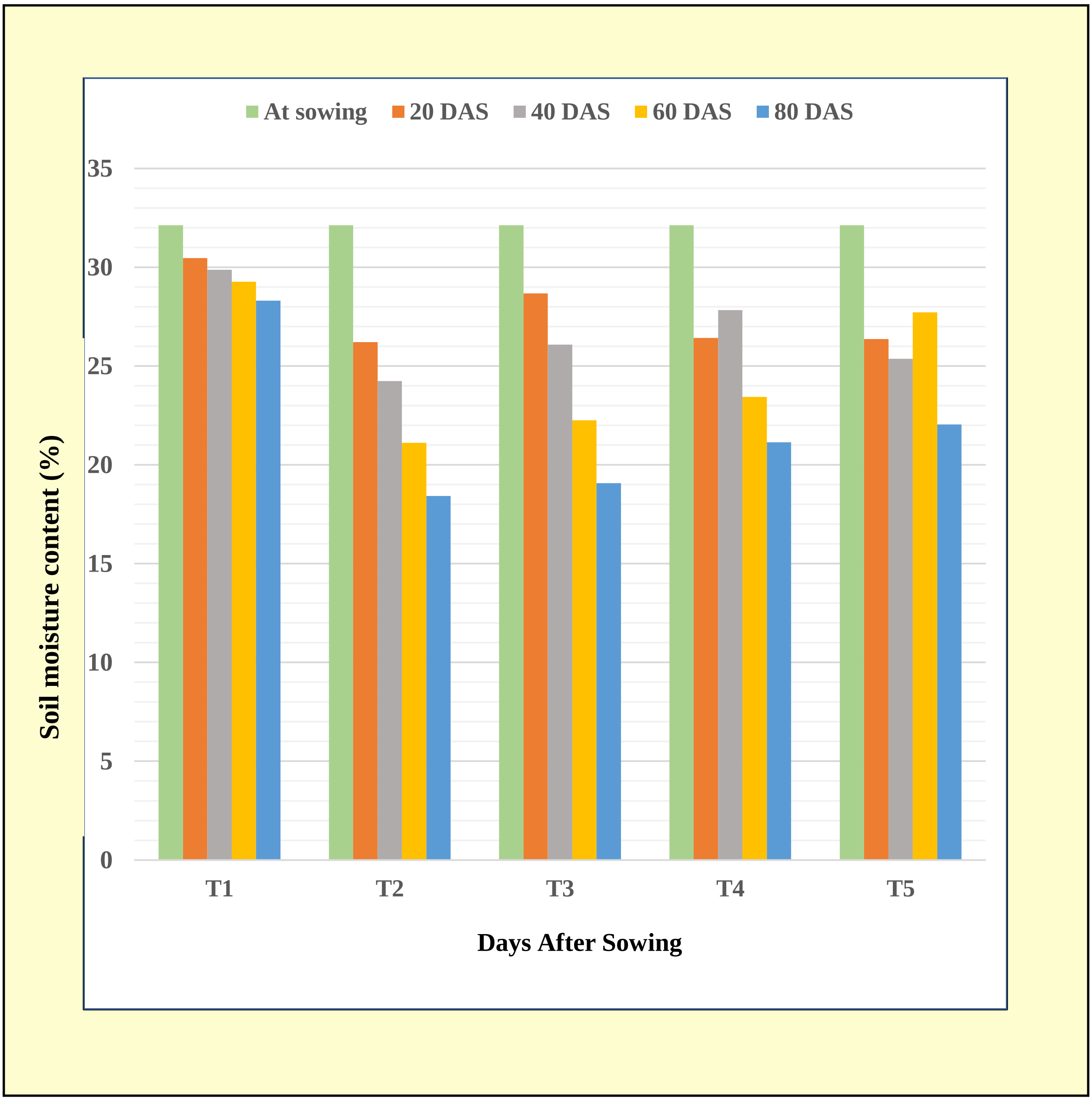


Fig.1. The per cent change in soil moisture content (%) during crop growth period.

Influence of water stress treatments

At 20 DAS, it was showed that there was significant difference among all treatments under water stress condition. The maximum mean plant height was found in treatment T_1 (9.873 cm) under water stress condition, whereas those treatments under remaining water stress condition were at par and minimum plant height was showed in treatment T_2 (8.591 cm).

At 40 DAS, the plants under each of stress treatments a significant difference was reported in respect of height under water stress condition. Among all the stress treatment T_1 (14.903 cm) recorded maximum plant height, whereas minimum was observed by the treatment T_2 (12.880 cm) under water stress condition. In water stress treatment condition, after treatment T_1 the highest plant height in vegetative and critical growth stages was observed in treatment T_4 (14.725 cm) at par with treatment T_3 (14.675 cm).

At 60 DAS, a significant difference was noted in plant height in all stress treatments with the growing age of crop growth was showed maximum in treatment T_1 (21.872 cm), followed by treatment T_4 (20.872 cm) while the minimum in treatment T_2 (16.182 cm).

At harvest, the plant height under water stress was noted maximum in treatment T_1 (27.652 cm), followed by treatment T_5 (25.460 cm) however, it was showed minimum in treatment T_2 (19.872 cm).

Influence of varietal differences

At 20 DAS, the varietal difference in plant height was recorded maximum in variety V_3 (9.905 cm) at par with variety V_1 (9.456 cm) while it was recorded minimum in the variety V_2 (8.512 cm) and V_4 (9.057 cm).

At 40 DAS, the maximum plant height was produced in variety V_3 (16.067 cm), followed by variety V_4 (14.755 cm) and variety V_1 (13.168 cm) which were at par with each other. The minimum plant height was recorded in variety V_2 (12.693 cm).

At 60 DAS, under water stress condition, the maximum plant height was showed in variety V_3 (23.197 cm), which was significantly better than rest of the all other variety and it was minimum noted in variety V_1 (16.211 cm).

At harvest, the plant height significantly differed in all treatments. The maximum plant height was found in variety V_3 (28.659 cm), followed by variety V_4 (24.905 cm) and variety V_2 (23.101 cm). However, the minimum plant height was observed in variety V_1 (19.969 cm), which was significantly lowest among all varieties.

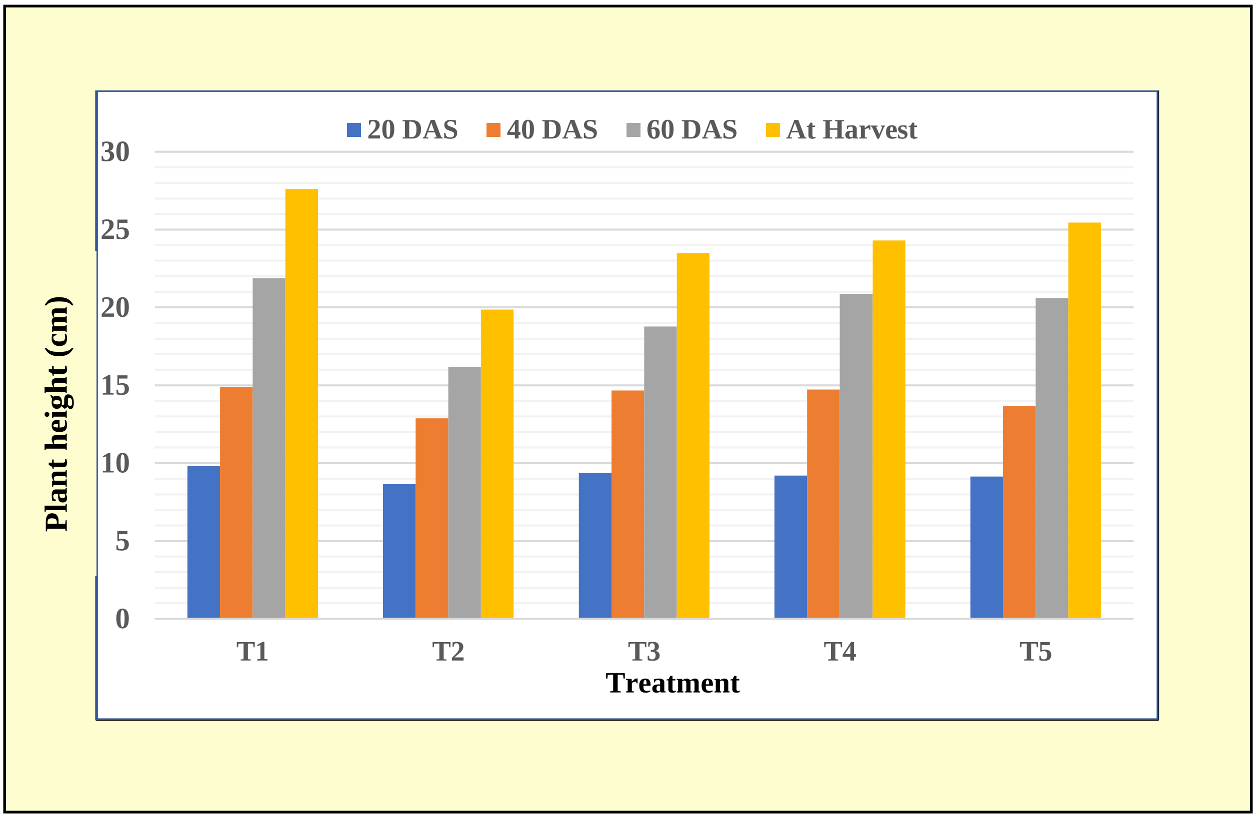
Table 4.2. Influence of different water stress treatments on plant height (cm) at various stages of plant growth of cowpea grown under water stress condition:

Genotypes	Treatments of water stress						SE ±	CD at 5%
	T_1	T_2	T_3	T_4	T_5	Mean		
20 DAS								
V_1	11.347	8.333	8.827	8.587	10.187	9.456	**V. 0.0323**	**0.1116**
V_2	8.520	8.287	8.727	8.540	8.487	8.512	**T. 0.0217**	**0.0709**
V_3	10.360	8.453	10.740	10.533	9.440	9.905	**T x V**	
V_4	9.260	9.293	9.153	9.133	8.447	9.057	**0.0447**	**0.1378**
Mean	9.873	8.591	9.362	9.198	9.140	9.233		
40 DAS								
V_1	13.247	12.500	13.240	13.187	13.667	13.168	**V. 0.0419**	**0.1451**
V_2	13.473	11.427	13.033	13.127	12.407	12.693	**T. 0.0512**	**0.1669**
V_3	17.420	14.293	17.267	17.220	14.133	16.067	**T x V**	
V_4	15.473	13.300	15.160	15.367	14.473	14.755	**0.0880**	**0.2568**
Mean	14.903	12.880	14.675	14.725	13.670	14.171		
60 DAS								
V_1	17.407	14.573	15.593	17.087	16.393	16.211	**V. 0.2909**	**1.0068**
V_2	20.373	14.340	17.453	20.260	19.200	18.325	**T. 0.3850**	**1.2554**
V_3	26.327	19.273	22.200	23.693	24.493	23.197	**T x V**	
V_4	23.380	16.540	19.867	22.447	22.327	20.912	**0.4754**	**1.3875**
Mean	21.872	16.182	18.778	20.872	20.603	19.661		
At harvest								
V_1	21.450	18.507	19.687	19.553	20.647	19.969	**V. 0.0451**	**0.1562**
V_2	27.353	17.587	22.207	23.747	24.613	23.101	**T. 0.0418**	**0.1363**
V_3	32.233	22.593	28.467	29.173	30.827	28.659	**T x V**	
V_4	29.573	20.800	23.673	24.727	25.753	24.905	**0.1149**	**0.3352**
Mean	27.652	19.872	23.508	24.300	25.460	24.159		

V.- Variety T.- Treatment T. x V.- Treatment x Variety

Influence of interaction

It was observed that, there were significant variation observed among interactions between water stress treatment and variety under water stress condition. At 20 DAS, minimum plant height was recorded in treatment T_2V_2 (8.287 cm) and it was noted maximum in T_1V_1 (11.347 cm), followed by treatment T_3V_3 (10.740 cm) and treatment T_4V_3 (10.533 cm), which were at par with each other under water stress condition.



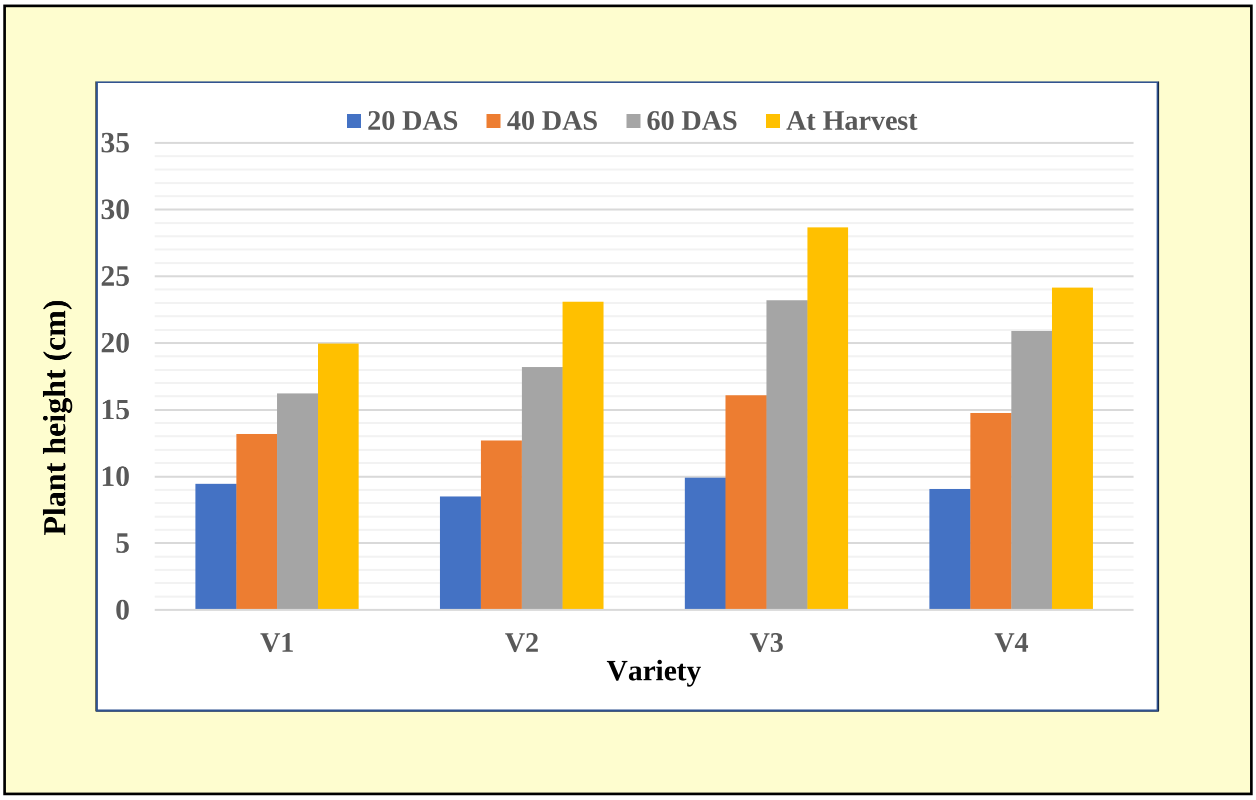


Fig.2. Influence of different water stress treatments on plant height (cm) at various stages of plant growth of cowpea grown under water stress condition.

T_1V_1

T_2V_1

T_1V_2

T_2V_2

T_1V_3

T_2V_3

T_1V_4

T_2V_4

Plate 2. Influence of different water stress treatments on plant height (cm) at harvest of cowpea grown under water stress condition.

T_3V_1 T_4V_1

T_3V_2 T_4V_2

T_3V_3 T_4V_3

T_3V_4 T_4V_4

Plate 3. Influence of different water stress treatments on plant height (cm) at harvest of cowpea grown under water stress condition.

T_5V_1

T_5V_2

T_5V_3

T_5V_4

Plate 4. Influence of different water stress treatments on plant height (cm) at harvest of cowpea grown under water stress condition.

At 40 DAS, the lowest plant height was recorded in treatment T_2V_2 (11.427 cm) and the highest was found in T_1V_3 (17.420 cm), followed by treatment T_3V_3 (17.267 cm) and treatment T_4V_3 (17.220 cm), as they were at par with each other under water stress condition.

At 60 DAS, it was recorded minimum plant height in treatment T_2V_2 (14.340 cm) and maximum was found in T_1V_3 (26.327 cm), followed by treatment T_5V_3 (24.493 cm) and treatment T_4V_3 (23.693 cm), which were at par with each other under water stress condition.

At harvest, the lowest plant height was recorded in treatment T_2V_2 (17.587 cm) and highest was found in T_1V_3 (32.233 cm), followed by treatment T_5V_3 (30.827 cm) and treatment T_1V_4 (29.573 cm) at par with each other under water stress condition.

4.2.2 Number of branches per plant

The statistical analysis of the data on number of branches per plant shows that significant difference was found among all treatments under water stress condition and there was significant variation among the interaction between water stress treatment and variety under water stress condition. The data was presented in the Table 4.3 and described in the Fig 3.

Influence of water stress treatments

At 20 DAS, among all the water stress treatments, variation in number of branches per plant was at the top with the highest in treatment T_1 (3.483), followed by treatment T_3 (3.350) treatment T_4 (3.217) while it was lowest in treatment T_2 (2.433), under water stress condition.

At 40 DAS, a significant difference was observed with respect to number of branches per plant in all water stress treatments. The highest number of branches per plant was observed in treatment T_1 (6.983), followed by treatment T_4 (6.283) and treatment T_3 (5.367), however number of branches per plant was lowest in the treatment T_2 (4.683), under water stress condition.

At 60 DAS, under water stress condition number of branches was maximum in treatment T_1 (10.050), followed by treatment T_4 (7.667) and treatment T_3 (7.183) while number of branches per plant was minimum in treatment T_2 (5.467), under water stress condition.

At harvest, it was observed variation in mean number of branches per plant in all water stress treatments. Maximum number of branches per plant was observed in treatment T_1 (11.917) and it was minimum in treatment T_2 (6.750), under water stress condition.

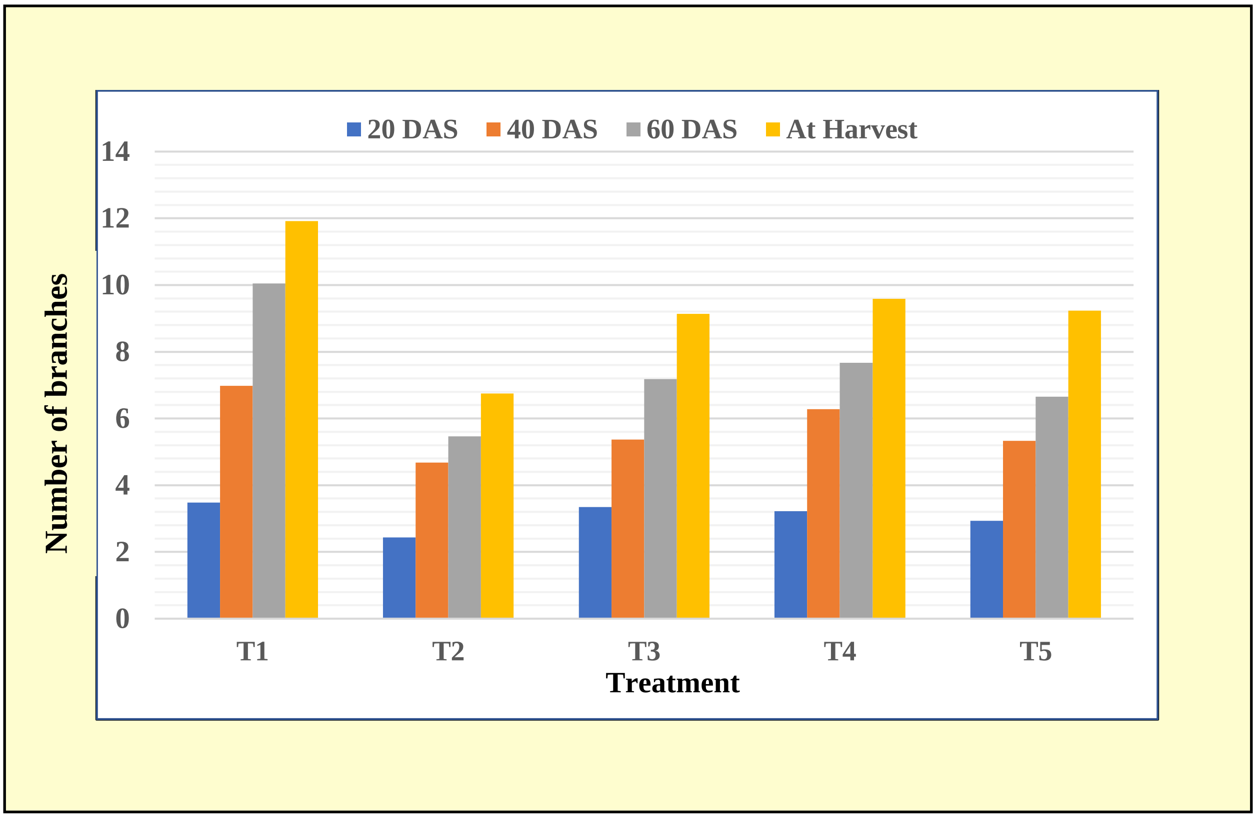
Table 4.3. Influence of different water stress treatments on number of branches per plant at various stages of plant growth of cowpea grown under water stress condition:

Genotypes	Treatments of water stress						SE ±	CD at 5%
	T_1	T_2	T_3	T_4	T_5	Mean		
20 DAS								
V_1	2.933	2.333	3.600	3.533	2.667	3.013	**V. 0.0451**	**0.1559**
V_2	3.800	2.667	3.666	3.667	2.867	3.333	**T. 0.0458**	**0.1493**
V_3	3.667	2.733	3.466	3.267	3.600	3.347	**T x V 0.1133**	**0.3307**
V_4	3.533	2.000	2.666	2.400	2.600	2.640		
Mean	3.483	2.433	3.350	3.217	2.933	3.083		
40 DAS								
V_1	7.267	4.133	5.467	5.267	5.000	5.427	**V. 0.0822**	**0.2844**
V_2	7.933	5.733	7.067	6.867	5.733	6.667	**T. 0.0647**	**0.2109**
V_3	7.333	4.533	4.800	6.133	5.933	5.747	**T x V 0.1232**	**0.3595**
V_4	5.400	4.333	4.133	6.867	4.667	5.080		
Mean	6.983	4.683	5.367	6.283	5.333	5.730		
60 DAS								
V_1	10.000	4.800	7.733	7.333	6.133	7.200	**V. 0.690**	**0.2386**
V_2	11.600	6.733	7.867	8.667	7.000	8.373	**T. 0.554**	**0.1807**
V_3	9.800	5.733	7.267	6.867	7.733	7.480	**T x V 0.1138**	**0.3321**
V_4	8.800	4.600	5.867	7.800	5.733	6.560		
Mean	10.050	5.467	7.183	7.667	6.650	7.403		
At harvest								
V_1	11.800	6.000	8.667	8.800	8.067	8.667	**V. 0.0512**	**0.1772**
V_2	12.400	7.800	9.867	10.600	8.733	9.880	**T. 0.0891**	**0.2907**
V_3	12.800	7.267	10.267	9.667	10.133	10.027	**T x V 0.1238**	**0.3614**
V_4	10.667	5.933	7.733	9.267	8.133	8.347		
Mean	11.917	6.750	9.133	9.583	8.767	9.230		

V.- Variety T.- Treatment T. x V.- Treatment x Variety

Influence of varietal difference

At 20 DAS, the varietal variation was showed among all water stress treatment in respect of mean number of branches per plant. It was highest in variety V_3 (3.347), while lowest number of branches per plant was observed in variety V_4 (2.640), under water stress condition.



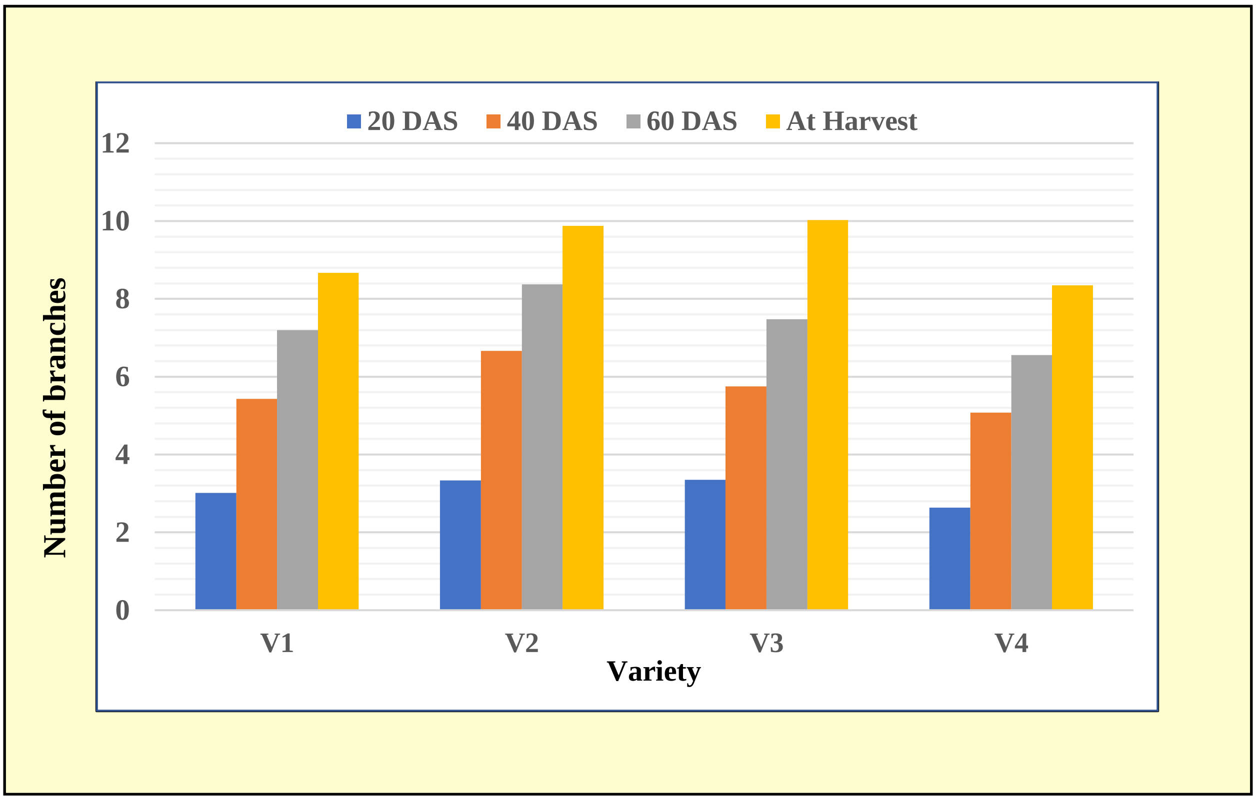


Fig.3. Influence of different water stress treatments on number of branches at various stages of plant growth of cowpea grown under water stress condition.

At 40 DAS, the variety V_2 (6.667) was recorded highest number of branches followed by variety V_3 (5.747) and variety V_1 (5.427) while it was lowest in variety V_4 (5.080) under water stress condition.

At 60 DAS, the highest number of branches per plant was recorded in variety V_2 (8.373), followed by variety V_3 (7.480) and variety V_1 (7.200). The lowest was found in variety V_4 (6.560) under water stress condition.

At harvest, variety V_3 (10.027) found maximum number of branches per plant, followed by variety V_2 (9.880) and minimum was recorded in variety V_4 (8.347) under water stress condition

Influence of interaction

At 20 DAS, the maximum number of branches was noted in treatment combination T_1V_2 (3.800) followed by treatment T_4V_2 (3.667) and treatment T_3V_2 (3.666), whereas minimum in the treatment T_2V_4 (2.000), under water stress condition.

At 40 DAS, it was recorded minimum number of branches per plant in treatment T_2V_1 (4.133) and in treatment T_3V_4 (4.133) and maximum number of branches was found in T_1V_2 (7.933), followed by treatment T_1V_3 (7.333), treatment T_1V_1 (7.267) and treatment T_3V_2 (7.067), which were at par with each other under water stress condition.

At 60 DAS, it was recorded minimum number of branches in treatment T_2V_4 (4.600). The maximum number of branches were recorded in treatment T_1V_2 (11.600) which was followed by treatment T_1V_1 (10.000) and treatment T_1V_3 (9.800), they were at par with each other under water stress condition.

At harvest, the lowest number of branches per plant was recorded in treatment T_2V_4 (5.933) and highest was found in treatment T_1V_3 (12.800), followed by treatment T_1V_2 (12.400) and treatment T_1V_1 (11.800) they were at par with each other under water stress condition.

4.2.3 Number of leaves per plant

The statistical analysis of data number of leaves per plant resulted that significant variation among all treatments under water condition also there was variation among the interaction between water stress treatment and variety. The concern data was presented in the Table 4.4 and depicted in the Fig 4.

Influence of water stress treatments

At 20 DAS, among all the treatments variation in number of leaves per plant was maximum in treatment T_1 (4.950), while minimum number of branches in treatment T_2 (3.200), under water stress condition.

From 40 DAS, significant difference was observed with respect to number of leaves per plant in all the treatments. Highest number of leaves per plant was observed in treatment T_1 (13.283), followed by treatment T_4 (12.633) and treatment T_3 (12.067), however number of leaves per plant was minimum in the treatment T_2 (7.933), under water stress condition.

At 60 DAS, the variation among all the treatment T_1 (17.133), produced maximum number of leaves per plant followed by treatment T_4 (14.933) and treatment T_5 (13.983), whereas minimum was recorded in treatment T_2 (11.167), under water stress condition.

At harvest, it was observed that variation in mean number of leaves per plant due to different water stress treatments. The highest number of leaves per plant was recorded in treatment T_1 (16.133), followed by treatment T_4 (13.917), treatment T_5 (13.071). However, lowest in treatment T_2 (10.167), under water stress condition.

Influence of varietal difference

At 20 DAS, among all the stress treatment, variety V_3 (4.707) recorded maximum number of leaves per plant which was significantly better all over variety. The minimum was observed in variety V_1 (3.960), under water stress condition.

At 40 DAS, maximum number of leaves per plant was recorded in variety V_1 (12.373), followed by variety V_3 (11.933) and variety V_2 (11.333), they were at par with each other. The minimum number of leaves per plant was noted in variety V_4 (10.720), under water stress condition.

At 60 DAS, maximum number of leaves per plant was recorded in variety V_1 (15.707), followed by variety V_3 (14.507). The minimum number of leaves per plant was noted in variety V_4 (12.640), under water stress condition. From 60 DAS onwards all the variety showed a decline number of leaves.

At harvest, the highest number of leaves per plant was recorded in variety V_1 (14.707), followed by variety V_3 (13.493). The lowest number of leaves per plant was noted in variety V_4 (11.683), under water stress condition.

Table 4.4. Influence of different water stress treatments on number of leaves per plant at various stages of plant growth of cowpea grown under water stress condition:

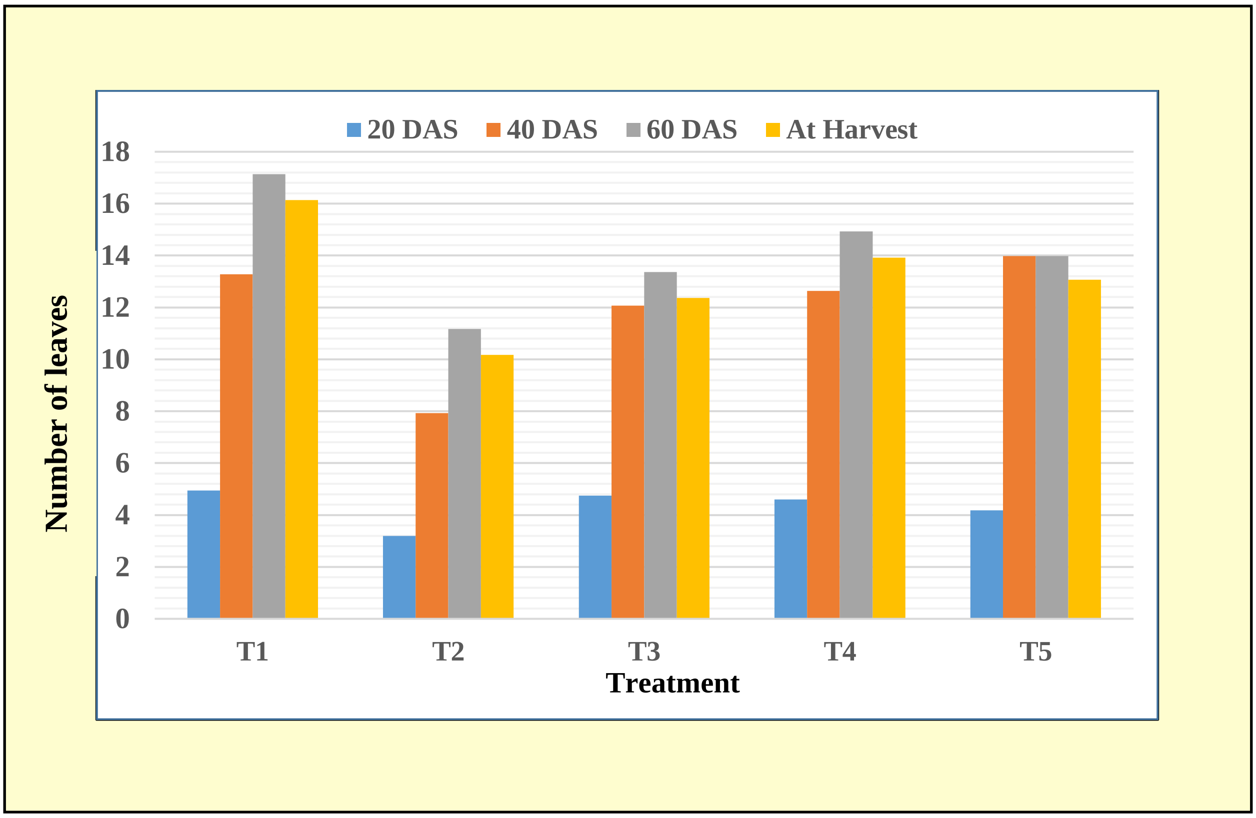
Genotypes	Treatments of water stress						SE ±	CD at 5%
	T_1	T_2	T_3	T_4	T_5	Mean		
20 DAS								
V_1	5.133	2.600	4.733	4.133	3.200	3.960	**V. 0.0460**	**0.1593**
V_2	4.800	3.333	4.467	4.400	4.533	4.307	**T. 0.0557**	**0.1815**
V_3	5.333	3.467	5.000	5.200	4.533	4.707	**T x V 0.1538**	**0.4489**
V_4	4.533	3.400	4.800	4.667	4.467	4.373		
Mean	4.950	3.200	4.750	4.600	4.183	4.337		
40 DAS								
V_1	14.600	7.467	13.667	13.600	12.533	12.373	**V. 0.0968**	**0.3351**
V_2	12.800	8.533	11.600	11.533	12.200	11.333	**T. 0.1166**	**0.3803**
V_3	13.333	7.467	12.533	13.667	12.667	11.933	**T x V 0.2581**	**0.7533**
V_4	12.400	8.267	10.467	11.733	10.733	10.720		
Mean	13.283	7.933	12.067	12.633	12.033	11.590		
60 DAS								
V_1	19.200	12.667	15.000	16.267	15.400	15.707	**V. 0.0435**	**0.1507**
V_2	16.467	10.533	12.933	14.400	13.733	13.613	**T. 0.1301**	**0.4242**
V_3	17.400	11.600	13.800	15.467	14.267	14.507	**T x V 0.1722**	**0.5027**
V_4	15.467	9.867	11.733	13.600	12.533	12.640		
Mean	17.133	11.167	13.367	14.933	13.983	14.117		
At harvest								
V_1	18.200	11.667	14.000	15.267	14.400	14.707	**V. 0.0526**	**0.1820**
V_2	15.467	9.533	11.933	13.400	12.867	12.640	**T. 0.1347**	**0.4393**
V_3	16.400	10.600	12.800	14.400	13.267	13.493	**T x V 0.1616**	**0.4717**
V_4	14.467	8.867	10.733	12.600	11.750	11.683		
Mean	16.133	10.167	12.367	13.917	13.071	13.131		

V.- Variety T.- Treatment T. x V.- Treatment x Variety

Influence of interaction

At 20 DAS, the maximum number of leaves were noted in treatment combination T_1V_3 (5.333) whereas minimum was observed in the treatment T_2V_1 (2.600) under water stress condition.

At 40 DAS, it was recorded minimum number of leaves per plant in treatment T_2V_1 (7.467) also in treatment T_2V_3 (7.467) and some more was found in T_2V_4 (8.267). It was recorded maximum number of leaves per plant in treatment T_1V_1 (14.600), followed by treatment T_3V_1 (13.667) which were at par with each other under water stress condition.



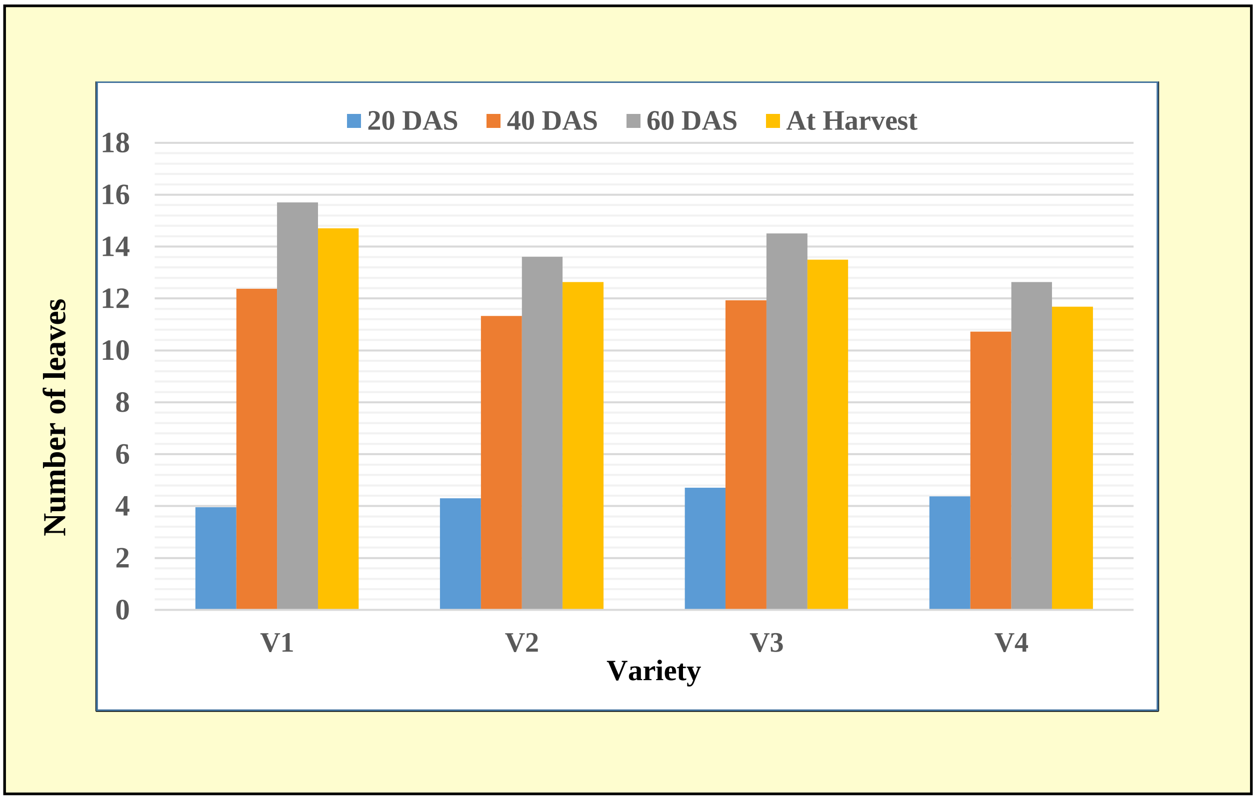


Fig.4. Influence of different water stress treatments on number of leaves at various stages of plant growth of cowpea grown under water stress condition.

At 60 DAS, it was recorded maximum number of leaves in treatment T_1V_1 (19.200) which was followed by treatment T_1V_3 (17.400) under water stress condition. The minimum number of leaves was recorded in treatment T_2V_4 (9.867) and some more was found in T_2V_2 (10.533), under water stress condition.

At harvest, the minimum number of leaves per plant was recorded in treatment T_2V_4 (8.867) and maximum was found in treatment T_1V_1 (18.200), followed by treatment T_1V_3 (16.400) and treatment T_1V_2 (15.467) which were at par with each other under water stress condition.

4.2.4 Leaf area per plant (dm^2)

The findings experiment that there was a variety of difference among all the treatments, yet means leaf area per plant varied at all stages of plant growth. The statistical analysis of the data on leaf area per plant as revealed a significant variation among water stress treatments as well as among interaction effect between stress treatments and variety under water stress condition. The leaf area per plant progressively increased with the advancing age of plant growth. Initially leaf area per plant was increased then rather slow, but during period from 40 to 60 DAS, the leaf area per plant constantly increased. The data was presented in the Table 4.5 and illustrated in the Fig 5.

Influence of water stress treatment

At 20 DAS, it was observed that there was significant difference among all treatments. Treatment T_1 (7.212 dm^2) was observed maximum leaf area per plant, followed by treatment T_3 (7.095 dm^2), whereas treatment T_2 (5.295 dm^2) noted minimum leaf area per plant under water stress condition.

At 40 DAS, significant difference was observed with respect to leaf area per plant in all the treatments. Maximum leaf area per plant was observed in treatment T_1 (44.89 dm^2), followed by treatment T_3 (44.59 dm^2) and treatment T_4 (43.60 dm^2), however leaf area per plant was minimum in the treatment T_2 (27.75 dm^2), under water stress condition.

At 60 DAS, the variation among all treatments, treatment T_1 (79.55 dm^2), produced maximum leaf area per plant followed by treatment T_4 (73.29 dm^2) and treatment T_3 (70.94 dm^2), whereas minimum was recorded in treatment T_2 (47.82 dm^2), under water stress condition.

At harvest, it was observed that variation in mean leaf area per plant due to different stress treatments. The maximum leaf area per plant was recorded in treatment T_1 (63.96 dm^2), followed by treatment T_4 (48.36 dm^2) and treatment T_5 (44.69 dm^2). However, minimum in treatment T_2 (22.47 dm^2), under water stress condition.

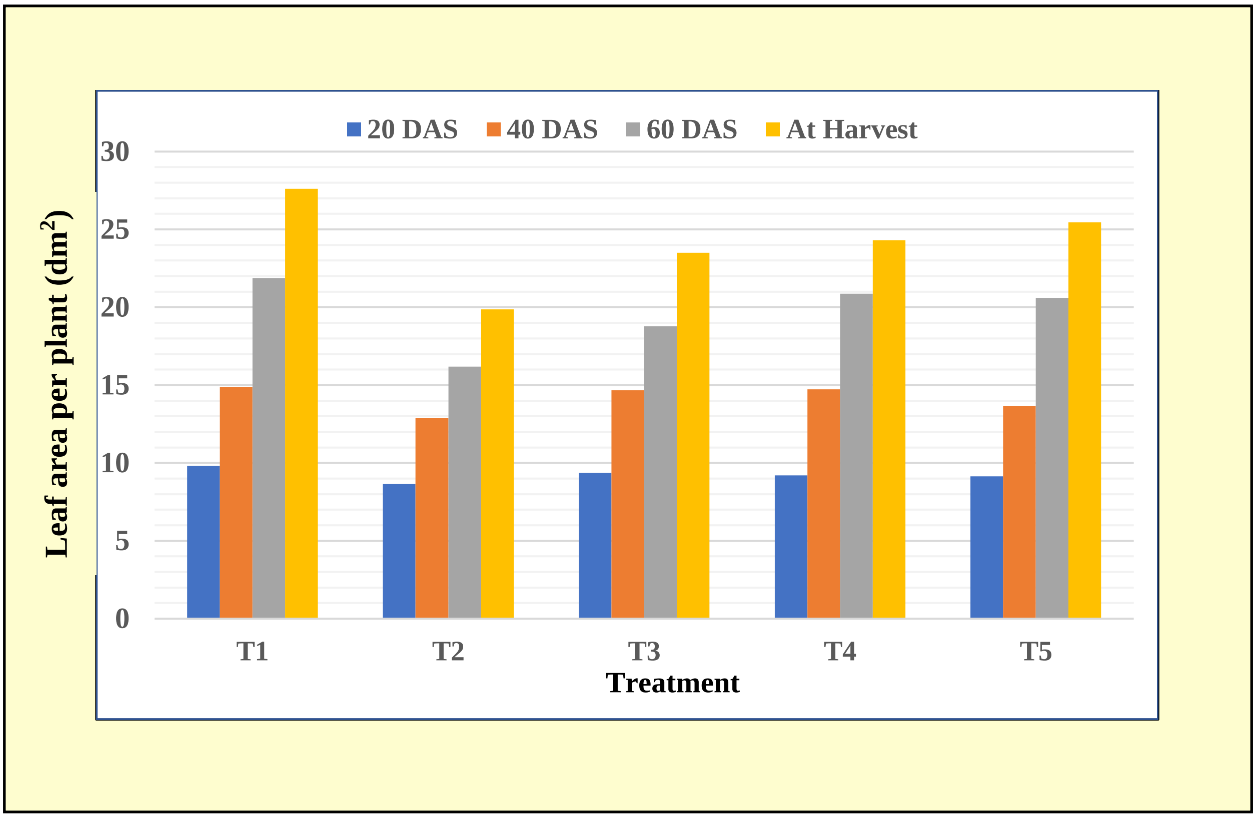
Table 4.5. Influence of different water stress treatments on leaf area per plant (dm²/plant) at various stages of plant growth of cowpea grown under water stress condition:

Genotypes	Treatments of water stress						SE ±	CD at 5%
	T_1	T_2	T_3	T_4	T_5	Mean		
20 DAS								
V_1	5.414	5.320	5.279	6.639	5.524	6.235	V. 0.0095	0.0330
V_2	5.487	5.135	5.365	5.359	5.257	5.321	T. 0.0105	0.0343
V_3	9.350	7.912	9.246	8.398	8.251	8.631	T x V 0.0200	0.0585
V_4	7.597	6.812	7.491	7.516	7.423	7.368		
Mean	7.212	5.295	7.095	5.978	6.864	6.889		
40 DAS								
V_1	50.51	27.29	50.62	49.80	47.45	45.14	V. 0.1165	0.4031
V_2	34.24	29.55	38.60	37.40	32.29	34.42	T. 0.1604	0.5232
V_3	54.60	32.44	54.60	53.82	51.55	49.40	T x V 0.1913	0.5583
V_4	40.21	21.70	34.50	33.39	36.72	33.30		
Mean	44.89	27.75	44.59	43.60	42.01	40.567		
60 DAS								
V_1	88.22	47.84	79.85	80.76	77.00	74.73	V. 0.0765	0.2647
V_2	75.52	48.60	59.86	62.38	57.26	60.72	T. 0.1691	0.5515
V_3	88.69	54.17	80.32	83.76	57.27	72.84	T x V 0.3148	0.9188
V_4	65.75	40.68	63.75	66.27	63.36	59.96		
Mean	79.55	47.82	70.94	73.29	63.73	67.066		
At harvest								
V_1	65.99	21.02	43.15	48.15	42.25	44.11	V. 0.1100	0.3807
V_2	67.29	20.84	42.36	47.01	45.65	44.63	T. 0.1110	0.3621
V_3	68.48	27.51	48.45	57.69	50.95	50.62	T x V 0.2248	0.6563
V_4	54.06	20.51	37.58	40.61	39.91	38.53		
Mean	63.96	22.47	42.89	48.36	44.69	44.472		

V.- Variety T.- Treatment T. x V.- Treatment x Variety

Influence of varietal difference

At 20 DAS, among all the stress condition, variety V_3 (8.631 dm^2) recorded maximum leaf area per plant which was significantly better all over other variety. The minimum was observed in variety V_2 (5.321 dm^2), under water stress condition.



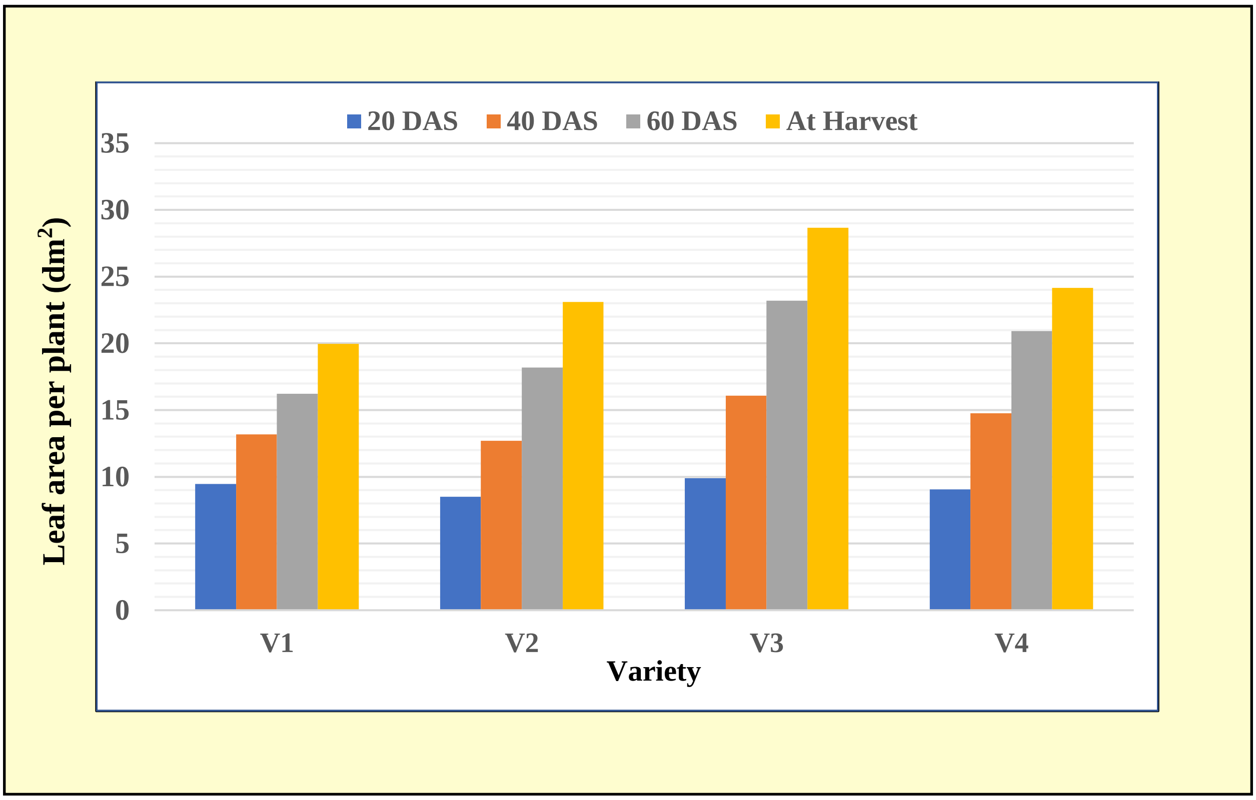


Fig.5. Influence of different water stress treatments on leaf area per plant (dm^2) at various stages of plant growth of cowpea grown under water stress condition.

At 40 DAS, the highest leaf area per plant was recorded in variety V_3 (49.40 dm^2), followed by variety V_1 (45.14 dm^2) and variety V_2 (34.42 dm^2). The lowest leaf area per plant was noted in variety V_4 (33.30 dm^2), under water stress condition.

At 60 DAS, maximum leaf area per plant was recorded in variety V_1 (74.73 dm^2), followed by variety V_3 (72.84 dm^2). The minimum leaf area per plant was noted in variety V_4 (59.96 dm^2), under water stress condition.

At harvest, the maximum leaf area per plant was recorded in variety V_3 (50.62 dm^2), followed by variety V_2 (44.63 dm^2). The minimum leaf area per plant was noted in variety V_4 (38.53 dm^2), under water stress condition.

Influence of interaction

At 20 DAS, the maximum leaf area was noted in treatment combination T_1V_3 (9.350 dm^2), whereas minimum in the treatment T_1V_2 (5.135 dm^2), under water stress condition.

At 40 DAS, minimum leaf area per plant was observed in treatment T_2V_4 (21.70 dm^2) and some more was found in T_2V_1 (27.29 dm^2), under water stress condition. It was recorded maximum leaf area per plant in treatment T_1V_3 (54.60 dm^2) also in treatment T_3V_3 (54.60 dm^2).

At 60 DAS, it was recorded maximum leaf area per plant in treatment T_1V_3 (88.69 dm^2) which was followed by treatment T_1V_1 (88.22 dm^2) they were at par with each other under water stress condition. The minimum leaf area per plant were recorded in treatment T_2V_4 (40.68 dm^2) and some more was found in T_2V_1 (47.84 dm^2).

At harvest, the lowest leaf area per plant was recorded in treatment T_2V_4 (20.51 dm^2) and highest was found in treatment T_1V_3 (68.48 dm^2), followed by treatment T_1V_2 (67.29 dm^2), under water stress condition.

4.3. Biochemical observations:

4.3.1. Total chlorophyll content (mg/g)

In further study, the data with respect to total chlorophyll content was observed that there was significant difference in total chlorophyll content among all the treatments under water stress condition. The data was presented in the Table 4.6 and displayed in the Fig 6.

Influence of water stress treatment

At 20 DAS, it was recorded that there was significant difference found among all treatments. Treatment T_1 (9.507 mg/g) recorded maximum total chlorophyll content, whereas treatment T_2 (6.595 mg/g) recorded minimum total chlorophyll content under water stress condition.

At 40 DAS, maximum total chlorophyll content was observed in treatment T_1 (11.528 mg/g), followed by treatment T_3 (10.513 mg/g), while it was minimum in treatment T_2 (8.202 mg/g), under water stress condition.

At 60 DAS, it was clearly seen that there was significant variation among all treatments. Treatment T_1 (14.070 mg/g) recorded maximum total chlorophyll content and treatment T_2 (9.812 mg/g) produced minimum total chlorophyll content, under water stress condition.

At harvest, maximum total chlorophyll content was recorded in the treatment T_1 (11.955 mg /g), followed by treatment T_4 (10.227 mg/g) and treatment T_5 (10.090 mg/g) which was at par with each other. However minimum was recorded in the treatment T_2 (8.387 mg/g), under water stress condition.

Influence of varietal difference

At 20 DAS, the varietal significant difference was showed with respect to total chlorophyll content. Variety V_2 (8.783 mg/g) produced highest total chlorophyll content and lowest was found in variety V_4 (6.119 mg/g), under water stress condition.

At 40 DAS, among all the stress condition, variety V_2 (10.809 mg/g) recorded maximum total chlorophyll content which was significantly better all over variety. The minimum was observed in variety V_4 (7.629 mg/g), under water stress condition.

At 60 DAS, the highest total chlorophyll content was recorded in variety V_2 (12.998 mg/g), followed by variety V_1 (12.087 mg/g) they were at par with each other. The lowest total chlorophyll content was noted in variety V_4 (9.089 mg/g), under water stress condition.

At harvest, under water stress condition maximum total chlorophyll content was recorded in variety V_2 (11.360 mg/g), followed by variety V_3 (10.588 mg/g) and variety V_1 (10.405 mg/g), which were at par with each other. However, minimum was found in variety V_4 (8.132 mg/g).

Influence of interaction

At 20 DAS, the maximum total chlorophyll content which were noted in treatment combination T_1V_1 (10.577 mg/g), followed by treatment T_1V_2 (10.513 mg/g) which was at par with each other. However minimum in the treatment T_2V_4 (5.060 mg/g), under water stress condition.

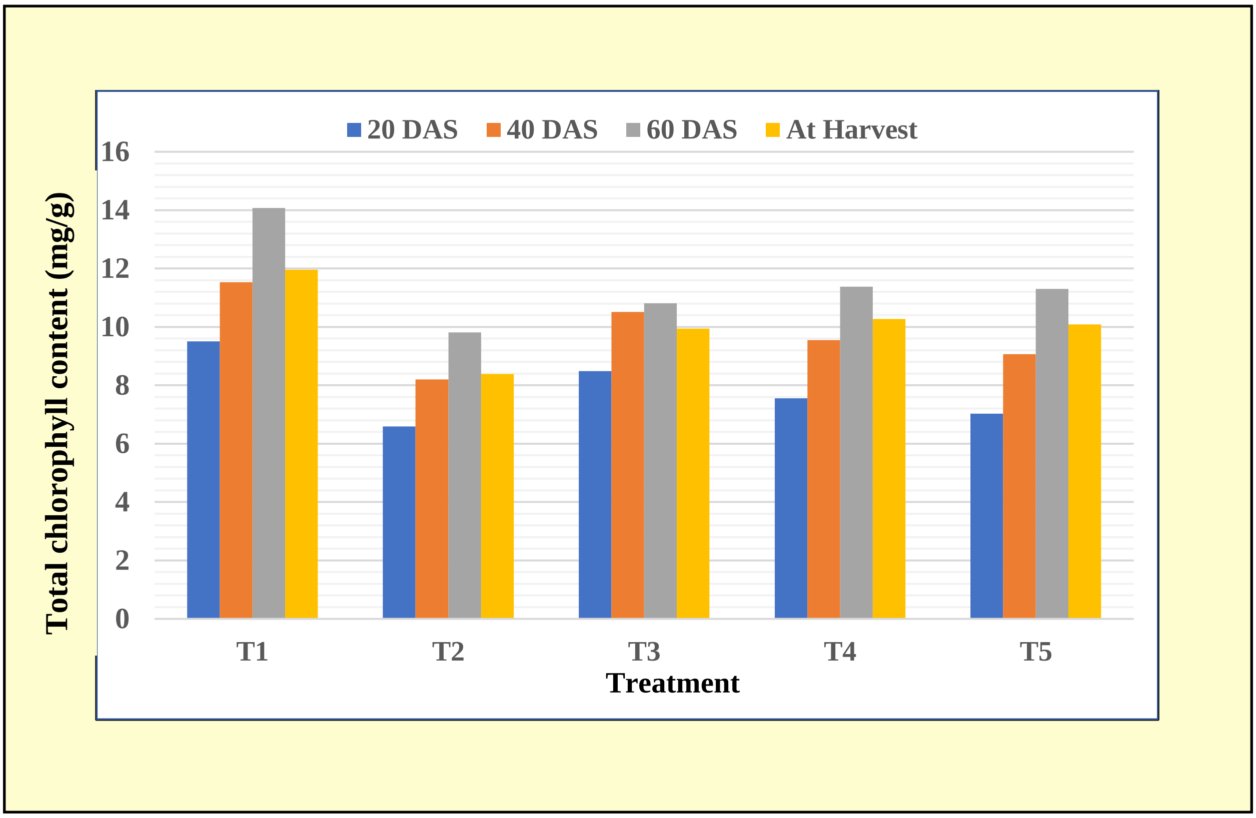
At 40 DAS, it was recorded minimum total chlorophyll content in treatment T_2V_4 (5.470 mg/g) and some more was found in T_5V_4 (7.333 mg/g). It was recorded maximum total chlorophyll content in treatment T_1V_1 (12.583 mg/g), followed by treatment T_1V_2 (12.517 mg/g), which were at par with each other under water stress condition.

Table 4.6. Influence of different water stress treatments on total chlorophyll content of leaves (mg/g) at various stages of plant growth of cowpea grown under water stress condition:

Genotypes	Treatments of water stress						SE ±	CD at 5%
	T_1	T_2	T_3	T_4	T_5	Mean		
20 DAS								
V_1	10.577	7.433	9.543	8.450	7.863	8.773	V. 0.0046	0.0158
V_2	10.513	7.250	9.473	8.590	8.090	8.783	T. 0.0046	0.0266
V_3	9.710	6.637	8.697	6.370	6.890	7.661	T x V 0.0113	0.0330
V_4	7.230	5.060	6.223	6.790	5.290	6.119		
Mean	9.507	6.595	8.484	7.550	7.033	7.834		
40 DAS								
V_1	12.583	9.360	11.570	10.370	9.897	10.756	V. 0.0071	0.0285
V_2	12.517	9.310	11.497	10.603	10.120	10.809	T. 0.0087	0.0246
V_3	11.740	8.670	10.733	9.423	8.933	9.900	T x V 0.0116	0.0339
V_4	9.273	5.470	8.253	7.817	7.333	7.629		
Mean	11.528	8.202	10.513	9.553	9.071	9.774		
60 DAS								
V_1	14.527	10.687	11.677	11.363	12.180	12.087	V. 0.0030	0.0105
V_2	15.687	11.040	12.027	13.710	12.527	12.998	T. 0.0087	0.0283
V_3	14.777	10.103	11.123	11.030	11.600	11.727	T x V 0.0157	0.0459
V_4	11.290	7.420	8.413	9.410	8.910	9.089		
Mean	14.070	9.812	10.810	11.378	11.304	11.475		
At harvest								
V_1	12.410	8.270	10.327	10.590	10.427	10.405	V. 0.0266	0.0922
V_2	13.670	9.130	11.227	11.410	11.363	11.360	T. 0.0251	0.0819
V_3	12.550	8.940	10.210	10.740	10.500	10.588	T x V 0.0607	0.1773
V_4	9.190	7.210	8.020	8.170	8.070	8.132		
Mean	11.955	8.387	9.946	10.227	10.090	10.121		

V.- Variety T.- Treatment T. x V.- Treatment x Variety

At 60 DAS, it was recorded maximum total chlorophyll content in treatment T_1V_2 (15.687 mg/g) which was followed by treatment T_1V_3 (14.777 mg/g) and treatment T_1V_1 (14.527 mg/g), they were at par with each other under water stress condition. The minimum total chlorophyll content which was recorded in treatment T_2V_4 (7.420 mg/g).



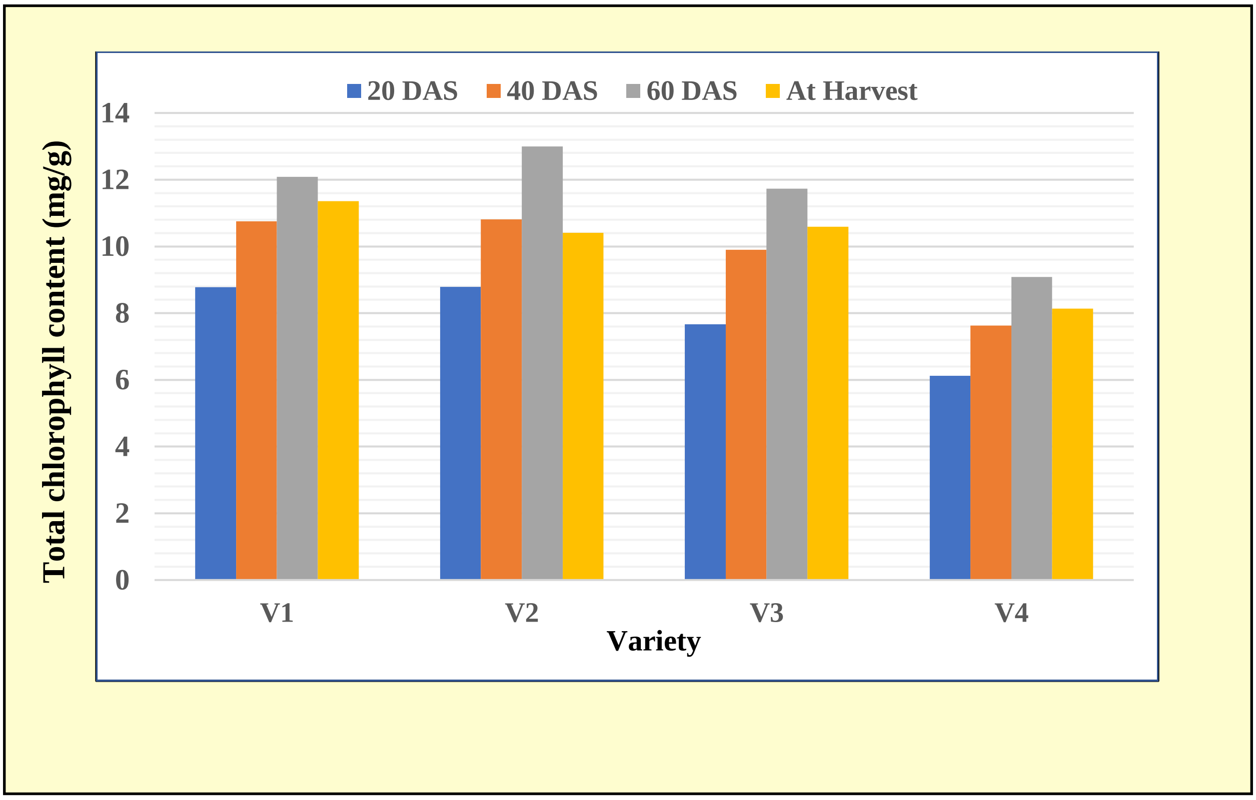


Fig.6. Influence of different water stress treatments on total chlorophyll content of leaves (mg/g) at various stages of plant growth of cowpea grown under water stress condition.

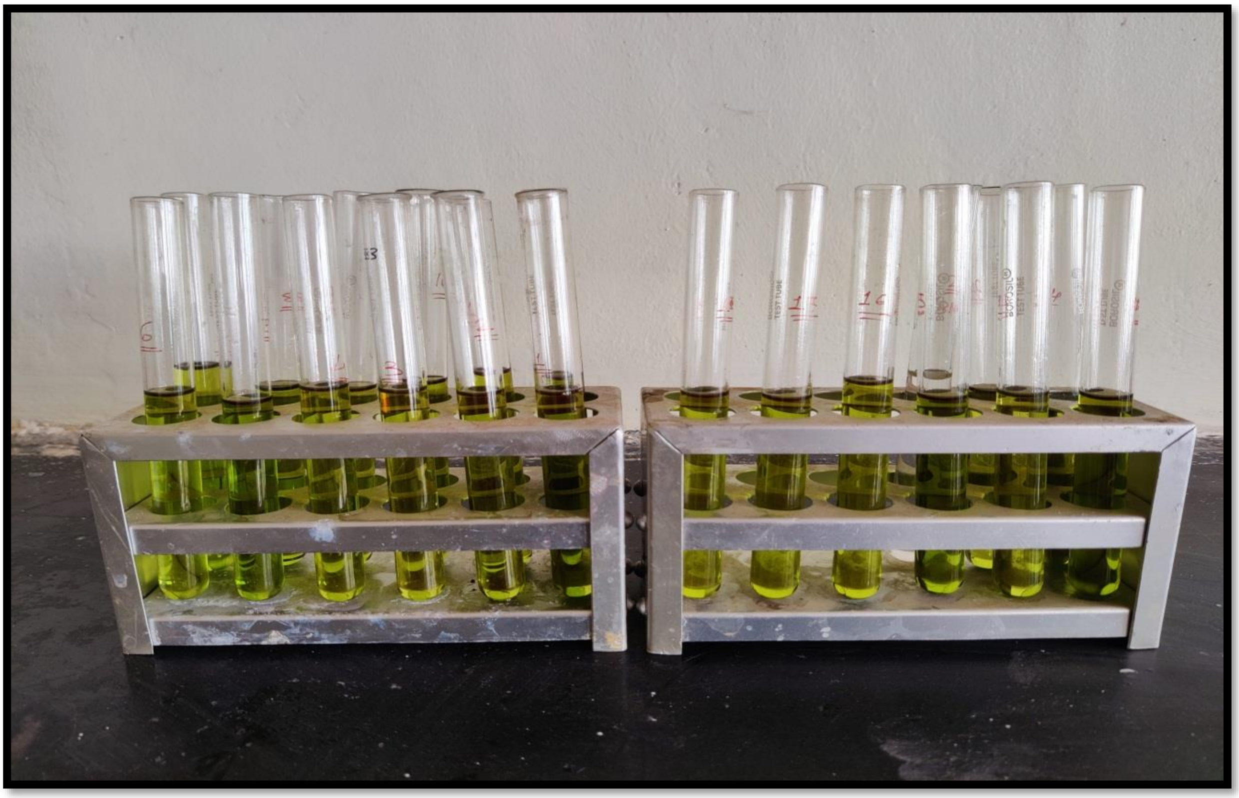


Plate 5. Variation in chlorophyll content (mg/g) of four different genotypes of cowpea grown under different water stress treatment.

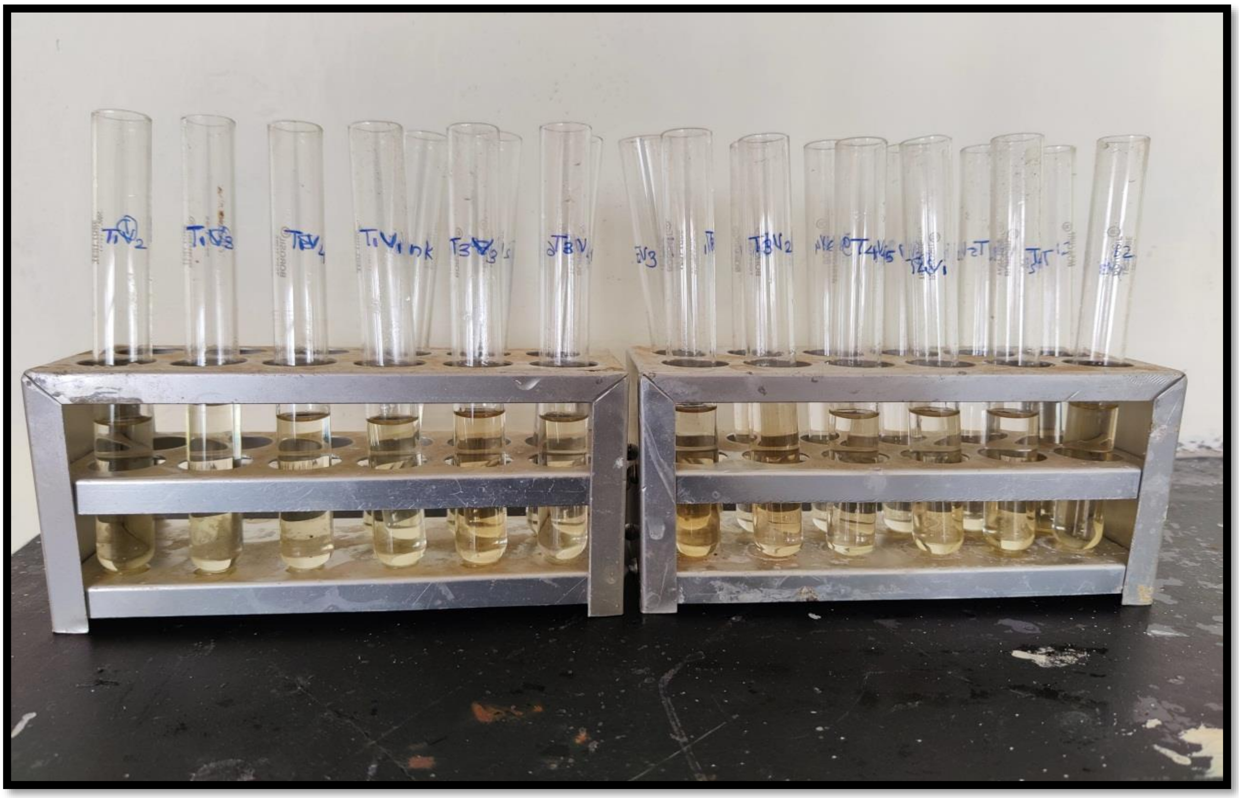


Plate 6. Variation in proline content (µmol/g) of four different genotypes of cowpea grown under different water stress treatment.

At harvest, the lowest total chlorophyll content was recorded in treatment T_2V_4 (7.210 mg/g) and highest was found in treatment T_1V_2 (13.670 mg/g), followed by treatment T_1V_3 (12.550 mg/g) and treatment T_1V_1 (12.410 mg/g) at par with each other under water stress condition.

4.3.2. Proline content (µmol/g)

It was observed that there was significant variation in proline content among four varieties studied at 20, 40, 60 DAS and at harvest. The data was presented in the Table 4.7 and illustrated in the Fig 7.

Influence of water stress treatment

At 20 DAS, it was noted that there was significant differences found among treatments. Among all the treatment T_3 (0.2746 µmol/g) recorded maximum proline content, whereas treatment T_2 (0.2315 µmol/g) was minimum proline content, under water stress condition.

At 40 DAS, maximum proline content was observed in treatment T_2 (0.5555 µmol/g), followed by treatment T_5 (0.5220 µmol/g) and treatment T_4 (0.5192 µmol/g), while it was minimum in treatment T_1 (0.4462 µmol/g), under water stress condition.

At 60 DAS, it was clearly seen that there was significant variation among all treatments. Treatment T_2 (0.7942 µmol/g) recorded maximum proline content and treatment T_1 (0.5036 µmol/g) noted minimum proline content, under water stress condition.

At harvest, maximum proline content was recorded in the treatment T_2 (0.9549 µmol/g), followed by treatment T_3 (0.8392 µmol/g) and treatment T_4 (0.8227 µmol/g) which was at par with each other. However minimum was recorded in the treatment T_1 (0.5381 µmol/g), under water stress condition.

Influence of varietal difference

At 20 DAS, the varietal significant difference was showed with respect to proline content. Variety V_1 (0.2863 µmol/g) noted maximum proline content and minimum was recorded in variety V_3 (0.2257 µmol/g), under water stress condition.

At 40 DAS, among all the stress condition, variety V_1 (0.5989 µmol/g) recorded maximum proline content which was significantly better all over variety. The minimum was observed in variety V_3 (0.4059 µmol/g) under water stress condition.

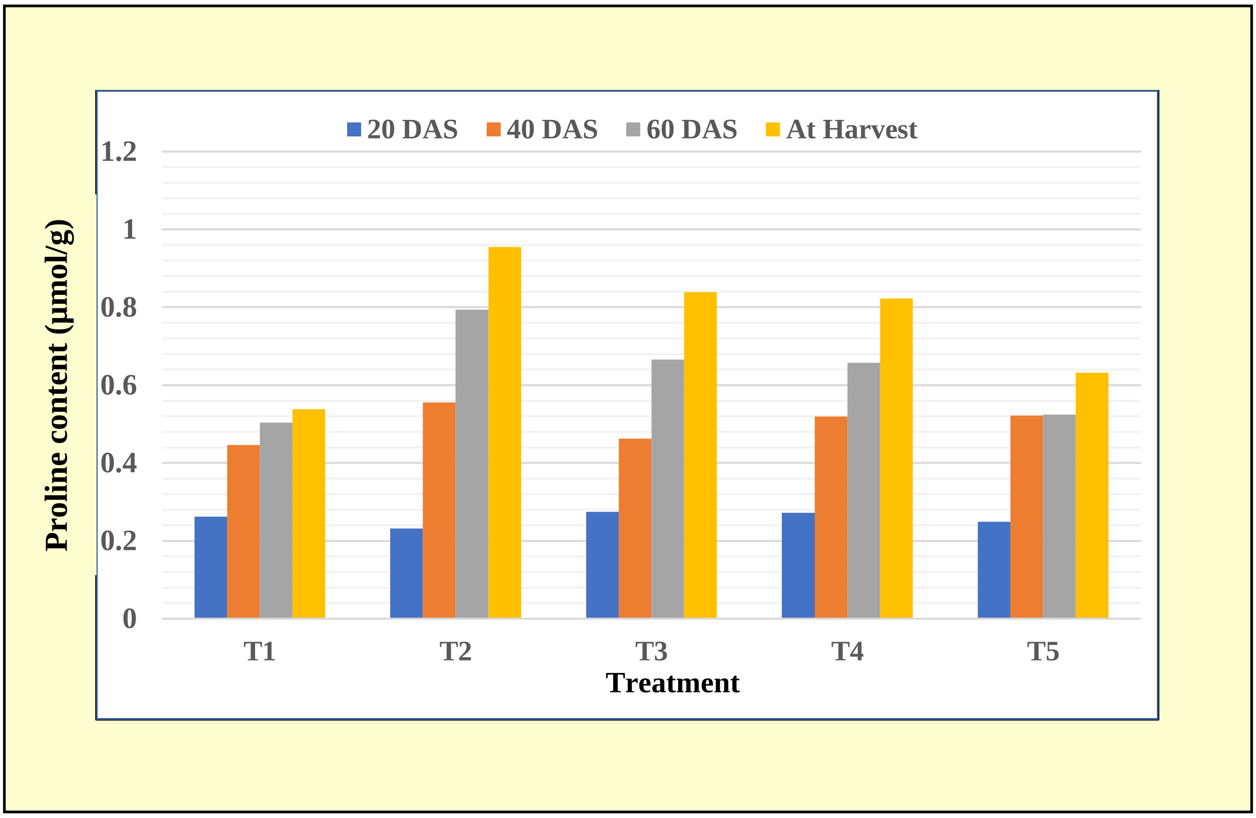
Table 4.7. Influence of different water stress treatments on proline content (µmol/g) at various stages of plant growth of cowpea grown under water stress condition:

Genotypes	Treatments of water stress						SE ±	CD at 5%
	T_1	T_2	T_3	T_4	T_5	Mean		
20 DAS								
V_1	0.3490	0.2137	0.3330	0.2730	0.2630	0.2863	**V. 0.0007**	**0.0024**
V_2	0.2297	0.2280	0.2510	0.3210	0.2783	0.2616	**T. 0.0010**	**0.0033**
V_3	0.2043	0.2330	0.2433	0.2450	0.2027	0.2257	**T x V 0.0014**	**0.0040**
V_4	0.2643	0.2513	0.2713	0.2487	0.2077	0.2573		
Mean	0.2618	0.2315	0.2746	0.2719	0.2486	0.258		
40 DAS								
V_1	0.5630	0.6930	0.5703	0.6650	0.5033	0.5989	**V. 0.0010**	**0.0012**
V_2	0.4313	0.5753	0.4530	0.5130	0.6643	0.5274	**T. 0.0003**	**0.0008**
V_3	0.3253	0.4559	0.3483	0.4233	0.4750	0.4059	**T x V 0.0010**	**0.0031**
V_4	0.4650	0.4963	0.4753	0.4753	0.4453	0.4721		
Mean	0.4462	0.5555	0.4626	0.5192	0.5220	0.501		
60 DAS								
V_1	0.5173	0.8663	0.7253	0.6867	0.5130	0.6617	**V. 0.0044**	**0.0151**
V_2	0.5877	0.8530	0.6587	0.7973	0.5483	0.6890	**T. 0.0045**	**0.0145**
V_3	0.4787	0.8463	0.7310	0.6650	0.4510	0.6344	**T x V 0.0080**	**0.0233**
V_4	0.4307	0.6110	0.5473	0.4820	0.5833	0.5309		
Mean	0.5036	0.7942	0.6656	0.6578	0.5239	0.629		
At harvest								
V_1	0.5757	0.9093	0.9340	0.8673	0.6633	0.7899	**V. 0.0104**	**0.0360**
V_2	0.5973	1.1510	0.7633	0.8713	0.6663	0.8099	**T. 0.0123**	**0.0401**
V_3	0.5097	0.9243	0.8970	0.8630	0.6127	0.7625	**T x V 0.0219**	**0.0639**
V_4	0.4690	0.8350	0.7627	0.7063	0.5810	0.6708		
Mean	0.5381	0.9549	0.8392	0.8227	0.6323	0.758		

V.- Variety T.- Treatment T. x V.- Treatment x Variety

At 60 DAS, the highest proline content was recorded in variety V_2 (0.6890 µmol/g), followed by variety V_1 (0.6617 µmol/g) they were at par with each other. The lowest proline content was noted in variety V_4 (0.5309 µmol/g), under water stress condition.

At harvest, under water stress condition maximum proline content was recorded in variety V_2 (0.8099 µmol/g), followed by variety V_1 (0.7899 µmol/g) which were at par with each other. However, minimum was noted in variety V_4 (0.6708 µmol/g).



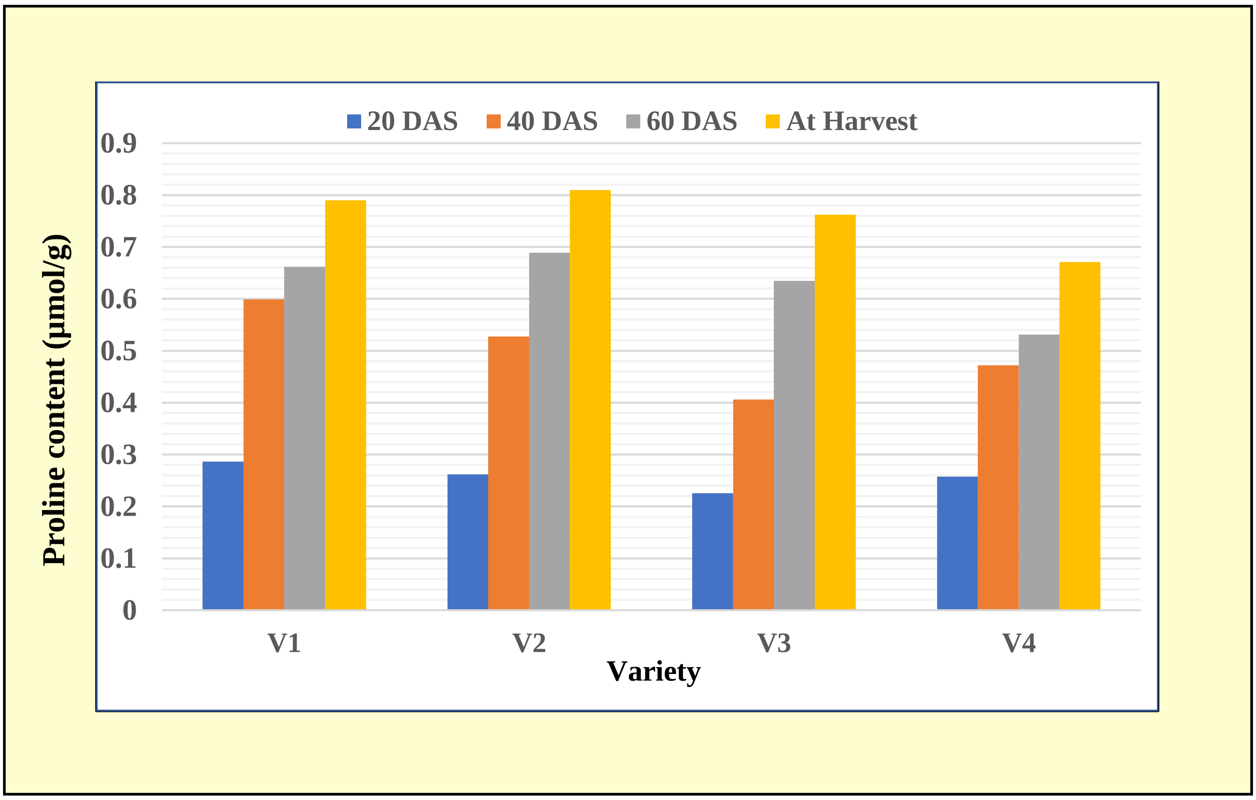


Fig.7. Influence of different water stress treatments on proline content (µmol/g) at various stages of plant growth of cowpea grown under water stress condition

Influence of interaction

At 20 DAS, the maximum proline content was noted in treatment combination T_1V_1 (0.3490 µmol/g), whereas minimum in the treatment T_2V_1 (0.2137 µmol/g), under water stress condition.

At 40 DAS, it was recorded minimum proline content in treatment T_1V_3 (0.3253 µmol/g) and some more was found in T_3V_3 (0.3483 µmol/g). It was recorded maximum proline content in treatment T_2V_1 (0.6930 µmol/g), followed by treatment T_4V_1 (0.6650 µmol/g) and treatment T_5V_2 (0.6643 µmol/g) which were at par with each other under water stress condition.

At 60 DAS, it was recorded maximum proline content in treatment T_2V_1 (0.8663 µmol/g) which was followed by treatment T_2V_2 (0.8530 µmol/g) and treatment T_2V_3 (0.8463 µmol/g), they were at par with each other under water stress condition. The minimum proline content was recorded in treatment T_1V_4 (0.4307 µmol/g) and some more was found in T_1V_3 (0.4787 µmol/g).

At harvest, the lowest proline content was recorded in treatment T_1V_4 (0.4690 µmol/g) and highest was found in treatment T_2V_2 (1.1510 µmol/g), followed by treatment T_3V_1 (0.9340 µmol/g) and treatment T_2V_3 (0.9243 µmol/g) which was at par with each other under water stress condition.

4.4. Physiological observations:

4.4.1 Relative water content (%)

It was observed that there was significant variation among four variety studied at 20, 40, 60 DAS and at harvest. As the crop growth increased, relative water content was found to be decreased. It was resulted that plants under regular irrigation had maintained maximum relative water content as compared to plants under different water stress treatment The data was represented in the Table 4.8 and displayed in the Fig 8.

Influence of water stress treatment

At 20 DAS, it was recorded that there was significant difference found among all treatments. Among all the treatments, treatment T_1 (81.07 %) recorded maximum relative water content, whereas treatment T_2 (76.69 %) was minimum relative water content, under water stress condition.

At 40 DAS, maximum relative water content was observed in treatment T_1 (79.48 %) followed by treatment T_3 (79.08 %) which was at par with each other, while it was minimum in treatment T_2 (64.23 %), under water stress condition.

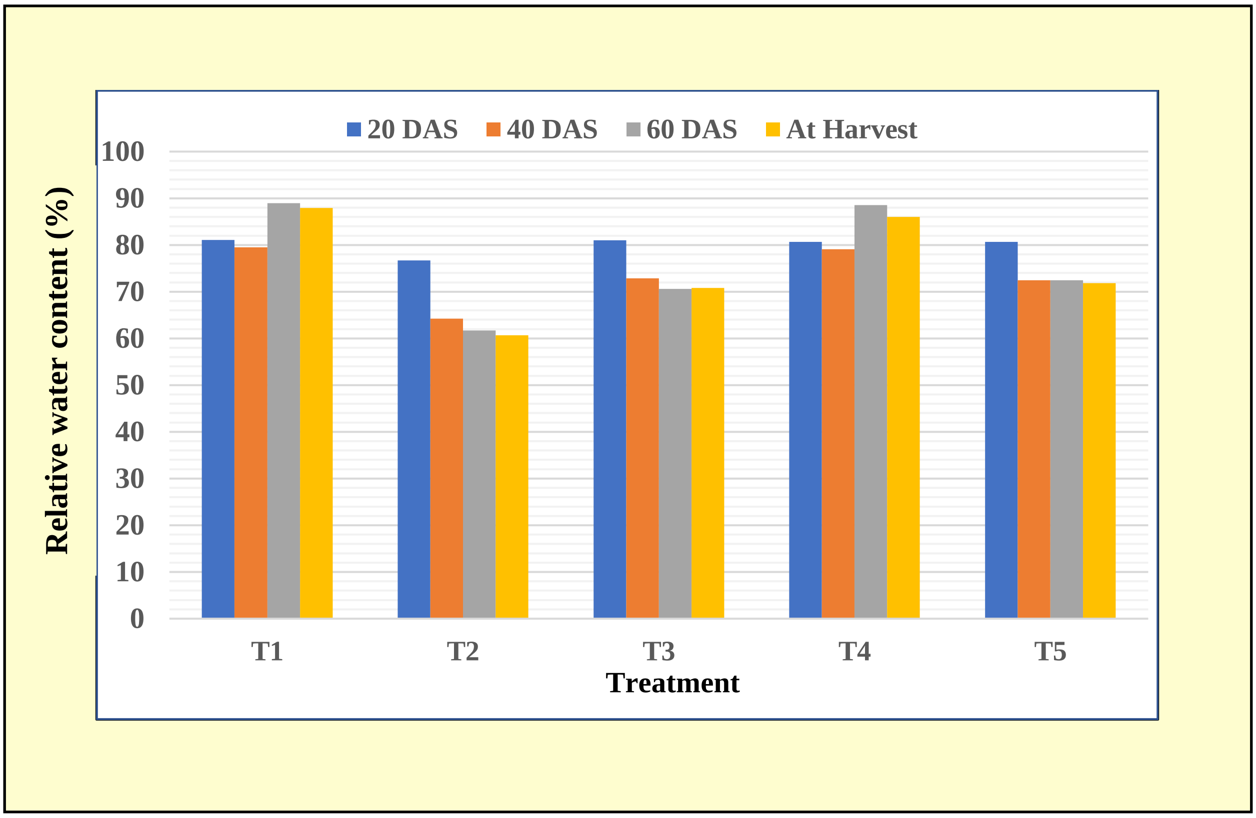
Table 4.8. Influence of different water stress treatments on relative water content (%) at various stages of plant growth of cowpea grown under water stress condition:

Genotypes	Treatments of water stress						SE ±	CD at 5%
	T_1	T_2	T_3	T_4	T_5	Mean		
20 DAS								
V_1	82.55	77.81	82.16	82.27	81.62	81.28	V. 0.0402	0.1389
V_2	81.43	76.68	81.78	81.21	81.13	80.45	T. 0.0351	0.1146
V_3	84.15	78.67	84.12	83.85	83.94	82.95	T x V 0.0717	0.2092
V_4	76.14	73.58	76.10	75.39	76.01	75.44		
Mean	81.07	76.69	81.04	80.68	80.68	80.03		
40 DAS								
V_1	80.98	65.25	74.22	80.46	73.54	74.89	V. 0.0038	0.0131
V_2	83.77	68.73	77.15	83.23	76.38	77.85	T. 0.0085	0.0279
V_3	80.04	63.49	73.09	79.78	72.63	73.81	T x V 0.0160	0.0467
V_4	73.12	59.44	67.03	72.86	67.26	67.94		
Mean	79.48	64.23	72.87	79.08	72.45	73.62		
60 DAS								
V_1	90.04	62.54	74.83	89.36	76.23	78.60	V. 0.0047	0.0161
V_2	92.38	68.23	70.43	91.91	75.29	79.65	T. 0.0060	0.0195
V_3	87.11	60.77	72.79	86.96	73.22	76.17	T x V 0.0146	0.0428
V_4	86.29	55.37	64.43	85.97	65.18	71.45		
Mean	88.95	61.73	70.62	88.55	72.48	76.46		
At harvest								
V_1	88.31	62.22	75.90	84.56	75.33	77.26	V. 0.2354	0.8223
V_2	93.30	68.48	69.60	91.33	76.24	79.79	T. 0.3003	0.9794
V_3	86.15	58.56	72.31	84.66	72.30	74.79	T x V 0.5054	1.4751
V_4	83.93	53.43	65.43	83.44	63.50	69.95		
Mean	87.92	60.67	70.81	86.00	71.84	75.44		

V.- Variety T.- Treatment T. x V.- Treatment x Variety

From 60 DAS, it was clearly seen that, there was significant variation among all treatments. Treatment T_1 (88.95 %) recorded maximum relative water content was followed by treatment T_4 (88.55 %) which was at par with each other. While in treatment T_2 (61.73 %) noted minimum relative water content, under water stress condition.

At harvest, maximum relative water content was recorded in the treatment T_1 (87.92 %), followed by treatment T_4 (86.00 %) which was at par with each other. However minimum was recorded in the treatment T_2 (60.67 %), under water stress condition.



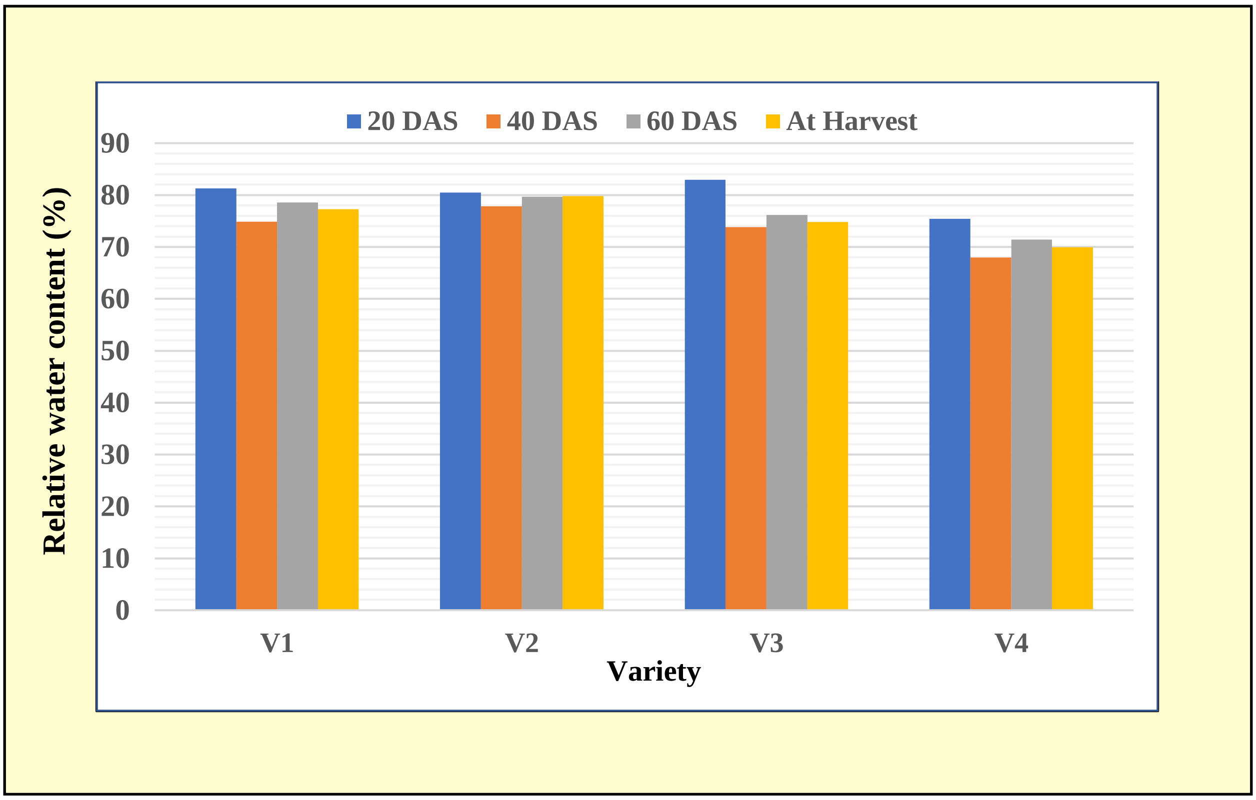


Fig.8. Influence of different water stress treatments on relative water content (%) at various stages of plant growth of cowpea grown under water stress condition

Influence of varietal differences

At 20 DAS, the varietal significant difference was showed with respect to relative water content. Variety V_3 (82.95 %) produced highest relative water content and lowest was found in variety V_4 (75.44 %), under water stress condition.

At 40 DAS, among all the stress condition, variety V_2 (77.85 %) recorded maximum relative water content which was consequently better all over other variety. The minimum was observed in variety V_4 (67.94 %) under water stress condition.

At 60 DAS, maximum relative water content was recorded by variety V_2 (79.65 %), followed by variety V_1 (78.60 %) they were at par with each other. The lowest relative water content was noted in variety V_4 (71.45 %), under water stress condition.

At harvest, under water stress condition maximum relative water content was recorded by the variety V_2 (79.79 %), followed by variety V_1 (77.26 %). However, minimum was found in variety V_4 (69.95 %).

Influence of interaction

At 20 DAS, the maximum relative water content which were noted in treatment combination T_1V_3 (84.15 %), whereas minimum in treatment T_2V_4 (73.58 %), under water stress condition.

At 40 DAS, it was recorded minimum relative water content in treatment T_2V_4 (59.44 %) and some more was found in T_2V_3 (63.49 %). It was recorded maximum in treatment T_1V_2 (83.77 %), followed by treatment T_4V_2 (83.23 %), under water stress condition.

At 60 DAS, it was recorded maximum relative water content in treatment T_1V_2 (92.38 %) which was followed by treatment T_4V_2 (91.91 %) and treatment T_1V_1 (90.04 %), they were at par with each other under water stress condition. The minimum relative water content which was recorded in treatment T_2V_4 (55.37 %).

At harvest, the lowest relative water content was recorded in treatment T_2V_4 (53.43 %) and highest was found in treatment T_1V_2 (93.30 %), followed by treatment T_4V_1 (91.33 %) which were at par with each other under water stress condition.

4.4.2. Chlorophyll stability index (%)

The statistical analysis of the data on chlorophyll stability index revealed a significant variation found among all treatments and variety as well as interaction effects under different water stress condition. The data was presented in the Table 4.9. and displayed in the Fig 9. The data found that significant variation among four variety studied at 20, 40, 60 DAS and at harvest.

Influence of water stress treatments

At 20 DAS, it was recorded that there was significant difference found among all treatments. Among all the treatment T_1 (54.89 %) recorded maximum chlorophyll stability index, whereas treatment T_2 (49.53 %) was noted minimum chlorophyll stability index, under water stress condition.

At 40 DAS, maximum chlorophyll stability index was observed in treatment T_1 (64.86 %), followed by treatment T_3 (63.98 %), while it was minimum in treatment T_2 (53.98 %), under water stress condition.

At 60 DAS, it was clearly seen that there was significant variation among all treatments. Treatment T_1 (68.50 %) recorded maximum chlorophyll stability index and treatment T_2 (57.51 %) produced minimum chlorophyll stability index, under water stress condition.

At harvest, maximum chlorophyll stability index was recorded in the treatment T_1 (62.80 %), followed by treatment T_4 (60.46 %) which was at par with each other. However minimum was recorded in treatment T_2 (50.69 %), under water stress condition.

Influence of varietal differences

At 20 DAS, the varietal significant difference was showed with respect to chlorophyll stability index. Variety V_2 (53.62 %) was noted maximum chlorophyll stability and minimum was found in variety V_3 (51.90 %), under water stress condition.

At 40 DAS, among all the stress condition, variety V_2 (62.39 %) recorded maximum chlorophyll stability index which was significantly better all other variety. The minimum was observed in variety V_4 (58.74 %), under water stress condition.

At 60 DAS, the highest chlorophyll stability index was recorded in variety V_2 (67.31 %), followed by variety V_1 (66.44 %) they were at par with each other. The lowest chlorophyll stability index was noted in variety V_4 (63.15 %), under water stress condition.

At harvest, under water stress condition maximum chlorophyll stability index was recorded in variety V_2 (60.29 %), followed by variety V_1 (59.34 %) which were at par with each other. However, minimum was found in variety V_4 (56.52 %).

Influence of interaction

At 20 DAS, the maximum chlorophyll stability index was noted in treatment combination T_1V_2 (56.60 %), whereas minimum in treatment T_2V_3 (47.47 %), under water stress condition.

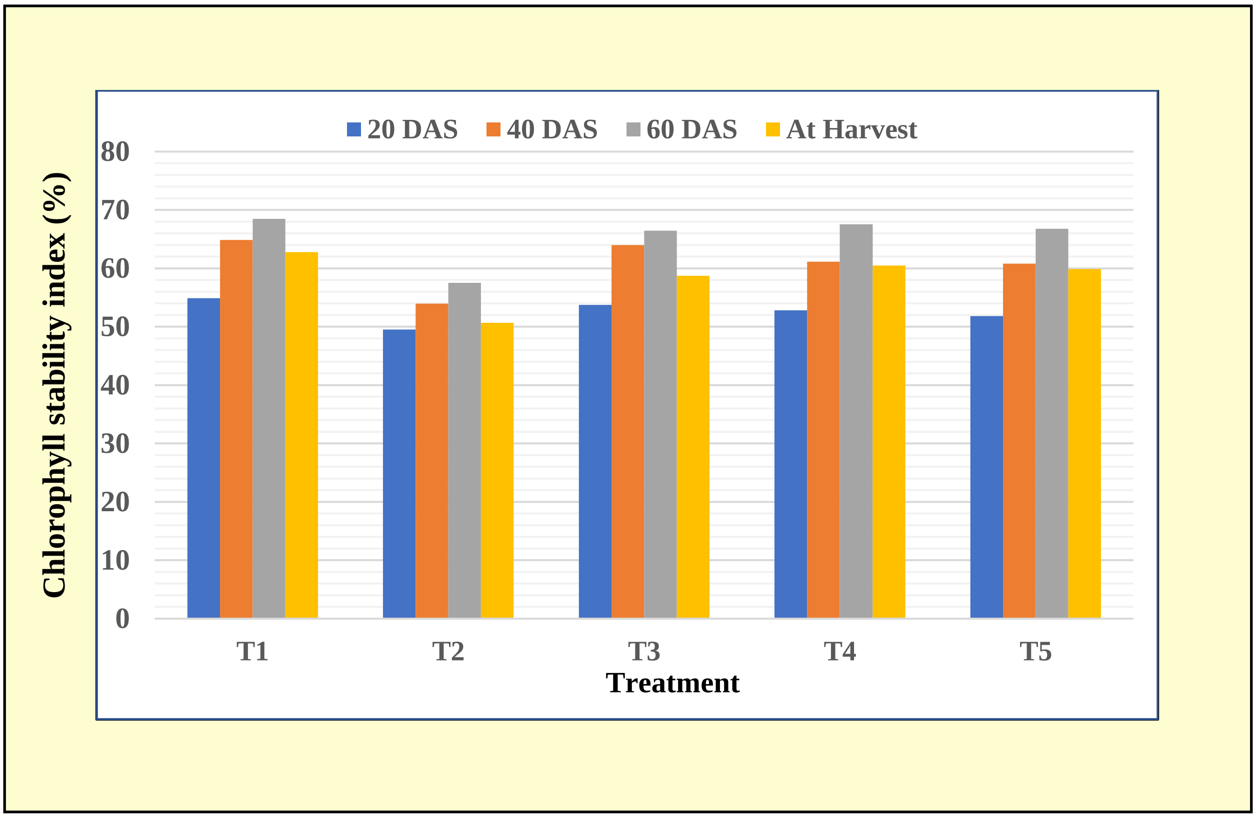
Table 4.9. Influence of different water stress treatments on chlorophyll stability index (%) at various stages of plant growth of cowpea grown under water stress condition:

Genotypes	Treatments of water stress						SE ±	CD at 5%
	T_1	T_2	T_3	T_4	T_5	Mean		
20 DAS								
V_1	55.41	48.70	53.69	53.11	52.59	52.70	**V. 0.0716**	**0.2477**
V_2	56.60	49.48	55.38	53.82	52.81	53.62	**T. 0.1447**	**0.4719**
V_3	54.42	47.47	53.51	52.75	51.37	51.90	**T x V 0.1809**	**0.5281**
V_4	53.12	52.46	52.35	51.53	50.43	51.98		
Mean	54.89	49.53	53.73	52.80	51.80	52.55		
40 DAS								
V_1	65.38	55.68	64.29	62.42	62.06	61.97	**V. 0.0843**	**0.2916**
V_2	66.37	56.30	65.56	62.08	61.63	62.39	**T. 0.0720**	**0.2348**
V_3	64.35	54.46	63.35	61.22	60.71	60.71	**T x V 0.1248**	**0.3643**
V_4	63.34	49.47	62.71	58.75	58.74	58.74		
Mean	64.86	53.98	63.98	61.12	60.83	60.95		
60 DAS								
V_1	69.53	58.65	67.53	68.60	67.91	66.44	**V. 0.0876**	**0.3030**
V_2	70.26	59.45	68.52	69.59	68.74	67.31	**T. 0.0874**	**0.2849**
V_3	67.64	57.50	65.38	66.25	65.89	64.53	**T x V 0.1181**	**0.3446**
V_4	66.58	54.44	64.27	65.82	64.66	63.15		
Mean	68.50	57.51	66.43	67.56	66.80	65.360		
At harvest								
V_1	63.37	51.42	60.29	61.39	60.25	59.34	**V. 0.0974**	**0.3370**
V_2	63.87	52.59	61.08	62.55	61.37	60.29	**T. 0.0625**	**0.2037**
V_3	62.37	50.88	57.20	59.56	59.54	57.91	**T x V 0.2176**	**0.6351**
V_4	61.61	47.86	56.34	58.35	58.44	56.52		
Mean	62.80	50.69	58.73	60.46	59.90	58.516		

V.- Variety T.- Treatment T. x V.- Treatment x Variety

At 40 DAS, it was recorded minimum chlorophyll stability index in treatment T_2V_4 (49.47 %) and some more was found in T_2V_3 (54.46 %). It was recorded maximum chlorophyll stability index in treatment T_1V_2 (66.37 %), followed by treatment T_3V_2 (65.56 %) and treatment T_1V_1 (65.38 %), which were at par with each other under water stress condition.

At 60 DAS, it was recorded maximum chlorophyll stability index in treatment T_1V_2 (70.26 %) which was followed by treatment T_4V_2 (69.59 %) and treatment T_1V_1 (69.53 %), they were at par with each other under water stress condition. The minimum chlorophyll stability



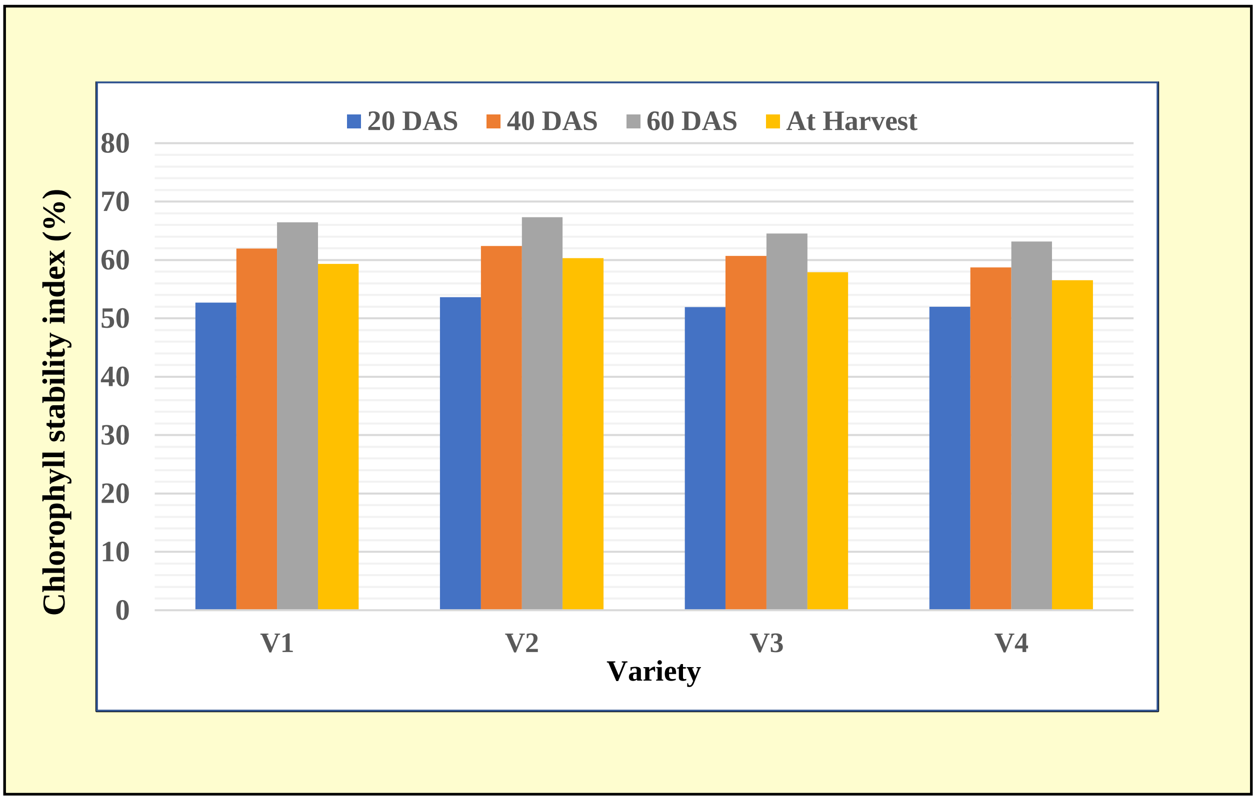


Fig.9. Influence of different water stress treatments on chlorophyll stability index (%) at various stages of plant growth of cowpea grown under water stress condition

index which was recorded in treatment T_2V_4 (54.44 %) and some more was found in T_2V_3 (57.50 %).

At harvest, the lowest chlorophyll stability index was recorded in treatment T_2V_4 (47.86 %) and highest was found in treatment T_1V_2 (63.87 %), followed by treatment T_1V_1 (63.37 %), which was at par with each other under water stress condition.

4.5. Dry matter studies:

4.5.1 Total dry matter per plant (g)

There was significant difference found in total dry matter production among all the treatments at various stages of plant growth. The statistical analysis of the data on total dry matter per plant resulted that significant variation observed among all treatments, as well as interaction effects under different water stress condition. The data was presented in the Table 4.10 and displayed in the Fig 10.

Influence of water stress treatments

At 20 DAS, it was recorded that there was consequent difference found among all treatments. Among all the treatment T_1 (2.9165 g) recorded maximum total dry matter per plant, whereas treatment T_2 (2.7298 g) was noted minimum total dry matter per plant under water stress condition.

At 40 DAS, maximum total dry matter per plant was observed in treatment T_1 (22.849 g), followed by treatment T_4 (21.732 g) and treatment T_3 (21.705 g), which was at par with each other. While it was minimum in treatment T_2 (4.581 g), under water stress condition.

At 60 DAS, it was clearly seen that there was significant variation among all treatments. Treatment T_1 (38.21 g) recorded maximum total dry matter per plant and treatment T_2 (7.64 g) was recorded minimum total dry matter per plant under water stress condition.

At harvest, maximum total dry matter per plant was recorded in the treatment T_1 (43.85 g), followed by treatment T_5 (41.78 g) and treatment T_4 (36.04 g). However minimum was recorded in the treatment T_2 (15.61 g), under water stress condition.

Influence of varietal differences

At 20 DAS, the varietal significant difference was showed with respect to total dry matter per plant. Variety V_3 (2.9525 g) was recorded total dry matter per plant and minimum was observed in variety V_4 (2.7801 g), under water stress condition.

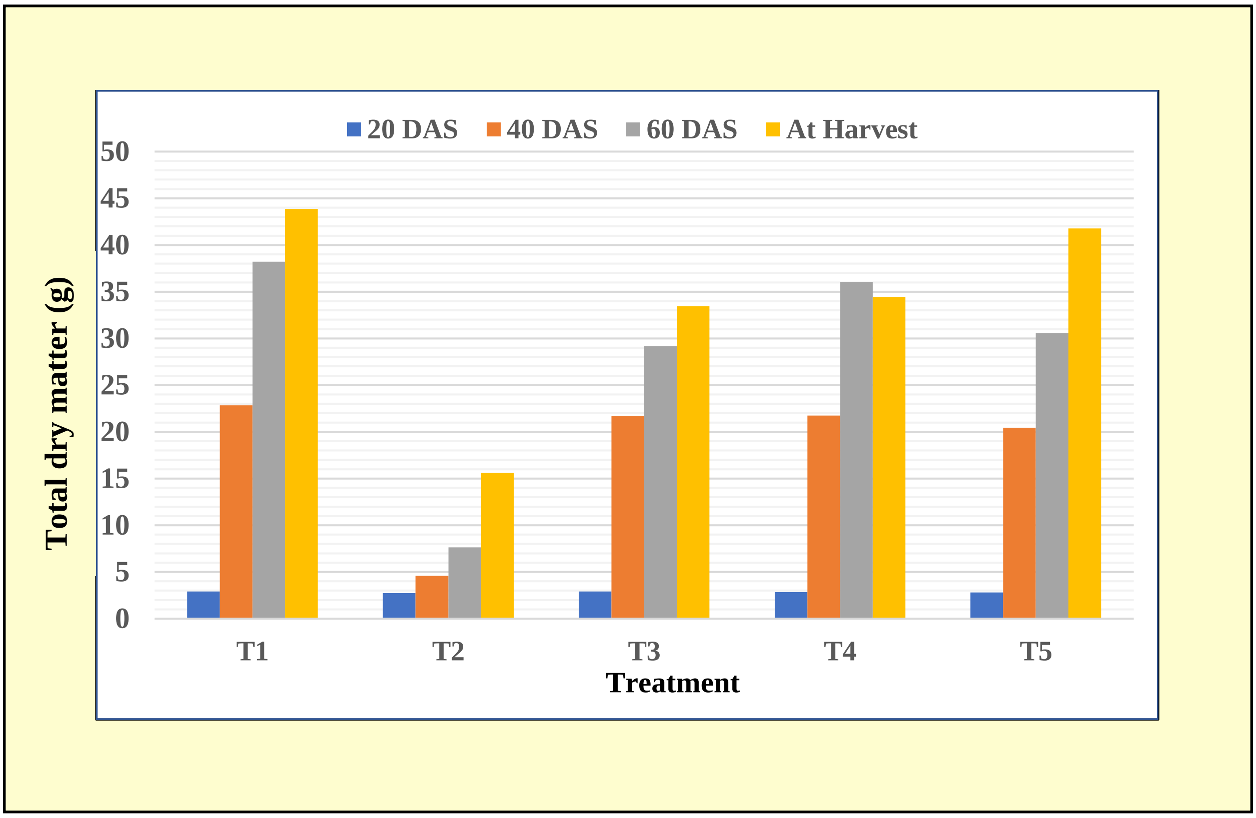
Table 4.10. Influence of different water stress treatments on total dry matter (g) at various stages of plant growth of cowpea grown under water stress condition:

Genotypes	Treatments of water stress						SE ±	CD at 5%
	T_1	T_2	T_3	T_4	T_5	Mean		
20 DAS								
V_1	2.9080	2.7350	2.8057	2.8735	2.7745	2.8194	V. 0.0030	0.0104
V_2	2.8849	2.7263	2.7909	2.8914	2.7863	2.8160	T. 0.0031	0.0103
V_3	3.0305	2.7335	2.9893	3.0157	2.9935	2.9525	T x V 0.0621	0.1823
V_4	2.8425	2.7241	2.7407	2.8607	2.7325	2.7801		
Mean	2.9165	2.7298	2.9103	2.8317	2.8217	2.842		
40 DAS								
V_1	23.445	4.856	22.343	21.824	20.524	18.598	V. 0.0083	0.0267
V_2	23.077	4.640	22.005	22.654	21.357	18.747	T. 0.0034	0.0110
V_3	24.565	4.625	23.365	22.509	21.206	19.254	T x V 0.0231	0.0631
V_4	20.311	4.204	19.107	19.941	18.634	16.439		
Mean	22.849	4.581	21.705	21.732	20.430	18.260		
60 DAS								
V_1	39.05	7.79	29.52	34.01	30.73	28.82	V. 0.0217	0.0752
V_2	38.56	8.23	29.83	35.49	31.44	28.88	T. 0.0316	0.1031
V_3	39.52	7.89	30.02	35.65	31.52	29.23	T x V 0.0609	0.1778
V_4	35.73	6.66	27.27	32.64	27.27	26.38		
Mean	38.21	7.64	29.16	34.45	30.59	28.329		
At harvest								
V_1	43.43	15.62	33.02	37.01	41.12	33.44	V. 0.0544	0.0871
V_2	45.09	16.24	34.48	36.46	43.20	34.90	T. 0.0290	0.0946
V_3	45.48	16.22	34.65	37.22	43.37	35.08	T x V 0.0544	0.1589
V_4	41.41	14.36	31.64	33.49	39.42	31.90		
Mean	43.85	15.61	33.45	36.04	41.78	33.829		

V.- Variety T.- Treatment T. x V.- Treatment x Variety

At 40 DAS, among all the water stress condition variety V_3 (19.254 g) recorded maximum total dry matter per plant which was significantly superior all over variety. The significantly lowest was observed in variety V_4 (16.439 g), under water stress condition.

At 60 DAS, the highest total dry matter was recorded in variety V_3 (29.23 g), followed by variety V_2 (28.88 g) and variety V_1 (28.82 g), they were at par with each other. The lowest total dry matter per plant was noted in variety V_4 (26.38 g), under water stress condition.



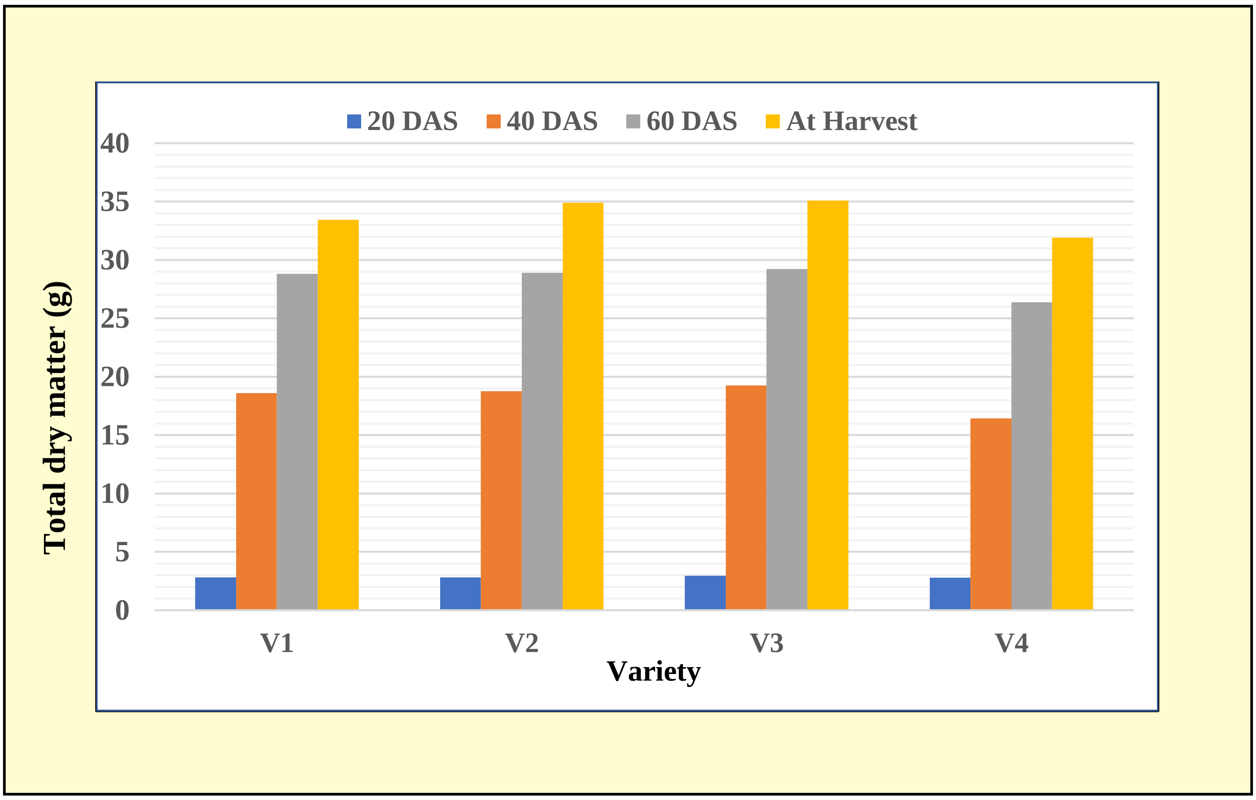


Fig.10. Influence of different water stress treatments on total dry matter (g) at various stages of plant growth of cowpea grown under water stress condition.

At harvest, under water stress condition maximum total dry matter per plant was recorded in variety V_3 (35.08 g), followed by variety V_2 (34.90 g), which were at par with each other. However, minimum was found in variety V_4 (31.90 g).

Influence of interaction

At 20 DAS, the maximum total dry matter per plant was noted in treatment combination T_1V_3 (3.0305 g), whereas it was minimum in treatment T_2V_4 (2.7241 g), under water stress condition.

At 40 DAS, it was recorded minimum total dry matter per plant in treatment T_2V_4 (4.204 g), while it was recorded maximum in treatment T_1V_3 (24.565 g), followed by treatment T_1V_1 (23.445 g), which were at par with each other under water stress condition.

At 60 DAS, it was recorded maximum total dry matter per plant in treatment T_1V_3 (39.52 g) which was followed by treatment T_1V_1 (39.05 g) and treatment T_1V_2 (38.56 g), they were at par with each other under water stress condition. The minimum total dry matter per plant was recorded in treatment T_2V_4 (6.66 g).

At harvest, the lowest total dry matter per plant was recorded in treatment T_2V_4 (14.36 g) and highest was found in treatment T_1V_3 (45.48 g), followed by treatment T_1V_2 (45.09 g), under water stress condition.

4.5.3. Leaves dry weight per plant (g)

Leaves dry weight per plant varied significantly at different stages of crop growth and treatments. The statistical analysis of the data on leaves dry weight per plant resulted a significant difference among all treatments under water stress condition as well as interaction effects among different water stress treatments and variety were found significant for leaves dry weight per plant. The data was presented in the Table 4.11.

Influence of water stress treatments

At 20 DAS, it was recorded that there was significant difference found among all treatments. Among all the treatment T_1 (1.2387 g) was recorded maximum leaves dry weight per plant, whereas treatment T_2 (1.2215 g) was recorded minimum leaves dry weight per plant, under water stress condition.

At 40 DAS, maximum leaves dry weight per plant was observed in treatment T_1 (20.787 g), followed by treatment T_4 (20.286 g) which was at par with each other. While it was minimum in treatment T_2 (4.210 g), under water stress condition.

Table 4.11. Influence of different water stress treatments on leaves dry weight (g) at various stages of plant growth of cowpea grown under water stress condition:

Genotypes	Treatments of water stress						SE ±	CD at 5%
	T_1	T_2	T_3	T_4	T_5	Mean		
20 DAS								
V_1	1.2056	1.9998	1.2041	1.2062	1.1913	1.2014	V. 0.0015	0.0051
V_2	1.2565	1.2498	1.2579	1.2459	1.2435	1.2498	T. 0.0016	0.0052
V_3	1.2462	1.2081	1.2331	1.2353	1.2337	1.2313	T x V 0.0027	0.0080
V_4	1.2466	1.2329	1.2449	1.2453	1.2284	1.2396		
Mean	1.2387	1.2215	1.2350	1.2331	1.2242	1.231		
40 DAS								
V_1	18.275	3.844	17.784	19.280	16.774	15.191	V. 0.0032	0.0109
V_2	22.495	4.272	20.553	21.494	19.544	17.672	T.0.0036	0.0119
V_3	20.944	4.238	20.117	19.944	19.115	16.872	T x V 0.0077	0.0224
V_4	21.434	4.483	20.308	20.427	19.266	17.183		
Mean	20.787	4.210	19.690	20.286	18.675	16.730		
60 DAS								
V_1	32.58	4.82	24.45	27.35	26.54	23.15	V. 0.0156	0.0541
V_2	36.32	6.68	26.71	29.61	28.71	25.60	T. 0.0126	0.0412
V_3	35.43	6.35	26.63	29.53	28.59	25.31	T x V 0.0313	0.0913
V_4	35.95	6.23	26.63	29.61	28.72	25.43		
Mean	35.07	6.02	26.11	29.03	28.14	24.871		
At harvest								
V_1	20.366	3.145	14.345	16.211	17.325	14.279	V. 0.0278	0.0963
V_2	23.575	4.774	16.693	18.394	19.614	16.610	T. 0.0305	0.0995
V_3	23.483	4.614	16.472	18.424	19.494	16.497	T x V 0.0555	0.1621
V_4	23.405	4.224	16.724	18.305	19.624	16.456		
Mean	22.707	4.189	16.059	17.834	19.014	15.961		

V.- Variety T.- Treatment T. x V.- Treatment x Variety

At 60 DAS, it was clearly seen that, there was significant variation among all treatments. Treatment T_1 (35.07 g) was recorded maximum leaves dry weight per plant and treatment T_2 (6.02 g) was recorded minimum leaves dry weight per plant, under water stress condition.

At harvest, maximum leaves dry weight per plant was recorded in treatment T_1 (22.707 g), followed by treatment T_5 (19.014 g). However minimum was recorded in treatment T_2 (4.189 g), under water stress condition.

Influence of varietal differences

At 20 DAS, the varietal significant difference was showed with respect to leaves dry weight per plant. Variety V_2 (1.2498 g) was noted highest leaves dry weight and lowest was found in variety V_1 (1.2014 g), under water stress condition.

At 40 DAS, among all the stress condition, variety V_2 (17.672 g) was recorded maximum leaves dry weight per plant which was significantly better all over variety. The minimum was observed in variety V_1 (15.191 g), under water stress condition.

At 60 DAS, the highest leaves dry weight was recorded in variety V_2 (25.60 g), followed by variety V_4 (25.43 g) and variety V_3 (25.31 g), they were at par with each other. The lowest leaves dry weight per plant was noted in variety V_1 (23.15 g), under water stress condition.

At harvest, under water stress condition maximum leaves dry weight per plant was recorded in variety V_2 (16.610 g), followed by variety V_3 (16.497 g) and variety V_4 (16.456 g), which were at par with each other. However, minimum was found in variety V_1 (14.279 g).

Influence of interaction

At 20 DAS, maximum leaves dry weight per plant were noted in treatment combination T_1V_2 (1.2565 g), whereas minimum was noted in treatment T_2V_1 (1.9998 g), under water stress condition.

At 40 DAS, minimum leaves dry weight per plant was recorded in treatment T_2V_1 (3.844 g). It was recorded maximum in treatment T_1V_2 (22.495 g), followed by treatment T_4V_2 (21.494 g) and treatment T_1V_4 (21.434 g), which were at par with each other under water stress condition.

At 60 DAS, it was recorded maximum leaves dry weight per plant in treatment T_1V_2 (36.32 g) which was followed by treatment T_1V_4 (35.95 g) and treatment T_1V_3 (35.43 g), they were at par with each other under water stress condition. The minimum leaves dry weight per plant was recorded in treatment T_2V_1 (4.82 g).

At harvest, minimum leaves dry weight per plant was recorded in treatment T_2V_1 (3.145 g), while maximum was found in treatment T_1V_2 (23.575 g), followed by treatment T_1V_3 (23.483 g) and treatment T_1V_4 (23.405 g), which was at par with each other under water stress condition.

4.5.3. Stem dry weight per plant (g)

Stem dry weight per plant was observed a significant difference among all treatments. The statistical analysis of the data on stem dry weight per plant was resulted a significant difference among all treatments and variety under water stress condition. The data was presented in the Table 4.12.

Influence of water stress treatments

At 20 DAS, it was found that there was significant difference found among all treatments. Among all the treatment T_1 (0.6697 g) recorded maximum stem dry weight per plant, whereas treatment T_2 (0.4871 g) was noted minimum stem dry weight per plant, under water stress condition.

At 40 DAS, maximum stem dry weight per plant was observed in treatment T_1 (2.0615 g), followed by treatment T_3 (2.0525 g), which was at par with each other. While it was minimum in treatment T_2 (1.4006 g), under water stress condition.

At 60 DAS, it was clearly seen that, there was significant variation among all treatments. Treatment T_1 (3.259 g) recorded maximum stem dry weight per plant and treatment T_2 (1.617 g) recorded minimum stem dry weight per plant, under water stress condition.

At harvest, maximum stem dry weight per plant was recorded in the treatment T_1 (2.4485 g), followed by treatment T_5 (2.3975 g), which was at par with each other. However minimum was recorded in treatment T_2 (1.4543 g), under water stress condition.

Influence of varietal differences

At 20 DAS, the varietal significant difference was showed with respect to stem dry weight per plant. Variety V_3 (0.7144 g) was recorded highest stem dry weight per plant and lowest was found in variety V_4 (0.5741 g), under water stress condition.

At 40 DAS, among all the stress condition, variety V_3 (2.0508 g) recorded maximum stem dry weight per plant which was consequently better all over variety. The minimum was observed in variety V_4 (1.6277 g), under water stress condition.

At 60 DAS, the highest stem dry weight was recorded in variety V_3 (2.7371 g), followed by variety V_2 (2.5973 g). The lowest stem dry weight per plant was noted in variety V_4 (2.2726 g), under water stress condition.

At harvest, under water stress condition maximum stem dry weight per plant was recorded in variety V_3 (2.3988 g), followed by variety V_2 (2.1682 g). However, minimum was found in variety V_1 (1.8844 g).

Influence of interaction

At 20 DAS, the maximum stem dry weight per plant were noted in treatment combination T_1V_3 (0.7807 g), whereas it was less in treatment T_2V_4 (0.3962 g), under water stress condition.

Table 4.12. Influence of different water stress treatments on stem dry weight (g) at various stages of plant growth of cowpea grown under water stress condition:

Genotypes	Treatments of water stress						SE ±	CD at 5%
	T_1	T_2	T_3	T_4	T_5	Mean		
20 DAS								
V_1	0.6365	0.5134	0.6335	0.6358	0.5884	0.6015	V. 0.0120	0.0417
V_2	0.6333	0.5155	0.6255	0.6255	0.5942	0.6005	T. 0.0131	0.0428
V_3	0.7807	0.5233	0.7841	0.7841	0.6991	0.7144	T x V 0.0223	0.0768
V_4	0.6283	0.3962	0.6243	0.6243	0.5933	0.5741		
Mean	0.6697	0.4871	0.6668	0.6626	0.6188	0.621		
40 DAS								
V_1	2.0323	1.3860	2.1649	2.1333	1.8535	1.9140	V. 0.0031	0.0112
V_2	2.0659	1.4050	2.1057	2.0741	1.8471	1.8996	T. 0.0032	0.0118
V_3	2.1333	1.4155	2.3851	2.3549	1.1955	2.0508	T x V 0.0268	0.0839
V_4	2.0147	1.3957	1.5544	1.5279	1.6457	1.6277		
Mean	2.0615	1.4006	2.0525	2.0226	1.8280	1.873		
60 DAS								
V_1	3.1545	1.6054	2.2355	2.3157	2.2861	2.3194	V. 0.0212	0.0713
V_2	3.4846	1.6155	2.5919	2.6587	2.6356	2.5973	T. 0.0235	0.0822
V_3	3.2923	1.6258	2.8805	2.9546	2.9325	2.7371	T x V 0.0714	0.2341
V_4	3.1066	1.6211	2.1750	2.2453	2.2151	2.2726		
Mean	3.259	1.617	2.471	2.544	2.517	2.482		
At harvest								
V_1	1.9962	1.4436	1.8333	1.8652	2.2835	1.8844	V. 0.0267	0.0736
V_2	2.3955	1.4545	2.1859	2.3549	2.4501	2.1682	T. 0.0277	0.0984
V_3	2.9777	1.4647	2.4753	2.3249	2.7512	2.3988	T x V 0.0755	0.2451
V_4	2.4245	1.4544	1.7741	2.1833	2.1051	1.9893		
Mean	2.4485	1.4543	2.0671	2.1821	2.3975	2.110		

V.- Variety T.- Treatment T. x V.- Treatment x Variety

At 40 DAS, it was recorded minimum stem dry weight per plant in treatment T_2V_1 (1.3860 g). It was recorded maximum stem dry weight per plant in treatment T_3V_3 (2.3851g), followed by treatment T_4V_3 (2.3549 g), which were at par with each other under water stress condition.

At 60 DAS, it was recorded maximum stem dry weight per plant in treatment T_1V_2 (3.4846 g), which was followed by treatment T_1V_3 (3.2923 g) and treatment T_1V_1 (3.1545 g), they were at par with each other under water stress condition. The minimum stem dry weight per plant were recorded in treatment T_2V_1 (1.6054 g).

At harvest, the minimum stem dry weight per plant was recorded in treatment T_2V_1 (1.4436 g) and maximum was found in treatment T_1V_3 (2.9777 g), followed by treatment T_5V_3 (2.7512 g), under water stress condition.

4.5.4. Root dry weight per plant (g)

Root dry weight per plant observed significant difference at different plant growth stages among all treatments. The statistical analysis of the data on root dry weight per plant resulted that consequent variation found among all treatments under water stress condition. The data was presented in the Table 4.13.

Influence of water stress treatments

At 20 DAS, it was found that there was consequent difference found among all treatments. Among all the treatment T_1 (0.02310 g) was recorded maximum root dry weight per plant, whereas treatment T_2 (0.02239 g) was minimum root dry weight per plant, under water stress condition.

At 40 DAS, maximum root dry weight per plant was observed in treatment T_1 (0.3559 g), followed by treatment T_3 (0.3548 g), which was at par with each other. While it was minimum in treatment T_2 (0.1510 g) under water stress condition.

At 60 DAS, it was clearly seen that, there was significant variation among all treatments. Treatment T_1 (0.8252 g) recorded maximum root dry weight per plant and treatment T_2 (0.2665 g) found minimum root dry weight per plant, under water stress condition.

At harvest, maximum root dry weight per plant was recorded in treatment T_1 (0.8749 g), followed by treatment T_5 (0.6246 g). However less was recorded in treatment T_2 (0.3270 g), under water stress condition.

Influence of varietal differences

At 20 DAS, the varietal significant difference was showed with respect to root dry weight per plant. Variety V_1 (0.02330 g) produced highest root dry weight and lowest was found in variety V_4 (0.02239 g), under water stress condition.

At 40 DAS, among all the stress condition, variety V_3 (0.3201 g) recorded maximum root dry weight per plant which was consequently better all over variety. The minimum was observed in variety V_1 (0.2952 g).

Table 4.13. Influence of different water stress treatments on root dry weight (g) at various stages of plant growth of cowpea grown under water stress condition:

Genotypes	Treatments of water stress						SE ±	CD at 5%
	T_1	T_2	T_3	T_4	T_5	Mean		
20 DAS								
V_1	0.02328	0.02246	0.02464	0.02227	0.02386	0.02330	**V. 0.0001**	**0.0004**
V_2	0.02327	0.02283	0.02256	0.02319	0.02307	0.02298	**T. 0.0001**	**0.0005**
V_3	0.02236	0.02230	0.02300	0.02360	0.02262	0.02277	**T x V 0.0003**	**0.0007**
V_4	0.02350	0.02199	0.02189	0.02242	0.02217	0.02239		
Mean	0.02310	0.02239	0.02302	0.02287	0.02293	0.024		
40 DAS								
V_1	0.3384	0.1457	0.3403	0.3307	0.3212	0.2952	**V. 0.0006**	**0.0022**
V_2	0.3409	0.1563	0.3429	0.3307	0.3159	0.2974	**T. 0.0008**	**0.0026**
V_3	0.3734	0.1667	0.3726	0.3637	0.3243	0.3201	**T x V 0.0017**	**0.0049**
V_4	0.3628	0.1353	0.3633	0.3508	0.3163	0.3057		
Mean	0.3559	0.1510	0.3548	0.3440	0.3194	0.305		
60 DAS								
V_1	0.8504	0.2451	0.4099	0.4949	0.5115	0.5148	**V. 0.0015**	**0.0050**
V_2	0.7532	0.2613	0.3909	0.5256	0.4919	0.4865	**T.0.0015**	**0.0048**
V_3	0.9298	0.2937	0.4868	0.5745	0.5882	0.5867	**T x V 0.0033**	**0.0095**
V_4	0.7674	0.2657	0.4081	0.4945	0.5075	0.5005		
Mean	0.8252	0.2665	0.4239	0.5224	0.5248	0.522		
At harvest								
V_1	0.9845	0.2855	0.3936	0.5571	0.5947	0.5506	**V. 0.0011**	**0.0038**
V_2	0.6840	0.3448	0.4251	0.5352	0.6343	0.5227	**T. 0.0009**	**0.0029**
V_3	0.8551	0.3641	0.4649	0.6350	0.6742	0.5866	**T x V 0.0023**	**0.0067**
V_4	0.9761	0.3135	0.3933	0.5540	0.5953	0.5546		
Mean	0.8749	0.3270	0.4192	0.5703	0.6246	0.554		

V.- Variety T.- Treatment T. x V.- Treatment x Variety

At 60 DAS, the highest root dry weight was recorded in variety V_3 (0.5867 g), followed by variety V_1 (0.5148 g) and variety V_4 (0.5005 g), they were at par with each other. The lowest root dry weight per plant was noted in variety V_2 (0.4865 g), under water stress condition.

At harvest, under water stress condition maximum root dry weight per plant was recorded in variety V_3 (0.5866 g), followed by variety V_4 (0.5546 g) and variety V_1 (0.5506 g), which were at par with each other. However, minimum was found in variety V_2 (0.5227 g).

Influence of interaction

At 20 DAS, the maximum root dry weight per plant were noted in treatment combination T_4V_3 (0.02360 g), whereas minimum in treatment T_3V_4 (0.02189 g), under water stress condition.

At 40 DAS, it was recorded minimum root dry weight per plant in treatment T_2V_4 (0.1353 g). It was recorded maximum root dry weight per plant in treatment T_1V_3 (0.3734 g), followed by treatment T_3V_3 (0.3726 g) and treatment T_4V_3 (0.3637 g), which were at par with each other under water stress condition.

At 60 DAS, it was recorded maximum root dry weight per plant in treatment T_1V_3 (0.9298 g) which was followed by treatment T_1V_1 (0.8504 g), under water stress condition. The minimum root dry weight per plant was recorded in treatment T_2V_1 (0.2451 g).

At harvest, the lowest root dry weight per plant was recorded in treatment T_2V_1 (0.2855 g) and highest was found in treatment T_1V_1 (0.9845 g), followed by treatment T_1V_4 (0.9761 g), which was at par with each other under water stress condition.

4.6. Growth parameters:

4.6.1. Leaf area per plant (dm^2)

The findings experiment that there was a huge variety of difference among all the treatments, yet means leaf area per plant varied at all stages of plant growth. The statistical analysis of the data on leaf area per plant as a revealed a significant variation among water stress treatments as well as among interaction effect between stress treatments and variety under water stress condition. The leaf area per plant progressively increased with the advancing age of plant growth. Initially leaf area per plant was increased then rather slow, but during period from 40 to 60 DAS, the leaf area per plant constantly increased. The data was presented in the Table 4.14

Influence of water stress treatment

At 20 DAS, it was observed that there was significant difference among all treatments. Treatment T_1 (7.212 dm^2) was observed maximum leaf area per plant, followed by treatment T_3 (7.095 dm^2), whereas treatment T_2 (5.295 dm^2) noted minimum leaf area per plant under water stress condition.

At 40 DAS, significant difference was observed with respect to leaf area per plant in all the treatments. Maximum leaf area per plant was observed in treatment T_1 (44.89 dm^2), followed by treatment T_3 (44.59 dm^2) and treatment T_4 (43.60 dm^2), however leaf area per plant was minimum in the treatment T_2 (27.75 dm^2), under water stress condition.

Table 4.14. Influence of different water stress treatments on leaf area per plant (dm^2/plant) at various stages of plant growth of cowpea grown under water stress condition:

Genotypes	Treatments of water stress						SE ±	CD at 5%
	T_1	T_2	T_3	T_4	T_5	Mean		
20 DAS								
V_1	5.414	5.320	5.279	6.639	5.524	6.235	**V. 0.0095**	**0.0330**
V_2	5.487	5.135	5.365	5.359	5.257	5.321	**T. 0.0105**	**0.0343**
V_3	9.350	7.912	9.246	8.398	8.251	8.631	**T x V 0.0200**	**0.0585**
V_4	7.597	6.812	7.491	7.516	7.423	7.368		
Mean	7.212	5.295	7.095	5.978	6.864	6.889		
40 DAS								
V_1	50.51	27.29	50.62	49.80	47.45	45.14	**V. 0.1165**	**0.4031**
V_2	34.24	29.55	38.60	37.40	32.29	34.42	**T. 0.1604**	**0.5232**
V_3	54.60	32.44	54.60	53.82	51.55	49.40	**T x V 0.1913**	**0.5583**
V_4	40.21	21.70	34.50	33.39	36.72	33.30		
Mean	44.89	27.75	44.59	43.60	42.01	40.567		
60 DAS								
V_1	88.22	47.84	79.85	80.76	77.00	74.73	**V. 0.0765**	**0.2647**
V_2	75.52	48.60	59.86	62.38	57.26	60.72	**T. 0.1691**	**0.5515**
V_3	88.69	54.17	80.32	83.76	57.27	72.84	**T x V 0.3148**	**0.9188**
V_4	65.75	40.68	63.75	66.27	63.36	59.96		
Mean	79.55	47.82	70.94	73.29	63.73	67.066		
At harvest								
V_1	65.99	21.02	43.15	48.15	42.25	44.11	**V. 0.1100**	**0.3807**
V_2	67.29	20.84	42.36	47.01	45.65	44.63	**T. 0.1110**	**0.3621**
V_3	68.48	27.51	48.45	57.69	50.95	50.62	**T x V 0.2248**	**0.6563**
V_4	54.06	20.51	37.58	40.61	39.91	38.53		
Mean	63.96	22.47	42.89	48.36	44.69	44.472		

V.- Variety T.- Treatment T. x V.- Treatment x Variety

At 60 DAS, the variation among all treatments, treatment T_1 (79.55 dm^2), produced significantly maximum leaf area per plant followed by treatment T_4 (73.29 dm^2) and treatment T_3 (70.94 dm^2), whereas minimum was recorded in treatment T_2 (47.82 dm^2), under water stress condition.

At harvest, the variation in mean leaf area per plant was observed due to different stress treatments. The maximum leaf area per plant was recorded in treatment T_1 (63.96 dm^2), followed by treatment T_4 (48.36 dm^2) and treatment T_5 (44.69 dm^2). However, minimum in treatment T_2 (22.47 dm^2), under water stress condition.

Influence of varietal difference

At 20 DAS, among all the stress condition, variety V_3 (8.631 dm^2) recorded maximum leaf area per plant which was significantly better all over variety. The minimum was observed in variety V_2 (5.321 dm^2).

At 40 DAS, the highest leaf area per plant was recorded in variety V_3 (49.40 dm^2), followed by variety V_1 (45.14 dm^2) and variety V_2 (34.42 dm^2). The lowest leaf area per plant was noted in variety V_4 (33.30 dm^2).

At 60 DAS, maximum leaf area per plant was recorded in variety V_1 (74.73 dm^2), followed by variety V_3 (72.84 dm^2). The minimum leaf area per plant was noted in variety V_4 (59.96 dm^2).

At harvest, the maximum leaf area per plant was recorded in variety V_3 (50.62 dm^2), followed by variety V_2 (44.63 dm^2). The minimum leaf area per plant was noted in variety V_4 (38.53 dm^2).

Influence of interaction

At 20 DAS, the maximum leaf area was noted in treatment combination T_1V_3 (9.350 dm^2), whereas minimum in the treatment T_1V_2 (5.135 dm^2), under water stress condition.

At 40 DAS, minimum leaf area per plant was observed in treatment T_2V_4 (21.70 dm^2) and some more was found in T_2V_1 (27.29 dm^2), under water stress condition. It was recorded maximum leaf area per plant in treatment T_1V_3 (54.60 dm^2) also in treatment T_3V_3 (54.60 dm^2).

At 60 DAS, it was recorded maximum leaf area per plant in treatment T_1V_3 (88.69 dm^2) which was followed by treatment T_1V_1 (88.22 dm^2) they were at par with each other under water stress condition. The minimum leaf area per plant were recorded in treatment T_2V_4 (40.68 dm^2) and some more was found in T_2V_1 (47.84 dm^2).

At harvest, the lowest leaf area per plant was recorded in treatment T_2V_4 (20.51 dm^2) and highest was found in treatment T_1V_3 (68.48 dm^2), followed by treatment T_1V_2 (67.29 dm^2) which was at par with each other under water stress condition.

4.6.2. Leaf area index

The findings experiment that there was a huge variety of difference among all the treatments, yet means leaf area index different among all the stages of plant growth. The statistical analysis of the data on leaf area index as influenced by different water stress treatments, also among interaction effect between water stress treatments and variety under water stress condition. The data was presented in the Table 4.15.

Influence of water stress treatment

At 20 DAS, it was observed that, there was significant difference among treatments. Treatment T_1 (0.04721) was resulted maximum leaf area index, followed by treatment T_3 (0.01599), whereas treatment T_2 (0.01371) was resulted minimum leaf area index, under water stress.

At 40 DAS, there was a significant difference was observed with respect to leaf area index in all treatments. Maximum leaf area index was observed in treatment T_1 (1.0013), followed by treatment T_4 (0.9908) and treatment T_3 (0.9690), however leaf area index was minimum in treatment T_2 (0.6181), under water stress condition.

At 60 DAS, the variation among all the treatment T_1 (1.7668), recorded maximum leaf area index, followed by treatment T_4 (1.6285) and treatment T_3 (1.5760), whereas minimum was recorded in treatment T_2 (1.0627).

At harvest, it was observed that significant variation in mean leaf area index due to different water stress treatments. The maximum leaf area index was recorded in treatment T_1 (1.4213), followed by treatment T_4 (1.0727), and treatment T_5 (0.9899). However, lowest in treatment T_2 (0.4995), under water stress condition.

Influence of varietal difference

At 20 DAS, among all the stress condition, variety V_3 (0.04412) recorded maximum leaf area index which was consequently better all over variety. The minimum was observed in variety V_1 (0.01389).

At 40 DAS, the highest leaf area index was recorded in variety V_3 (1.0979), followed by variety V_1 (1.0051), they were at par with each other. The lowest leaf area index was noted in variety V_4 (0.7443).

At 60 DAS, maximum leaf area index was recorded in variety V_1 (1.6608), followed by variety V_3 (1.6169), they were at par with each other. The lowest leaf area index was noted in variety V_4 (1.3332).

At harvest, the maximum leaf area index was recorded in variety V_3 (1.1187), followed by variety V_2 (0.9937). The minimum leaf area index was noted in variety V_4 (0.8563) under water stress condition.

Influence of interaction

At 20 DAS, the maximum leaf area index which were noted in treatment combination T_5V_3 (0.02054), whereas minimum in treatment T_2V_2 (0.01141), under water stress condition.

Table 4.15. Influence of different water stress treatments on leaf area index at various stages of plant growth of cowpea grown under water stress condition:

Genotypes	Treatments of water stress						SE ±	CD at 5%
	T_1	T_2	T_3	T_4	T_5	Mean		
20 DAS								
V_1	0.01425	0.01202	0.01449	0.01475	0.01395	0.01389	**V. 0.0081**	**0.0280**
V_2	0.01219	0.01141	0.01466	0.01166	0.01192	0.01877	**T. 0.0088**	**0.0287**
V_3	0.01454	0.01758	0.01833	0.01866	0.02054	0.04412	**T x V 0.154**	**0.0450**
V_4	0.01688	0.01383	0.01649	0.01670	0.01664	0.01611		
Mean	0.04721	0.01371	0.01599	0.01545	0.01577	0.023		
40 DAS								
V_1	1.1226	0.6064	1.1068	1.1256	1.0643	1.0051	**V. 0.0036**	**0.0125**
V_2	0.7610	0.6567	0.8313	0.8575	0.7178	0.7649	**T. 0.0048**	**0.0158**
V_3	1.2134	0.7210	1.1961	1.2101	1.1456	1.0979	**T x V 0.0049**	**0.0144**
V_4	0.9084	0.4882	0.7420	0.7666	0.8161	0.7443		
Mean	1.0013	0.6181	0.9690	0.9908	0.9360	0.903		
60 DAS								
V_1	1.9607	1.0630	1.7744	1.7946	1.7114	1.6608	**V. 0.0020**	**0.0069**
V_2	1.6789	1.0801	1.3282	1.3863	1.2724	1.3492	**T. 0.0035**	**0.0113**
V_3	1.9627	1.2038	1.7840	1.8612	1.2728	1.6169	**T x V 0.0072**	**0.0211**
V_4	1.4648	0.9039	1.4172	1.4719	1.4081	1.3332		
Mean	1.7668	1.0627	1.5760	1.6285	1.4162	1.490		
At harvest								
V_1	1.4664	0.4670	0.9589	1.0704	0.9388	0.9803	**V. 0.0024**	**0.0085**
V_2	1.4952	0.4639	0.9415	1.0506	0.9937	0.9937	**T. 0.0041**	**0.0135**
V_3	1.5219	0.6112	1.0767	1.2672	1.1187	1.1187	**T x V 0.0056**	**0.0162**
V_4	1.2015	0.4557	0.8351	0.9024	0.8563	0.8563		
Mean	1.4213	0.4995	0.9530	1.0727	0.9899	0.987		

V.- Variety T.- Treatment T. x V.- Treatment x Variety

At 40 DAS, it was recorded minimum leaf area index in treatment T_2V_4 (0.4882). It was recorded maximum leaf area index in treatment T_1V_3 (1.2134), followed by treatment T_4V_3 (1.2101), which were at par with each other under water stress condition.

At 60 DAS, it was recorded maximum leaf area index in treatment T_1V_3 (1.9627) which was followed by treatment T_1V_1 (1.9607) and treatment T_4V_3 (1.8612), they were at par with each other under water stress condition. The minimum leaf area index which was recorded in treatment T_2V_4 (0.9039).

At harvest, the lowest leaf area index was recorded in treatment T_2V_4 (0.4557) and highest was found in treatment T_1V_3 (1.5219), followed by treatment T_1V_2 (1.4952), which was at par with each other under water stress condition.

4.6.3. Specific leaf weight

The statistical analysis of the data on specific leaf weight revealed a significant variation among water stress treatments as well as among interaction effect between stress treatments and variety under water stress condition. The data was presented in the Table 4.16.

Influence of water stress treatment

At 20 DAS, it was observed that, there was significant difference among treatments. Treatment T_1 (0.32294 g/dm^2) was resulted maximum specific leaf weight, followed by treatment T_3 (0.20079 g/dm^2), whereas in treatment T_2 (0.17860 g/dm^2) was recorded lowest specific leaf weight, under water stress condition.

At 40 DAS, significant difference was observed with respect to specific leaf weight in all the treatments. Maximum specific leaf weight was observed in treatment T_1 (0.4871 g/dm^2), followed by treatment T_3 (0.4870 g/dm^2), which was at par with each other. However, specific leaf weight was minimum in treatment T_2 (0.1559 g/dm^2).

At 60 DAS, it was clearly seen that there was variation among all the treatment T_1 (0.4642 g/dm^2), was resulted maximum specific leaf weight followed by treatment T_4 (0.4388 g/dm^2), whereas minimum was recorded in treatment T_2 (0.1271 g/dm^2), under water stress condition.

At harvest, significant variation in mean specific leaf weight was observed due to different stress treatments. The maximum specific leaf weight was recorded in treatment T_1 (0.4289 g/dm^2), was followed by treatment T_4 (0.3780 g/dm^2) and treatment T_5 (0.3751 g/dm^2). However, lowest in treatment T_2 (0.1882 g/dm^2), under water stress condition.

Influence of varietal difference

At 20 DAS, among all the stress condition, variety V_1 (0.30785 g/dm^2) recorded maximum specific leaf weight which was consequently better all over variety. The minimum was observed in variety V_3 (0.14374 g/dm^2).

Table 4.16. Influence of different water stress treatments on specific leaf weight (g/dm²) at various stages of plant growth of cowpea grown under water stress condition:

Genotypes	Treatments of water stress						SE ±	CD at 5%
	T_1	T_2	T_3	T_4	T_5	Mean		
20 DAS								
V_1	0.76441	0.18773	0.22293	0.18159	0.18260	0.30785	**V. 0.0573**	**0.1982**
V_2	0.23214	0.22880	0.24264	0.23445	0.23700	0.23500	**T. 0.0642**	**0.2092**
V_3	0.13066	0.13400	0.15613	0.01483	0.14953	0.14374	**T x V 0.1282**	**0.3741**
V_4	0.16455	0.16388	0.18146	0.16586	0.16549	0.16825		
Mean	0.32294	0.17860	0.20079	0.18257	0.18365	0.214		
40 DAS								
V_1	0.3608	0.1410	0.3874	0.3523	0.3505	0.3184	**V. 0.0019**	**0.0066**
V_2	0.5828	0.1446	0.5754	0.6019	0.6089	0.5027	**T. 0.0025**	**0.0082**
V_3	0.3835	0.1309	0.3707	0.3694	0.3722	0.3254	**T x V 0.0027**	**0.0080**
V_4	0.6214	0.2072	0.6146	0.5066	0.5251	0.4950		
Mean	0.4871	0.1559	0.4870	0.4575	0.4642	0.410		
60 DAS								
V_1	0.3760	0.1006	0.3062	0.3553	0.3276	0.2932	**V. 0.0028**	**0.0099**
V_2	0.4844	0.1374	0.4463	0.5172	0.4723	0.4115	**T.0.0037**	**0.0122**
V_3	0.4263	0.1172	0.3312	0.4150	0.3414	0.3262	**T x V 0.0073**	**0.0212**
V_4	0.5703	0.1532	0.4192	0.4676	0.4335	0.4088		
Mean	0.4642	0.1271	0.3757	0.4388	0.3937	0.360		
At harvest								
V_1	0.4103	0.1498	0.3087	0.3325	0.3368	0.3076	**V. 0.0006**	**0.0019**
V_2	0.4302	0.2288	0.3505	0.3941	0.3948	0.3597	**T. 0.0011**	**0.0037**
V_3	0.3828	0.1680	0.3462	0.3405	0.3177	0.3110	**T x V 0.0024**	**0.0069**
V_4	0.4923	0.2061	0.4331	0.4451	0.4511	0.4055		
Mean	0.4289	0.1882	0.3596	0.3780	0.3751	0.346		

V.- Variety T.- Treatment T. x V.- Treatment x Variety

At 40 DAS, the highest specific leaf weight was recorded in variety V_2 (0.5027 g/dm²), followed by variety V_4 (0.4950 g/dm²). The lowest specific leaf weight was noted in variety V_1 (0.3184 g/dm²), under water stress condition.

At 60 DAS, maximum specific leaf weight was recorded by variety V_2 (0.4115 g/dm²), followed by variety V_4 (0.4088 g/dm²). The lowest specific leaf weight was noted in variety V_1 (0.2932 g/dm²).

At harvest, the maximum specific leaf weight was recorded in variety V_4 (0.4055 g/dm^2), followed by variety V_2 (0.3597 g/dm^2). The minimum specific leaf weight was noted in variety V_1 (0.3076 g/dm^2).

Influence of interaction

At 20 DAS, the maximum specific leaf weight which were noted in treatment combination T_1V_1 (0.76441 g/dm^2), whereas minimum in the treatment T_2V_3 (0.13400 g/dm^2), under water stress condition.

At 40 DAS, the minimum specific leaf weight in treatment T_2V_3 (0.1309 g/dm^2). It was recorded maximum specific leaf weight in treatment T_1V_4 (0.6214 g/dm^2)**,** followed by treatment T_3V_4 (0.6146 g/dm^2) and treatment T_5V_2 (0.6089 g/dm^2) which were at par with each other under water stress condition.

At 60 DAS, the maximum specific leaf weight in treatment T_1V_4 (0.5703 g/dm^2), which was followed by treatment T_4V_2 (0.5172 g/dm^2) and treatment T_1V_2 (0.4844 g/dm^2). The minimum specific leaf weight which was recorded in treatment T_2V_1 (0.1006 g/dm^2).

At harvest, the lowest specific leaf weight was recorded in treatment T_2V_1 (0.1498 g/dm^2) and highest was found in treatment T_1V_4 (0.4923 g/dm^2), followed by treatment T_5V_4 (0.4511 g/dm^2) and treatment T_4V_4 (0.4451 g/dm^2) which was at par with each other.

4.6.4 Absolute growth rate (g/day)

The statistical analysis of the data on absolute growth rate was revealed a significant variation among all treatments and among interaction effects between different stress treatment and variety. The data was depicted in the Table 4.17.

Influence of water stress treatments

At 20 to 40 DAS, the data indicated that there was significant variation among all treatments. Treatment T_1 (0.9966 g/day) was resulted maximum absolute growth rate, which was followed by treatment T_3 (0.9437 g/day) and treatment T_4 (0.9407 g/day), however treatment T_2 (0.0926 g/day) was recorded minimum absolute growth rate.

At 40 to 60 DAS, it was clearly seen that there was significant variation among all treatments. Treatment T_1 (0.7702 g/day), noted significantly maximum absolute growth rate which was followed by treatment T_4 (0.7168 g/day) and treatment T_3 (0.4453 g/day), under water stress condition. The minimum AGR was recorded in treatment T_2 (0.1530 g/day).

At 60 DAS to at harvest, maximum absolute growth rate was noted in treatment T_1 (0.4838 g/day), followed by treatment T_4 (0.4693 g/day) respectively, whereas treatment T_2 (0.2959 g/day) recorded minimum absolute growth rate under water stress condition.

Table 4.17. Influence of different water stress treatments on absolute growth rate (g/day) at various stages of plant growth of cowpea grown under water stress condition:

Genotypes	Treatments of water stress						SE ±	CD at 5%
	T_1	T_2	T_3	T_4	T_5	Mean		
20 DAS – 40 DAS								
V_1	1.0268	0.1061	0.9769	0.9455	0.8875	0.7885	**V. 0.0031**	**0.0101**
V_2	1.0096	0.0957	0.9608	0.9881	0.9285	0.7966	**T. 0.0022**	**0.0090**
V_3	1.0767	0.0946	1.0188	0.9751	0.9106	0.8152	**T x V 0.0051**	**0.0157**
V_4	0.8734	0.0740	0.8183	0.8540	0.7951	0.6830		
Mean	0.9966	0.0926	0.9437	0.9407	0.8804	0.771		
40 DAS – 60 DAS								
V_1	0.7801	0.1465	0.4548	0.7332	0.4499	0.5129	**V. 0.0053**	**0.0162**
V_2	0.7824	0.1795	0.4343	0.7226	0.4237	0.5085	**T. 0.0074**	**0.0222**
V_3	0.7477	0.1634	0.4508	0.6925	0.4407	0.4990	**T x V 0.0101**	**0.0299**
V_4	0.7707	0.1227	0.4415	0.7190	0.4316	0.4971		
Mean	0.7702	0.1530	0.4453	0.7168	0.4365	0.504		
60 DAS – At harvest								
V_1	0.4475	0.2282	0.3020	0.4476	0.2674	0.3385	**V. 0.0016**	**0.0057**
V_2	0.5396	0.3306	0.3218	0.4481	0.3307	0.3942	**T. 0.0041**	**0.0135**
V_3	0.5270	0.3536	0.4296	0.5376	0.4072	0.4510	**T x V 0.0246**	**0.0634**
V_4	0.4208	0.2711	0.2778	0.4440	0.3070	0.3441		
Mean	0.4838	0.2959	0.3328	0.4693	0.3281	0.382		

V.- Variety T.- Treatment T. x V.- Treatment x Variety

Influence of varietal differences

At 20 to 40 DAS, it was observed that all varieties varied significantly different with respect to absolute growth rate. Variety V_3 (0.8152 g/day) observed significantly higher absolute growth rate which was followed by variety V_2 (0.7966 g/day), while variety V_4 (0.6830 g/day) recorded minimum absolute growth rate, under water stress condition.

At 40 to 60 DAS, variety V_1 (0.5129 g/day) was at top with highest absolute growth rate, followed by variety V_2 (0.5085 g/day), while variety V_4 (0.4971 g/day) recorded minimum absolute growth rate, under water stress condition.

At 60 DAS to at harvest, under water stress condition, variety V_1 recorded lowest absolute growth rate (0.3385 g/day), while highest absolute growth rate was noted in variety V_3 (0.4510 g/day), followed by variety V_2 (0.3942 g/day) and variety V_4 (0.3441 g/day).

Influence of interaction

At 20 to 40 DAS, significantly highest absolute growth rate was noted in treatment T_1V_3 (1.0767 g/day) which was at par with treatment T_1V_1 (1.0268 g/day), treatment T_3V_3 (1.0188 g/day) and treatment T_1V_2 (1.0096 g/day), under water stress condition. Significantly lowest absolute growth rate was recorded in treatment T_2V_4 (0.0740 g/day) which was observed in all over other treatments.

At 40 to 60 DAS, treatment T_1V_2 (0.7824 g/day), followed by treatment T_1V_1 (0.7801 g/day) was recorded consequently highest absolute growth rate which was at par with all over other treatments, under water stress condition. Absolute growth rate was lowest in treatment T_2V_4 (0.1227 g/day).

At 60 DAS to at harvest, consequently highest absolute growth rate was observed in the treatment T_1V_2 (0.5396 g/day), followed by treatment T_4V_3 (0.5376 g/day) and treatment T_1V_3 (0.5270 g/day), they were at par with each other. Significantly lowest absolute growth rate was noted in treatment T_2V_1 (0.2282 g/day), under water stress condition.

4.6.5. Relative growth rate (g/g/day)

The statistical analysis of the data on relative growth rate (RGR) revealed a significant variation among all treatments under water stress condition. The data was presented in the Table 4.18.

Influence of water stress treatments

At 20 to 40 DAS, the data indicated that there was significant variation among all treatments. Treatment T_1 (0.04447 g/g/day) was maximum relative growth rate which was at par with treatment T_3 (0.04416 g/g/day) and treatment T_4 (0.04364 g/g/day), however treatment T_2 (0.01121 g/g/day) which was recorded minimum relative growth rate, under water stress condition.

At 40 to 60 DAS, it was clearly seen that there was significant variation among all treatments. Treatment T_1 (0.01122 g/g/day) noted significantly maximum relative growth rate which was at par with treatment T_4 (0.01101 g/g/day) and treatment T_3 (0.01093 g/g/day), under water stress condition. The minimum RGR was recorded in treatment T_2 (0.00747 g/g/day).

At 60 DAS to at harvest, maximum relative growth rate was noted in the treatment T_1 (0.01714 g/g/day), followed by treatment T_4 (0.00461 g/g/day) respectively, whereas treatment T_2 (0.00328 g/g/day) recorded minimum relative growth rate under water stress condition.

Table 4.18. Influence of different water stress treatments on relative growth rate (g/g/day) at various stages of plant growth of cowpea grown under water stress condition:

Genotypes	Treatments of water stress						SE ±	CD at 5%
	T_1	T_2	T_3	T_4	T_5	Mean		
20 DAS – 40 DAS								
V_1	0.04457	0.01247	0.04500	0.04403	0.04345	0.03790	**V. 0.0001**	**0.0003**
V_2	0.04515	0.01155	0.04484	0.04470	0.04423	0.03809	**T. 0.0001**	**0.0003**
V_3	0.04544	0.01142	0.04465	0.04365	0.04251	0.03753	**T x V 0.0002**	**0.0005**
V_4	0.04270	0.00942	0.04217	0.04217	0.04169	0.03563		
Mean	0.04447	0.01121	0.04416	0.04364	0.04297	0.037		
40 DAS – 60 DAS								
V_1	0.01107	0.00756	0.01025	0.01095	0.00789	0.00954	**V. 0.0001**	**0.0003**
V_2	0.01124	0.00704	0.01244	0.01096	0.00725	0.00979	**T. 0.0001**	**0.0004**
V_3	0.01032	0.00731	0.01160	0.01040	0.00754	0.00944	**T x V 0.0003**	**0.0009**
V_4	0.01226	0.00796	0.00998	0.01218	0.00826	0.01013		
Mean	0.01122	0.00747	0.01093	0.01101	0.00774	0.010		
60 DAS – At harvest								
V_1	0.01644	0.00252	0.00350	0.00415	0.00363	0.00605	**V. 0.00007**	**0.00021**
V_2	0.01587	0.00361	0.00423	0.00503	0.00391	0.00653	**T. 0.00006**	**0.00018**
V_3	0.01806	0.00376	0.00489	0.00482	0.00478	0.00726	**T x V 0.00011**	**0.00036**
V_4	0.01818	0.00325	0.00429	0.00445	0.00374	0.00678		
Mean	0.01714	0.00328	0.00423	0.00461	0.00401	0.007		

V.- Variety T.- Treatment T. x V.- Treatment x Variety

Influence of varietal differences

At 20 to 40 DAS, it was observed that all varieties varied significantly different with respect to relative growth rate. Variety V_2 (0.03809 g/g/day) observed significantly higher relative growth rate which was at par with variety V_1 (0.03790 g/g/day), whereas variety V_4 (0.03563 g/g/day) recorded minimum relative growth rate, under water stress condition.

At 40 to 60 DAS, variety V_4 (0.01013 g/g/day) was noted highest relative growth rate, followed by variety V_2 (0.00979 g/g/day), while variety V_3 (0.00944 g/g/day) recorded minimum relative growth rate, under water stress condition.

At 60 DAS to at harvest, under water stress condition, variety V_1 recorded lowest relative growth rate (0.00605 g/g/day), while highest relative growth rate was noted by the variety V_3 (0.00726 g/g/day), followed by variety V_4 (0.00678 g/g/day) and variety V_2 (0.00653 g/g/day).

Influence of interaction

At 20 to 40 DAS, significantly highest relative growth rate was noted in treatment T_1V_3 (0.04544 g/g/day) which was at par with treatment T_1V_2 (0.04515 g/g/day), treatment T_3V_1 (0.04500 g/g/day) and treatment T_3V_2 (0.04484 g/g/day), under water stress condition. Significantly lowest relative growth rate was recorded by treatment T_2V_4 (0.00942 g/g/day) which was noted in all over other treatments.

At 40 to 60 DAS, treatment T_1V_4 (0.01226 g/g/day) recorded significantly highest relative growth rate which was at par with all over treatments. Under water stress condition, relative growth rate was lowest in treatment T_2V_2 (0.00704 g/g/day).

At 60 DAS to at harvest, significantly highest relative growth rate was observed in the treatment T_1V_4 (0.01818 g/g/day), followed by treatment T_1V_3 (0.01806 g/g/day), they were at par with each other. Significantly lowest relative growth rate was noted in treatment T_2V_1 (0.00252 g/g/day), under water stress condition.

4.6.6. Net assimilation rate (g/dm^2/day)

The statistical analysis of the data on net assimilation rate (NAR) noted a significant variation among all treatments under water stress condition. The data was presented in the Table 4.19.

Influence of water stress treatments

At 20 to 40 DAS, the data indicated that there was significant variation among all treatments. Treatment T_1 (0.02175 g/dm^2/day) resulted maximum net assimilation rate which was at par with treatment T_3 (0.02106 g/dm^2/day) and treatment T_4 (0.02053 g/dm^2/day), however treatment T_2 (0.00281 g/dm^2/day) recorded minimum net assimilation rate, under water stress condition.

At 40 to 60 DAS, it was clearly seen that there was significant variation among all treatments. Treatment T_1 (0.00567 g/dm^2/day) noted significantly maximum net assimilation rate which was at par with treatment T_4 (0.00536 g/dm^2/day), under water stress condition. The minimum NAR was recorded in treatment T_2 (0.00180 g/dm^2/day).

At 60 DAS to at harvest, maximum net assimilation rate was noted in the treatment T_1 (0.00608 g/dm^2/day), followed by treatment T_4 (0.00408 g/dm^2/day) respectively, whereas treatment T_2 (0.00241 g/dm^2/day) was recorded minimum net assimilation rate under water stress condition.

Table 4.19. Influence of different water stress treatments on net assimilation rate (g/dm²/day) at various stages of plant growth of cowpea grown under water stress condition:

Genotypes	Treatments of water stress						SE ±	CD at 5%
	T_1	T_2	T_3	T_4	T_5	Mean		
20 DAS – 40 DAS								
V_1	0.02059	0.00340	0.01993	0.01926	0.01896	0.01643	**V. 0.0001**	**0.0003**
V_2	0.02604	0.00297	0.02548	0.02736	0.02696	0.02176	**T. 0.0001**	**0.0002**
V_3	0.01894	0.00236	0.01821	0.01652	0.01607	0.01442	**T x V 0.0001**	**0.0002**
V_4	0.02142	0.00250	0.02062	0.01898	0.01878	0.01646		
Mean	0.02175	0.00281	0.02106	0.02053	0.02019	0.017		
40 DAS – 60 DAS								
V_1	0.00500	0.00173	0.00318	0.00500	0.00306	0.00360	**V. 0.0001**	**0.0005**
V_2	0.00617	0.00203	0.00422	0.00657	0.00402	0.00460	**T. 0.0002**	**0.0005**
V_3	0.00462	0.00167	0.00352	0.00318	0.00287	0.00317	**T x V 0.0003**	**0.0009**
V_4	0.00690	0.00176	0.00384	0.00667	0.00368	0.00457		
Mean	0.00567	0.00180	0.00369	0.00536	0.00341	0.004		
60 DAS – At harvest								
V_1	0.00595	0.00213	0.00253	0.00166	0.00200	0.00285	**V. 0.0007**	**0.0024**
V_2	0.00592	0.00256	0.00327	0.00283	0.00281	0.00348	**T. 0.0008**	**0.0025**
V_3	0.00591	0.00265	0.00293	0.00243	0.00325	0.00343	**T x V 0.0016**	**0.0046**
V_4	0.00655	0.00230	0.00306	0.00942	0.00262	0.00479		
Mean	0.00608	0.00241	0.00295	0.00408	0.00267	0.004		

V.- Variety T.- Treatment T. x V.- Treatment x Variety

Influence of varietal differences

At 20 to 40 DAS, it was observed that all varieties varied significantly different with respect to net assimilation rate. Variety V_2 (0.02176 g/dm^2/day) was observed highest net assimilation rate which was followed by variety V_4 (0.01646 g/dm^2/day), however variety V_3 (0.01442 g/dm^2/day) recorded least net assimilation rate, under water stress condition.

At 40 to 60 DAS, variety V_2 (0.00460 g/dm^2/day) was noted highest net assimilation rate, followed by variety V_4 (0.00457 g/dm$^{2/}$day), while variety V_1 (0.00360 g/dm^2/day) recorded minimum net assimilation rate, under water stress condition.

At 60 DAS to at harvest, under water stress condition variety V_1 recorded lowest net assimilation rate (0.00285 g/dm^2/day), while highest net assimilation rate was noted in variety V_4 (0.00479 g/dm^2/day), followed by variety V_2 (0.00348 g/dm^2/day) and variety V_3 (0.00343 g/dm^2/day).

Influence of interaction

At 20 to 40 DAS, significantly highest net assimilation rate was noted in treatment T_4V_2 (0.02736 g/dm^2/day) which was at par with treatment T_5V_2 (0.02696 g/dm^2/day), treatment T_1V_2 (0.02604 g/dm^2/day) and T_3V_2 (0.02548 g/dm^2/day), under water stress condition. Significantly lowest net assimilation rate was recorded in treatment T_2V_3 (0.00236 g/dm^2/day) which was noted in all over other treatments, under water stress condition.

At 40 to 60 DAS, treatment T_1V_4 (0.00690 g/dm^2/day) recorded significantly highest net assimilation rate which was at par with treatment T_4V_2 (0.00657 g/dm^2/day), under water stress condition. Net assimilation rate was lowest in treatment T_2V_3 (0.00167 g/dm^2/day).

At 60 DAS to at harvest, significantly highest net assimilation rate was observed in the treatment T_4V_4 (0.00942 g/dm^2/day), followed by treatment T_1V_4 (0.00655 g/dm^2/day) and treatment T_1V_1 (0.00595 g/dm^2/day). Significantly lowest net assimilation rate was noted in treatment T_4V_1 (0.00166 g/dm^2/day), under water stress condition.

4.5.5 Leaf area ratio

The statistical analysis of the data on leaf area ratio (LAR) was noted a significant variation among all treatments under water stress condition The data was represented in the Table 4.20.

Influence of water stress treatments

At 20 to 40 DAS, the data indicated that there was significant variation among all treatments. Treatment T_1 (2.4716 dm^2/g/day) resulted maximum leaf area ratio which was at par with treatment T_3 (2.4489 dm^2/ g/day) and treatment T_5 (2.4194 dm^2/g/day), however treatment T_2 (2.3142 dm^2/g/day) recorded minimum leaf area ratio, under water stress condition.

At 40 to 60 DAS, it was clearly seen that there was significant variation among all treatments. Treatment T_1 (6.041 dm^2/g/day) noted significantly maximum leaf area ratio which was at par with treatment T_4 (2.067 dm^2/g/day) and treatment T_3 (2.057 dm^2/g/day), under water stress condition. The minimum LAR was recorded in treatment T_2 (1.939 dm^2/g/day).

At 60 DAS to at harvest, maximum leaf area ratio was noted in the treatment T_1 (6.255 dm^2/g/day), followed treatment T_4 (2.391 dm^2/g/day) respectively, whereas treatment T_2 (1.965 dm^2/g/day) recorded minimum leaf area ratio under water stress condition.

Table 4.20. Influence of different water stress treatments on leaf area ratio at various stages of plant growth of cowpea grown under water stress condition:

Genotypes	Treatments of water stress						SE ±	CD at 5%
	T_1	T_2	T_3	T_4	T_5	Mean		
20 DAS – 40 DAS								
V_1	2.2321	1.9783	2.2631	2.2829	2.3252	2.2163	**V. 0.0245**	**0.0849**
V_2	1.8976	1.8834	1.9254	1.8577	1.8838	1.8896	**T. 0.0246**	**0.0801**
V_3	3.1004	2.8944	3.0887	2.7711	2.7601	2.9229	**T x V 0.0484**	**0.1412**
V_4	2.6562	2.5006	2.5184	2.6444	2.7083	2.6056		
Mean	2.4716	2.3142	2.4489	2.3890	2.4194	2.409		
40 DAS -60 DAS								
V_1	5.620	2.160	2.334	2.314	2.229	2.931	**V. 0.0060**	**0.0207**
V_2	6.365	1.673	1.512	1.512	1.710	2.554	**T. 0.0114**	**0.0372**
V_3	7.014	2.223	2.431	2.426	2.304	3.279	**T x V 0.0135**	**0.0395**
V_4	5.162	1.698	1.951	2.017	1.748	2.515		
Mean	6.041	1.939	2.057	2.067	1.997	2.820		
60 DAS – At harvest								
V_1	5.144	2.158	2.608	2.612	2.259	3.156	**V. 0.0049**	**0.0168**
V_2	5.905	1.642	1.919	1.990	1.950	2.681	**T. 0.0071**	**0.0230**
V_3	5.863	2.158	1.908	2.657	2.244	3.166	**T x V 0.0155**	**0.0454**
V_4	5.109	1.904	2.324	2.303	1.840	2.896		
Mean	6.255	1.965	2.190	2.391	2.074	2.975		

V.- Variety T.- Treatment T. x V.- Treatment x Variety

Influence of varietal differences

At 20 to 40 DAS, it was observed that all varieties varied significantly different with respect to leaf area ratio. Variety V_3 (2.9229 dm^2/g/day) was observed significantly highest leaf area ratio which was followed by variety V_4 (2.6056 dm^2/g/day), whereas variety V_2 (1.8896 dm^2/g/day) recorded minimum leaf area ratio, under water stress condition.

At 40 to 60 DAS, variety V_3 (3.279 dm^2/g/day) was noted highest leaf area ratio followed by variety V_1 (2.931 dm^2/g/day), while variety V_4 (2.515 dm^2/g/day) recorded minimum leaf area ratio, under water stress condition.

At 60 DAS to at harvest, under water stress condition, variety V_2 recorded lowest leaf area ratio (2.681 dm^2/g/day), while highest leaf area ratio was noted by the variety V_3 (3.166 dm^2/g/day) followed by variety V_1 (3.156 dm^2/g/day) and variety V_4 (2.896 dm^2/g/day).

Influence of interaction

At 20 to 40 DAS, consequently highest leaf area ratio was noted in treatment T_1V_3 (3.1004 dm^2/g/day) which was followed by treatment T_3V_3 (3.0887 dm^2/g/day), treatment T_2V_3 (2.8944 dm^2/g/day) and treatment T_5V_3 (2.7601 dm^2/g/day), under water stress condition. Significantly lowest leaf area ratio was recorded by treatment T_2V_2 (1.8834 dm^2/g/day) which was noted in all over treatments, under water stress condition.

At 40 to 60 DAS, treatment T_1V_3 (7.014 dm^2/g/day) recorded consequently highest leaf area ratio which was at par with all over treatments, under water stress condition. The leaf area ratio was lowest in treatment T_3V_2 (1.512 dm^2/g/day).

At 60 DAS to at harvest, significantly highest leaf area ratio was observed in the treatment T_1V_2 (5.905 dm^2/g/day), followed by treatment T_1V_3 (5.863 dm^2/g/day) and treatment T_1V_1 (5.144 dm^2/g/day), they were at par with each other. Significantly lowest leaf area ratio was noted in treatment T_2V_2 (1.642 dm^2/g/day), under water stress condition.

4.7. Phenological Characters:

4.7.1 Days to flowering initiation

The data was recorded on days to flowering initiation influenced by different water stress treatment. The data was presented in the Table 4.21 and depicted in the Fig 11.

Influence of water stress treatments

The given data in the days to flowering initiation found to influenced significantly different under water stress treatments in cowpea. Minimum days required for flowering initiation was found in treatment T_2 (44.17 days) also in treatment T_4 (46.33 days). However maximum days required for flowering initiation was observed in treatment T_1 (48.50 days), followed by treatment T_3 (47.58 days) and treatment T_5 (47.50 days), which were at par with each other.

Influence of variety

The days to flowering initiation was noted significantly different among all water stress treatment. Maximum days to flowering initiation was found in variety V_4 (50.60 days), followed by variety V_3 (48.27 days), they were at par with each other and minimum days to flowering initiation was found in variety V_2 (40.53 days), under water stress condition.

Table 4.21. Influence of different water stress treatments on phenological characters at various stages of plant growth of cowpea grown under water stress condition:

Genotypes	Treatments of water stress						SE ±	CD at 5%
	T_1	T_2	T_3	T_4	T_5	Mean		
Days to flowering initiation								
V_1	49.33	42.67	50.33	45.67	51.33	47.87	V. 0.2253	0.1537
V_2	41.67	38.33	40.67	40.67	41.33	40.53	T. 0.7795	0.5011
V_3	50.33	47.33	48.33	48.67	46.67	48.27	T x V 0.3249	0.9483
V_4	52.67	48.33	51.00	50.33	50.67	50.60		
Mean	48.50	44.17	47.58	46.33	47.50	46.81		
Days to 50 % flowering								
V_1	55.67	50.67	57.67	52.67	59.33	55.20	V. 0.1139	0.5570
V_2	48.67	45.33	46.67	46.33	48.33	47.07	T. 0.1708	0.3940
V_3	57.00	54.67	55.33	55.67	54.33	55.40	T x V 0.3727	1.0878
V_4	60.67	54.33	57.67	57.67	57.33	57.53		
Mean	55.50	51.25	54.33	53.08	54.83	53.80		
Days to physiological maturity								
V_1	78.67	72.33	76.67	75.33	77.67	74.07	V. 0.1374	0.4756
V_2	68.67	61.33	64.67	65.67	67.33	65.60	T. 0.1787	0.5829
V_3	75.67	73.33	75.33	74.67	75.67	74.93	T x V 0.3626	1.0584
V_4	80.33	75.67	78.33	77.67	78.67	78.13		
Mean	75.83	70.67	73.75	73.33	74.83	73.25		

V.- Variety T.- Treatment T. x V.- Treatment x Variety

Influence of interaction

The interaction effect between different water stress treatments and variety were found to be significant for days to flowering initiation under water stress condition. Minimum days required for flowering initiation was found in treatment T_2V_2 (38.33 days). However maximum days to flowering initiation was observed in treatment T_1V_4 (52.67 days), followed by treatment T_5V_1 (51.33 days) which were at par with each other.

4.7.2 Days to 50 per cent flowering

The statistical analysis of the data on days to 50 per cent flowering observed a significant variation among all treatments. The data was represented in the Table 4.21 and depicted in the Fig 11.

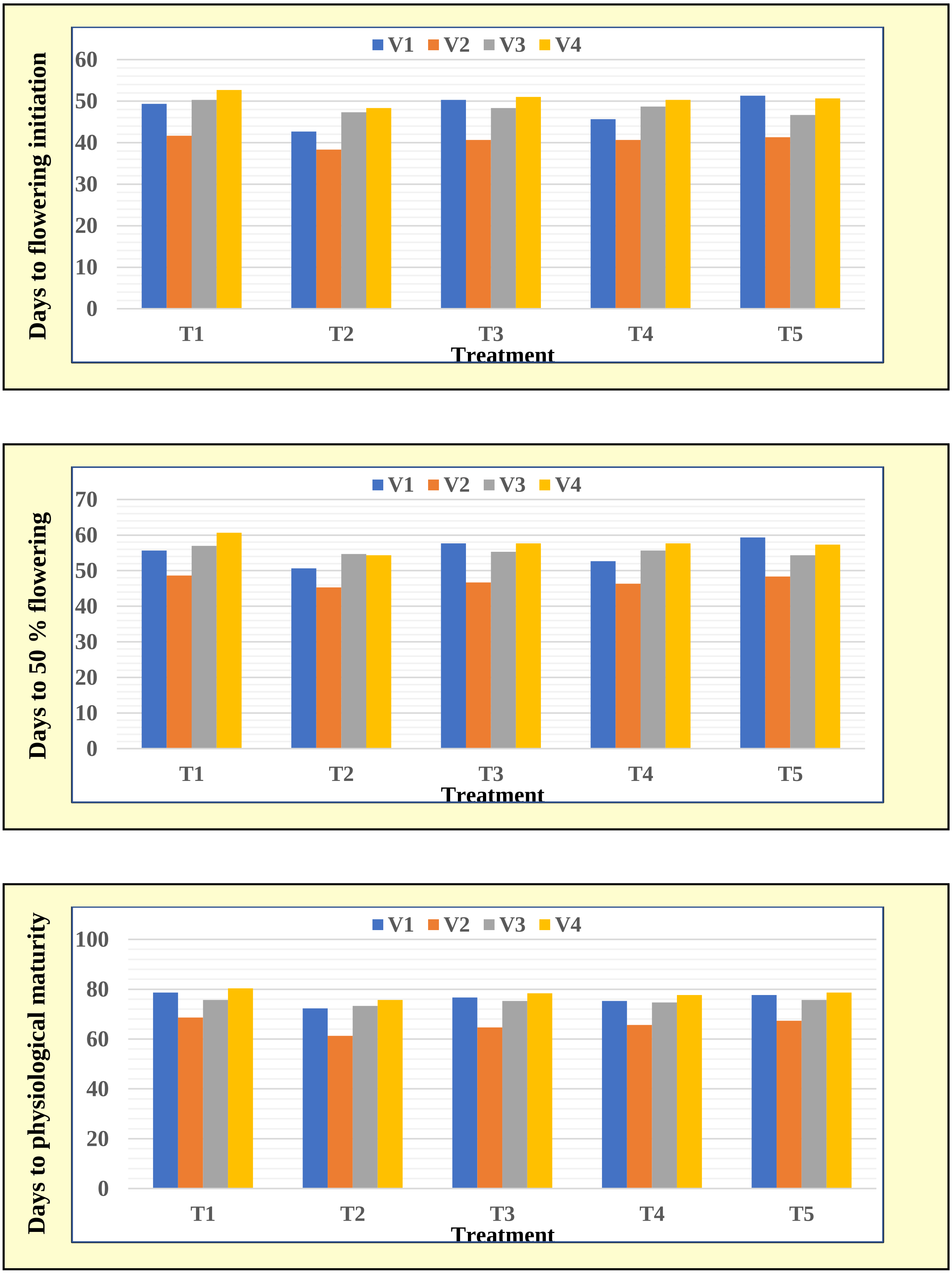


Fig.11. Influence of different water stress treatments on phenological characters at various stages of plant growth of cowpea grown under water stress condition.

Influence of water stress treatments

The given data in the days to 50 per cent flowering found to influenced significantly different under water stress condition. Minimum days required for 50 per cent flowering was found in treatment T_2 (51.25 days). However, maximum days required for 50 per cent flowering was observed in treatment T_1 (55.50 days), followed by treatment T_5 (54.83 days) and treatment T_3 (54.33 days), which were at par with each other.

Influence of varietal differences

The days to 50 per cent flowering was noted significantly different among all the water stress treatment. Maximum days to 50 per cent flowering was found in variety V_4 (57.53 days), followed by variety V_3 (55.40 days), they were at par with each other. Minimum days to 50 per cent flowering was found in variety V_2 (47.07 days), under water stress condition.

Influence of interaction

The interaction effect between different water stress treatments and variety were found to be significant different for days to 50 per cent flowering under water stress condition. Minimum days required for 50 per cent flowering was found in treatment T_2V_2 (45.33 days). However maximum days to 50 per cent flowering was observed in treatment T_1V_4 (60.67 days), followed by treatment T_3V_4 and T_4V_4 (57.67 days) which were at par with each other.

4.7.3 Days to Physiological Maturity

The further data indicated that, days required for physiological maturity was significantly different among all variety and treatment, the data were represented in Table 4.20 and depicted in the Fig 11.

Influence of water stress treatments

The given data in the days to physiological maturity found to influenced significantly different under water stress condition. Minimum days required for physiological maturity was found in treatment T_2 (70.67 days). However, maximum days required for physiological maturity was observed in treatment T_1 (75.83 days), followed by treatment T_5 (74.83 days) and treatment T_3 (73.75 days).

Influence of varietal difference

The days to physiological maturity noted significantly difference among all the water stress treatment. Maximum days to physiological maturity was found in variety V_4 (78.13 days), followed by variety V_3 (74.93 days), they were with each other, while minimum days to physiological maturity was found in variety V_2 (65.60 days), under water stress condition.

Influence of interaction

The interaction effect between different water stress treatments and variety were found to be significant difference for days to physiological maturity under water stress condition. Minimum days required for physiological maturity was found in treatment T_2V_2 (61.33 days). However maximum days to physiological maturity was observed in treatment T_1V_4 (80.33 days), followed by treatment T_5V_4 (78.67 days).

4.8. Yield and Yield attributes

The statistical analysis of the data on yield and yield attributes observed a consequent variation among all treatments under water stress condition. The data was presented in the Table 4.22 and depicted in the Fig 12 and 13.

4.8.1. Number of pods per plant

Number of pods per plant were significant differ among all treatments and interaction effects between different water stress treatments and variety was noted significant at harvest.

Influence of water stress treatments

It was clearly seen that there was significant variation among different water stress treatments. Treatment T_1 (7.35) observed significantly highest number of pods per plant in all over treatments, followed by treatment T_4 (5.35), while treatment T_2 (2.71) recorded significantly lowest number of pods per plant, under water stress condition.

Influence of varietal differences

Maximum number of pods per plant were found in the variety V_3 (5.60), followed by variety V_2 (4.88) which were at par with each other. However minimum number of pods per plant were recorded in variety V_4 (3.94).

Influence of interaction

It was found that treatments and varietal differences was significantly different with respect to number of pods per plant. Treatment T_1V_3 (8.40) observed significantly highest number of pods per plant all over rest of variety followed by treatment T_1V_2 (7.60) and treatment T_1V_1 (7.00). The lowest number of pods per plant were recorded in treatment T_2V_4 (2.26), under water stress condition.

4.8.2. Number of seeds per plant

Number of seeds per plant noted significant difference among all treatments and interaction effects between different stress treatments and variety.

Influence of water stress treatments

Data represented that, there was significant variation among different water stress treatments. Treatment T_1 (48.00) observed significantly maximum number of seeds per plant in all over treatments, while in treatment T_2 (15.73) was recorded minimum number of seeds per plant, under water stress condition.

Influence of varietal differences

Significantly maximum number of seeds per plant were found in variety V_3 (40.59), followed by variety V_2 (31.83) under water stress condition. However minimum number of seeds per plant were recorded in variety V_4 (25.39), under water stress condition.

Influence of interaction

It was found that treatments and varietal differences was significantly different with respect to number of seeds per plant. Treatment T_1V_3 (68.60) observed significantly highest number of seeds per plant all over rest of variety, followed by treatment T_1V_2 (46.13) and treatment T_4V_3 (43.93). The minimum number of seeds per plant were recorded in treatment T_2V_4 (12.67), under water stress condition.

4.8.3. Seed yield per plant (g)

Seed yield per plant resulted significant differences among all treatments and interaction effects between different water stress treatments and variety noted significant at harvest.

Influence of water stress treatments

Data indicated that, there was significant variation among different water stress treatments. Treatment T_1 (5.59 g) observed significantly highest seed yield per plant in all over treatments followed by treatment T_4 (4.04 g), while treatment T_2 (1.56 g) recorded lowest seed yield per plant, under water stress condition.

Influence of varietal differences

Maximum seed yield per plant was found in variety V_3 (5.25 g), followed by variety V_1 (3.54 g) and variety V_2 (3.04 g). However minimum seed yield per plant was recorded in variety V_4 (2.39 g), under water stress condition.

Table 4.22. Influence of different water stress treatments on yield and yield attributing characters at various stages of plant growth of cowpea grown under water stress condition:

Genotypes	Treatments of water stress						SE ±	CD at 5%
	T_1	T_2	T_3	T_4	T_5	Mean		
No. of pods per plant								
V_1	7.00	2.40	3.40	5.00	4.00	4.36	V. 0.0133	0.0461
V_2	7.60	2.80	3.80	5.60	4.60	4.88	T. 0.0091	0.0298
V_3	8.40	3.40	4.40	6.40	5.40	5.60	T x V 0.0183	0.0533
V_4	6.40	2.26	3.20	4.40	3.46	3.94		
Mean	7.35	2.71	3.70	5.35	4.36	4.69		
No. of seeds per plant								
V_1	38.93	14.40	25.47	30.53	27.87	27.44	V. 0.2634	0.9115
V_2	46.13	15.93	26.47	42.67	27.93	31.83	T. 0.3247	1.0590
V_3	68.60	19.93	34.73	43.93	35.73	40.59	T x V 0.6129	1.7890
V_4	38.33	12.67	22.87	29.60	23.47	25.39		
Mean	48.00	15.73	27.38	36.68	28.75	31.31		
Seed yield per plant (g)								
V_1	5.43	1.46	3.47	3.58	3.72	3.54	V. 0.0645	0.2232
V_2	4.75	1.17	2.81	3.64	2.85	3.04	T. 0.1135	0.3702
V_3	8.53	2.51	4.44	6.18	4.61	5.25	T x V 0.2456	0.7168
V_4	3.61	1.12	2.37	2.79	2.06	2.39		
Mean	5.59	1.56	3.27	4.04	3.31	3.55		
100 seed weight (g)								
V_1	12.14	8.37	9.28	11.41	10.55	10.35	V. 0.1071	0.3706
V_2	10.97	6.64	7.54	8.67	8.21	8.37	T. 0.1619	0.5279
V_3	12.76	10.36	11.20	11.69	11.39	11.48	T x V 0.1935	0.5647
V_4	11.09	8.09	8.19	9.56	8.93	9.17		
Mean	11.70	8.36	9.05	10.33	9.77	9.84		
Harvest index (%)								
V_1	12.44	8.40	8.49	10.86	11.27	10.29	V. 0.2291	0.7927
V_2	10.72	6.50	7.22	9.96	8.65	8.16	T. 0.2932	0.9562
V_3	18.56	9.87	17.20	17.02	14.42	15.41	T x V 0.7413	2.1637
V_4	8.80	6.02	7.49	8.41	6.60	7.46		
Mean	12.63	7.69	10.10	11.56	10.23	10.47		

V.- Variety T.- Treatment T. x V.- Treatment x Variety

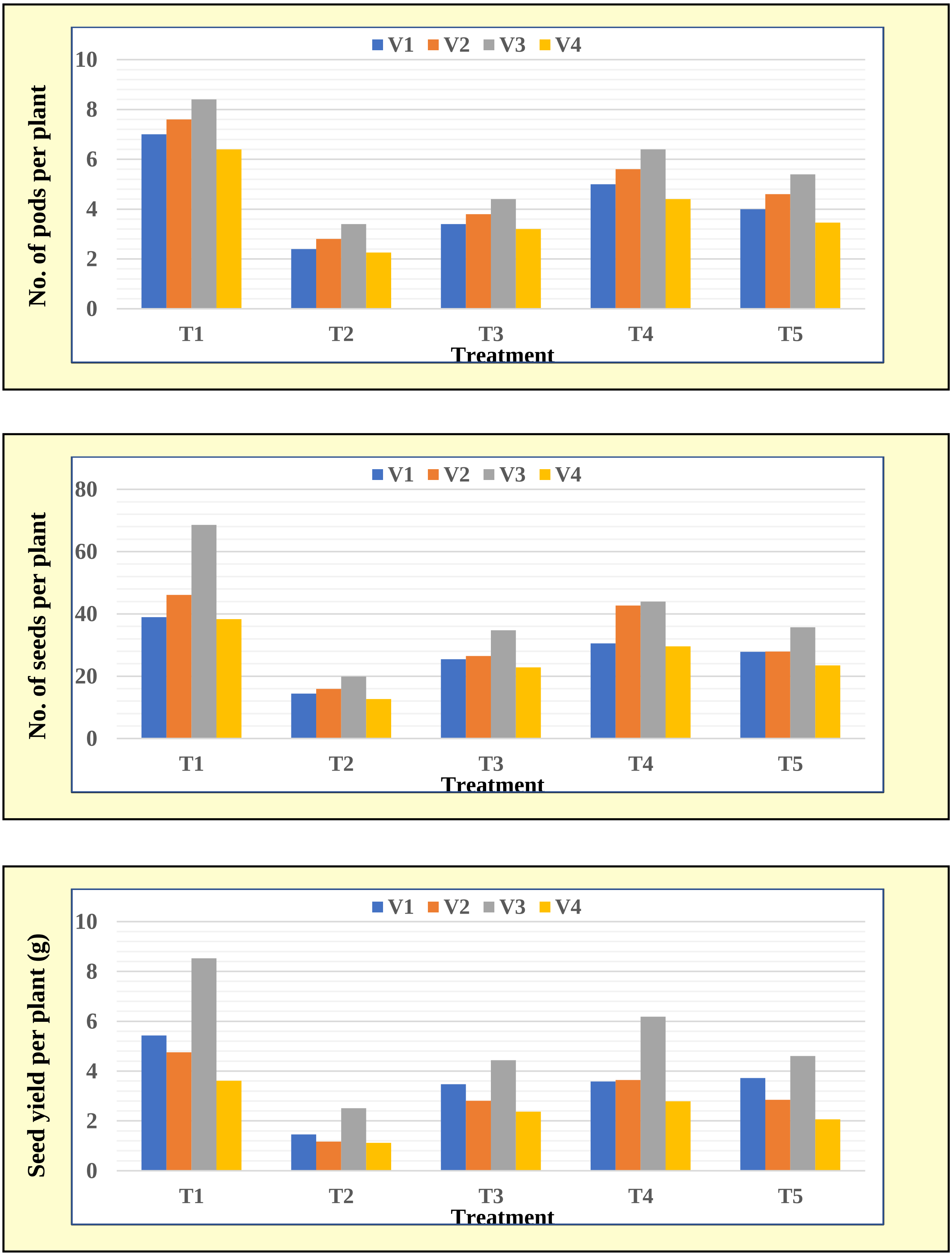
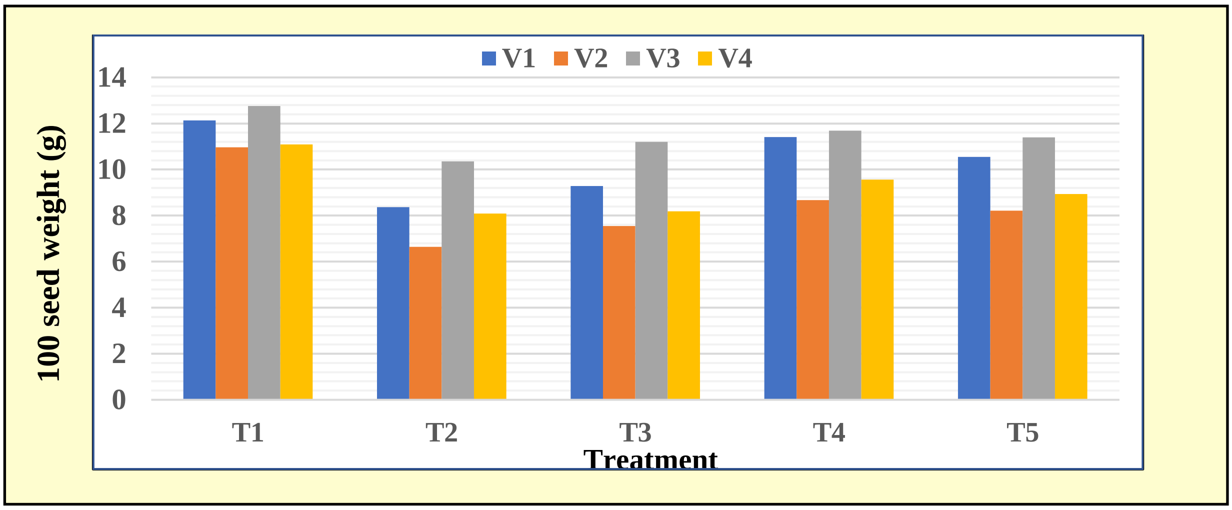


Fig.12. Influence of different water stress treatments on yield and yield attributing characters at various stages of plant growth of cowpea grown under water stress condition



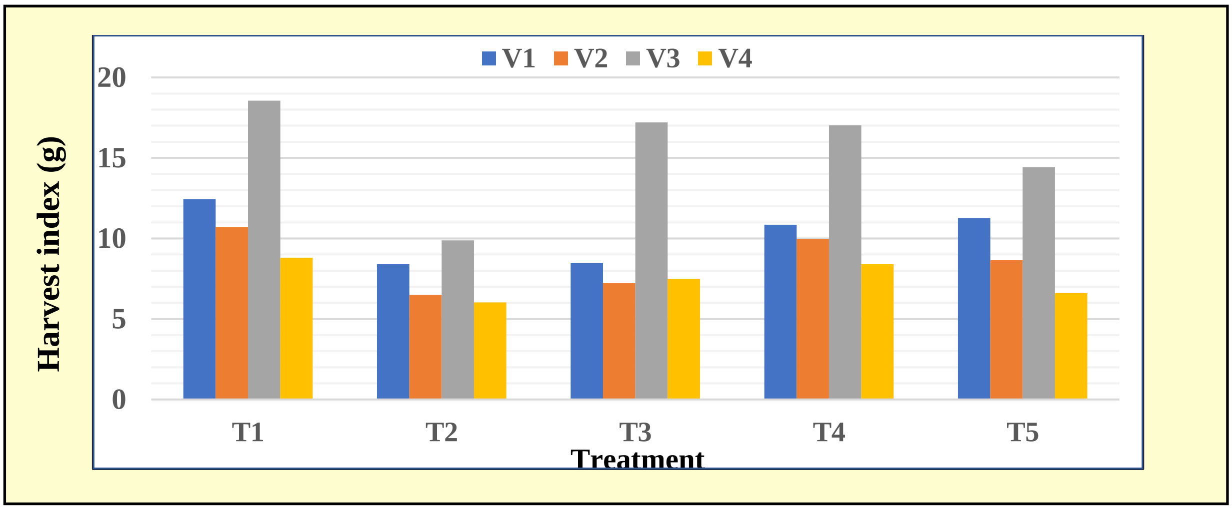
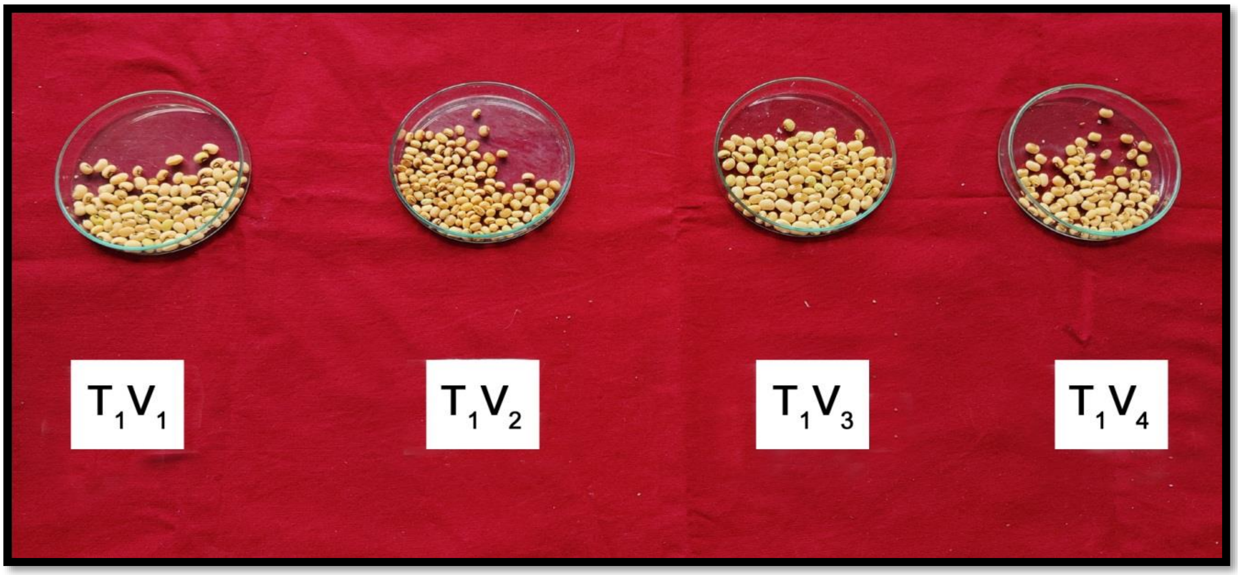
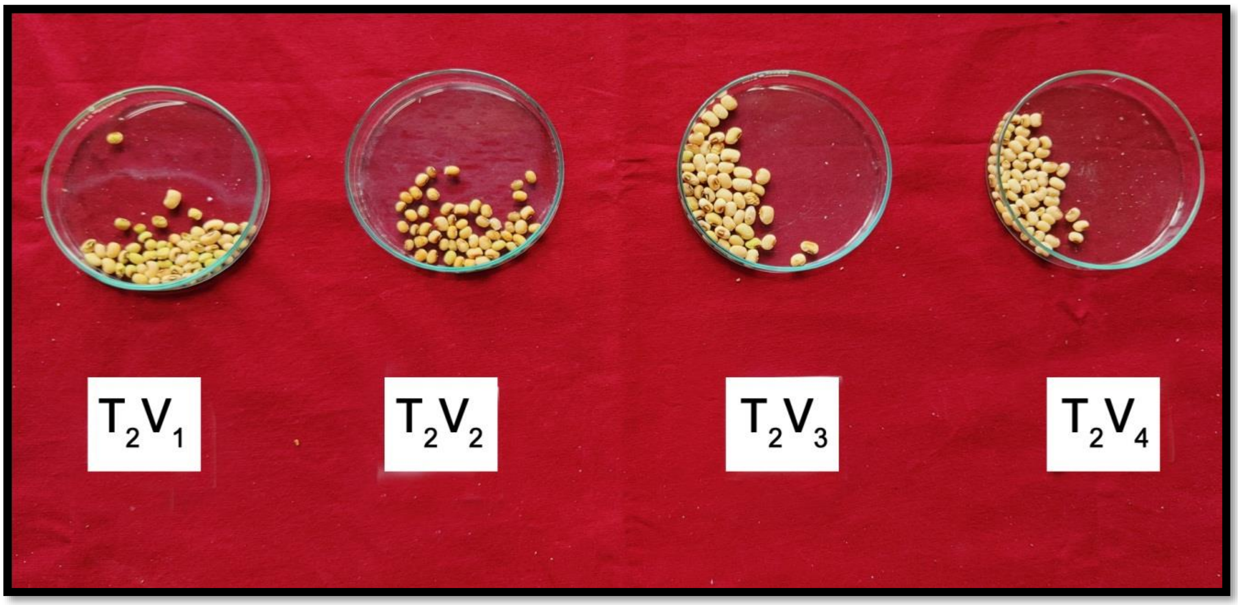


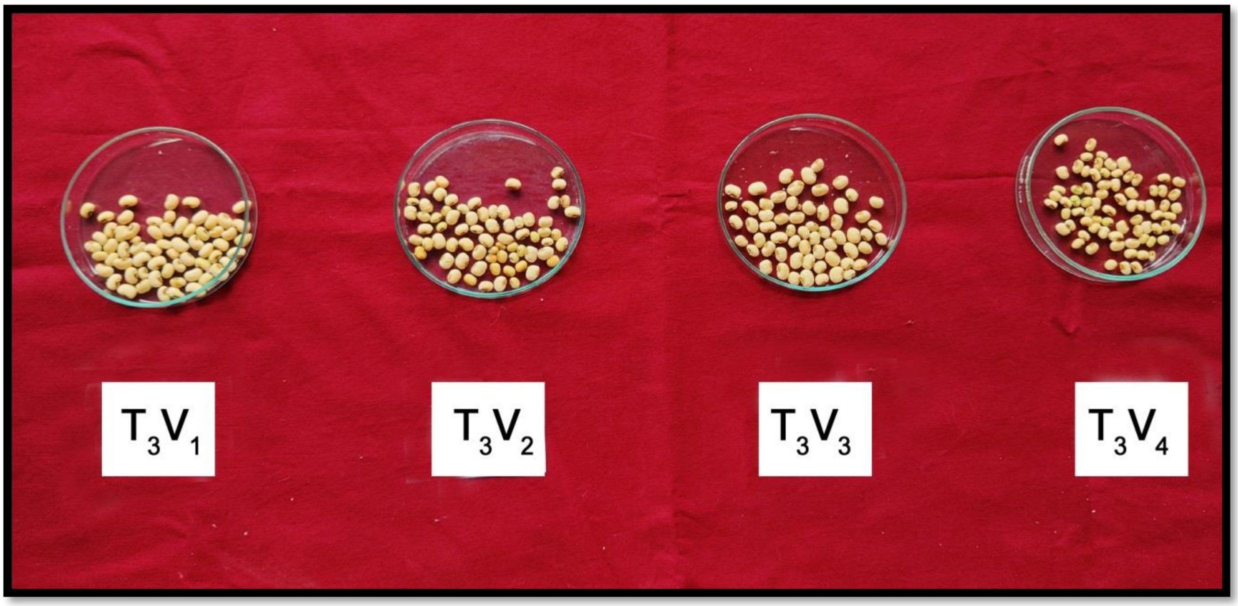
Fig.13. Influence of different water stress treatments on yield and yield attributing characters at various stages of plant growth of cowpea grown under water stress condition



T1 – Regular Irrigation (Absolute Control Condition)

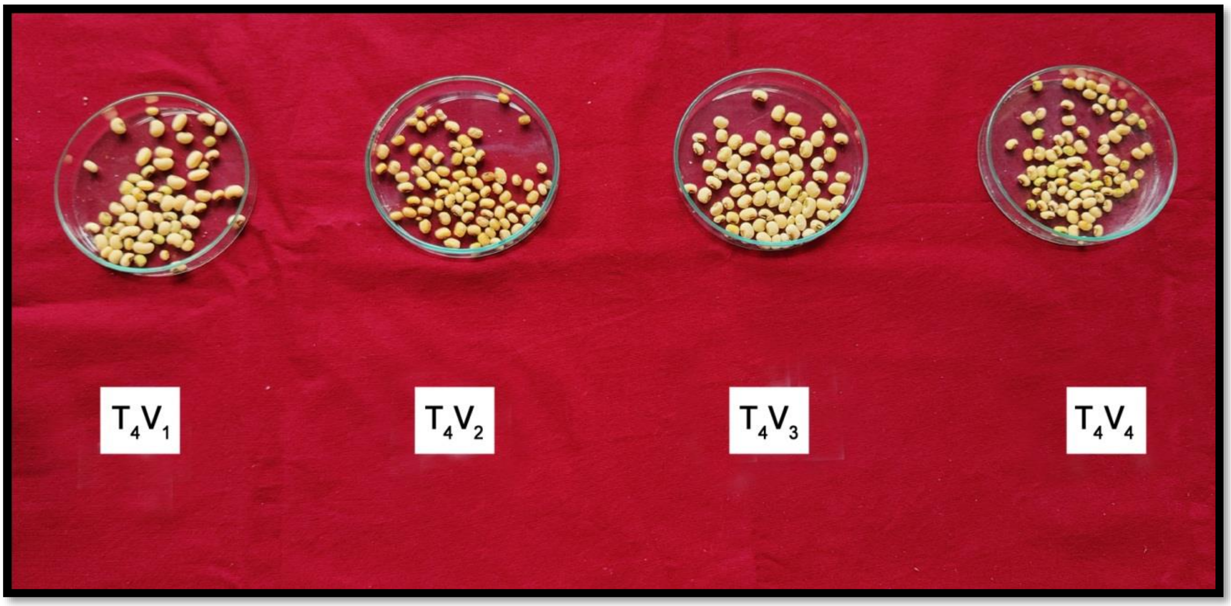


T2 – No Irrigation (Severe Stress)

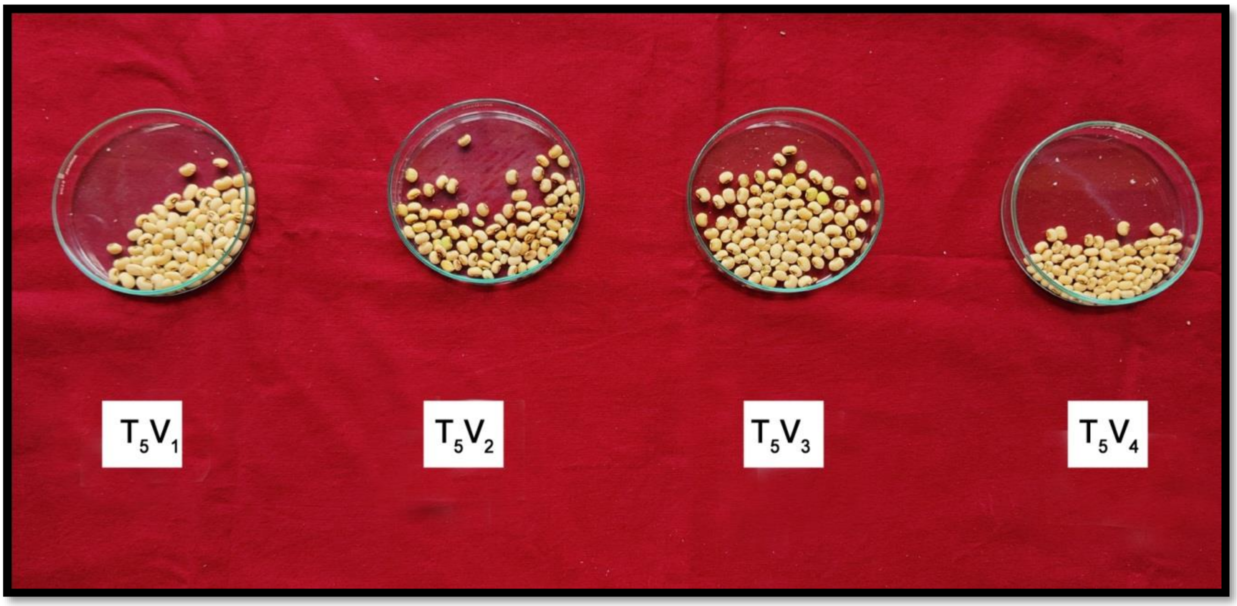


T3 – Irrigation at Branching Stage

Plate 7. Influence of different water stress treatments on plant seed yield per plant (g) at harvest of cowpea grown under water stress condition.



T_4 – Irrigation at Flowering Stage



T_5 – Irrigation at Pod Filling Stage

Plate 8. Influence of different water stress treatments on plant seed yield per plant (g) at harvest of cowpea grown under water stress condition.

Influence of interaction

It was found that treatments and varietal differences was significantly different among the seed yield per plant. Treatment T_1V_3 (8.53 g) was observed significantly maximum seed yield per plant all over variety followed by treatment T_4V_3 (6.18 g) and treatment T_1V_1 (5.43 g). The minimum seed yield per plant was recorded in treatment T_2V_4 (1.12 g), under water stress condition.

4.8.4. 100 seed weight (g)

The further data indicated that, the varieties differed significantly with respect to 100 seed weight. Under water stress condition, interaction effects between different water stress treatments and variety noted significant at harvest.

Influence of water stress treatments

It was found that, there was significant variation among different water stress treatments and 100 seed weight under water stress condition. Treatment T_1 (11.70 g) observed significantly maximum 100 seed weight in all over treatments followed by treatment T_4 (10.33 g), while treatment T_2 (8.36 g) recorded minimum100 seed yield, under water stress condition.

Influence of varietal differences

Maximum 100 seed yield was found in the variety V_3 (11.48 g), followed by variety V_1 (10.35 g) under water stress condition. However minimum 100 seed yield was recorded in variety V_2 (8.37 g), under water stress condition.

Influence of interaction

It was found that treatments and varietal differences was significantly different with respect to 100 seed yield. Treatment T_1V_3 (12.76 g) was observed significantly maximum 100 seed yield all over rest of variety followed by treatment T_4V_3 (11.69 g) and treatment T_5V_3 (11.39 g). The minimum 100 seed yield was recorded in treatment T_2V_2 (6.64 g), under water stress condition.

4.8.5. Harvest index (%)

The further data indicated that the mean per cent harvest index recorded under different water stress condition.

Influence of water stress treatments

It was observed that, maximum harvest index in treatment T_1 (12.63 %), followed by treatment T_4 (11.56 %) which was at par with each other under water stress condition. However, minimum harvest index was recorded in treatment T_2 (7.69 %), under water stress condition.

Influence of varietal differences

Maximum harvest index was found in the variety V_3 (15.41 %), followed by variety V_1 (10.29 %) and variety V_2 (8.16 %), under water stress condition. However minimum harvest index was recorded in variety V_4 (7.46 %), under water stress condition.

Influence of interaction

It was found that treatments and varietal differences was significantly different with respect to harvest index. Treatment T_1V_3 (18.56 %) observed significantly highest harvest index all over rest of variety followed by treatment T_3V_3 (17.20 %) and treatment T_4V_3 (17.02 %). The minimum harvest index was recorded in treatment T_2V_4 (6.02 %), under water stress condition.

Discussion

Currently, cowpea is grown mainly in the tropical and subtropical regions of the world, where rainfall resources are usually low (300-600mm) and unpredictable (Fussel, 1991). As compared to other pulse crops, cowpea generally has more biotic stress tolerance pulse crop. The soil moisture condition is enough, the indeterminate cowpea frequently flower over long period of time, produce more seeds, and minimal yield loss. However, when there is shortage of water, as there frequently is in semi-arid regions, the flowering period is shortened and the seed matures was earlier. In addition, the development of new floral nodes and flowers get delayed, thus there was reduced productivity (Turk 1980). One of the main factor resulting to the low production of pulses may be the reason of their cultivation is mostly confined to dry land conditions with low input. The majority of pulses cultivated in India are *rabi*/summer season. Previously the *kharif* paddy harvest in the *rabi* season, pulses like cowpea and lablab bean are grown on residual moisture. The crop was susceptible to various degrees of water stress as a result of reducing soil moisture and increases in temperature yet mean the soil moisture was sufficient at the time of sowing (Kumar and Sinha, 1988).

Cowpea (*Vigna unguiculata* (L.) Walp) is one of the most important and agro-morphologically versatile tropical legume crop in India, used as a pulse, vegetable (green bean and pod), concentrated feed for cattle, even as a natural medicine (Adebisi and Bosch 2004). It is common knowledge that cowpea has more developmental plasticity than some cultivated pulses, which promotes tolerance to drought.

The main objectives of the present study was to determine any crucial stages of growth in which cowpea become more sensitive to water shortages as well as to determine the effects of water stress applied at various stages of growth on yield and physiological parameters of comparing cowpea genotypes. In order to better understand the concepts of vegetative and critical growth stages and how they apply to the impact of stress on several aspects of cowpea growth and yield, the results and conclusions from these studies were examined and might be helpful. It can produce data for crop enhancement activities and effective management methods for cultivating cowpea in drought-prone areas.

In the present investigations, cowpea genotypes with different growth stages were selected and studied under the following objectives.

1. To study the morphological, physiological and biochemical changes occurring under water stress condition.
2. To study the yield response of different cowpea genotypes under water stress condition.

4.9 Stress Day Factor:

The simplest way of assessing whether the water is available in adequate amount or otherwise during crop growth period is to measure the soil moisture status from time to time. Hiller and Clark (1971) have proposed the technique of estimating 'Stress Day Factor's' on the basis of soil moisture data for exact quantification of inadequacy of water during crop growth. This factor is estimated by following formula.

$$\mathrm{SDF} = \frac{\mathrm{FC} - \mathrm{SMCi}}{\mathrm{FC}}$$

Where,

FC = Field capacity of top 20-22 cm soil

SMCi = Soil moisture content at i^{th} stage of crop growth.

Thus, stress day factor is actually the ratio of magnitude of deviation of soil moisture content from field capacity of soil on which crop is grown. The soil moisture content at field capacity of experiment site was 26.5 % whereas permanent wilting point was 16.00 %. On this basis the SDF were calculated at each stage of crop growth period were presented in Table 4.23.

Table 4.23. Stress Day Factor estimated during experiment.

Soil Moisture Content (%)			Stress Day Factor
Time of Sampling	**Treatment details**	**Moisture (%)**	**Moisture (%)**
At Sowing	T_1 (Regular irrigation)	32.21	-0.215
	T_2 (No irrigation)	32.21	-0.215
	T_3 (At branching stage)	32.21	-0.215
	T_4 (At flowering stage)	32.21	-0.215
	T_5 (At pod filling stage)	32.21	-0.215
20 DAS	T_1 (Regular irrigation)	30.47	-0.149
	T_2 (No irrigation)	26.21	0.010
	T_3 (At branching stage)	28.67	-0.081
	T_4 (At flowering stage)	26.43	0.002
	T_5 (At pod filling stage)	26.37	0.004
40 DAS	T_1 (Regular irrigation)	29.87	-0.127
	T_2 (No irrigation)	24.24	0.085
	T_3 (At branching stage)	26.09	0.015
	T_4 (At flowering stage)	27.83	-0.050
	T_5 (At pod filling stage)	25.37	0.042
60 DAS	T_1 (Regular irrigation)	29.27	-0.104
	T_2 (No irrigation)	21.12	0.203
	T_3 (At branching stage)	22.26	0.160
	T_4 (At flowering stage)	23.44	0.115
	T_5 (At pod filling stage)	27.72	-0.046
80 DAS	T_1 (Regular irrigation)	28.31	-0.068
	T_2 (No irrigation)	18.42	0.304
	T_3 (At branching stage)	19.08	0.280
	T_4 (At flowering stage)	21.14	0.202
	T_5 (At pod filling stage)	22.05	0.167

It is revealed that during the course of experiment, the SDF increases gradually approaching to the value of 0.304 in water stress condition which clearly suggested that the experiment material was subjected to over increasing the water stress, whereas under water stress condition SDF value increased up to 0.304 at 80 DAS. Initially, it was 0.010 to 0.004 or even negative which suggest that initially moisture content was adequate.

4.10. Morphological Observation

The vegetative stage regulates the general morphological behaviour of the plant and gets it ready for the reproductive phase, which is the next important developmental stage. Various morphological characteristics, such as plant height, number of branches per plant, number of leaves per plant and leaf area per plant, varied among all treatments.

4.10.1 Plant height (cm)

One of the most important traits is plant height. More dry matter is produced by plants with greater height with better canopies than by shorter plants, which are also more efficient at photosynthesis. In the current investigation, all four varieties plant height increased steadily up to harvest. 20 to 40 DAS, there was a noticeable increase in plant height that continued to grow steadily up to 60 DAS, after that the rate of plant growth reduced till up to harvest. Patil (1989) in cowpea, Parab (1991) in cowpea, and Shinde (1998) in five legumes crop these all noted tendency in plant height. Variety $V_{3,}$ one of the four varieties, revealed highest plant height at 60 DAS under treatment T_1 (26.327 cm) and treatment T_5 (24.493 cm) under water stress condition, followed by variety $V_{4,}$ which was noted (23.380 cm) and (22.447 cm) in treatment T_1 and T_4. The minimum plant height was noted in treatment T_2V_2 (14.340 cm).

At harvest, maximum plant height was found in treatment T_1V_3 (32.233 cm), followed by treatment T_5V_3 (30.827 cm) and treatment T_1V_4 (29.573 cm), variety V_3 to be more tolerant variety than the other variety under water stress condition. The minimum plant height was noted in treatment T_2V_2 (17.587 cm). The results of these study are similar with the research done by Tarun (1987) in lablab bean, Abidoye (2004) in cowpea, Abayomi *et al.,* (2009) in cowpea, Kardile (2011) found a varietal difference in plant height in cowpea crop, Makbul *et al.,* (2011) in soybean, Mustapha *et al.,* (2014) in soybean, Anita and Lakshmi (2015) in cowpea, Menon and Savitri (2015) in cowpea, Kurhe (2020) in lablab and Tetteh Rashied *et al.,* (2020) in cowpea.

4.10.2 Number of branches per plant

In the present study, number of branches per plant increased up to till harvest. It is recorded a significant difference among all the treatments. All four varieties number of branches per plant increased steadily up to harvest. 20 to 40 DAS, there was a noticeable increase in number of branches per plant that continued to grow steadily up to 60 DAS. Number of branches per plant was positively correlated with the plant height.

At harvest this study revealed that, the difference in mean number of branches per plant between treatments was more. Treatment T_2V_4 found lowest number of branches per plant

(5.933), whereas treatment T_1V_3 found highest number of branches per plant (12.800), followed treatment T_1V_2 (12.400), under water stress condition. The results of these study are similar with the research done by Mwanamwenge *et al.*, (1998) in fab bean, Shinde (1998) in five legume crops, Hassan *et al.*, (2014) in lablab, Mustapha *et al.*, (2014) in soybean, Menon and Savitri (2015) in cowpea, Shirodkar (2016) in lablab bean and Kurhe (2020) in lablab.

4.10.3. Number of leaves per plant

In the present study, number of leaves per plant expanded till the harvest. There was seen to be a considerable difference between all water stress treatments. In the present study, number of leaves per plant gradually increased with crop ageing, under water stress conditions. Initially, it was a relatively minimal number of leaves per plant, but it increased significantly during the crop's substantial growth stages. As the crop in matured stage, the number of leaves per plant was gradually decreased. Under water stress condition, reduced leaf area in plant leaves was caused by decreased leaf production or accelerated leaf senescence, which may be affected by moisture stress.

In treatment T_1, variety V_1 out of the four varieties, showed the highest number of leaves per plant at 60 DAS (19.200), but in treatment T_2, variety V_1 (12.667) and variety V_3 (11.600) both showed the least amount of reduction in the total number of leaves per plant compared to other genotypes studied, indicating morphologically better performance of varieties under water stress condition. Willson *et al.*, (1985) in cowpea, and Nair *et al.*, (2006), Kardile (2011) in cowpea, noted the varietal differences in number of leaves per plant in cowpea crop, under water stress conditions.

At harvest, this study revealed that, the difference in number of leaves per plant between treatments was more. Treatment T_2V_4 found lowest number of leaves per plant (8.867), whereas treatment T_1V_1 found highest number of leaves per plant (18.200), followed treatment T_1V_3 (16.400), under water stress condition. While studying on the cowpea crop, Nair *et al.*, (2006) shared similar results. Research results indicate that increased soil moisture stress severely decreased leaf number. The results of these present study are similar with the research done by Patil (1989) in cowpea, Parab (1991) in cowpea, Shinde (1998) in five legume crop, Abidoye (2004) in cowpea, and Abayomi *et al.*, (2009) in cowpea, Kardile (2011) in cowpea, Kurhe (2020) in lablab and Omalayo (2021) in cowpea.

4.10.4 Leaf area per plant (dm^2)

The size of the photosynthetic machinery is also determined by the leaf area. The ability for solar radiation absorption increases in plant with increase leaf area per plant. Under water stress condition, all treatments showed the maximum leaf area per plant during the flowering and pod filling stage, after that it decreased due to the defoliation of older leaves.

The results indicate that, there was a wide range of differences in the treatments, and mean leaf area per plant was changed over the entire growth stages of plant. The mean leaf area was highest 60 days after sowing and minimum at harvest stage. At 60 DAS, under water stress conditions, treatment T_1 found the highest leaf area per plant was (79.55 dm^2), followed by treatment T_3 (73.29 dm^2), while treatment T_2 found the lowest leaf area per plant was (47.82 dm^2). The similar treatment results are showed by Kardile (2011) in cowpea.

In all four varieties, moisture stress reduced leaf area in plant leaves. In cowpea crop, leaf area per plant at 60 DAS, variety V_3 showed maximum leaf area under treatment T_1 (88.69 dm^2), followed by variety V_1 (88.22 dm^2) than two other varieties, but in treatment T_2 showed high reduction leaf area in variety V_4 (40.68 dm^2). Willson *et al.*, (1983) in cowpea, Nair *et al.*, (2006), Patil (1989) in cowpea, Parab (1991) in cowpea, Shinde (1998) in five legume crops, Kardile (2011) in cowpea, Shirodkar (2016) in wal, Omalayo (2021) in cowpea showed similar results involving fluctuation in leaf area per plant from the vegetative stage to harvest stage.

4.11. Biochemical observation

4.11.1 Total chlorophyll content (mg/g)

The chemical compounds are the most important in the conversion of light energy into chemical energy. Some chemical pigments found within the chloroplast of the plant. The essential pigment for photosynthesis is chlorophyll. Finding the amount chlorophyll content is present in the leaf tissue is necessary for determining the plant's photosynthetic efficiency. The current study revealed that, the concentration of chlorophyll increased with ageing of crop growth and decreased during the stages of harvest. Another reason for the decrease in chlorophyll content lead by a water shortage that means moisture stress, which generates reactive oxygen species (ROS) like O_2^- and H_2O_2, can cause lipid peroxidation and consequently the destruction of chlorophyll. Also, as the content of chlorophyll reduces as a result of the leaf colour change from green to yellow, the incident radiation is reflected more intensely. The decrease in the plant's leaf water status may be the cause of the decline in the total chlorophyll concentration. It was discovered that, the total chlorophyll content was positively correlated with leaf area per plant, leaf area index and leaf area ratio.

Total chlorophyll content was found to vary significantly between all water stress treatments and was at highest during the first 60 days of crop growth and decreased during the period of harvesting means, at harvest leaf fall was highest. At 60 DAS, under the water stress conditions, treatment T_1 was noted the mean highest total chlorophyll content (14.070 mg/g), followed by treatment T_4 (11.387 mg/g). However, treatment T_2 (9.812 mg/g) was noted the lowest total chlorophyll content. Total chlorophyll content was lowest at the time of harvest. The results are similar by Kardile (2011) in cowpea.

In the present study, total chlorophyll content was found periodically among the four different varieties. At 60 DAS in treatment T_1, variety V_1 (15.687 mg/g), followed by variety V_3 (14.777 mg/g) noted maximum total chlorophyll content than two other varieties studied, while in treatment T_2 showed minimum total chlorophyll content in variety V_4 (7.420 mg/g). The variety V_1 and variety V_3 recorded comparatively higher photosynthetic rate along with lower transpiration rate which showed that the higher dry matter production and higher yield attributing characters in cowpea crop. The varietal differences for total chlorophyll content in cowpea crop were also similar in results by Reddy *et al.,* (2000) in cluster bean, Garg *et al.,* (2005) in legumes, Nair *et al.,* (2006), Kardile (2011) in cowpea and Kurhe (2020) in lablab.

4.11.2 Proline content (µmol/g)

The phenomenon of proline accumulation by plant tissues during water deficit has attracted considerable attention. There are evidences which suggest that proline accumulation provides protection to enzymes against dessication. It has been suggested that the proline accumulation is likely to occur in short time at cellular level against water stress (R. Seeraj *et.al.,* 2004). It has received considerably attention, plant tissues accumulate proline, when there is a water shortage. According to study by R. Seeraj *et al.,* (2004), proline accumulating at the cellular level was against water stress.

Proline accumulation and drought-resistant abilities have been well described in the current study. At harvest the amount of proline content was high under treatment T_2 (0.9549 µmol/g) and treatment T_3 (0.8392 µmol/g), under water stress condition compared to treatment T_1 *i.e.* control condition (0.5381 µmol/g). The current findings confirmed earlier research by Naidu *et al.,* (2001) in green gram and Kardile (2011) in cowpea which suggested that accumulation proline may have contributed with osmotic adjustment and was play important role in maintaining turgor in the presence of fluctuating soil water potential. In present study noted that, in treatment T_2, variety V_2 and variety V_3 accumulated (1.1510 µmol/g) and (0.9293 µmol/g) more proline content under severe water stress means treatment T_2 as compared to treatment T_1. In other words, varieties are showed a high proline synthesis tendency under water stress condition also they showed clear difference in accumulation of proline under water stress condition. These similar findings are consistent with those of Galston *et al.,* (1990), Schen *et al.,* (1990) in flat bean, Purushottam *et al.,* (1998) in groundnut, Chandrashekhar *et al.,* (2000) in wheat, Narshimha (2004) in chickpea, Ahire *et al.,* (2005) in chickpea Kumar *et al.,* (2011) in pigeon pea, Kardile (2011) in cowpea Kurhe (2020) in lablab.

Chlorophyll content and proline content could be used as one of the important parameters when screening for drought tolerance, it can be concluded from the above mentioned biochemical analysis.

4.11. Physiological observation

4.11.1 Relative Water Content (%)

The term relative water content (RWC) refers to a leaves actual water content to its highest turgidity. The current study revealed that, plants under treatment T_1 maintained maximum relative water content as compared to treatment T_2 under water stress condition. After 40 days after sowing, it was found that the relative water content differences among all varieties as a result of water stress treatments became more noticeable. The variety V_2 (93.30 %) and variety V_1 (88.31 %), showed maximum RWC at harvest under treatment T_1 and variety V_3 (58.56 %) and variety V_4 (53.43 %), showed minimum RWC under treatment T_2. This is due to varieties showed that superior maintenance of greater RWC, ensuring better hydration and more favourable internal water relations of tissue with a potentially larger pressure potential, as well as improved capacity to withstand drought. Thus, similar results reported by Parab (1990) in cowpea, Shinde (1998) in five legume crops, Kardile (2011) in cowpea, Kumar *et al.,* (2011) in pigeon pea, Kataria and Singh (2014) in mungbean and Kurhe (2020) in lablab.

4.11.2. Chlorophyll Stability Index (%)

The current study revealed that, the chlorophyll stability index increased with ageing of crop growth and decreased during the time of maturity stage under moisture stress. It found the information about the total chlorophyll content under water stress condition. The higher chlorophyll stability index noted that, the total chlorophyll content was highest under moisture stress. The chlorophyll stability index positively correlated with the both relative water content and total chlorophyll content.

The chlorophyll stability index increased with advanced ageing of crop growth stages at first 60 days, decreased during the harvest stage. Chlorophyll stability index was found maximum in treatment T_1V_2 (70.26 %) followed by T_4V_2 (69.59 %), while minimum was found in treatment T_2V_4 (54.44 %), under water stress at 60 DAS. However, at harvest maximum chlorophyll stability index was noted in treatment T_1V_2 (63.87 %), followed by treatment T_1V_1 (63.37 %) and minimum was noted in treatment T_2V_4 (47.86 %). The similar results are in confirmation with the resulted by Shinde (1998) in five legume crop, Shirodkar (2016) in wal, Hayatu and Mukhtar (2010) in cowpea and Kurhe (2020) in lablab.

4.12. Total dry weight per plant (g)

The production and progressive accumulation of dry matter in the plants are eventually caused by the plant's overall vegetative and reproductive processes. The biological productivity of plants is determined by observing the total amount of dry matter. All physiological activities, both catabolic and anabolic, lead to a net balance or formation of dry matter. The current studies clearly showed that dry-matter accumulation and production in each of the four cowpea varieties increased up to the harvest. The accumulation of dry matter was initially rather slow during the crop growth, but it gradually increased as the crop was mature. Researchers studying yield analysis have curiosity about the way of dry matter accumulation and distribution among the various plant parts. Progressively, dry matter accumulation are increases within the plant body as a result of overall plant production. A balanced distribution of total dry matter among the various plant parts is more important than overall dry matter production and accumulation. The gradual accumulation of dry matter in various plant parts was showed in each component of the plant has a unique function and utility.

The current investigation revealed that, the production of dry matter varied depending on the treatment. The production of overall dry matter is significantly influenced by the stem, which is the major translocation organ of photo-assimilates. While leaves dry matter increased during the first 60 DAS and then declined till harvest, stem dry matter found that to increase until harvest. In general, the stem accumulated the most total dry matter, followed by the leaves, and the least amount in the roots. Due to the rapid rate of leaf fall at maturity, the dry matter of the leaves was much lower at harvest than the dry matter of the stem.

There was consequent variation in total dry matter production among all water stress treatments found at various stages of crop growth. Total dry matter per plant increased progressively as crop age increased. Different water stress treatments resulted in different amounts of total dry matter being distributed among various plant parts such as leaves, stems, and roots. Treatment T_2 produced the minimum amount of total dry matter per plant (15.61 g), under water stress condition, whereas treatment T_1 produced the highest amount of total dry matter per plant (43.85 g), followed by treatment T_5 (41.78 g), and treatment T_4 (34.45 g), at harvest.

Among the four varieties studied, in treatment T_1, Variety V_1 (45.48 g/plant) noted consequently highest total dry matter production at harvest all over other varieties followed by variety V_2 (45.09 g/ plant). However, in treatment T_2, variety V_4 (14.36 g/plant) noted the minimum total dry matter production. Thus, the similar results here repeated by Patil (1989) in cowpea, Parab (1991) in cowpea, Shinde (1998) in five legume crops, Dhonde *et al.,* (2000) in chickpea, Deshmukh (2004) in chickpea, Kardile (2011) in cowpea, Shirodkar (2016) in wal and Kurhe (2020) in lablab.

As result, mean leaves dry weight accumulation, remarkable differences were observed at 40, 60 DAS in all four varieties. At 60 DAS, in treatment T_1, variety V_2 (23.575 g) showed maximum leaves dry weight followed by variety V_3 (23.483 g) under water stress condition.

However, in treatment T_2, variety V_4 (4.224 g) observed minimum leaves dry weight. Studies on mean leaves dry weight, indicated a consequent difference among all treatments and varieties. Thus, the similar results were showed by Patil (1989) in cowpea, Parab (1991) in cowpea, Shinde (1998) in five legume crops, Dhonde *et al.,* (2000) in chickpea, Deshmukh (2004) in chickpea, Kardile (2011) in cowpea, Shirodkar (2016) in wal and Kurhe (2020) in lablab.

As result, under water stress condition, treatment T_1 (2.4485 g) showed the maximum stem dry weight followed by treatment T_5 (2.3975 g). However minimum stem dry weight was observed in treatment T_2 (1.4543 g). Among four varieties in treatment T_1, Variety V_3 (2.9777 g) noted consequently highest stem dry weight at harvest all over other varieties followed by variety V_4 (2.4245 g). However, in treatment T_2, variety V_1 (1.4436 g) noted the minimum stem dry weight. The similar results were showed by Patil (1989) in cowpea, Parab (1991) in cowpea, Shinde (1998) in five legume crops, Dhonde *et al.,* (2000) in chickpea, Deshmukh (2004) in chickpea, Kardile (2011) in cowpea, Shirodkar (2016) in wal and Kurhe (2020) in lablab.

In current study revealed that, the rapidly increase in mean root dry weight was observed from 60 DAS up to harvest. Under water stress condition, treatment T_1 (0.8749 g) showed the maximum root dry weight followed by treatment T_5 (0.6246 g). However minimum root dry weight was observed in treatment T_2 (0.3270 g). Among four varieties in treatment T_1, variety V_1 (0.9845 g) noted consequently highest root dry weight at harvest all over other varieties followed by variety V_4 (0.9761 g). However, in treatment $T_{2,}$ variety V_1 (0.2855 g) noted the minimum root dry weight. Thus, the similar results are consistent with those of Patil (1989) in cowpea, Parab (1991) in cowpea, Shinde (1998) in five legume crops, Dhonde *et al.*, (2000) in chickpea, Deshmukh (2004) in chickpea, Kardile (2011) in cowpea, Shirodkar (2016) in wal and Kurhe (2020) in lablab.

4.13. Growth parameters

In determining growth indicators such as the leaf area per plant, leaf area ratio, specific leaf weight, absolute growth rate, relative growth rate, net assimilation rate and leaf area index in dry matter studies, the result of this variance must be studied both early and late in crop growth. Growth is complex phenomenon involving complicated changes ultimately leading to variation in yield, therefore for a complex analysis of biological yield, it is necessary to investigate the causes of such variation both during the early and late period of crop growth.

4.13.1. Leaf area per plant (dm^2)

The leaf area per plant was affects the size of the mechanism for photosynthesis. The ability for solar radiation absorption increases in plant with increase leaf area per plant. Under water stress condition, all treatments showed the maximum leaf area per plant during the flowering and pod filling stage, after that it decreased due to the defoliation of older leaves.

The results indicate that, there was a wide range of differences in the treatments, and mean leaf area per plant was changed over the entire growth stages of plant. The leaf area was highest 60 days after sowing and minimum at harvest stage. At 60 DAS, under water stress conditions, treatment T_1 found the highest mean leaf area per plant was (79.55 dm^2), followed by treatment T_4 (73.29 dm^2), while treatment T_2 found the lowest leaf area per plant was (47.82 dm^2). The similar treatment results are showed by Kardile (2011) in cowpea.

In all four varieties, moisture stress reduced leaf area in plant leaves. In cowpea crop, leaf area per plant at 60 DAS, variety V_3 showed less reduction leaf area under treatment T_1 (88.69 dm^2), followed by variety V_1 (88.22 dm^2) than two other varieties, but in treatment T_2 showed high reduction leaf area in variety V_4 (40.68 dm^2). Willson *et al.*, (1983) in cowpea, Nair *et al.*, (2006), Patil (1989) in cowpea, Parab (1991) in cowpea, Shinde (1998) in five legume crops, Kardile (2011) in cowpea, Shirodkar (2016) in wal showed similar results involving fluctuation in leaf area per plant from the vegetative stage to harvest stage.

4.13.2 Leaf Area Index

The ratio of the leaf surface (on one side only) to the ground area occupied by the crop is expressed by the leaf area index (LAI). It also reflects the functional size of the plant structure's assimilatory apparatus and several as a primary value in the calculation of other growth factors (Watson 1952). A crop stand assimilatory surface area and growth determine how much solar energy is absorbed by the canopy and represent the crop's productive capability. The size of the photosynthetic system is indicated.

In current study, irrespective of four varieties under different water stress treatments, it was observed that LAI progressively increased with the advancing age of the crop. The progressive increase in LAI might be due to increase in number of leaves and leaf area. But at the time of maturity, the LAI decreased. The LAI progressively increased with advancing age of the crop till 60 DAS. However, after 60 DAS onwards, decrease in LAI was noticed. Under water stress condition leaf area index was maximum in treatment T_1 (1.4213) followed by treatment T_4 (1.0727), while leaf area index was noted minimum in treatment T_2 (0.4995) at harvest. These results are similar with the results obtained by, Patil (1989) in cowpea, Shinde (1998) in five legume crops, Nair *et al.*, (2006) in cowpea, Kardile (2011) in cowpea.

At 60 DAS, variety V_3 noted maximum LAI under treatment T_1 (1.5219), followed variety V_2 (1.4952), while minimum LAI was observed in treatment T_2, variety V_4 (0.4557) under the water stress condition. The varietal difference in leaf area index under water stress conditions in cowpea crop was also reported by, Turk *et al.*, (1980) in cowpea, Willson *et al.*, (1983) in legumes, Kardile (2011) in cowpea, Shirodkar (2016) in wal and Kurhe (2020) in lablab.

4.13.3. Specific Leaf Weight (g/dm^2)

The daily increase in dry matter over a given period of time is the SLW. It shows the growth pattern at different developmental stages. The results of this study showed that SLW increased at 60 days after sowing then decrease at the time of harvesting. Increase in SLW during the early stages of crop growth as a result increased total dry weight per plant throughout those stages as it is entirely dependent on dry matter accumulation.

The early stage of crop growth was shown to have the highest specific leaf weight, while it declined in later stage. Mean SLW was maximum in treatment T_1 (0.4289 g/dm^2) followed by treatment T_4 (0.3780 g/dm^2), while it was noted minimum in treatment T_2 (0.1882 g/dm^2) under water stress condition at 60 DAS to harvest. As a result, variety V_4 noted maximum SLW under treatment T_1 (0.4923 g/dm^2), followed by treatment T_5, variety V_4 (0.4511 g/dm^2), while minimum SLW was observed in treatment T_2, variety V_1 (0.1498 g/dm^2) under the water stress condition. The similar results showed Shinde (1998) in five legumes crop, Thiyagarajan *et al.*, (2009) in groundnut and Kurhe (2020) in lablab.

4.13.4. Absolute Growth Rate (g/day)

Amongst various growth parameters, AGR is a plain and simple measure of rate of increase in weight. The AGR is the daily increase in dry matter over a certain period of time. It illustrates the pattern of growth at various stages of development. According to the findings of the present study, AGR was higher at 40 to 60 days after sowing then lower at the time of harvest. Increase in AGR during the early stages plant growth due to increased total dry weight per plant throughout those stages as it is entirely depends on dry matter accumulation.

AGR was found to be highest at initial stage of crop growth and it declined in later stages. Mean AGR was maximum in treatment T_1 (0.4838 g/day) followed by treatment T_4 (0.4693 g/day), while it was noted minimum in treatment T_2 (0.2959 g/day) under water stress condition at 60 DAS to harvest. As a result, variety V_2 noted maximum AGR under treatment T_1 (0.5396 g/day), followed by treatment T_4, variety V_3 (0.5376 g/day), while minimum AGR was observed in treatment T_2, variety V_1 (0.2282 g/day) under the water stress condition. These results are similar with the results obtained by, Parab (1990) in cowpea, Shinde (1998) in lablab, Kardile (2011) in cowpea, Mustapha *et al.*, (2014) in soybean and Shirodkar (2016) in wal.

4.13.5. Relative Growth Rate (g/g/day)

The relative growth rate (RGR) is the rate of increase in dry matter production at a certain period of time over the plants previously accumulated dry matter production. As a result, it gradually declined up to maturity, with a quicker rate of reduction during 60 to at harvest. The RGR at 40 to 60 DAS was the highest because it represents the rate of increase of RGR over zero in the previous stage. However, it decreased up to 60 DAS to harvest since the pace of increase in DMP was slower than the previous period's relatively high values. As a result, RGR values at maturity decreased little as compared to previous maturity intervals.

In present study, decrease in relative growth rate was noted as crop growth proceeded. Mean relative growth rate highest was observed in treatment T_1 (0.01714 g/g/day), followed by treatment T_4 (0.00461 g/g/day), while lowest relative growth rate was recorded in treatment T_2 (0.00328 g/g/day) under water stress condition at 60 DAS to at harvest. As a result, variety V_4 noted maximum RGR under treatment T_1 (0.01818 g/g/day), followed variety V_3 (0.01806 g/g/day), while minimum RGR was observed in treatment T_2, variety V_1 (0.00252 g/g/day) under the water stress condition. Similar results in chickpea and cowpea crop were also reported by Parab *et al.,* (1991) in cowpea, Kardile (2011) in cowpea, Mustapha *et al.,* (2014) in soybean, Shirodkar (2016) in wal, Kurhe (2020) in lablab.

4.13.6. Net Assimilation Rate (g/dm^2/day)

The net assimilation rate is the rate of increase in dry weight per unit leaf area if both dry weight and leaf area increased exponentially. The present investigation, found that the NAR was maximum 40 to 60 days after sowing and then decreased at the time of harvest. This could be attributed to reduced leaf area at maturity.

Net assimilation rate recorded significantly different among all treatments under water stress. NAR was highest at 40 to 60 DAS and it was lowest at 60 DAS to harvest. Maximum mean value of NAR was observed in treatment T_1 (0.00608 g/dm^2/day), followed by treatment T_4 (0.00408 g/dm^2/day), while minimum value was noted in treatment T_2 (0.00241 g/dm^2/day) under water stress condition at 60 DAS to harvest. As a result, variety V_4 noted maximum NAR under treatment T_1 (0.00655 g/dm^2/day), followed variety V_1 (0.00595 g/dm^2/day), while minimum NAR was observed in treatment T_2, variety V_1 (0.00231 g/dm^2/day) under the water stress condition. The results of present investigation, confirm the earlier findings Singh and Singh (1994) in sugarcane and they found that, interception of maximum solar radiation by upper leaves showed higher rate of photosynthesis than the lower leaves. This may account for higher NAR under water stress condition as observed in these varieties may be regarded as a characteristic feature of drought tolerant.

The varietal difference in NAR under water stress conditions in cowpea crop was accordance with Parab (1991) in cowpea, Shinde (1998) in five legumes crop, Kardile (2011) in cowpea, Mustapha *et al.,* (2014) in soybean, Shirodkar (2016) in wal.

4.13.7 Leaf Area Ratio

The efficiency with which a plant utilises its photosynthetic resource is measured by the leaf area ratio (LAR), which is the amount of photosynthetic surface area per unit dry weight of a plant.

In the current study, it was observed that leaf area ratio varied significantly in all treatments under water stress condition. Leaf area ratio was noted maximum in 60-at harvest. Maximum mean value of LAR was observed in treatment T_1 (6.255), followed by treatment T_4 (2.391), while minimum value was noted in treatment T_2 (1.965) under water stress condition at 60 DAS to harvest. As a result, variety V_2 noted maximum LAR under treatment T_1 (5.905), followed variety V_3 (5.863), while minimum LAR was observed in treatment T_2, variety V_2 (1.642) under the water stress condition. These similar results shows research done by Parab *et al.,* (1991) in cowpea, Mwanamwenge *et al.,* (1998) and Shirodkar (2016) in wal.

4.14. Phenological Characters

Early flowering is one of the most desired traits in crops. It determines the period of time required to start monitoring returns. Days to flowering initiation, days to 50 per cent flowering and days to physiological maturity, were increased with lower moisture stress treatments in the current study. Under water stress conditions, it was found that there was less variation in the days to flowering initiation.

Days to flower initiation under water stress found to be lowest in treatment T_2 (44.17 days) and highest in treatment T_1 (48.50 days), followed by treatment T_3 (47.58 days) and treatment T_5 (47.50 days). Among four varieties in treatment T_2, Variety V_2 (38.33 days) noted consequently minimum days to flower initiation all over other varieties. However, in treatment T_1, variety V_4 (52.67 days) noted the maximum days to flower initiation.

In current study it was studied that the number of days required to 50 per cent flowering varied significantly different under all water stress treatments. Under water stress condition minimum days required for 50 per cent flowering was observed in the treatment T_2 (51.25 days) and maximum in T_1 (55.50 days), followed by treatment T_5 (54.83 days) and treatment T_3 (54.33 days). Among four varieties in treatment T_2, Variety V_2 (45.33 days) noted consequently minimum days to 50 per cent flowering all over other varieties. However, in treatment T_1, variety V_4 (60.67 days), followed by in treatment T_5, variety V_1 (59.33 days) noted the maximum days to 50 per cent flowering.

The number of days required for physiological maturity significantly different from all the water stress condition. Under water stress condition, minimum days required for physiological maturity were observed in the treatment T_2 (70.67 days) and maximum in T_1 (75.83 days), followed by treatment T_5 (74.83 days) and treatment T_3 (73.75 days). Among four varieties in treatment T_2, Variety V_2 (61.33 days) noted consequently minimum days to physiological maturity all over other varieties. However, in treatment T_1, variety V_4 (80.33 days), followed by in treatment T_5, variety V_4 (78.67 days) noted the maximum days to physiological maturity. The variation in days to flowering and maturity in cowpea crop was also reported by Turk *et al.,* (1980) in cowpea, Patil (1989) in cowpea, Parab (1991) in cowpea, Shinde (1998) in five legumes crop, Kardile (2011) in cowpea and Kurhe (2020) in lablab stated that early 50 per cent flowering and days to physiological maturity in moisture stress treatments might be related to a plant's conservation mechanism that minimizes water loss from transpiration, shortening the vegetative growth and diverting metabolic assimilates towards the reproductive stage.

4.15 Yield and Yield attributes

Crop yield is based on total assimilation during the growing season and how it is distributed between the designated storage structures and the rest of the plant. Yield is a compound character made up of the sum of the contributions produced by various physiological traits. It is the end result of a several different character interactions and actions among the different parts of the plant. It is the net economic gain from the source and sink capacity, as per point of view of plant physiologist. Treatments were evaluated for various yield parameters such as number of pods per plant, number of seeds per plant, seed yield per plant, 100 seed weight and harvest index.

4.15.1 Number of pods per plant

The number of pods per plant is an important trait that has the most direct influence on pod yield per plant. Under all water stress treatments in the current investigation, it was found that the number of pods produced per plant varied significantly. The increase plant height and number of branches per plant may be the cause of the increase in the number of pods produced per plant. There were significant differences in the number of pods per plant recorded at harvest for all treatments. Maximum number of pods was recorded in treatment T_1 (7.35) which was followed by treatment T_4 (5.35) and treatment T_5 (4.36) over rest of the all treatments. However, minimum number of pods per plant was observed in treatment T_2 (2.71), under water stress condition. Among four varieties in treatment T_1, Variety V_3 (8.40) was noted consequently highest number of pods per plant all over other varieties followed by variety V_2 (7.60). However, in treatment $T_{2,}$ variety V_4 (2.26) noted the minimum number of pods per plant. Similar results were reported by Parab (1991) in cowpea, Shinde (1998) in five legumes crop, Abidoye (2004) in cowpea, Futuless and Bake (2009) in cowpea, Kardile (2011) in cowpea, Menon and Savitri (2015) in cowpea, Ricardo Santas *et al.,* (2020) in cowpea.

4.15.2. Number of seeds per plant

Number of seed per plant is desired character which has direct effect over number of pods per plant. It was noted that there is a significantly different in number of seeds per plant among all treatments under water stress. Maximum number of seeds per plant was noted in treatment T_1 (48.00) which was followed by treatment T_4 (36.68) and treatment T_5 (28.75) over rest of the all treatments. However, minimum number of seeds per plant was observed in treatment T_2 (15.73), under water stress condition. Among four varieties in treatment T_1, Variety V_3 (68.60) was noted consequently highest number of seeds per plant all over other varieties followed by variety V_2 (46.13). However, in treatment $T_{2,}$ variety V_4 (12.67) noted the minimum number of seeds per plant. This similar results were recorded by Parab (1991) in cowpea, Shinde (1998) in five legumes crop, Abidoye (2004) in cowpea, Kardile (2011) in cowpea, Menon and Savitri (2015) in cowpea, Ricardo Santas *et al.,* (2020) in cowpea.

4.15.3. Seed yield per plant (g)

Seed is the economic part of the total dry matter production. It is the net economic grain from the source and sink capacity, according to plant physiologist. In current study, under water stress condition significantly maximum seed yield per plant was found in treatment T_1 (5.59 g) which was followed by treatment T_4 (4.04 g) and treatment T_5 (3.31 g) over rest of the all treatments. However, minimum seed yield per plant was observed in treatment T_2 (1.56 g), under water stress condition. Among four varieties in treatment T_1, Variety V_3 (8.53 g) was noted consequently highest seed yield per plant all over other varieties followed by variety V_3 (6.18 g) in treatment T_4. However, in treatment $T_{2,}$ variety V_4 (1.12 g) noted the minimum seed yield per plant. This similar results were recorded by Parab (1991) in cowpea, Shinde (1998) in five legumes crop, Abidoye (2004) in cowpea, Kardile (2011) in cowpea, Menon and Savitri (2015) in cowpea, Ricardo Santas *et al.,* (2020) in cowpea.

4.15.4. 100 seed weight (g)

100 seed weight is another important factor which indicates yield of the crop. In current study, variation in 100 seed weight was observed among all water stress treatments. In present study, under water stress condition significantly maximum 100 seed weight was found in treatment T_1 (11.70 g) which was followed by treatment T_4 (10.33 g) and treatment T_5 (9.77 g) over rest of the all treatments. However, minimum 100 seed weight was observed in treatment T_2 (8.36 g), under water stress condition. Among four varieties in treatment T_1, Variety V_3 (12.76 g)

was noted consequently highest 100 seed weight all over other varieties followed by variety V_1 (12.14 g). However, in treatment T_2, variety V_2 (6.64 g) noted the minimum 100 seed weight. This similar results were recorded by Parab (1991) in cowpea, Shinde (1998) in five legumes crops, Abidoye (2004) in cowpea, Kardile (2011) in cowpea, Menon and Savitri (2015) in cowpea, Kurhe (2020) in lablab, Ricardo Santas *et al.*, (2020) in cowpea.

4.15.5. Harvest index (%)

Although, the importance of both seed and biomass production, seed yield is more important than biomass production; as a result, the relationship between seed and biomass has to be studied. Harvest index means the percentage of biological yield represented by economic yield. Donald (1962) gives the term of harvest index as the ratio of grain weight to the total dry weight of above ground parts at harvest of the crop. Since each crop's yield is influenced by its capacity to produce dry matter partitioning of economic and non-economic parts, is interest to plant researchers, because the yield of any crop is depends on the its capacity to produce dry matter production and its efficient partitioning between the economic and noneconomic parts. How much of the total dry matter turns into an economic component is shown by the harvest index. The higher this conversion, the higher the harvest index, this would help in the development of an ideal plant type in which a greater proportion of the total dry matter is converted into economic components.

In present investigation, harvest index significantly different among all treatments under water stress condition. The range between the harvest index was 6.02 to 18.56 %. Under water stress condition highest mean harvest index was observed in treatment T_1 (12.63 %), followed by treatment T_4 (11.56 %) while lowest harvest index was observed in treatment T_2 (7.69 %). Among four varieties in treatment T_1, Variety V_3 (18.56 %) was noted consequently highest harvest index all over other varieties followed by variety V_3 (17.20 %) in treatment T_3. However, in treatment T_2, variety V_4 (6.02 %) noted the minimum harvest index. This similar results were recorded by Parab (1991) in cowpea, Shinde (1998) in five legumes crops, Abidoye (2004) in cowpea, Kardile (2011) in cowpea, Menon and Savitri (2015) in cowpea, Ricardo Santas *et al.*, (2020) in cowpea.

SUMMARY AND CONCLUSIONS

CHAPTER V: SUMMARY AND CONCLUSIONS

The present investigation entitled **"Evaluation of Cowpea (*Vigna unguiculata* (L.) Walp) Genotypes under Water Stress Condition in Konkan"** was carried out at Education and Research farm, Department of Agricultural Botany, College of Agriculture, Dapoli, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri. during *Rabi* (2022-23) season with following objectives:

1. To study the morphological, physiological and biochemical changes occurring under water stress condition.
2. To study the yield response of different cowpea genotypes under water stress condition.

In the current investigation, the experiment was carried out in five treatments with four genotypes *i.e.* (Konkan Safed, Konkan Sadabahar, Phule Sonali, Phule Rukmini). Cultivation of these genotypes was grown in strip plot design with three replications during Rabi 2022-2023. Observations were recorded in context with morphological, biochemical, physiological, dry matter studies, growth parameters, phenological and yield attributing parameters. The data on plant height, number of branches per plant, number of leaves per plant, leaf area per plant, total chlorophyll content, proline content, relative water content, chlorophyll stability index, total dry matter production, growth parameters, days to first flowering, days to 50 % flowering, days to physiological maturity, yield and yield attributing components of cowpea grown under water stress were studied and important findings obtained from this investigation are summarized below.

1. The available soil moisture content in all treatments at the initial stage (at crop sowing stage) was in sufficient as compared to the moisture content at field capacity, means the maximum soil moisture content. The soil moisture content 20-60 DAS was changed after irrigation at critical growth stages in treatment of stress condition. The soil moisture content at harvest in control condition was maximum than other stress treatment that is other stress treatment rapidly declined and reached the minimum after 60-80 DAS. In a further course of study, under water stress condition the soil moisture content quickly decreased from initial stage to harvest and remained below the permanent wilting point in the water stress condition (no irrigation/severe stress) was reverse 20, 40,60 and 80 DAS.
2. The mean plant height continued to increase as the crop matured up to harvest. Plants from absolute control condition recorded maximum plant height as compared to plants from other water stress treatments. The maximum plant height was recorded at

treatment T_1 (27.652 cm) while minimum plant height was at treatment T_2 (19.872 cm). In treatment T_1, variety V_3 (32.233 cm) has been showed maximum plant height as compared to other variety under all water stress treatments. Under water stress treatment T_2, the variety V_3 (22.593 cm) appeared to be high stress tolerant as far as plant height is concerned than all other variety.

3. The result showed that, the number of branches increased gradually with crop age, with a significant difference detected between control condition and in all the water stressed condition. It was noted that, the variation in average number of branches per plant between treatments was greatest at harvest. Treatment T_2 observed minimum number of branches (6.75) whereas treatment T_1 observed maximum number of branches (11.917). In treatment T_1, variety V_3 showed maximum number of branches (12.8) which was at par with variety V_2 (12.4) over rest of the treatments, while minimum number of branches were produced by variety V_4 (5.933) in treatment T_2.

4. Further study revealed that, number of leaves rapidly increased with the age of advancing the crop up to 60 DAS, whereas gradually decreased in all stressed treatment conditions. The plants from treatment T_1 (absolute control condition) showed maximum number of leaves (16.133), whereas treatment T_2 showed minimum number of leaves (10.167) as compared to the other stress treatment. Variety V_1 recorded (18.200) increased in the number of leaves under non stress treatment T_1. Thus treatment T_4 (13.917) showed the maximum number of leaves as compared to treatment T_3 and T_5, indicating the morphologically better performance of all critical growth stages treatment. In treatment T_1 (absolute control condition), variety V_1 observed maximum number of leaves (18.200) over rest of the treatments, while treatment T_2, minimum number of leaves was produced by variety V_4 (8.867) which was at par with variety V_2 (9.533).

5. Among the different water stress treatment, the results demonstrate that, there was a huge variety of difference among the treatments, yet mean leaf area per plant varied at all stages of plant growth. The leaf area per plant was highest at 60 days after sowing and lowest at harvest. At 60 DAS, under water stress condition maximum leaf area was recorded in treatment T_1 (79.55 dm^2) followed by treatment T_4 (73.29 dm^2) while minimum leaf area per plant was recorded in treatment T_2 (47.82 dm^2). In treatment T_1 maximum leaf area per plant was observed in variety V_3 (88.69 dm^2) which was at par with variety V_2 (88.22 dm^2), under water stress condition, in treatment T_2 (severe stress) maximum leaf area per plant was observed in variety V_2 (48.60 dm^2) which was at par with V_1 (47.84 dm^2) at 60 DAS.

6. It was revealed that, there was significant difference in total chlorophyll content within treatments and that was highest at the 60 DAS of crop growth and then began to decline. Maximum total chlorophyll content was recorded in treatment T_1 (14.070 mg/g) while minimum total chlorophyll content was recorded in treatment T_2 (9.812 mg/g) at 60 days after sowing, under water stress condition. The variety V_2 (15.687 mg/g) showed increase total chlorophyll content over all other variety in treatment T_1 while variety V_4 (7.420 mg/g) showed decrease total chlorophyll content in treatment T_2. Under water stress condition, treatment T_1 followed by T_4 showed maximum total chlorophyll content (11.378 mg/g) as compared to treatment T_3 and treatment T_5 produced lower total chlorophyll content (10.810 mg/g and 11.304 mg/g) at 60 DAS. Total chlorophyll content was decreased at the time of harvesting.

7. The result showed that, the proline accumulation was maximum under treatment T_2 (severe stress/ no irrigation) than control condition treatment T_1 and irrigation at critical growth stages such as treatment T_3, T_4 and $T_{5.}$ At harvest further treatment $T_{2,}$ variety V_2 recorded (1.1510 µmol/g) higher proline accumulation than that of the all over variety. In other word stress tolerant variety showed a tendency to generate a better amount of proline under water stress condition. Consequently, from above biochemical studies, it could be inferred that chlorophyll content and proline content could be taken as one of the parameter while analysed for water stress.

8. As the crop growth preceeds relative water content was found the actual water content to its maximum turgidity. It was recorded that plants under control condition, treatment T_1 had maintained higher relative water content as compared to plants under water stress condition, treatment T_2. Significantly highest relative water content was found in variety V_2 (92.38%) while lowest relative water content was found in variety V_4 (86.29%) under water stress condition in treatment T_1 at 60 DAS. Maximum relative water content was recorded in variety V_2 (68.23%) and minimum in variety V_4 (55.37%) in treatment T_2 (severe stress) under water condition, at 60 DAS.

9. The chlorophyll stability index increased with advancing age of crop, reaching its peak during the first 60 days of crop growth and then decreased. Chlorophyll stability index was maximum in treatment T_1 (68.50 %) and minimum in treatment T_2 (57.51 %) under water stress at 60 days after sowing. In treatment $T_{1,}$ highest chlorophyll stability index was in variety V_2 (70.26 %) whereas lowest chlorophyll stability index was in variety V_4 (66.58 %) at 60 DAS. In treatment T_2, highest chlorophyll stability index was in variety V_2 (59.45 %) while lowest chlorophyll stability index was variety V_4 (54.44 %) at 60 DAS.

10. There was significant difference in total dry matter production among the all treatments examined at various phases of crop growth. The total dry weight increased gradually as crop age increased. The distribution of dry matter studies across various plant parts such as leaves, stems, and roots varied among all treatments. Under water stress condition, treatment T_2 generated minimum total dry weight (15.61 g) while maximum total dry weight was generated by the treatment T_1 (43.85 g) at the time of harvest. Maximum total dry weight was generated by Variety V_3 (45.48 g) and minimum total dry weight was produced by variety V_4 (41.41 g) at harvest, in treatment T_1. Whereas minimum total dry weight was recorded by variety V_4 (14.36 g) in treatment T_2 and maximum total dry weight was recorded by variety V_2 (16.24 g) at the time of harvest.

11. At different crop growth stages and treatments, leaves dry weight varied significantly. At 20 DAS, leaves dry weight was more followed by stem dry weight and root dry weight. An increase in leaves dry weight was recorded up to harvesting stage. Under water stress condition, maximum leaves dry weight was recorded in treatment T_1 (22.707 g) while minimum leaves dry weight was recorded in treatment T_2 (4.189 g) at the time of harvest. At harvesting stage, maximum leaves dry weight was noted in variety V_2 (23.575 g) and minimum leaves dry weight was observed in variety V_1 (20.366 g), in treatment T_1 (absolute control condition). At harvest, maximum leaves dry weight was recorded in variety V_2 (4.774 g) in treatment T_2 (no irrigation) whereas minimum leaves dry weight was recorded in variety V_1 (3.145 g)

12. The data revealed that, there was a significant difference among all treatments in stem dry weight. Treatment T_1 recorded maximum stem dry weight (2.4485 g) and treatment T_2 noted minimum stem dry weight (1.4543 g) under water stress condition. In treatment T_1 maximum stem dry weight was produced in variety V_3 (2.9777 g) whereas minimum stem dry weight was recorded in variety V_1 (1.9962 g) as compared to treatment T_3, T_4 and $T_{5.}$ Under water stress condition, stem dry weight in treatment T_2 was showed the minimum value in variety V_1 (1.4436 g) while maximum value in variety V_3 (1.464 g) at harvest.

13. It was observed that, root dry weight varied significantly at different growth stages of crop among all treatments. As the crop age gradually increased root dry weight increased in a progressive manner up to harvest. The maximum root dry weight was recorded in treatment T_1 (0.8749 g) and minimum root dry weight was observed in treatment T_2 (0.3270 g) at the time of harvest, under water stress condition. At harvest, maximum root dry weight was noted in variety V_1 (0.9845 g) and minimum root dry weight was observed in variety V_2 (0.6840 g), in treatment T_1 (control condition). At harvest,

maximum root dry weight was recorded in variety V_3 (0.3641 g) in treatment T_2 (no irrigation) whereas minimum root dry weight was recorded in variety V_1 (0.2855 g).

14. Among the different water stress treatment, the results demonstrate that there was a huge variety of difference among the treatments, yet mean leaf area per plant varied at all stages of plant growth. The leaf area per plant was highest at 60 days after sowing and lowest at harvest. At 60 DAS, under water stress condition maximum leaf area was recorded in treatment T_1 (79.55 dm^2) followed by treatment T_4 (73.29 dm^2) while minimum leaf area per plant was recorded in treatment T_2 (47.82 dm^2). In control condition maximum leaf area per plant was observed in variety V_3 (88.69 dm^2) which was at par with V_1 (88.22 dm^2), under water stress condition, treatment T_2 (severe stress), maximum leaf area per plant was observed in variety V_3 (54.17 dm^2) at 60 DAS.

15. The further, study revealed that leaf area index (LAI) rapidly increased up to 60 DAS, thereafter gradually decreased in water stressed treatment. Plants recorded higher leaf area index (1.7668) and (1.6285) over plants under treatment T_1 and treatment T_4 than the treatment T_3 and T_5 under water stressed conditions. Plants recorded lower leaf area index (1.0627) under treatment $T_{2.}$ Variety V_3 showed lower reduction in leaf area index under treatment T_1 (1.9627) and treatment T_4 (1.8612), followed by variety V_1 (1.9607) and (1.7744) than all other variety studied, indicating the ability of the variety to move with stand under water stress condition.

16. Specific leaf weight showed significant variation among all treatments under water stress condition. SLW was maximum in treatment T_1 (0.4642 g/dm^2) and minimum in treatment T_2 (0.1271 g/dm^2) under water stress at 60 days after sowing. In treatment $T_{1,}$ highest SLW was in variety V_2 (0.4844 g/dm^2) whereas lowest SLW was in variety V_1 (0.3760 g/dm^2) at 60 DAS. In treatment T_2, highest SLW was in variety V_4 (0.1532 g/dm^2) while lowest SLW was variety V_1 (0.1006 g/dm^2) at 60 DAS.

17. Among five different water stress treatments, absolute growth rate (AGR) increased rapidly up to 40-60 DAS and decreased in at the time of harvesting. Positive and highly significant association of AGR with grain yield was showed in plants under treatment T_1 during the period 40 to 60 DAS. Among the four variety under five different water stress conditions studied, at 40-60 DAS, variety V_2 showed lower reduction in AGR under treatment T_1 (0.7801 g/day) and treatment T_4, variety V_1 (0.7332 g/day) than all other variety respectively, indicating the sustainability of genotypes more robustly under water stress conditions.

18. Decreased RGR was recorded as crop growth increase. Higher relative growth rate was showed in treatment T_1 (0.01714 g/g/day) and lower relative growth rate was showed in treatment T_2 (0.00328 g/g/day) under water stress condition at 60 DAS to harvest. At the time of harvesting, maximum RGR was in variety V_4 (0.01818 g/g/day) while minimum RGR was in variety V_2 (0.01587 g/g/day) under treatment T_1 followed by treatment T_4 maximum RGR was in variety V_2 (0.00503 g/g/day) whereas minimum RGR was in variety V_1 (0.00415 g/g/day) under water stress condition.

19. Net assimilation rate resulted significant variation among all treatments under water stress condition. NAR was highest at 40 to 60 DAS and it was lowest at 60 DAS to at harvest. Maximum value of NAR was observed in treatment T_1 (0.00608 g/dm^2/day) and minimum value was in treatment T_2 (0.00241 g/dm^2/day), under water stress condition at 60 DAS to at harvest. Variety V_4 (0.00655 g/dm^2/day) showed highest NAR whereas variety V_3 (0.00591 g/dm^2/day) showed lowest NAR in treatment T_1 at 60 DAS to at harvest. Under water stress condition, variety V_3 (0.00265 g/dm^2/day) showed highest NAR whereas variety V_1 (0.00213 g/dm^2/day) showed lowest NAR in treatment T_2 at 60 DAS to at harvest.

20. The average leaf area ratio increase gradually up to 40-60 DAS. LAR was maximum in treatment T_1 (6.255) and minimum in treatment T_2 (1.965) under water stress at 60 days after sowing. Under water stress condition, treatment $T_{1,}$ highest LAR was in variety V_2 (5.905) whereas lowest LAR was in variety V_4 (5.109) at 60 DAS. In treatment T_2, highest LAR was in variety V_3 (2.158) also in variety V_1 (2.158) while lowest LAR was variety V_2 (1.642) as compared to rest of the variety, indicating the higher efficiency of this variety for maintaining high photo-synthetically active tissues at critical growth stages at 60 DAS.

21. It was showed that there was less difference in days to flowering initiation. Days to flowering initiation under water stress condition were found to be lowest in treatment T_2 (44.17 days) and highest in treatment T_1 (48.50 days). Under water stress condition in treatment T_2 (severe stress), days to flower initiation were found to be lowest number of days in variety V_2 (38.33 days), and highest number of days in variety V_4 (48.33 days). Whereas, in treatment T_1 (absolute control condition), days to flower initiation was found to be lowest in variety V_2 (41.67 days), and highest in variety V_4 (52.67 days) followed by treatment T_4 variety.

22. The number of days required to 50 per cent flowering varies significantly amongst all treatments under water stress condition. Under water stress condition, minimum days required for 50 per cent flowering were in the treatment T_2 *i.e.* severe stress (51.25

days) and maximum days required in treatment T_1 (55.50 days) over the rest of the other treatment T_3, T_4 and T_5. In treatment T_2, minimum days to 50 per cent flowering were in variety V_2 (45.33 days) and maximum days required was in variety V_3 (54.67 days). In treatment T_1, minimum days to 50 per cent flowering were in variety V_2 (48.67 days) and maximum days required was in variety V_4 (60.67 days). In treatment T_2, all varieties were earliest to flowering and showed less reduction for days to flowering as compared to other stress treatments.

23. The days required for physiological maturity significantly different from one another and from the control. Under water stress condition minimum days required for physiological maturity were in treatment T_2 (70.67 days) and considerably maximum days required for physiological maturity were in the treatment T_1 (75.83 days). In treatment T_1, all four varieties were showed less variation between days to physiological maturity, in treatment T_2, minimum days required for days to physiological maturity were in the variety V_2 (61.33 days) while maximum days required for physiological maturity were in the variety V_4 (75.67 days). In treatment T_1, maximum days required for days to physiological maturity in the variety V_4 (80.33 days) while minimum days required for physiological maturity was in the variety V_2 (68.67 days)

24. It was observed that, number of pods per plant noted significantly difference among all treatments at harvest. Maximum number of pods were showed in treatment T_1 (7.35), while minimum number of pods were showed in treatment T_2 (2.71) over rest of the all treatments. In treatment T_1, maximum number of pods were in variety V_3 (8.40) while minimum number of pods were in variety V_4 (6.40) under water stress condition. In treatment T_2, minimum number of pods were in variety V_4 (2.26) while maximum number of pods was in variety V_3 (3.40).

25. It was studied that, there was a significant variation in number of seeds per plant among all treatments under water stress at harvest. Maximum number of seeds per plant was in treatment T_1 (48.00) whereas minimum was in treatment T_2 (15.73) under water stress condition. In treatment T_1, maximum number of seeds per plant was in variety V_3 (68.60) and minimum number of seeds per plant was in variety V_4 (38.33) under water stress condition. In treatment T_2, minimum number of seeds per plant was in variety V_4 (12.67) while maximum number of seeds per plant was in variety V_3 (19.93). In treatment T_4, number of seeds per plant which showed less reduction than other two treatment T_3 and T_5.

26. This study resulted that, seed yield per plant there was significantly different among all treatments. Significantly higher seed yield was obtained in treatment T_1 (5.59 g) and

lower seed yield per plant was in treatment T_2 (1.56 g), under water stress condition. In treatment T_1, maximum seed yield per plant was in variety V_3 (8.53 g) and minimum seed yield per plant was in variety V_4 (3.61 g) under water stress condition. In treatment T_2, minimum seed yield per plant was in variety V_4 (1.12 g) while maximum seed yield per plant was in variety V_3 (2.51g). In treatment T_4, seed yield per plant which showed less reduction than other two treatment T_3 and T_5.

27. It was noted that, there was significant variation in 100 seed weight among all treatments. Under water stress condition, maximum 100 seed weight was showed in treatment T_1 (11.70 g) which was at par with treatment T_4 and T_5 over rest of the treatments while minimum 100 seed weight was in treatment T_2 (8.36 g). In treatment T_2, maximum 100 seed weight was in variety V_3 (10.36 g) and minimum 100 seed weight was in variety V_2 (6.64 g) under water stress condition. In treatment T_1, minimum 100 seed weight was in variety V_2 (10.97 g) while maximum 100 seed weight was in variety V_3 (12.76 g).

28. The result recorded in harvest index shows significant variation among all treatments under water stress. Under water stress condition, highest harvest index was in treatment T_1 (12.63 %) which was at par with treatment T_4 (11.56 %) over rest of the treatments whereas lowest harvest index was observed in treatment T_2 (7.69 %). In treatment T_2, highest harvest index was in variety V_3 (9.87 %) and lowest harvest index was in variety V_4 (6.02 %) under water stress condition. In treatment T_1, lowest harvest index was in variety V_4 (8.80 %) while highest harvest index was in variety V_3 (18.56 %).

CONCLUSION

Following conclusions can be drawn from the results of present investigation.

In the current investigation, there was a wide range of variability for the different morpho-physiological and biochemical parameters among four genotypes (Konkan Safed, Konkan Sadabahar, Phule Sonali, Phule Rukmini) of cowpea studied, under five different water stress treatments. Under water stress condition, treatment T_2 (severe stress) was showed a decrease in yield and yield attributing components. In treatment T_2, variety V_3 followed by variety V_1 recorded high yield. By maintaining a higher relative water content, treatment T_1 increased amount of water productivity. Among all treatments, T_1 (absolute control) was found to be significantly superior followed by treatment T_4 (at flowering stage) reported better performance in context with plant height, number of branches, number of leaves, leaf area per plant, total chlorophyll content, relative water content, chlorophyll stability index, total dry matter, leaf area index, specific leaf weight, absolute growth rate, relative growth rate, net assimilation rate, leaf area ratio along with highest yield and yield attributing components like number of pods, number of seeds per plant, 100 seed weight, seed yield per plant and harvest index when compared with rest of the treatments. In treatment T_2 (severe stress) was showed high proline accumulation compared to other stress treatments. Irrigation at flowering stage (T_4) was found to be most effective treatment than irrigation at branching stage (T_3) and irrigation at pod filling stage (T_5). Thus, the current study revealed that, the use of irrigation at their vegetative and critical growth stages of plant growth like irrigation at branching stage, irrigation at flowering stage, irrigation at pod filling stage was beneficial enhancing the yield of cowpea grown under water stress condition. Among all varieties, variety V_3 (Phule Sonali) followed by variety V_2 (Konkan Sadabahar) found to be relatively moisture stress tolerant since yield reduction was comparatively less. It will be better to include the data on yield reduction (%) in different genotypes under various moisture stress treatments.

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APPENDICES

APPENDIX I

Meteorological observation during the period of experiment Rabi, 2022-2023 at Dapoli

Period	MW	T_{max} (^0C)	T_{min} (^0C)	RH-I (%)	RH-II (%)	Rainfall (mm)	RD day	BSS (hrs.)
17.12 - 23.12	51	30.2	15.5	94	56	0.0	0	6.8
24.12 - 31.12	52	30.6	16.2	95	63	0.0	0	6.7
01.01 - 07.01	1	32.0	18.5	96	66	0.0	0	5.3
08.01 - 14.01	2	32.7	19.3	94	61	16.4	2	5.9
15.01 - 21.01	3	32.4	15.6	94	54	0.0	0	7.8
22.01 - 28.01	4	31.5	12.9	94	49	0.0	0	8.4
29.01 - 04.02	5	32.7	12.8	91	47	0.0	0	8.6
05.02 - 11.02	6	33.4	11.2	88	54	0.0	0	9.3
12.02 - 18.02	7	31.5	14.1	92	65	0.0	0	8.3
19.02 - 25.02	8	33.3	15.2	88	55	0.4	0	7.3
26.02 - 04.03	9	35.8	15.0	86	51	0.0	0	9.8
05.03 - 11.03	10	35.0	14.9	91	48	0.0	0	9.4
12.03 - 18.03	11	34.3	16.2	87	49	0.0	0	9.0
19.03 - 25.03	12	34.4	17.2	86	46	0.0	0	8.1
26.03 - 01.04	13	36.2	17.4	84	53	0.0	0	9.2
02.04 - 08.04	14	33.1	18.8	88	60	0.0	0	8.9
09.04 - 15.04	15	34.3	20.1	87	62	0.0	0	7.9

BSS*: Bright Sun Shine hours

RH I: Morning Relative Humidity

RH II: Evening Relative Humidity

T max: Temperature Maximum

T min: Temperature Minimum

THESIS ABSTRACT

a)	Title of the thesis	:	"Evaluation of Cowpea (*Vigna unguiculata* (L.) Walp) Genotypes under Water Stress Condition in Konkan Region"
b)	Full name of the student	:	Miss. Pooja Changdeo Jadhav
c)	Name and address of the major advisor	:	Dr. J. S. Tumdam College of Horticulture, Mulde. Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli
d)	Degree to be awarded	:	M.Sc. (Agri.)
e)	Year of award of degree	:	2023
f)	Major subject	:	Plant Physiology
g)	Total number of pages in the thesis	:	112
h)	Number of words in the abstract	:	530
i)	Signature of student	:	
j)	Signature, name and address of forwarding authority	:	HEAD, Department of Agril. Botany Dr.B.S.Konkan Krishi Vidyapeeth Dapoli, Dist.Ratnagiri (415712)

The present investigation entitled "Evaluation of cowpea (*Vigna unguiculata* (L.) Walp) under water stress condition in Konkan region" was carried out at Research and Education farm, Department of Agricultural Botany, College of Agriculture, Dapoli during the *rabi* 2022-23. The experiment was carried out in different water stress treatment such as T_1, T_2, T_3, T_4, T_5 *i.e.* (regular irrigation, no irrigation, irrigation at branching stage, irrigation at flowering stage, irrigation at pod filling stage) with four genotypes such as V_1, V_2, V_3, V_4 *i.e.* (Konkan Safed, Konkan Sadabahar, Phule Sonali, Phule Rukmini). Cultivation of these genotypes was grown in strip plot design with three replications. Observations were recorded in context with morphological, physiological, biochemical, phenological and yield attributing parameters. There was a broad range of variability for the different morpho-physiological and biochemical characteristics among all treatments under water stress condition.

Among the different water stress treatment, treatment T_1 recorded maximum plant height, number of branches, number of leaves, leaf area, total chlorophyll content, relative water content, chlorophyll stability index, total dry matter, leaf area index, specific leaf weight, absolute growth rate, relative growth rate, net assimilation rate, leaf area ratio, and yield attributing characters. Accumulation of maximum proline was found at treatment T_2.

Among the four variety used for study, variety V_3 recorded maximum plant height, number of branches, leaf area, total dry matter, leaf area index, absolute growth rate, relative growth rate, leaf area ratio, no. of pods per plant, no. of seeds per plant, seed yield per plant, 100 seed weight and harvest index. While considering the drought tolerant capacity of variety V_2 had higher accumulation of proline content and relative water content at severe water stress (treatment T_2). Among all treatments, treatment T_1 recorded better performance in context with all the characters followed by treatment T_4 as compared to other stress treatment such as treatment T_2, T_3, T_5. When compared to yield attributing characters in four varieties, variety V_3 recorded high yield in treatment T_1, owing to their high efficiency to produce maximum economic yield.

Among all interaction treatment T_1V_3 was found to be significantly superior reporting better performance in context with plant height, number of branches, number of leaves, leaf area, total chlorophyll content, relative water content, chlorophyll stability index, total dry matter, leaf area index, specific leaf weight, absolute growth rate, relative growth rate, net assimilation rate, leaf area ratio, along with highest yield and yield attributing components *viz.* no. of pods per plant, no. of seeds per plant, seed yield per plant, 100 seed weight and harvest index when compared with over rest of the all treatments. The treatment T_2V_2 had higher accumulation of proline content and relative water content due to its high drought tolerant capacity.

Wide range of variability exists for different morpho-physiological and biochemical parameters among four varieties of cowpea under different water stress condition. This information may be helpful for better understanding of concept of critical stages of vegetative and reproductive growth and its application to the effect of water stress at various aspects of growth and yield of cowpea. It can be employed for the improvement programme as well as efficient management practices for cowpea in moisture stress condition.

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PC Jadhav
M.Sc. Student, Department of Agricultural Botany, College of Agriculture, Dr. B. S. Konkan Krishi Vidyapeeth, Dapoli, Ratnagiri, Maharashtra, India

JS Tumdam
Assistant Professor, College of Horticulture Mulde, Dr. B. S. Konkan Krishi Vidyapeeth, Dapoli, Ratnagiri, Maharashtra, India

AV Mane
Deputy Director of Research (Seed), Dr. B. S. Konkan Krishi Vidyapeeth, Dapoli, Ratnagiri, Maharashtra, India

UB Pethe
Associate Professor (CAS), Department of Agricultural Botany, College of Agriculture, Dr. B. S. Konkan Krishi Vidyapeeth, Dapoli, Ratnagiri, Maharashtra, India

RV Dhopavkar
Deputy Director of Research (Agri), Dr. B. S. Konkan Krishi Vidyapeeth, Dapoli, Ratnagiri, Maharashtra, India

RR Salunkhe
PhD Scholar, Department of Plant Physiology, Indian Agricultural Research Institute, Pusa Campas, New Delhi, India

Corresponding Author:
PC Jadhav
M.Sc. Student, Department of Agricultural Botany, College of Agriculture, Dr. B. S. Konkan Krishi Vidyapeeth, Dapoli, Ratnagiri, Maharashtra, India

Evaluation of cowpea (*Vigna unguiculata* (L.) Walp) genotypes under water stress condition in Konkan region

PC Jadhav, JS Tumdam, AV Mane, UB Pethe, RV Dhopavkar and RR Salunkhe

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Abstract
The field experiment was conducted during *rabi* season 2022 at Research and Education farm, Department of Agricultural Botany, College of Agriculture, Dapoli to evaluate the cowpea *(Vigna unguiculata* (L.) Walp) genotypes under water stress condition in Konkan region. The field experiment was laid out in strip plot design comprising five different water stress treatments with four genotypes replicated thrice. The result revealed that, the yield attributing characters of cowpea is highest in treatment T_1 as compared other water stress treatment and when we consider about four different varieties, the variety V_3 recorded highest yield attributing characters such as No. of pods per plant, No. of seeds per plant, 100 seed weight and harvest index.

Keywords: Treatment, variety, cowpea, water stress, yield

Introduction

Cowpea (*Vigna unguiculata* (L.) Walp) is most important legume crop in Asia, Africa, Australia and grown throughout the region of semiarid tropics of Asia, Africa, Southern Europe (Timko *et al.*, 2007) [17]. The origin of cowpea is west and central region of Africa. The other names of cowpea are *chawali,* Southern Pea, etc. belonging to family *leguminaceae* (Mackie and Smith, 1935) [10].

Cowpea is used for fodder purpose makes an important contribution to feed supplies for animals to maintain their health in dry season. (Quin, 1997) [14] It is also called as Poor man’s meat. The green tender pod has 84.9% moisture, 4.3% protein, 8.0% carbohydrates, 2% fats (Aykroyd, 1963) [3]. Cowpea seeds contain on an average 21.0-26.7% of protein (Weng *et. al.* 2017) [18] and 2.2% lipid (Frota *et al.* 2008) [5].

Cowpea is grown in different types of climatic conditions. It is an annual crop that is adapted to warm conditions and sensitive to chilling. It is 750 to 1100 mm rainfall ranges, grow well in low rainfall and diseases and pests attack increase due to high rainfall. The temperature requirement of cowpea lies between 21-35 °C. Through the symbiotic bacteria, cowpea fixes atmospheric nitrogen to the extent of 563 kg ha^{-1}.

In the konkan region, the common pulses such as pigeon pea, horse gram, wal, cowpea and moth bean are sown during late *kharif* or immediately after the end of monsoon. Water stress is one of the major abiotic factors limiting plant growth and crop productivity in South Africa, Semi and Arid countries (Kramer, 1983) [8]. Due to water stress, yield of cowpea is reduced. Other reports stated that the cowpea is sensitive to water deficit during the flowering stage and pod filling stages (Akyeampong 1986) [2]. Water deficit is known as one of the major factors decreasing crop yield in different region.

Generally, water stress occurred to the *rabi*, cowpea shows the reduction in grain yield at the range of 24-89% under mild to severe stress (Patil 1989) [13]. In cowpea, water stress basically affects the plant growth and development and recognized as one of the most important factors influencing crop yield (Kramer and Boyer 1995) [9].

Materials and Methods

The present study was carried out at Research and Education farm, Department of Agricultural Botany, College of Agriculture, Dr. B.S.K.K.V. Dapoli (MH) during rabi season of 2022. The field experiment was laid out in five treatments with four genotypes. Cultivation of these genotypes was grown in strip plot design with three replications. The water stress treatments were imposed at five different levels. In first water stress treatment (T_1), crop was grown on absolute control condition means the regular irrigation from sowing to maturity. In second water stress treatment (T_2), cowpea crop was grown on available soil moisture stress from sowing to harvesting. In third water stress treatment, irrigation was done at only branching stage. In fourth water stress treatment (T_4), irrigation was done only at flowering stage. In fifth water stress treatment (T_5), irrigation was done only at pod filling stage. The experiment comprised of four varieties of cowpea such as Konkan Safed (V_1), Konkan Sadabahar (V_2), Phule Sonali (V_3), Phule Rukmini (V_4).

Result and Discussion

The results pertaining in the present study is presented in table 3. Plant yield is based on total assimilation during the growing season and how it is distributed between the designated storage structures and the rest of the plant. Yield is a compound character made up of the sum of the contributions produced by various physiological traits. It is the net economic gain from the source and sink capacity, as per point of view of plant physiologist. The present investigation of yield attributing characters was presented under the following heads.

Number of pods per plant

It is important factor that is directly affects the number of pods produced per plant is the pod yield per plant. The increase plant height and number of branches per plant may be the cause of the increase in the number of pods produced per plant. There were significant differences in the number of pods per plant recorded at harvest for all treatments. Maximum number of pods was recorded in treatment T_1 (7.35) which was followed by treatment T_4 (5.35) and treatment T_5 (4.36) over rest of the all treatments. However, minimum number of pods per plant was observed in treatment T_2 (2.71), under water stress condition. Among four varieties in treatment T_1, Variety V_3 (8.40) was noted consequently highest number of pods per plant all over other varieties followed by variety V_2 (7.60). However, in treatment T_2, variety V_4 (2.26) noted the minimum number of pods per plant. Similar results were reported by Parab (1991) [12] in cowpea, Shinde (1998) [16] in five legumes crop, Abidoye (2004) [1] in cowpea, Futuless and Bake (2009) [6] in cowpea, Kardile (2011) [7] in cowpea, Menon and Savitri (2015) [11] in cowpea, Ricardo Santas *et al.*, (2020) [15] in cowpea crop.

Number of seeds per plant

Number of seed per plant is desired character which has direct effect over number of pods per plant. It was noted that there is a significantly different in number of seeds per plant among all treatments under water stress. Maximum number of seeds per plant was noted in treatment T_1 (48.00) which was followed by treatment T_4 (36.68) and treatment T_5 (28.75) over rest of the all treatments. However, minimum number of seeds per plant was observed in treatment T_2 (15.73), under water stress condition. Among four varieties in treatment T_1, Variety V_3 (68.60) was noted consequently highest number of seeds per plant all over other varieties followed by variety V_2 (46.13). However, in treatment T_2, variety V_4 (12.67) noted the minimum number of seeds per plant. Similar results were recorded by Parab (1991) [12] in cowpea, Shinde (1998) [16] in five legumes crop, Abidoye (2004) [1] in cowpea, Kardile (2011) [7] in cowpea, Menon and Savitri (2015) [11] in cowpea, Ricardo Santas *et al.*, (2020) [15] in cowpea.

Table 1: Influence of different water stress treatments on yield attributing characters at various stages of plant growth of cowpea grown under water stress condition

Genotypes	Treatments of water stress						SE ±	CD at 5%
	T_1	T_2	T_3	T_4	T_5	Mean		
No. of pods per plant								
V_1	7.00	2.40	3.40	5.00	4.00	4.36	V. 0.0133	0.0461
V_2	7.60	2.80	3.80	5.60	4.60	4.88	T. 0.0091	0.0298
V_3	8.40	3.40	4.40	6.40	5.40	5.60	T x V 0.0183	0.0533
V_4	6.40	2.26	3.20	4.40	3.46	3.94		
Mean	7.35	2.71	3.70	5.35	4.36	4.69		
No. of seeds per plant								
V_1	38.93	14.40	25.47	30.53	27.87	27.44	V. 0.2634	0.9115
V_2	46.13	15.93	26.47	42.67	27.93	31.83	T. 0.3247	1.0590
V_3	68.60	19.93	34.73	43.93	35.73	40.59	T x V 0.6129	1.7890
V_4	38.33	12.67	22.87	29.60	23.47	25.39		
Mean	48.00	15.73	27.38	36.68	28.75	31.31		
100 seed weight (g)								
V_1	12.14	8.37	9.28	11.41	10.55	10.35	V. 0.1071	0.3706
V_2	10.97	6.64	7.54	8.67	8.21	8.37	T. 0.1619	0.5279
V_3	12.76	10.36	11.20	11.69	11.39	11.48	T x V 0.1935	0.5647
V_4	11.09	8.09	8.19	9.56	8.93	9.17		
Mean	11.70	8.36	9.05	10.33	9.77	9.84		
Harvest index (%)								
V_1	12.44	8.40	8.49	10.86	11.27	10.29	V. 0.2291	0.7927
V_2	10.72	6.50	7.22	9.96	8.65	8.16	T. 0.2932	0.9562
V_3	18.56	9.87	17.20	17.02	14.42	15.41	T x V 0.7413	2.1637
V_4	8.80	6.02	7.49	8.41	6.60	7.46		
Mean	12.63	7.69	10.10	11.56	10.23	10.47		

V. - Variety T. - Treatment T. x V. - Treatment x Variety

100 seed weight (g)
100 seed weight is another important factor which indicates yield of the crop. In current study, variation in 100 seed weight was observed among all water stress treatments. In present study, under water stress condition significantly maximum 100 seed weight was found in treatment T_1 (11.70 g) which was followed by treatment T_4 (10.33 g) and treatment T_5 (9.77 g) over rest of the all treatments. However, minimum 100 seed weight was observed in treatment T_2 (8.36 g). Among four varieties in treatment T_1, Variety V_3 (12.76 g) was noted consequently highest 100 seed weight all over other varieties followed by variety V_1 (12.14 g). However, in treatment T_2, variety V_2 (6.64 g) noted the minimum 100 seed weight. Similar results were recorded by Parab (1991) [12] in cowpea, Shinde (1998) [16] in five legumes crops, Abidoye (2004) [1] in cowpea, Kardile (2011) [7] in cowpea, Menon and Savitri (2015) [11] in cowpea, in lablab, Ricardo Santas *et al.*, (2020) [15] in cowpea.

Harvest index (%)
Although, the importance of both seed and biomass production, seed yield is more important than biomass production; as a result, the relationship between seed and biomass has to be studied. Harvest index means the percentage of biological yield represented by economic yield. Donald (1962) [4] gives the term of harvest index as the ratio of grain weight to the total dry weight of above ground parts at harvest of the crop. Since each crop's yield is influenced by its capacity to produce dry matter partitioning of economic and non-economic parts, is interest to plant researchers, because the yield of any crop was depend on the its capacity to produce dry matter production and its efficient partitioning between the economic and noneconomic parts.

In present study, highest mean harvest index was observed in treatment T_1 (12.63%), followed by treatment T_4 (11.56%) while lowest harvest index was observed in treatment T_2 (7.69%). Among four varieties in treatment T_1, variety V_3 (18.56%) was noted consequently highest harvest index all over other varieties followed by variety V_3 (17.20%) in treatment T_3. However, in treatment T_2, variety V_4 (6.02%) noted the minimum harvest index. Similar results were recorded by Parab (1991) [12] in cowpea, Shinde (1998) [16] in five legumes crops, Abidoye (2004) [1] in cowpea, Kardile (2011) [7] in cowpea, Menon and Savitri (2015) [11] in cowpea, Ricardo Santas *et al.*, (2020) [15] in cowpea.

Conclusion
Among all treatments, T_1 was found to be significantly superior followed by treatment T_4 reported better performance in context with highest yield attributing components like number of pods, number of seeds per plant, 100 seed weight and harvest index when compared with rest of the treatments.

Thus, the current study revealed that, the use of irrigation at their vegetative and critical growth stages of plant growth like irrigation at branching stage, irrigation at flowering stage, irrigation at pod filling stage was enhanced the yield of cowpea grown under water stress condition. Among all treatments, variety V_3 followed by variety V_2 enhanced the yield of cowpea grown under water stress condition.

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Dr. Balasaheb Sawant Konkan Krishi Vidyaapeeth,

Certificate of Plagiarism Check for Thesis

Author Name	Pooja Changdeo Jadhav
Course of Study	M. Sc. Agri.
Name of Guide	Dr. J. S. Tumdam
Department	Plant Physiology
Acceptable Maximum Limit	50
Submitted By	mgpalshetkar@dbskkv.ac.in
Paper Title	Evaluation of Cowpea genotypes under water stress condition in Konkan region
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Signature of Guide

Signature of Head of the Department

Associate Dean

VITA

1. Name of Student : **Miss. Pooja Changdeo Jadhav**
2. Father's Name : Shri. Changdeo Dashrath Jadhav
3. Date of Birth : 25/05/1997
4. Name of the College : College of Agriculture, Dapoli
5. Residential address : At /Post: Sarafwadi,
   Taluka: Indapur,
   District: Pune,
   State: Maharashtra,
   Pin Code- 413114.
   Phone Number – 7350709384
6. Email : jadhavpooja1001@gmail.com
7. Academic qualifications :

Sr. No.	Name of Degree awarded	Year in which obtained	Division or Class	Name of awarding university	Subject
1.	B. Sc. (Agri.)	2020	Second	Mahatma Phule Krishi Vidyapeeth, Rahuri	Agriculture

8. Research papers published:

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Date: 11/03/2024

(Miss. Pooja Changdeo Jadhav)

Signature of Student