EFFECT OF HUMIC ACID AND HYDROGEL ON SOIL MOISTURE RETENTION AND PRODUCTIVITY OF *RABI* BLACKGRAM (*Vigna mungo* L.)

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BY

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B.Sc.(Ag.)

THESIS SUBMITTED TO THE ACHARYA N.G.RANGA AGRICULTURAL UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF

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2020

DECLARATION

I, AVULA MANOGNA, hereby declare that the thesis entitled **"EFFECT OF HUMIC ACID AND HYDROGEL ON SOIL MOISTURE RETENTION AND PRODUCTIVITY OF *RABI* BLACKGRAM (*Vigna mungo* L.)"** submitted to the **Acharya N.G. Ranga Agricultural University** for the degree of **Master of Science in Agriculture** is the result of original research work done by me. I also declare that no material contained in the thesis has been published earlier in any manner.

Place**:**	**(AVULA MANOGNA)**
Date:	**I.D. No. GAM/18-20**

CERTIFICATE

Ms**. AVULA MANOGNA** has satisfactorily prosecuted the course of research and that thesis entitled **"EFFECT OF HUMIC ACID AND HYDROGEL ON SOIL MOISTURE RETENTION AND PRODUCTIVITY OF *RABI* BLACKGRAM (*Vigna mungo* L.)"** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that neither the thesis nor its part thereof has been previously submitted by her for a degree of any University.

Date: **(S. PRATHIBHA SREE)**
Chairperson

CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF HUMIC ACID AND HYDROGEL ON SOIL MOISTURE RETENTION AND PRODUCTIVITY OF *RABI* BLACKGRAM (*Vigna mungo* L.)"** submitted in partial fulfillment of the requirements for the degree of '**Master of Science in Agriculture'** of the Acharya N.G. Ranga Agricultural University, Lam, Guntur is a record of the bonafide original research work carried out by **Ms. AVULA MANOGNA** under our guidance and supervision.

No part of the thesis has been submitted by the student for any other degree or diploma. The published part and all assistance received during the course of investigations have been duly acknowledged by the author of the thesis.

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Date: **(AVULA MANOGNA)**

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LIST OF SYMBOLS AND ABBREVIATIONS

%	:	Per cent
@	:	At the rate of
^0C	:	Degree centigrade
a.i.	:	Active ingredient
ASMD	:	Available soil moisture depletion
BCR	:	Benefit cost ratio
BD	:	Bulk density
CD	:	Critical difference
Cm	:	Centimetre
CPE	:	Cumulative pan evaporation
CU	:	Consumptive use
CV	:	Coefficient of variation
DAS	:	Days after sowing
DASM	:	Depletion of available soil moisture
DMA	:	Dry matter accumulation
$dS\ m^{-1}$	:	Deci Siemens per metre
EC	:	Electrical conductivity
E_{pan}	:	Pan evaporation
Etc	:	Crop Evapo-Transpiration
et al.,	:	And others / Co-workers
FC	:	Field capacity
FN	:	Fortnight
Fig.	:	Figure
G	:	Gram
$g\ cc^{-1}$	:	Gram per cubic centimeter
$g\ m^{-3}$	:	Gram per meter cube
$g\ L^{-1}$	:	Gram per litrer
i.e.,	:	That is
IW	:	Irrigation water
IW/CPE	:	Irrigation Water/ Cumulative Pan Evaporation
IWUE	:	Irrigation water use efficiency
K	:	Potassium

kg	:	Kilogram
kg fed^{-1}	:	Kilogram per feddan
kg ha^{-1}	:	Kilogram per hectare
kg m^{-3}	:	Kilogram per cubic metre
kg ha-cm^{-1}	:	Kilogram per hectare centimeter
kg ha-mm^{-1}	:	Kilogram per hectare millimeter
LBG	:	Lam Blackgram
M	:	Metre
m^{-2}	:	Per square metre
m^{-3}	:	Per cubic metre
$m^{3}fed^{-1}$	:	Cubic metre per feddan
Mm	:	Milli metre
mm day^{-1}	:	Milli metre per day
MW	:	Meteorological week
N ha^{-1}	:	Nitrogen per hectare
NS	:	Non significant
pH	:	Potential of Hydrogen ion concentration
q ha^{-1}	:	Quintal per hectare
RH	:	Relative humidity
Rs	:	Rupees
Rs ha^{-1}	:	Rupees per hectare
SEm ±	:	Standard error of mean
SMW	:	Standard meteorological week
t ha^{-1}	:	Tonnes per hectare
USWB	:	United States Weather Bureau
viz.,	:	Namely
WHO	:	World Health Organization
WP	:	Water Productivity
WSD	:	Water soluble dust
WUE	:	Water use efficiency
YVM	:	Yellow Vein Mosaic

ABSTRACT

Author	:	**AVULA MANOGNA**
Title of the thesis	:	**EFFECT OF HUMIC ACID AND HYDROGEL ON SOIL MOISTURE RETENTION AND PRODUCTIVITY OF *RABI* BLACKGRAM (*Vigna mungo* L.)**
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University	:	**ACHARYA N. G. RANGA AGRICULTURAL UNIVERSITY**
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A field trial entitled "**Effect of Humic Acid and Hydrogel on Soil Moisture Retention and Productivity of *Rabi* Blackgram (*Vigna mungo* L.)**" was conducted on clay soils of Advanced Post Graduate Centre, Lam, Guntur during *rabi* 2019-20 using split-plot design and replicated four times with three irrigation schedules *viz.*, one irrigation at pre-flowering stage (I_1), one irrigation at pod formation stage (I_2) and two irrigations at pre-flowering and pod formation stages (I_3) as main plots and three soil amendment treatments *viz*., soil application of Humic acid @ 20 kg ha^{-1} (S_1), Hydrogel @ 2.5 kg ha^{-1} (S_2), Farm Yard Manure @ 5 t ha^{-1} (S_3) as sub plots.

Irrigation and soil amendments significantly influenced the plant height of blackgram at all the stages of crop growth except at 15 DAS. A significant influence of irrigation schedules and soil amendments on number of branches plant^{-1} was found at all stages but not at 30 DAS. Accumulation of dry matter at different crop growth stages was significantly influenced by irrigation schedules and soil amendments. The highest accumulation of dry matter was recorded with two irrigations at pre-flowering and pod formation stages at all crop growth stages and was significantly superior to one irrigation at pod formation stage but comparable with one irrigation at pre-flowering stage at 30 and 45 DAS. Among the soil amendments, soil application of hydrogel @ 2.5 kg ha^{-1} recorded maximum dry matter accumulation and comparable with soil application of humic acid @ 20 kg ha^{-1} and significantly superior to FYM @ 5 t ha^{-1} at all stages of crop growth.

The impact of irrigation and soil amendments on clusters plant^{-1}, pods cluster^{-1} and test weight was found to be significant. However, significant difference in seeds pod^{-1} was not noticed. Maximum number of yield attributes were observed in I_3 and minimum were observed in I_2. Among soil amendments, hydrogel @ 2.5 kg ha^{-1} realized maximum yield attributing parameters and minimum were observed with FYM @ 5 t ha^{-1}. Irrigation and soil amendments interaction on growth, yield and yield

attributes of blackgram was found non significant. The seed yield and haulm were observed to be highest when irrigation was given at I_3 but comparable with I_1 and superior to I_2. Among soil amendments soil application of hydrogel @ 2.5 kg ha^{-1} recorded the highest seed yield which was comparable with humic acid @ 20 kg ha^{-1}. A significant difference in harvest index of blackgram was not noticed with irrigation schedules, soil amendments and their interaction.

Maximum N, P and K uptake was recorded in two irrigations at pre-flowering and pod formation stages. Nitrogen uptake was not influenced by soil amendments. Soil application of humic acid @ 20 kg ha^{-1} recorded maximum uptake of potassium and phosphorus but on a par with hydrogel @ 2.5 kg ha^{-1} and minimum was recorded with FYM @ 5 t ha^{-1} .

Consumptive use of water and daily soil moisture use rate were observed to be highest at two irrigations at pre-flowering and pod formation stages. Water use efficiency was highest with one irrigation at pre-flowering stage which was comparable with one irrigation at pod formation stage, but the influence of soil amendments on water use efficiency of blackgram was non significant. Two irrigations at pre-flowering and pod formation stages and soil application of hydrogel @ 2.5 kg ha^{-1} recorded higher gross returns, net returns and benefit cost ratio.

The present study revealed that two irrigations at pre-flowering and pod formation stages and soil application of hydrogel @ 2.5 kg ha^{-1} was noticed to be better in realizing higher growth, yield and water use efficiency of *rabi* blackgram. However, humic acid @ 20 kg ha^{-1} also showed better performance in achieving higher yields in *rabi* blackgram.

Chapter-I

Introduction

Chapter I

INTRODUCTION

Blackgram (*Vigna mungo* L.) also known as urd bean, mash is a short duration pulse crop cultivated in many regions of India. Blackgram seed contains 60 % carbohydrates, 26 % proteins, 1.5 % fat, minerals combination, amino acids and essential vitamins. India is the largest producer and consumer of blackgram. The per cent share of blackgram to India's total pulse production is 10 %. As per the recommendations of WHO per capita consumption of pulses should be 80 g day^{-1}. But the present consumption is very less i.e only around 40 g day^{-1}. In India blackgram crop occupies an area of 4.5 m ha with a production of 2.8 m t and productivity of 632 kg ha^{-1}. In Andhra Pradesh it is grown in an area of 5 lakh hectares with a production of 3.29 lakh tonnes and productivity of 658 kg ha^{-1} (www.indiastat.com).

The productivity of blackgram is low because the crop is mainly grown in poor and marginal soils having poor fertility status. Lack of water and nutrients during critical stages of crop growth, various physiological and inherent factors associated with the crop might have resulted in lower productivity. Moisture stress at ctritical stages reduces the rate of photosynthesis and uptake of nutrients. Water stress also affects crop phenology, flowering, pod setting and finally results in lower yield. Lack of moisture at the time of flower initiation causes flower abortion, whereas stress at pod filling stage reduces the seed number and seed weight.

Critical growth period is a stage of growth of plant at which moisture stress exercises the greatest influence on both the quantity and quality of produce. Hence, irrigation scheduling technique at critical growth stages assumes greater significance.

Proper supplementation of irrigation at critical periods results in higher water productivity. To exploit the full genetic potentiality of blackgram, use of improved crop management technology can invariably increase the productivity by 50 to 100 per cent (Annadurai *et al*., 2001). Apart from the genetic makeup, the physiological factor *viz.*, insufficient portioning of assimilates, poor pod setting due to the flower abscission and lack of nutrients during critical stages of crop growth, coupled with a number of diseases and pests (Mahala *et al.*, 2001) were the reasons for the poor yield.

Under moisture scarce conditions application of soil amendments may result in efficient absorption and usage of moisture. Humic Acid (HA) is an organic growth stimulant, with positive effects on enzyme activity, plant nutrient absorption. It also increases the infiltration and water-holding capacity of the soil and thereby increases the yield of the crops. The high cation exchange capacity of humic acid prevents nutrients from leaching. It absorbs the nutrients from chemical fertilizers and these exchanged nutrients are slowly released to the plant. The effect of shortage of water can be compensated by increasing the available water in soils by the use of polymers is one best option.

Hydrogels are cross-linked polymers with a hydrophilic group which have the capacity to absorb large quantities of water without dissolving in water. The super absorbent polymer hydrogel potentially influences soil permeability, density, structure, texture, evaporation and infiltration rates of water through the soils.

Hydrogel may be a practically convenient and economically feasible option to achieve the goal of agricultural productivity under conditions of water scarcity. It can be easily applied directly in the soil at the time of sowing of field crops. The information available on soil application of humic acid and hydrogel at different moisture regimes is meagre.

Keeping this in view, the present experiment entitled "**Effect of Humic Acid and Hydrogel on Soil Moisture Retention and Productivity of *Rabi* Blackgram (*Vigna mungo* L.)**" is proposed to study the performance of *rabi* blackgram in clay soils of APGC, Lam, Guntur at different soil moisture regimes with the following objectives.

Objectives of investigation:

1. To study the effect of different irrigation schedules on productivity of blackgram.

2. To study the effect of soil application of humic acid and hydrogel on growth, yield and water use efficiency of blackgram.

3 To study the interaction effect of soil application of humic acid and hydrogel at different irrigation schedules on productivity of blackgram.

Chapter-II

Review of Literature

Chapter II

REVIEW OF LITERATURE

Blackgram is one of the most important pulse crop of Andhra Pradesh. The relevant information available on "Effect of Humic acid and Hydrogel on Soil Moisture Retention and Productivity of *rabi* Blackgram (*Vigna mungo* L.)" is reviewed in this chapter under different sub heads:

2.1 Effect of different irrigation treatments on productivity of field crops

2.2 Effect of soil application of Humic acid, Hydrogel and FYM and on growth, yield and Water use efficiency of field crops

2.3 Interaction effect of soil application of Humic acid and Hydrogel at different irrigation schedules on productivity of field crops

2.4 Effect of irrigation treatments and soil amendments on economics of field crops

2.1 EFFECT OF DIFFERENT IRRIGATION TREATMENTS ON PRODUCTIVITY OF FIELD CROPS

2.1.1 Growth

Arya *et al.* (2005) conducted a field experiment on sandy loam soils of Kanpur, Uttarpradesh and reported that the cumulative pan evaporation (CPE) of 60mm produced significantly higher mean plant height, number of functional leaves and plant dry matter than CPE of 80 mm in chickpea

Abraham *et al.* (2010) reported that application of two irrigations at pre flowering and pod filling stages recorded the highest dry matter accumulation and grain yield of chickpea, on sandy loam soils of Uttarpradesh

Karshanbhai (2010) carried out a field experiment on sandy loam soils at Anand Agricultural University, Gujarat and reported that plant height, No.of branches per plant were highest when irrigation scheduled at 0.8 IW/CPE ratio followed by 0.6 IW/CPE ratio in greengram

Chaudhary *et al.* (2015) conducted a field experiment to study the influence of spacing and scheduling of irrigation on growth, yield, yield attributes and economics of summer greengram and reported that highest plant height (50.33cm) and No. of branches plant^{-1} (5.13) were recorded when irrigation was scheduled at 1.0 IW:CPE ratio followed by 0.8 IW:CPE ratio on sandy loams of Dantiwada Agricultural University, Sardarkrushinagar

Kumbhar *et al.* (2015) conducted a field experiment on loamy sand soils of Anand and reported that growth attributes of *rabi* pigeonpea were significantly influenced by frequent irrigation scheduled at 0.8 IW/CPE ratio. Maximum values of plant height at harvest (145.92 cm), number of branches plant^{-1} (12.1) were recorded under 0.8 IW/CPE ratio

Patel *et al.* (2016) reported that higher values of growth characters like plant height (49.783 cm) and No. of branches plant (3.44) were recorded under irrigation (0.8 IW: CPE ratio) on sandy loam soils of Gujarat

Rao *et al.* (2016) revealed that application of three irrigations at 50 days after sowing, flowering initiation and pod development recorded significantly higher plant height and number of branches plant^{-1} compared to that of less number of irrigations (either two or one) given at critical growth stages of pigeonpea on clay loam soils of RARS, Guntur

Lende and Patil (2017) from Rahuri reported that all growth parameters like plant height (45.60 cm), no. of primary branches plant^{-1} (6.50), Dry matter per plant^{-1} (35.80g), Number of root nodules (22.60) and growth functions viz., absolute growth rate, net assimilation rate, crop growth rate were significantly higher when irrigation applied at branching and pod development stage of chickpea with all furrows irrigated as compared to control.

Purushottam *et al.* (2018) reported that irrigation at branching + pre flowering + pod development stages has significantly increased the growth and yield parameters of chickpea on lateritic soils of West Bengal

Komal *et al.* (2018) reported that irrigation frequencies in significantly influenced the growth parameters like plant height (70.23cm) and number of primary branches plant^{-1} (26.12) in chickpea when irrigation was applied at (pre sowing and flowering stages) compared to other treatments in Udaipur, Rajasthan

Lakshmi *et al.* (2018) conducted field experiment to study the effects of irrigation and foliar nutrition on growth, yield and nutrient uptake of blackgram and reported that irrigation given at vegetative stage (33 DAS) i.e, at 0.5 IW/CPE ratio was found to be better in improving growth parameters like plant height (34.1cm), number of branches plant^{-1} (6.9) and dry matter production (3793 kg ha^{-1}) on sandy loam soils of Agricultural Research Station, Jangamaheswarapuram

Mondal *et al.* (2018) reported that irrigation given at critical stages was found to be better in improving growth parameters like Plant height , No.of branches plant^{-1} and dry matter accumulation (kg ha^{-1}) in greengram on sandy soils of West Bengal.

Shirgapure and Fathima (2018) conducted a field experiment on red sandy loam soils of Mandya, Karnataka and observed plant height (32.44cm), leaf area (32.44%) and dry matter production (36.32%) at harvest were recorded highest with irrigation at 80% CPE followed by irrigation at 100% CPE as compared to recommended practice.

Singh *et al.* (2018) conducted an experiment on sandy loam soils of Madhya Pradesh and reported that irrigation at 0.6 IW/CPE ratio has recorded significantly higher growth parameters like plant height (32.1cm), number of branches plant^{-1} (9.6), number of leaves plant^{-1} (24) in french bean. Irrigation at 0.6 IW/CPE ratio has performed better by 36.1% compared with 0.4 IW/CPE ratio

Jaybhay *et al.* (2019) conducted an experiment on response of Soybean to Irrigation at Different Growth Stages and reported that highest plant height was recorded when irrigation was given at (seedling+ flower initiation+ seed filling stages) on vertisols of Pune.

2.1.2 Yield and Yield Attributes

Arya *et al*. (2005) conducted a field experiment on sandy loam soils of IIPR, Kanpur to study the effect of fertilizers and tillage management in rice-chickpea cropping system under varying irrigation schedules and revealed that three irrigations given at CPE of 60 mm proved beneficial in increasing all the yield attributes of chickpea than two irrigations given at CPE of 80 mm. However, higher grain and straw yields of chickpea were obtained with three irrigations given at CPE of 60 mm than CPE of 80 mm.

Basu and Bandyopadhyay (2009) studied the effect of irrigation at different physiological growth stages like branching (B), flowering (F) and pod formation (P) stages and their different combinations on the yield components and yield of pigeonpea and reported that three irrigations applied one each at branching, flowering and pod formation stages produced the highest seed yield (772 kg ha^{-1}) but it was at par with two irrigations applied at branching and flowering stages (703 kg ha^{-1}) on clay loam soils of Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal

Karshanbhai (2010) carried out a field experiment on sandy loam soils at Anand Agricultural University, Gujarat and reported that yield attributing characters *viz.,* Number of pods $plant^{-1}$, pod length, number of seeds pod^{-1} and seed yield (1133 kg ha^{-1}) and stover yields (2143 kg ha^{-1}) were highest when irrigation scheduled at 0.8 IW/CPE ratio followed by 0.6 IW/CPE ration in greengram

Patel *et al.* (2010) conducted a field experiment on loamy sand soils of Sardarkrushinagar, Gujarat revealed that seed and straw yield increased significantly with increasing levels of irrigation up to 1.0 IW/CPE ratio and recorded 68 and 28 per cent higher seed yield of frenchbean than that of 0.6 and 0.8 IW/CPE ratio.

Chaudhary *et al.* (2015) conducted a field experiment to study the Influence of spacing and scheduling of irrigation on yield and yield attributes of summer greengram and reported that number of pods $plant^{-1}$, pod length, number of seeds pod^{-1}, seed yield and stover yield were observed significantly higher under the irrigation treatment of 1.0 IW:CPE ratio followed by 0.8 IW:CPE ratio on sandy loams of Dantiwada Agricultural University, Sardarkrushinagar

Kumbhar *et al.* (2015) reported that irrigation scheduled at 0.8 IW/CPE ratio recorded highest number of pods per plant (155.42), number of seeds per pod (4.20), 1000 seed weight (121.67 g) and highest seed yield (1677 kg ha^{-1}) and haulm yield (4858 kg ha^{-1}) in pigeonpea on loamy sand soils of Anand.

Rao *et al.* (2016) revealed that application of three irrigations (50 days after sowing, flowering initiation + pod development recorded significantly higher grain yields in both years of study (1701 kg ha^{-1} and 1595 kg ha^{-1} respectively) compared to that of less number of irrigations (either two or one) given at critical growth stages of pigeonpea on clay loam soils of RARS, Guntur

Lende and Patil (2017) from Rahuri conducted an experiment on Irrigation management on growth, yield and quality of chickpea and reported that all growth parameters like number of pods plant^{-1} (46.50), test weight (24.10 g), Seed yield (26.92 q ha ha^{-1}), stover yield (31.80 q ha^{-1}) were significantly higher when irrigation applied at branching and pod development stage with all furrows irrigated as compared to control

Mondal *et al.* (2018) reported that irrigation given at critical stages was found to be better in improving yield parameters like number of pods plant^{-1} and seeds pod^{-1} , test Weight (g), (Yield kg ha^{-1}), Stover (Yield kg ha^{-1}), harvest Index (%) in greengram on sandy soils of West Bengal.

Shirgapure and Fathima (2018) conducted a field experiment on red sandy loam soils of Mandya, Karnataka to study the growth and yield of pulses as influenced by irrigation levels and observed that yield attributes, seed yield (1222 kg ha^{-1}) in blackgram were recorded highest with irrigation at 80% CPE followed by irrigation at 100% CPE as compared to recommended practice (irrigation at 5cm depth)

Komal *et al.* (2018) carried out a field experiment to study the response of chickpea productivity under different irrigation frequencies and mulching and reported that irrigation frequencies significantly influenced the number of pods plant^{-1} (37.33), seed weight pod^{-1} (0.21 gm), and yield (20.29 q ha^{-1}) when irrigation was applied at pre sowing and flowering stages

A field experiment was conducted to study the effects of irrigation and foliar nutrition on growth, yield and nutrient uptake of blackgram and reported that irrigation given at vegetative stage (33 DAS) i.e, 0.5 IW/CPE ratio was found to be better in improving the Seed yield (959 kg ha^{-1}) Haulm yield (1935 kg ha^{-1}) and Harvest index (33.2 %) on sandy loam soils of Agricultural Research Station, Jangamaheswarapuram (Lakshmi *et al.*, 2018)

Singh *et al.* (2018) conducted an experiment on sandy loam soils of Madhya Pradesh and reported that irrigation at 0.6 IW/CPE ratio (4,079 m^{-3}water ha^{-1}) has recorded significantly higher yield attributes in french bean by 36.1% compared with 0.4 IW/CPE ratio (2,741 m^{-1}water ha^{-1}).

Karande *et al.* (2019) reported that higher grain yield (1408) was found in I_1(0.8 IW: CPE) followed by I_2 (0.6 IW: CPE) and I_3 (0.4 IW: CPE) in both the years of experimentation Pooled results revealed increase in grain yield in irrigation level I_1 was to the tune of 18.5 and 83.8 per cent when compared with levels I_2 and I_3 respectively.

2.1.3 Nutrient Uptake

Arya *et al.* (2005) conducted field experiment on sandy loam soils of IIPR, Kanpur to study the effect of fertilizers and tillage management in rice-chickpea cropping system under varying irrigation schedules and revealed that the higher nitrogen, phosphorus and potassium upatake by rice and chickpea were recorded with CPE ratio of 60 mm than CPE of 80 mm.

Srinivasulu *et al.* (2015) carried out a field experiment and reported that increasing trend of irrigations from 0.5 to 0.9 IW/CPE ratio's significantly increased the nutrient uptake by chickpea. Scheduling irrigation at 0.9 IW/CPE ratio showed significantly higher nitrogen, phosphorus, potassium and sulphur uptake by seed and stover and found at par with 0.7 IW/CPE ratio. The increase in uptake of N, P, K and S by seed was 20, 22, 18 and 27 per cent whereas by stover it was to the tune of 41, 30, 37 and 43 per cent, respectively over farmers practice on medium black and clay soils of JAU, Junagadh.

Lakshmi *et al.* (2018) conducted an experiment to study the effects of irrigation and foliar nutrition on growth, yield and nutrient uptake of blackgram and reported that increasing trend of irrigations from 0.3 to 0.5 IW/CPE ratio's significantly increased the nutrient uptake by blackgram. Scheduling irrigation at 0.5 IW/CPE ratio showed significantly higher nitrogen (110), phosphorus (21), potassium (124) uptake on sandy loam soils of ARS, Jangameswarapuram

2.2 EFFECT OF SOIL APPLICATION OF HUMIC ACID, FYM AND HYDROGEL ON GROWTH, YIELD AND WATER USE EFFICIENCY OF FIELD CROPS

2.2.1 Growth

Sharif *et al*. (2002) reported that application of humic acid with inorganic fertilizers has significantly increased the shoot and root dry weight of maize plants at Peshawar, Pakistan

Talavia (2002) conducted an experiment to study the effect of different methods and levels of humic acid on soil properties, yield and nutrient uptake by summer groundnut and reported that soil application of humic acid @ 20 kg ha^{-1} has increased number of flowers (41.25) and number of nodules (114) on black calcareous soil of Junagadh.

Shah *et al.* (2009) conducted an experiment on growth and yield response of maize to organic and inorganic sources of nitrogen and reported that all growth and yield parameters were significantly increased due to combined application of urea @ 260 kg $ha^{-1}$and Farm Yard Manure (FYM) @ 15000 kg ha^{-1}on sandy clay loam soils of Faisalabad.

Koushal and Singh (2011) conducted an experiment on sandy loam soil of Amritsar and reported that plant height of 16.89 cm, 65.78 cm, and 73.37 cm at 30, 60 and 90 DAS was recorded in the treatment where 50 per cent recommended N applied through urea + 50 per cent N through FYM + PSB and the lowest of these were found in the control treatment in soybean

Patil *et al*. (2011) conducted an experiment to study the effect of postassium humate on growth and yield of soybean and blackgram and reported that soil application of potassium humate @ 12.5 kg ha^{-1} in two doses (first dose along with sowing and second 40 days after sowing) has increased plant height (45cm) (40.11cm) and number of root nodules (66.98) (65.45) in both soybean and blackgram respectively in Parbhani

Effect of humic acid on growth and yield of mustard was studied (Rajpar *et al*., 2011) and found that soil application of humic acid @ 16 kg ha^{-1} at the time of sowing with basal N, P and K fertilizers has increased the growth and yield parameters over control.

Rehman *et al.* (2011) conducted an experiment on effect of hydrogel on the performance of aerobic rice sown under different techniques and reported that soil application of hydrogel at the rate of 2.5 kg ha^{-1} at the time of sowing has increased plant height (90.33cm) and number of fertile tillers (m^{-2}) on sandy loam soils at university of Agriculture, Faisalabad.

Saruhan *et al*. (2011) reported that all growth parameters, yield and crude protein content in common millet were significantly influenced with soil and foliar application of humic acid. Plant height, bunch length were highest when humic acid was applied on leafs (100%) which was on a par with application of humic acid (soil 50%+ leaf 50%) in clay soils of Poland

Tahir *et al*. (2011) conducted a pot experiment in the greenhouse of the Land Resource Research Programme, Islamabad and revealed that the largest increase in plant height and shoot fresh and dry weights were found with humic acid (HA) (60 mg kg^{-1} soil) as compared to the control without HA in wheat

Gomma *et al.* (2014) carried out field experiment on clay loam soils of Alexandria university and stated that soil application of 14.4 kg ha^{-1} humic acid along with inorganic fertilizer has recorded higher plant height (179.59cm) and Leaf area index (LAI) (5.23) in maize.

Kokani *et al.* (2014) carried out a field experiment on Growth, yield attributes and yield of summer blackgram as influenced by FYM, phosphorus and sulphur and reported that application of FYM @ 5 t ha^{-1} was recorded significantly higher plant height at 60 DAS (32.35 cm) and at harvest (36.73 cm) and number of branches per plant (5.02) as compared to control on caly soils of Navsari Agricultural University, Navsari

Arjumend *et al*. (2015) conducted a greenhouse experiment to study the effect of lignite derived humic acid on some selected soil properties, growth and nutrient uptake of wheat and concluded that all growth parameters, Nutrient uptake and yield were significantly increased by the soil application of humic acid @ 200 mg kg^{-1} on silt loam soils of Rawalakot, Pakistan

Tyagi *et al*. (2015) carried out a field experiment on sandy loam soils of Banaras Hindu university, Varanasi and stated that application of hydrogel @ 5 kg ha^{-1} +100% N,P,K application has significantly increased growth and yield parameters in Wheat

Kahraman (2016) conducted an experiment to study the effect of humic acid doses on yield and quality parameters of cowpea and studied that soil application of humic acid at the rate of 110 kg ha^{-1} has increased plant height (42.33cm) in clay loam soils of Turkey

Pradeep kumar and Rajkumara (2016) reported that soil application of Hydrogel @ 5kg ha^{-1} has recorded higher growth parameters like plant height (44cm), secondary branches $plant^{-1}$ (12.77) and dry matter production (36.36 g $plant^{-1}$) in chickpea on vertisols of Dharwad.

Singh *et al*. (2017b) revealed that soil application of pusa hydrogel @ 5 kg ha^{-1} at the time of planting in sugarcane has increased plant height (160.4cm) and LAI (4.50) at 165 DAP on sandy loam soils at Indian institute of sugarcane research, Lucknow

A pot experiment was conducted to study the effect of potassium humate and bio-inoculants on growth and yield of cowpea and found that application of potassium humate @ 10 mg/kg soil and seed inoculation with Rhizobium + VAM+ PSB was recorded the maximum growth attributes *viz.* plant height, no. of branches per plant, no. of total and effective nodules per plant, dry matter accumulation at flowering and at harvesting stage at Jobner ,Rajasthan (Tripura *et al.*, 2017)

Burondkar *et al*. (2018) conducted a field experiment to study the effect of pusa hydrogel and chitosan on wheat growth and yield under water deficit condition and revealed that application of hydrogel at the time of sowing + foliar application of antitranspirant chitosan at jointing and booting stage has significantly increased the growth parameters like plant height, number of tillers per hill, flag leaf length and days to maturity in sandy loam soils of Uttarpradesh.

Soil application of hydrogel @ 5 kg ha^{-1} at the time of sowing along with foliar spray of NPK (19:19:19) @ 0.5% at flower initiation and pod formation stages has significantly increased plant height (60.1cm), number of branches $plant^{-1}$ (2.0) in lentil (Ram *et al*., 2018) on clayloam soils of Agriculture university, Kota, Rajasthan.

Thakur *et al*. (2018) revealed that combined application of recommended dose of fertilizers (RDF) + humic acid granules @ 12.5 kg ha^{-1}(basal) significantly influenced days to 50% flowering, stem girth, SPAD chlorophyll meter readings, head diameter and thousand seed weight in sunflower on sandyloam soils of Rajendranagar, Hyderabad.

Ali *et al*. (2019) reported a significant increase in number of leaves $plant^{-1}$ (57) and plant height (52.2 cm) of greengram obtained in treatment with humic acid applied at the rate of 12 kg ha^{-1} as soil application at the time of sowing in clay loam soils of Pakistann

Belal *et al*. (2019) reported higher plant height (67.5 cm) in barley due to soil application of humic acid at the rate of 100 kg ha^{-1} at the time of sowing along with basal N,P,K and FYM application in calcareous soils of Egypt.

Kumar *et al*. (2019) revealed that a significant increase in plant height (89.16cm) , dry matter accumulation (671.30 g m^{-2}) of wheat obtained in treatment with application of pusa hydrogel @ 2.5 kg ha^{-1} in Rajasthan

Khan *et al*. (2019) reported that higher plant height (213 cm), leaves $plant^{-1}$ (13), leaf area $plant^{-1}$ (5499 cm^{-2}) and leaf area index LAI (3.82) in maize due to soil application of humic acid at the rate of 1.8 kg ha^{-1} applied at 14 DAS along with nitrogen at the rate of 120 kg ha^{-1} in two splits at 17 DAS and 35 DAS in silty loams of Swabi, Pakistan

Nalia and Sengupta (2019) from Nadia, West Bengal reported that soil application of Humic acid at the rate of 15 l ha^{-1} along with compost at the rate of 10t ha^{-1} showed maximum enhancement of growth characters in redgram

Roy *et al*. (2019) conducted an experiment to study the impact of pusa hydrogel on yield and productivity of rainfed wheat and reported that hydrogel application @ 5 kg ha^{-1} has significantly improved growth and yield attributes on sandy loam soils of Dehradun.

Sen *et al*. (2019) revealed that combined application of trichoderma seed treatment @12 kg ha^{-1} and soil application of hydrogel in rice resulted in significantly higher growth and yield attributing characters on sandy clayloam soils of Varanasi

Sharma and Pathania (2019) reported that plant height was recorded significantly highest with the application of 40 kg P2O5/ha + FYM + PSB and higher dry matter accumulation at 30, 60 DAS and at harvest was recorded with the FYM applied @ 10 t ha on sandy clay loam soils of Bilaspur.

Ahmad *et al*. (2020) conducted a field experiment on clayloam soils of agriculture research station Serai, Naurang to study the effect of humic acid in enhancing maize yield and revealed that soil application of humic acid 7.5 kg ha^{-1} with 120 kg ha^{-1} of phosphorus has significantly increased plant height (187cm), leaf area (3334.57 cm^{-2}) and leaf area index LAI (16549.8cm^{-2}) in maize.

Santosh *et al*. (2020) conducted an experiment to study the effect of soil and foliar application of humic acid (HA) on productivity of groundnut and reported that combined application of 30 kg HA ha^{-1} to soil as basal followed by foliar spray of 2 per cent HA at 45 days after sowing (DAS) along with recommended dose of fertilizers (RDF) recorded significantly higher plant height (21.06 cm), number of branches per plant (8.53), total dry matter production per plant (29.67 g) at harvest on clay soils of Agricultural Research Station, Nipani

2.2.2 Yield Attributes and Yield

Talavia (2002) conducted an experiment to study the effect of different methods and levels of humic acid on soil properties, yield and nutrient uptake by summer groundnut and reported that highest pod yield (1286 kg ha^{-1}), kernel yield (900 kg ha^{-1}) , haulm yield (2746 kg ha^{-1}) and oil yield (457 kg ha^{-1}) are due to soil application of humicacid @ 20 kg ha^{-1} on medium black calcareous soils of Junagadh

Kumar *et al*. (2017) revealed that soil application of humic acid @ 20 kg ha^{-1} along with inorganic fertilizers in rice has significantly increased the grain yield (4253 kg ha^{-1}) and straw yield (6380 kg ha^{-1}) in clay loam soils of Killikulam, Tamilnadu.

Sharma and Abraham (2010) from Allahabad conducted an experiment to study the response of blackgram to nitrogen, zinc and FYM and results of the study revealed that the application of nitrogen @ 20 kg ha^{-1}, zinc @ 15 kg ha^{-1}and farm yard manure @ 10 t ha^{-1} showed a significant increment in the yield, and yield attributes of blackgram over the control

Koushal and Singh (2011) conducted an experiment on sandy loam soil of amritsar and reported that highest number of pods per plant (80), seed yield (1149 kg ha^{-1}) and test weight(17.02g) were recorded in the treatment where 50 per cent recommended N applied through urea + 50 per cent N through FYM +PSB and the lowest of these were found in the control treatment in Soybean.

Patil *et al*. (2011) conducted an experiment to study the effect of postassium humate on growth and yield of soybean and blackgram and reported that application of potassium humate has increased number of pods plant^{-1} (85) (55.21), yield (8.60 q acre^{-1})(5.71 q acre^{-1}) in both redgram and blackgram respectively in Parbhani

Rehman *et al.* (2011) conducted an experiment on effect of hydrogel on the performance of aerobic rice sown under different techniques and reported that soil application of hydrogel at the rate of 2.5 kg ha^{-1} at the time of sowing has increased grain yield (2.29 t ha^{-1}) , number of grains $panicle^{-1}$ (67.80) and 1000 grain weight (17.26g) on sandy loam soils at university of agriculture, Faisalabad.

Saruhan *et al.* (2011) reported that yield, 1000 grain weight and crude protein content in common millet were significantly influenced with soil and foliar application of humic acid in clay soils of Poland

Effect of humic acid on growth and yield of mustard was studied by (Rajpar *et al.*, 2011) and found that soil application of humic acid at the time of sowing with basal N, P and K fertilizers has increased the yield parameters over control.

Sarwar *et al.* (2014) reported that application of humic acid @ 50 kg ha^{-1} along with P_2O_5 @ 45 kg ha^{-1} in presence of PGPR inoculation in mung bean has recorded the highest grain yield (1.96 t ha^{-1}) and straw yield(4.8t ha^{-1}) compared to only P_2O_5 treated plots on clay loam soils of Islamabad, Pakistan.

Waqas *et al.* (2014) conducted an experiment on evaluation of humic acid application methods for yield and yield components of mungbean and revealed that soil application of humic acid @ kg ha^{-1} has significantly increased the yield attributes like number of pods $plant^{-1}$ (25.3), grains pod^{-1} (11.6), 1000 grain weight (49.4g), grain yield (1085 kg ha^{-1}) and biological yield (4575 kg ha^{-1}) on silty clay loam soils of Peshawar, Pakistan.

Tyagi *et al.* (2015) carried out a field experiment on sandy loam soils of Banaras Hindu university, Varanasi and stated that application of hydrogel @ 5 kg ha^{-1} along with basal N,P,K application has significantly increased yield parameters in wheat

Kahraman (2016) conducted an experiment to study the effect of humic acid doses on yield and quality parameters of cowpea and studied that soil application of humic acid at the rate of 150 kg ha^{-1} has increased seed yield (2543.29 kg ha^{-1}) in clay loam soils of Turkey.

Dhanasekharan (2017) from Tamilnadu carried out a field experiment to study the effect of lignite humic acid and NPK application on the yield and nutrient uptake by cotton and revealed that combined application of humic acid @ 50 kg ha^{-1} along with 100% NPK has increased yield characters like number of bolls plant, boll weight, seed cotton yield and also NPK uptake in cotton.

Singh *et al*. (2017a) conducted an experiment to study the effect of hydrogel and thiourea on yield, quality and nutrient uptake of Indian mustard under moisture stress condition and reported that significant improvement in yield and qualitative traits (oil & protein content and their recovery) as well as nutrient content and their uptake to mustard was recorded due to basal application of 2.5 kg ha^{-1} of hydrogel accompanied with 100% RDF followed by two foliar applications of 0.05% of thiourea at 50% flowering and 50% pod formation

Singh *et al*. (2017b) reported that Pusa hydrogel application at 2.5 kg ha^{-1} significantly improved yield attributes (cane length, cane weight, number of millable cane) over control in sugarcane on sandy loam soils at Indian institute of sugarcane research, Lucknow

Singh *et al*. (2017c) reported that blackgram variety Sekhar-2 with 75% Organic (22.5 q ha^{-1} FYM + 125.03 kg ha^{-1} Bone Meal) + 25% Inorganic (27.75 kg ha^{-1}) DAP + 6.25 kg ha^{-1} MOP) has recorded maximum dry weight per plant (12.49 g), highest number of pods $plant^{-1}$ (24.55), number of seeds pod^{-1} (7.07) and test weight (42.19 g), highest grain yield (872 kg ha^{-1}), stover yield (2511 kg ha^{-1}) and harvest index (33.60%) on sandy loam soil of Allahabad

A pot experiment was conducted to study the Effect of Potassium Humate and Bio-Inoculants on growth and yield of cowpea and found that application of potassium humate @ 10mg/kg soil and seed inoculation with Rhizobium + VAM+ PSB was recorded the maximum yield attributes *viz.* no. of pods per plant, no. of seed per pod , seed, straw and biological yield at Jobner ,Rajasthan (Tripura *et al*., 2017)

The impact of soil application of humic substances @ 5 kg ha^{-1} at sowing + foliar application of humic substances from vermicompost (0.2%) at 40 DAS resulted in significantly higher grain yield (1741 kg ha^{-1}), haulm yield (2862 kg ha^{-1}) and nutrient uptake in soybean on sandy loam soils of shivamogga (Savita *et al*., 2018)

Thakur *et al*. (2018) revealed that combined application of recommended dose of fertilizers (RDF) + humic acid granules @ 12.5 kg ha^{-1}(basal) has increased the yield parameters in sunflower on sandyloam soils of Rajendranagar, Hyderabad.

Tyagi *et al.* (2018) conducted an experiment on evaluation of hydrogel on the performance of *rabi* maize and reported that application of 150 % gel dose has significantly influenced the yield attributes like number of cobs per m^{-2}, number of rows per cob, number of grains per row, length of cob, girth of cob and number of grains per cob ,grain and stover yield compared to other treatments on silty loam soils of Bihar Agricultural College Farm, Sabour, Bhagalpur.

Burondkar *et al*. (2018) conducted a field experiment to study the effect of pusa hydrogel and chitosan on wheat growth and yield under water deficit condition and revealed that application of hydrogel at the time of sowing + foliar application of antitranspirant chitosan at jointing and booting stage has significantly increased the yield attributes in sandy loam soils of Uttarpradesh.

Soil application of hydrogel @ 5 kg ha^{-1} at the time of sowing has significantly increased grain yield (1210 kg ha^{-1}) and Harvest Index (30.82 %) in lentil (Ram *et al*., 2018) on clay loam soils of Agriculture university, Kota, Rajasthan.

Ali *et al*. (2019) conducted an experiment on humic acid and nitrogen levels optimizing productivity of green gram (*vigna radiata* L.) and reported that combined application of humic acid @ of 12 along with nitrogen in the form of urea @ 40 kg ha^{-1} has recorded highest number of pods $plant^{1}$ (13), seeds pod^{1} (10), thousand seed weight (44.4g), seed yield (1312.7 kg ha^{-1}), Harvest index (21.8%) in clayloam soils of Pakistan

The combined application of humic acid @ 1.8 kg ha^{-1} along with nitrogen @ 120 kg ha^{-1} has significantly increased the yield and nutrient uptake compared to control in maize on silty loam soils of Pakistan (Khan *et al*., 2019)

Belal *et al*. (2019) reported that soil application of humic acid at the rate of 100 kg ha^{-1} at the time of sowing along with basal N,P,K and FYM application has significantly increased grain yield and straw yield in barley in calcareous soils of Egypt.

Sen *et al*. (2019) revealed that combined application of trichoderma seed treatment @12 kg ha^{-1} and soil application of hydrogel in rice resulted in significantly higher yield attributing characters on sandy clayloam soils of Varanasi

Kumar *et al.* (2019) revealed that a significant increase in Grain yield (3.41t ha^{-1}), Straw yield (4.28t ha^{-1}), No. of grains $spike^{-1}$ (28.05), Test weight (36.61g) of wheat obtained in treatment with application of pusa hydrogel @ 2.5 kg ha^{-1} in Rajasthan

Nalia and Sengupta (2019) from Nadia, West Bengal reported that soil application of humic acid at the rate of 15 litre ha^{-1} along with compost at the rate of 10 t ha^{-1} showed maximum enhancement of seed yield and harvest index in redgram

Pal (2019) from Bihar conducted an experiment on evaluation of pusa hydrogel for higher productivity of wheat and reported that combined application of hydrogel @ 2.5 kg ha^{-1} mixed with NPK (12:32:16) at the time of sowing has significantly increased grain yield (6120 kg ha^{-1}), biological yield (12356 kg ha^{-1}) grains ear^{1} (65.21) and harvest index (51.80%)

Bharat *et al.* (2019) reported that higher seed yield (1303.4 kg ha^{-1}), harvest index (23.2 %) and 1000 grain weight (3.6g) were obtained in Indian mustard due to soil application of hydrogel @ 5 kg ha^{-1}in Jammu

Suriyaprakash *et al.* (2019) conducted a pot culture experiment to investigate the morpho-physiological studies on response of blackgram under soil water deficit amended with hydrogel and revealed that significant increase number of pods per plant, number of seeds per pod and seed yield per plant with application of hydrogel of 0.6g per kg soil when compared to control under 50% field capacity on clay loam soils of Tamilnadu Agricultural University, Coimbatore

Ahmad *et al*. (2020) revealed that plant height (187 cm), leaf area (334 cm^{-2}), leaf area index (16549 cm^{-2}), grains ear^{-1}(310), biological yield (16471 kg ha^{-1}), 100 grain weight (24.44g), grain yield (3085 kg ha^{-1}) in maize were found significantly higher in the plots receiving humic acid @ 120 kg ha^{-1} along with phosphorus (P_2O_5) @ 120 kg ha^{-1} on clay loam soils of Pakistan

Shreelatha *et al.* (2020) reported that higher seed and stover yield of chickpea (1659 & 1743.7 kg ha^{-1}), pods per plant (77.0), 100 seed weight (24.3 g) and better uptake of major and micro nutrients by seed and straw of chickpea was recorded due to application of recommended dose of N and P through vermicompost along with soil application of HA @ 5 kg $ha^{-1}$and foliar spray @ 0.25 per cent compared to other treatments on clay soils of Raichur

Santosh *et al*. (2020) reported that combined application of humic acid @ 30 kg ha^{-1} to soil as basal followed by foliar spray of humic acid @ 2% at 45 days after sowing (DAS) along with recommended dose of fertilizers (RDF) recorded significantly higher number of pods per plant (21.1), pod weight per plant (19.9 g), pod (2802 kg ha^{-1}), haulm (3924 kg ha^{-1}) and kernel yield (1971 kg ha^{-1}) as compared to RDF alone (21.06 cm, 8.53, 29.67 g, 15.3, 13.6 g, 2319 kg ha^{-1}, 3273 kg $ha^{-1}$and 1536 kg ha^{-1}, respectively) in groundnut on clay soils of Agricultural Research Station, Nipani

2.2.3 Nutrient Uptake

Sivakumar *et al.* (2007) reported that application of humic acid (HA) upto 20 kg ha^{-1} along with 100 per cent (150:50:50 NPK ha^{-1}) recommended dose resulted in highest total uptake of nitrogen (132.0 kg ha-1), phosphorus (20.75 kg ha^{-1}) and potassium (86.98 kg ha^{-1}) in rice. The total N uptake significantly increased from 20.3 (control) to 132.0 kg ha^{-1} (100 per cent NPK + 20 kg HA ha^{-1}). The total P and K uptake also increased from 5.82 (control) to 20.75 kg ha^{-1} (100% NPK + 20 kg HA) and 28.97 (control) to 86.98 kg ha^{-1} (100% NPK + 20 kg HA) respectively.

Jat *et al*. (2012) reported that application of FYM @ 5 t ha^{-1} in greengram has significantly increased the total nitrogen ,phosphorus and potassium content in grain and straw compared to no FYM treated plots on vertisols of Navsari

Tyagi *et al*. (2015) carried out a field experiment on sandy loam soils of Banaras Hindu Bniversity, Varanasi and stated that application of hydrogel @ 5 kg ha^{-1} along with basal N,P,K application has significantly increased the N, P, K uptake of wheat (69.46 kg ha^{-1}, 12.73 kg ha^{-1}, 19.73 kg ha^{-1}) respectively .

A pot culture experiment was conducted on sandy loam soils of Banaras Hindu University, Varanasi to investigate the influence of potassium humate and chemical fertilizers on yield and nutrient uptake of rice and found that soil application of potassium humate @10 mg kg^{1} soil along with 100 % NPK and 12.5 mg Zn kg^{1} has significantly increased the total nitrogen,phosphorus and potassium content in grain and straw compared to control. (Kumar *et al.*, 2017)

Singh *et al.* (2017c) reported that application of 7.5 kg ha^{-1} hydrogel has resulted in higher nutrient uptake of nitrogen (83.93 kg ha^{-1}), potassium (62.71 kg ha^{-1}) and phosphorus (15.05 kg ha^{-1} over rest of the treatments on sandy clay loam soils of Banaras Hindu University, Varanasi.

Ryan *et al.* (2018) carried out a field experiment on sandy loam soils of Bengaluru to study the effect of organic manures and super absorbent polymers on nutrients uptake and economics of soybean and revealed that application of recommended doses of fertilizers RDF + Potassium polyacrylate @ 7.5 kg ha^{-1} has significantly increased the nitrogen (217.9 kg ha^{-1}) phosphorus (29.89 kg ha^{-1}) and potassium (195.4 kg ha^{-1}) uptake over rest of the treatments.

2.2.4 Water Use Efficiency

Arya *et al.* (2005) conducted a field experiment on rice-chickpea at IIPR, Kanpur and observed that two and one irrigations given at CPE of 80 mm showed higher water-use efficiency (13.91 and 8.62 kg ha-mm^{-1}) compared to CPE of 60 mm respectively in sandy loam soils.

Jat *et al.* (2012) conducted an experiment on response of saline water irrigated greengram to land configuration, fertilizers and farm yard manure in tapi command area of south Gujarat and reported that application of FYM at 5 t ha^{-1} significantly improved the irrigation water use efficiency (2.7 kg ha-mm^{-1}) over no application of FYM

Awwad *et al.* (2015) conducted an experiment on effect of potassium humate appliction and irrigation water levels on maize yield, crop water productivity and some soil properties and revealed that the maximum value of water use efficiency 1.89 kg m^{-3} was obtained in case of treatment of potassium humate at rate of 15 kg per fed., and minimum of 1.02 kg m^{-3} water use efficiency was with control treatment without application potassium humate. The interaction between irrigation water levels (w) and potassium humate had significant effect on WUE and the combination between irrigation x water application at rate of 15 kg fed^{-1} achieved maximum value of water use efficiency (2.41 kg m^{-3})

Chaudhary *et al.* (2015) carried out a field experiment on loamy sands of Sardarkrushinagar, Gujarat and revealed that water-use efficiency (WUE) decreased with increase in irrigation levels. The highest WUE was reported when irrigation was applied at critical growth stages (3.28 kg ha mm^{-1}) in greengram

Gopal *et al.* (2015) studied on the effect of moisture regimes on growth and yield of frenchbean and noticed that the maximum water use efficiency was recorded under 0.9 IW/CPE ratio which was higher than those obtained under 0.7 and 0.5 IW/CPE ratios, respectively on silty loam soils of Kumarganj, Faizabad.

Pradeepkumar and Rajkumara (2016) conducted an experiment to study the effect of irrigation and hydrogel application on chickpea varieties and reported that irrigation scheduled at 0.6 IW/CPE + 2.5 kg ha^{-1} hydrogel recorded significantly higher WUE (9.08 kg $hamm^{-1}$) compared to other treatment combinations on Vertisols of Dharwad.

Singh *et al.* (2017b) reported that the highest irrigation water use efficiency (1.86 t $ha^{-1}cm^{-1}$) was obtained in Pusa hydrogel application at 5.0 kg ha^{-1} which was comparable to Pusa hydrogel at 2.5 kg ha^{-1} (1.80 t $ha^{-1}cm^{-1}$), higher than control at both the levels of irrigation on sandy loam soils at Indian institute of sugarcane research, Lucknow.

Bharat *et al.* (2019) from Jammu conducted an experiment to study the effect of hydrogel and irrigation scheduling on water use efficiency and productivity of Indian mustard and studied that application of hydrogel @ 5.0 kg $ha^{-1}$and irrigation scheduling at 0.8 IW/CPE ratio resulted in significant increase in the water use efficiency (6.97 Kg ha-mm^{-1}) of Indian mustard than control.

Dar and Ram (2016) reported that water-use efficiency (WUE) decreased with increase in irrigation levels while it showed an increasing trend with increase in hydrogel dose. The highest WUE was found with no irrigation+ recommended dose of fertilizers (RDF)100% + 5 kg ha^{-1} hydrogel which was statistically at par with application of 2 irrigations +100% RDF + 5 kg ha^{-1} hydrogel and no irrigation +100% RDF + 2.5 kg ha^{-1} of hydrogel in wheat.

2.2.5 Consumptive Use

Nimje (1991) worked at Bhopal reported that consumptive use of water by chickpea increased with increase in number of irrigations. Crop supplied with three irrigations consumed 84 per cent more water (368 mm) than rainfed (200 mm) crop of chickpea. The highest water use efficiency (WUE) was observed with one irrigation (7.52 kg ha mm^{-1}) due to less consumption of water and higher yields.

Jadhav *et al.* (1994) observed higher consumptive use of water (232.79 mm) resulted in lower WUE (11.82 kg ha-mm^{-1}) under adequate irrigation management, in chickpea at College of Agriculture, Pune.

Shiva Dhar and Singh (1995) carried out field experiment on silty clay loam soils of Pantnagar, U.P and suggested that the consumptive use of water and moisture extraction were higher in frenchbean when 3 irrigations given at 25,50 and 75 days during the first year and 3 irrigations at 50,75 and 100 days during the second year and the lower consumptive use was recorded from one irrigation at 100 days and irrigation at 0.4 IW/CPE ratio during first year and second year respectively.

Gopal *et al.* (2015) conducted field experiment on silty loam soils of Faizabad and noticed that the wettest moisture regimes (0.9 IW/CPE) recorded a consumptive use of 27.77 cm which registered an increase of 8.45 and 3.93 cm over 0.5 and 0.7 IW/CPE, respectively in frenchbean.

2.2.6 Soil Moisture Use

Parihar (1990) observed that the percentage depletion from the deeper layer was comparatively more under 0.4 IW/CPE ratio than under 0.6 and 0.8 IW/CPE ratios which indicates that when less number of irrigations were applied under 0.4 IW/CPE ratio, deeper layers were subjected to more moisture depletion since moisture stress under such conditions promotes extensive root growth in lower layers in chickpea, on sandy clay loam soils at IIT, Kharagpur

Dixit *et al.* (1993b) conducted a field experiment on deep black vertisols of Powarkheda, Madhya Pradesh and reported that soil moisture extraction by chickpea was maximum (34.63 to 36.44 per cent) between 15 and 30 cm soil depths. The soil moisture extraction decreased with an increase in depth of soil (12.20 to 14.31 per cent) at 45 - 60 cm depth. The soil moisture extraction was higher (41.33 per cent) under no irrigation than that under irrigated condition.

Shiva Dhar and Singh (1995) observed that the treatments with lower number of irrigations resulted in more contribution of water extraction from lower or deep layers, whereas with more irrigations upper layer contributed more, as the Frenchbean is a shallow rooted crop on silty clay loam soils of Pantnagar, U.P.

Koupai *et al.* (2008) conducted a laboratory experiment in central Iran and reported that there is significant difference between samples containing hydrogels and the control (without hydrogels). Available water content increased 1.8 fold of control in clay and 2.2 to 3.2 fold in loamy and sandy loam soil, respectively, with a hydrogel application of 8 g/kg.

Narjary *et al.* (2012) reported that the result of the soil water characteristic curve revealed that the water release per unit suction change in the 10–100 kPa range (available to plants) in soil samples not treated with gel was significantly lower compared to that in soil samples treated with gel for all soil types.

Gopal *et al.* (2015) conducted field experiment on silty loam soils of Kumarganj, Faizabad and concluded that the maximum moisture depletion of 22.30 cm was noticed under 0.9 IW/CPE ratio while it was minimum (15.41 cm) under 0.5 IW/CPE ratio in frenchbean.

2.3 INTERACTION EFFECT OF SOIL APPLICATION OF HUMIC ACID AND HYDROGEL AT DIFFERENT IRRIGATION SCHEDULES ON PRODUCTIVITY OF FIELD CROPS

Almarshadi and Ismail (2014) conducted a field experiment for two years to study the effect of barley growth and productivity as affected by soil amendments under fully and minimum irrigation conditions and reported that the barley growth and yield components increased with application of humic acid @10 kg ha^{-1} and gel polymer @ 16 kg ha^{-1} under full irrigation conditions (100% of water requirement) compared to control. Plant Height , Leaf Area Index, N.o of tillers m^{-1} , 1000 grain weight , Biological yield and Grain yield were highest in humic acid treatments followed by gel polymer treatments in sandy loam soils of Saudi Arabia

2.4 EFFECT OF IRRIGATION TREATMENTS AND SOIL AMENDMENTS ON ECONOMICS OF FIELD CROPS

Arya *et al.* (2005) studied the effect of fertilizers and tillage management in rice-chickpea cropping system on sandy loam soils of IIPR, Kanpur under varying irrigation schedules and concluded that the CPE of 60 mm recorded higher net returns and benefit cost ratio over CPE of 80 mm.

Chaudhary *et al.* (2015) conducted an experiment on Influence of spacing and scheduling of irrigation on growth, yield, yield attributes and economics of summer greengram and reported that scheduling of irrigation at 1.0 IW:CPE ratio with spacing of 30 x 10 cm registered highest net realization of Rs. 49118 ha^{-1} with BCR value of 1:3.14 followed by treatment combination where irrigation scheduled at 0.8 IW:CPE ratio with spacing of 30 x 10 cm

Kumbhar *et al* .(2015) conducted a field experiment on loamy sand soils of AAU, Anand to study the influence of irrigation scheduling (IW/CPE ratio) and sulphur on yield, quality and economics of *rabi*pigeonpea and revealed that application of irrigation at 0.8 IW/CPE ratio gave the highest net returns (Rs. 37, 591 ha^{-1}) and maximum BCR value (2.34).

A field experiment was conducted for two years to study the effect of sowing time and supplemental irrigation on yield and economics of rabi pigeonpea and revealed that application of three irrigations at 50 days after sowing, flowering initiation and pod development recorded significantly higher grain yields (1701 kg ha^{-1} and 1595 kg ha^{-1}), net returns (Rs. 55,773/- and Rs. 61,023/-) and BCR (0.97 and 1.12), respectively, during both the years of study (Rao *et al.*,2016)

Lende and Patil (2017) conducted an experiment to study the effect of irrigation management on growth, yield and quality of chickpea and reported that irrigation scheduling at branching and pod development stage with all furrows irrigated has recorded higher gross monetary return (Rs.82558 ha^{-1}), net monetary return (Rs. 55,308 ha^{-1}) and benefit cost ratio (3.03) than rest of the treatments.

Singh *et al* . (2017b) conducted an experiment on Growth, yield, irrigation water use efficiency, juice quality and economics of sugarcane in pusa hydrogel application under different irrigation scheduling and reported that the net return (Rs.

110951.00 ha^{-1}) and B:C ratio (1.95) were the highest in pusa hydrogel application at 2.5 kg ha^{-1} under irrigation scheduling at IW/CPE ratio of 0.75 with the addition income of Rs. 5339 ha^{-1} over control.

Sah *et al.* (2018) reported that treatment getting 50% N through FYM and 50% RDF through inorganic fertilizers recorded higher net returns and B: C ratio (Rs.36735, Rs. 49951, Rs. 86686, 1.02, 1.62 and 1.30 in rice, wheat and rice-wheat system, respectively) compared to other treatments.

Kumar *et al*. (2019) carried out a field experiment to study the effect of irrigation levels and moisture conserving polymers on growth, productivity and profitability of wheat and revealed that the highest gross returns (76924 ha^{-1}) net returns (` 45548 ha^{-1}) were recorded with application of Pusa hydrogel @ 2.5 kg ha^{-1} over control.

Pal (2019) carried out a field experiment to study the Evaluation of Pusa Hydrogel for higher Productivity of Wheat in Bihar and the economic analysis of the findings reflected that the highest B:C ratio (3.43) was recorded with application of hydrogel @ 2.5 kg ha^{-1} as compared to other treatments

Ahmad *et al.* (2020) conducted an experiment to study the effect of humic acid, an effective amendment used for amelioration of phosphatic fertilizer and enhancing maize yield and reported that the benefit cost ratio (BCR) was found higher (2.90) for the plots receiving Humic acid along with phosphatic fertilizer @ 120 kg ha^{-1}as compared with the rest of the treatments.

Chapter-III

Material and Methods

Chapter III

MATERIAL AND METHODS

A field experiment entitled "**Effect of Hydrogel and Humic Acid on Soil Moisture Retention and Productivity of *rabi* Blackgram (*Vigna Mungo L.*)"** was conducted at Advanced Post Graduate Centre, Lam, Guntur during *rabi,* 2019-20. The details of materials used and methods followed in the investigation are described in this chapter.

3.1 LOCATION OF THE EXPERIMENTAL SITE

The experimental site was geographically situated at an altitude of 315 m above mean sea level, 16° 36´ N latitude and 80° 43´ E longitude. It is about 8 km away from the Guntur town in the Krishna Agro-climatic Zone of Andhra Pradesh, India.

3.2 WEATHER CONDITIONS

The data pertaining to different weather parameters during the crop growth period (28-11-2019 to 21-02-2020) recorded at the meteorological observatory, Regional Agricultural Research Station, Lam, Guntur are presented in Table 3.1 and depicted in Fig. 3.1.

The data on weather parameters recorded during the crop growth period at the meteorological observatory RARS, Lam, Guntur are presented in Table 3.1 and depicted in Fig. 3.1. The weekly mean maximum temperatures during the crop growth period ranged from 30.4^0C to 33.9^0C while the weekly mean minimum temperatures ranged from 16.5^0C to 21.0^0C. A total rainfall of 14.0 mm was received during the period of experimentation with two rainy days during the reproductive stage of crop growth. The rainfall received during the crop growth period was found to be effective which coincides with the critical growth stages of crop and favored the crop growth. The weekly mean relative humidity ranged from 64.2 to 77.6 per cent. All the weather parameters favorably affected blackgram crop growth and ultimately average seed yields of blackgram were recorded.

Table 3.1. Weather data averaged weekly during the crop growth period (28-11-2019 to 21-02-2020)

Standard Meteorological week	Date and Month	Mean Temperature (°C)		Mean RH (%)	Rainfall (mm)	No.of rainy days
		Max.	Min.			
48	Nov 26 - 02 Dec 2019	30.9	20.7	74.3	1.6	0.0
49	Dec 03 – 09 Dec 2019	30.4	19.9	75.2	0.0	0.0
50	Dec 10 - 16 Dec 2019	33.9	19.4	72.3	0.0	0.0
51	Dec 17 - 23 Dec 2019	31.2	16.5	76.1	0.0	0.0
52	Dec 24 - 31 Dec 2019	31.2	20.5	74.2	0.0	0.0
01	Jan 01 – 07 Jan 2020	32.8	21.0	75.7	7.6	1
02	Jan 08 – 14 Jan 2020	30.9	18.4	73.0	0.0	0.0
03	Jan 15 – 21 Jan 2020	31.7	18.0	74.4	0.0	0.0
04	Jan 22 – 28 Jan 2020	32.3	18.4	77.6	0.0	0.0
05	Jan 29 – 04 Feb 2020	32.5	20.5	71.4	0.0	0.0
06	Feb 05 – 11 Feb 2020	31.7	19.6	68.3	0.0	0.0
07	Feb 12 – 18 Feb 2020	33.4	19.7	64.2	4.8	1
08	Feb 19 – 25 Feb 2020	32.8	19.3	69.3	0.0	0.0
Total		415.7	252.7	956.9	14.0	2
Mean		31.9	19.3	73.1		

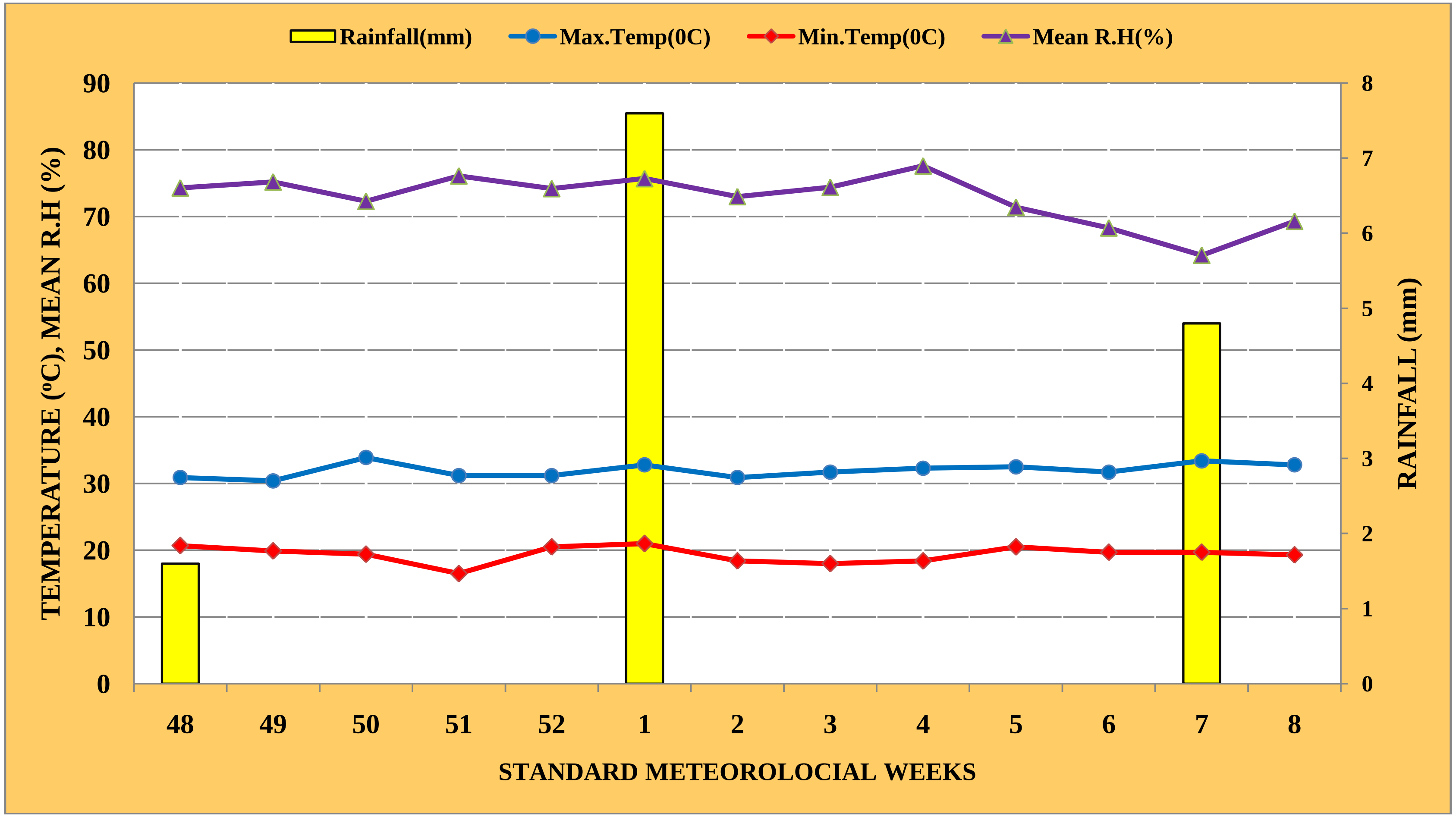


Fig. 3.1. Mean weekly weather data during the crop growth period

3.3 CHARACTERISTICS OF THE EXPERIMENTAL SITE

Initial soil samples were collected randomly from 0-30 cm soil depth before sowing of the experimental field and a homogeneous composite soil sample was prepared and analysed for physical and physico-chemical properties by following standard methods. The results of soil analysis (Table 3.2) indicated that the experimental soil was clay in texture, slightly alkaline in reaction with medium organic carbon and low in available nitrogen, low in available phosphorus and medium in available potassium.

Table 3.2. Physical and physico-chemical properties of the experimental soil

S. No.	Particulars	Value	Method of Analysis
I	**Mechanical Analysis**		
1	a) Sand (%) b) Silt (%) c) Clay (%)	17.0 14.4 68.6	Bouyoucos hydrometer method (Piper, 1966)
2	Textural class	Clay	
II	**Physico-chemical properties**		
1	pH (1:2.5 soil: water)	8.3	Glass electrode pH meter (Jackson, 1973)
2	Electrical conductivity (dS m^{-1}) (1:2.5 soil: water)	0.4	Digital electrical conductivity meter (Jackson, 1973)
3	Organic carbon (%)	0.6	Walkley and Black’s modified method (Walkley and Black, 1934)
4	Available N (kg ha^{-1})	183.0	Alkaline permanganate (Subbiah and Asija, 1956)
5	Available P_2O_5 (kg ha^{-1})	17.0	Olsen’s method (Olsen *et al.*, 1954)
6	Available K_20 (kg ha^{-1})	189.0	Neutral normal ammonium acetate Method (Jackson, 1973)

3.4 CROPPING HISTORY OF THE EXPERIMENTAL FIELD

The cropping history of the experimental field for the three consecutive years preceding the present study is summarized below.

Year	*Kharif*	*Rabi*
2017-2018	Dhaincha	Fallow
2018-2019	Sunhemp	Sorghum
2019-2020	Fallow	Blackgram (present experiment)

3.5 MOISTURE HOLDING PROPERTIES OF THE EXPERIMENTAL FIELD

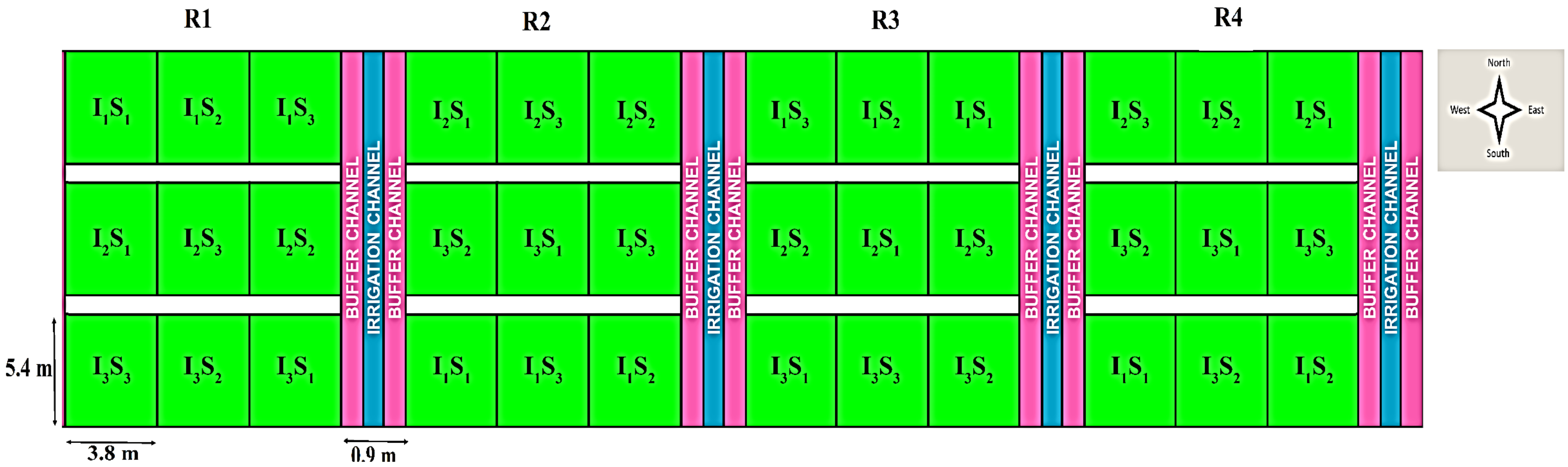
Field capacity, Permanent wilting point and bulk density of the experimental soil were estimated for every 15 cm soil depth up to 60 cm by following the standard procedures and the resultant data are presented in Table 3.3.

$$\text{Bulk Density } (\text{Mg m}^{-3}) = \frac{\text{Weight of oven dry soil}}{\text{Volume of soil}}$$

Amount of moisture in soil (cm) = Gravimetric moisture content of soil (%) x Bulk density x depth of soil (cm)

Table 3.3. Soil moisture constants of the experimental site

Particulars	Depth of soil (cm)				Method
	0-15	15-30	30-45	45-60	
Field capacity (%)	32.45	32.40	32.42	32.18	Field method (Dastane, 1967)
Permanent wilting point (%)	17.18	17.04	16.20	16.01	Sunflower method (Taylor and Ashcroft, 1972)
Bulk density(g cc^{-1})	1.20	1.21	1.23	1.25	Core sampling method (Piper,1966)



Design	:	Split Plot Design
Treatments	:	Main plots: 3, Sub plots: 3
Replications	:	4
Gross Plot size	:	5.4 m × 3.8.0 m
Net Plot size	:	4.2 m × 3.0 m

Main plots: Irrigation schedules

I_1: One irrigation at pre-flowering stage

I_2: One irrigation at pod forming stage

I_3: Two irrigations at pre-flowering and pod formation stages

Sub plots: Soil amendments

S_1: Soil application of Humic acid @ 20 kg ha^{-1}

S_2: Soil application of Hydrogel @ 2.5 kg ha^{-1}

S_3: Soil application of FYM @ 5 t ha^{-1}

Fig. 3.2 Layout plan of the experimental field

Plate 1. Application of soil amendments before sowing of blackgram crop

Plate 2. General view of the experimental field

Plate 3. Recording of soil moisture data in the experimental field

3.6 EXPERIMENTAL DETAILS

The field experiment was laid out in a spilt plot design with three irrigation schedules as main plots and three soil amendment treatments as subplots, replicated four times. The field layout plan is depicted in Fig 3.2 and the general view of experimental field depicted in Plate 2. The details of the experiment are given below.

Location	:	Advanced post graduate centre, Lam, Guntur
Crop	:	Blackgram (*Vigna mungo* L.)
Variety	:	LBG-787
Season	:	*rabi*, 2019-20
Design	:	Split Plot Design
Treatments	:	Main plots: 3, Sub plots: 3
Replications	:	4
Gross Plot size	:	5.4 m × 3.8 m
Net Plot size	:	4.2 m × 3.0 m
Spacing	:	30 cm × 10 cm
Date of sowing	:	28-11-2019

3.5.1 Details of Treatments

Main plots: Irrigation schedules

I_1: One irrigation at pre-flowering stage

I_2: One irrigation at pod formation stage

I_3: Two irrigations at pre-flowering and pod formation stages

Sub plots: Soil amendments

S_1: Soil application of Humic acid @ 20 kg ha^{-1}

S_2: Soil application of Hydrogel @ 2.5 kg ha^{-1}

S_3: Soil application of FYM @ 5 t ha^{-1}

Table 3.4. Irrigation schedules

S. No	Treatments	Time of application
1	One irrigation at pre-flowering stage	33 DAS
2	One irrigation at pod formation stage	52 DAS
3	Two irrigations at pre-flowering and pod formation stages	33 DAS & 52 DAS

3.5.3 Details of soil amendments

(1) Humic acid

Humic acid is a naturally occurring organic compound with carboxylic, phenolic, alcoholic and carbonyl fractions extracted from various sources such as lignite, peat, coal, FYM, coir pith besides natural persistence in soil. Humic acid comprise modification of soil physio chemical and biological environment such as aggregation, aeration, permeability, water holding capacity, hormonal activity, microbial growth, organic matter mineralization, cation exchange capacity, transport and availability of nutrients due to which it enhances plant growth. Humirate (98 WSD) with humic acid composition (85% by w/w) was mixed with sand and was then applied in soil at a depth of 20-25cm before sowing of blackgram seed in the respective plots.The commercial product of humic acid namely Humirate marketed by Ag cropchem (P) limited Hyderabad is a free flowing crystalline shiny dark black flakes was mixed with sand and applied as basal at the time of sowing.

Composition of Humic Acid used in the experimental field

Nutrient Contents	**Percent by Weight (w/w)**
Humic Acid (on dry basis)	85 %
Fulvic Acid	5 %
Organic Potash (as K_2o) (on dry basis)	8 %
Water solubility	98 % - 100 %
PH (1% Solution)	9.0 – 11.0

Drawbacks of Humic acid

- Humic acid is available in various forms like dust, liquid and granules so there should be proper idea on which one to use in various crops.
- The percentage of humic acid also differs from dust, liquid and granules so proper information should be given for application in field.

(2) Hydrogel

It is an insoluble, cross-linked three-dimensional semi-synthetic polymer which absorbs water more than 500 times of its weight and gradually releases it and also improves soil hydro-physical properties such as porosity, aggregate stability and hydraulic conductivity. It has also been reported to improve seed germination, root growth and density, and help plants withstand extended moisture stress and has shown potential to realize higher yield with limited water. Hydrogel with trade name of Water Force was mixed with sand in 1:10 proportion respectively and was then applied in soil at a depth of 20-25 cm before sowing of blackgram seed in the experimental plots.

Drawbacks of Hydrogel

- Hydrogels are found to be effective in absorbing and withholding the moisture from soil but their role in releasing the moisture into the soil in field conditions is not clearly found
- Hydrogels are very costly which limits their use to high value crops such as potted ornamental plants, landscape trees and for home garden uses.
- Apart from moisture holding properties hydrogels do not have any nutrients in it and is not found to involve directly in increasing the nutrient concentration in soil

(3) FYM

Farm Yard Mannure **(**FYM) is an organic material supplies all major nutrients (N, P, K, Ca, Mg, S,) necessary for plant growth, as well as micronutrients (Fe, Mn, Cu and Zn). Hence, it acts as a mixed fertilizer. FYM improves soil physical, chemical and biological properties. Improvement in the soil structure due to FYM application leads to a better environment for root development. FYM also improves soil water holding capacity, nutrient availability and thus improves the yield of crops.

Drawbacks of FYM

- FYM is required in large quantities for application in field but now a days it is not available easily.
- FYM needs more cost/ unit weight of nutrients during handling, storage and application as compared to fertilizers.
- Its decomposition releases harmful gases that pollutes the atmosphere.

Table 3.5. Doses and method of application of soil amendments

S. No	Soil amendments	Dose	Method of Application
1	Humic acid	20 kg ha^{-1}	Sand mix application
2	Hydrogel	2.5 kg ha^{-1}	Sand mix application
3	Farm Yard Manure (FYM)	5 t ha^{-1}	Broadcasting

3.7 CULTIVAR DESCRIPTION

LBG-787

The variety was released by Acharya N.G Ranga agricultural university, Regional Agricultural Research Station , Lam , Guntur. It is a photo insensitive high yielding, Yellow Vein Mosaic (YMV) resistant blackgram culture. Seeds are medium bold and shiny. Dark green leaves with purple ting on leaf margins. Pods are sparsely hairy and born on main stem in addition to solitary bearing. It is suitable for cultivation in all the seasons including rice fallow situation. Duration of crop maturity is 75-80 days. The variety was released by central varietal release committee during 2015 for commercial cultivation in south zone (A.P, Telangana, Karnataka, Tamilnadu, Kerala)

3.8 CULTIVATION DETAILS

The following field operations were carried out during the experimentation period

3.8.1 Field Preparation

The experiment was conducted at the Advanced Post Graduate Centre, Lam, Guntur. The experimental field was ploughed twice with a tractor drawn cultivator, later harrowed with a rotavator to get a fine tilth. The area was cleared off weed-trash and divided into required number of plots as shown in the layout plan (Fig. 3.2).

3.8.2 Fertilizer Application

Nitrogen and phosphorous were applied as basal @ 20 kg N ha^{-1} in the form of urea and 50 kg P_2O_5 ha^{-1} in the form of di ammonium phosphate uniformly to all the experimental plots at the time of sowing.

3.8.3 Sowing

Blackgram variety LBG 787 was selected for this study. Sowing was done on 28th November, 2019 by line sowing method with a spacing of 30 cm between the rows and 10 cm between plants with in the row. The seeds were covered immediately with the soil and a light irrigation was given for good establishment of plant population.

3.8.4 Thinning and Gap Filling

Gap filling was done at 5 days after sowing to maintain optimum plant population. Thinning was done at 10 DAS (days after sowing) by removing excess plants by keeping one seedling per hill in all the treatments to maintain the optimum plant population and gaps were filled with fresh seed.

3.8.5 Weeding

Pre-emergence herbicide Pendimethalin 30 % EC @ 750 g a.i ha^{-1} was sprayed one day after sowing to arrest the weed growth. Two hand weedings were taken up at 15 and 30 DAS.

3.8.6 Plant Protection Measures

Prophylactic measures were taken to prevent the incidence of pests and diseases. Acephate @ 1 ml L^{-1} was sprayed from 15 DAS to prevent the attack of *Bemisia tabaci* . Flubendamide @ 0.2 ml L^{-1} and Chloranthraniliprole @ 0.3 ml L^{-1} from 40 DAS to control the attack of *Maruca vitrata.*

3.8.7 Harvesting and Threshing

Blackgram crop was harvested when more than 80 percent of the pods attained maturity. The border rows from each plot were harvested first and collected as bulk separately. Later, net plot area was harvested after separating the plants designated for recording biometric observations and kept for sun drying. The sun-dried plants were beaten with sticks and the seed yield for each plot was recorded after drying and finally yield ha^{-1} was computed.

3.9 PRE HARVEST OBSERVATIONS

Five plants selected at random from the net plot area were labelled and used for recording biometric observations at different stages. For recording dry matter production, which involved destructive sampling, five successive plants in the second row from the border row in each plot were sampled at each time.

3.9.1 Plant Population

The initial plant population after thinning and final plant population at crop maturity stage m^{-2} was recorded from each treatment.

3.9.2 Plant Height (cm)

The labelled plants in the net plot area were used for recording plant height at 15, 30, 45, 60 DAS and at harvest. The height of the plant was measured from ground level to the tip of the plant and expressed in cm.

3.9.3 Number of Branches per Plant

The total number of branches of five labelled plants was counted in the net plot area and average was worked out to report as total number of branches per plant.

3.9.4 Dry Matter Accumulation (kg ha^{-1})

Five plants serially from the sampling row at 15, 30, 45, 60 DAS and at harvesting stages were up rooted and their roots were removed. The above ground portions of the plants were sun dried for two to three days and then dried in a hot air oven at 65^0C for 48 hours, and later the plants were weighed on top pan balance. The final weight was recorded and the dry matter was expressed in kg ha^{-1}.

3.10 POST HARVEST OBSERVATIONS

3.10.1 Number of Clusters per Plant

The total number of clusters were counted from five tagged plants, averaged and expressed as number of clusters $plant^{-1}$.

3.10.2 Number of Pods per Cluster

The number of pods from the five tagged plants were counted and the average was expressed as number of pods $plant^{-1}$.

3.10.3 Number of Seeds per Pod

The number of seeds per pod was calculated by dividing the total number of seeds from the sampled plants by total number of pods from the sampled plants.

3.10.4 Test Weight (100 seed weight) (g)

A small sample of seed was drawn from each net plot seed yield. One hundred grains were counted from these samples and weights were recorded and expressed as the test weight in grams.

3.10.5 Seed Yield (kg ha^{-1})

At maturity, all the above ground blackgram biomass from each net plot area was harvested and transported to the threshing floor. After drying in the sun for seven days, the biomass from the each plot was weighed before subjecting it for threshing. After threshing, weight of the seeds was recorded plot-wise and expressed in kg ha^{-1}. Seed yield obtained from the plants designated for biometric observations was also added to respective net plot seed yield.

3.10.6 Haulm Yield (kg ha^{-1})

Before threshing, the total biological yield from the net plot area was recorded. Later the haulm yield per plot was obtained by deducting the seed yield per plot from the biological yield per plot and expressed in kg ha^{-1}.

3.10.7 Biological Yield (kg ha^{-1})

Before threshing, the total biological yield from the net plot area was recorded per plot and expressed in kg ha^{-1}.

3.10.8 Harvest Index (%)

Harvest index (HI) was computed by dividing seed yield with the total biological yield and was expressed in percentage (Donald and Humblin, 1976).

$$HI\ (\%) = \frac{\text{Seed yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}} \times 100$$

3.11 SOIL MOISTURE STUDIES

Soil moisture was determined thermo-gravimetrically from three different soil layers *viz.*, 0-15, 15-30, 30-45 cm and 45-60 cm. The soil samples were drawn at the time of sowing, and at 15 days interval from sowing to harvest. In addition, samples were taken before and after each irrigation. The soil samples were drawn from different layers separately with the help of a screw auger and collected into soil moisture cans and dried in the hot air oven at 105^0C for 24 hours and moisture content was estimated. These values were used to compute the seasonal consumptive use and moisture extraction pattern by the crop.

3.11.1 Consumptive Use of Water

Consumptive use of blackgram was estimated thermo gravimetrically taking soil samples before and after each irrigation up to a depth of 60 cm in four layers consisting of 0-15, 15-30, 30-45 and 45-60 cm as described by Dastane, 1967.

$$CU = \sum_{K=1}^{N} (E_P \times 0.8) + \sum_{i=1}^{n} [(M_1i - M_2i) / 100] \times dbi \times D_i + ER$$

Where,

CU = Consumptive use of water (mm)

Ep = Pan Evaporation value (mm) from the USWB class A pan for the interval from the date of irrigation to the date of sampling after irrigation

0.8 = A constant factor used to get ET value on the date of sampling before irrigation

M_1i = Moisture % of i^{th} layer on the date of sampling after irrigation

M_2i = Moisture % of i^{th} layer on the date of sampling before irrigation

db_i = Bulk density of i^{th} layer

(Bulk density at 0-15 cm, 15-30 cm, 30-45 cm and 45-60 cm are 1.20 g cm^{-3} , 1.21 g cm^{-3} , 1.23 g cm^{-3} , 1.25 g cm^{-3} respectively)

D_i = Depth of i^{th} layer (0-15 cm, 15-30 cm, 30-45 cm and 45-60 cm)

ER = Effective rainfall (mm)

n = Number of soil layers (four layers)

N = Number of days from irrigation to sampling after irrigation (two days)

3.11.2 Moisture Use Rate

The daily moisture use rate (mm day^{-1}) was worked out from the soil moisture depleted from the root zone during the given sampling interval and the number of days in the interval.

3.11.3 Water Use Efficiency

Water use efficiency in kg ha-mm^{-1} for a given treatment was calculated by dividing the seed yield with the total consumptive use of water for the crop period.

$$\text{Water use efficiency} = \frac{\text{Seed yield (kg ha}^{-1}\text{)}}{\text{Consumptive use of water (mm)}}$$

3.11.4 Soil Moisture Depletion Pattern

Soil moisture depletion was worked out for four different layers viz., 0-15, 15-30, 30-45 and 45-60 cm separately and summed up treatment wise over the entire crop season. Layer wise soil moisture depletion was also expressed as percentage of total quantity of moisture depleted from the root zone under a given treatment.

3.12 CHEMICAL ANALYSIS OF PLANT MATERIAL

The plant samples collected for dry matter estimation at maturity from different treatments were oven dried, ground into powder and were analysed for nitrogen (Modified micro kjeldhal method, Piper, 1966 using Kelplus N analyser); phosphorus (Vanado – molybdo phosphoric yellow colour method, Jackson, 1973), potassium (Flame photometer method, Jackson, 1973).

From the chemical analysis data, uptake of the individual nutrient was calculated as shown below. Uptake was calculated by multiplying the nutrient content by the respective dry weights of seed and haulm and then summed up to represent the nutrient uptake in seed and haulm at harvest.

$$\text{Nutrient Uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%) X Dry weight of seed/haulm (kg ha}^{-1}\text{)}}{100}$$

3.13 ECONOMICS

The economics of different treatments were calculated by considering the input costs and output prices prevailing at the time of the harvest. The net returns ha^{-1} was calculated by deducting the cost of cultivation worked out with the then prevailing cost of input and labour wages.

$$\text{Net returns (Rs ha}^{-1}\text{)} = \text{Gross returns (Rs ha}^{-1}\text{)} – \text{Cost of cultivation (Rs ha}^{-1}\text{)}$$

Benefit Cost Ratio (BCR) for all the treatments was worked out on the basis of net returns in the terms of rupees after deducting the cost of treatments from gross returns.

$$\text{BCR} = \frac{\text{Net returns (Rs ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs ha}^{-1}\text{)}}$$

3.14 STATISTICAL ANALYSIS

The data generated on various parameters during the course of investigation were statistically analyzed by applying the technique of analysis of variance contained in the procedures suggested by (Gomez and Gomez, 1984). Statistical significance was tested by applying F-test at 0.05 level of probability and critical differences were calculated for those parameters which were found significant ($P<0.05$) to compare the effects of different treatments. Whenever the treatment differences were found to be significant (F test), critical difference was worked out at five per cent probability level and the values were furnished. The treatment differences that were not significant were expressed as non-significant and denoted by "NS".

Chapter-IV

Results and Discussion

Chapter IV

RESULTS AND DISCUSSION

The present investigation entitled " **Effect of Humic acid and Hydrogel on Soil Moisture Retention and Productivity of *rabi* Blackgram (*Vigna mungo* L.)"** was conducted on clay soil during *rabi*, 2019-2020 at Advanced Post Graduate Centre, Lam, Guntur district, Andhra Pradesh.

The experimental results were analyzed statistically and are presented and discussed below with appropriate research evidences under the following heads.

4.1. WEATHER CONDITIONS PREVAILED DURING CROP GROWTH PERIOD

The data on weather parameters observed during the crop growth period at the meteorological observatory RARS, Lam, Guntur are given in Table 3.1 and depicted in Fig. 3.1. The weekly mean maximum temperatures during the period of crop growth ranged from 30.4^{0}C to 33.9^{0}C while the weekly mean minimum temperatures ranged from 16.5^{0}C to 21.0 ^{0}C. A total rainfall of 14.0 mm was received during the period of experimentation with two rainy days during the reproductive stage of crop growth. The rainfall received during the period of crop growth was found to be effective which coincides with the critical growth stages of crop and favored the crop growth. The weekly mean relative humidity ranged from 64.2 to 77.6 per cent. All the weather parameters favorably affected blackgram crop growth. However, minor incidence of YMV disease and maruca pod borer were noticed at the flowering stage and necessary plant protection measures were taken up and ultimately average seed yields of blackgram were realized.

4.2 GROWTH PARAMETERS

4.2.1 Plant Population (Number of Plants m^{-2})

Uniform initial plant population was maintained in all the treatment plots. The initial and final plant population of blackgram was not influenced by the irrigation schedules, soil amendments and by their interaction. The data on final plant population was presented in Table 4.1. However, maximum final plant population (24.31 plants m^{-2}) was recorded when irrigation given at pre-flowering and pod formation stages and minimum final plant population (22.09 plants m^{-2}) was recorded when irrigation was given at pod formation stage. Among soil amendment treatments hydrogel plot recorded maximum final plant population (24.08 plants m^{-2}). Anupama and Parmar (2012) reported hydrophilic nature of hydrogel, this property of hydrogel helped in maintaining adequate soil moisture around the root zone and hence augmented germination in blackgram. Similar findings are reported by Roy *et al.* (2019).

Table 4.1. Final plant population (m^{-2}) of blackgram as influenced by irrigation schedules and soil amendments

Final plant population (m^{-2})				
Soil amendments (S)	**Irrigation schedules (I)**			
	I_1	**I_2**	**I_3**	**Mean**
S_1 -Humic acid @ 20 kg ha^{-1}	22.50	22.40	24.20	23.03
S_2-Hydrogel @ 2.5 kg ha^{-1}	23.82	22.57	25.85	24.08
S_3- FYM @ 5 t ha^{-1}	23.05	21.30	22.90	22.41
Mean	23.12	22.09	24.31	
	SEm±	**CD (p=0.05)**	**CV (%)**	
Irrigation schedules (I)	0.57	NS	8.47	
Soil amendments (S)	0.57	NS	8.50	
Interaction (IxS)	0.98	NS		

4.2.2 Plant Height (cm)

Plant height (cm) measured at various stages of crop growth *i.e.*, at 15, 30, 45, 60 DAS and at harvest was analyzed and data is presented in Table 4.2. (Fig. 4.1.)

Blackgram plant height was significantly influenced by irrigation schedules and soil amendments at all stages of crop growth except at 15 DAS, but their interaction was found to be non significant at all stages. Plant height continued to increase with the advancement of crop age with an increasing rate from 15 DAS to 45 DAS and at decreasing rate from there after. Irrigation given at I_3 (pre flowering + pod formation stages) recorded maximum plant height (24.92 cm, 33.09 cm, 38.24 cm and 39.24 cm) at 30, 45, 60 DAS and at harvest respectively which is significantly on a par with I_1 (one irrigation at pre flowering stage) at 30 DAS and significantly superior to I_1 and I_2 treatments (one irrigation at pod formation stage) at 45, 60 DAS and at harvest.

This might be due to more no.of irrigations applied in I_3(two irrigations at pre flowering and pod formation stages) compared to I_1 and I_2 resulted in optimum soil moisture availability during critical stages of plant growth coupled with higher water potential and turgidity of the plant cells which ultimately lead to higher assimilation of photosynthates. These findings are in confirmation with Lende and Patil (2017), Komal *et al*. (2018), Mondal *et al*. (2018), Jaybhay *et al.* (2019),

Significantly taller plants (24.75, 32.52 cm, 37.53 cm, 38.55 cm) at 30, 45, 60 DAS and at harvest respectively were observed with soil application of hydrogel @ 2.5 kg ha^{-1} when compared to FYM @ 5 t ha^{-1} treated plot but comparable with humic acid @ 20 kg ha^{-1} treated plot. "Hydrogel have been reported to increase the activity of cell division, cell expansion and cell elongation, ultimately leading to an increased plant height". Similar results are found with the findings of Pradeep kumar and Rajkumara (2016), Singh *et al.* (2017b), Ram *et al.* (2018), Ali *et al*. (2019), Suriyaprakash *et al*. (2019) and Santosh *et al*. (2020).

Table 4.2. Plant height (cm) of blackgram at different growth stages as influenced by irrigation schedules and soil amendments

Treatments	Plant height (cm)				
Irrigation schedules (I)	**15 DAS**	**30 DAS**	**45 DAS**	**60 DAS**	**Harvest**
I_1- One irrigation at pre-flowering stage	14.63	23.43	30.68	35.66	37.10
I_2- One irrigation at pod formation stage	14.58	22.80	28.76	34.29	34.53
I_3- Two irrigations at pre-flowering and pod formation stages	15.91	24.92	33.09	38.24	39.24
SEm ±	0.38	0.44	0.66	0.67	0.73
CD (P=0.05)	NS	1.52	2.28	2.31	2.52
CV%	8.67	6.41	7.39	6.42	6.85
Soil amendements (S)					
S_1 -Humic acid @ 20 kg ha^{-1}	15.05	23.69	30.95	36.05	36.56
S_2-Hydrogel @ 2.5 kg ha^{-1}	15.40	24.75	32.52	37.53	38.55
S_3- FYM @ 5 t ha^{-1}	14.67	22.71	29.06	34.61	35.23
SEm ±	0.22	0.46	0.71	0.56	0.55
CD (P=0.05)	NS	1.38	2.13	1.66	1.65
CV%	5.16	6.78	8.01	5.35	5.21
Interaction (I x S)	NS	NS	NS	NS	NS

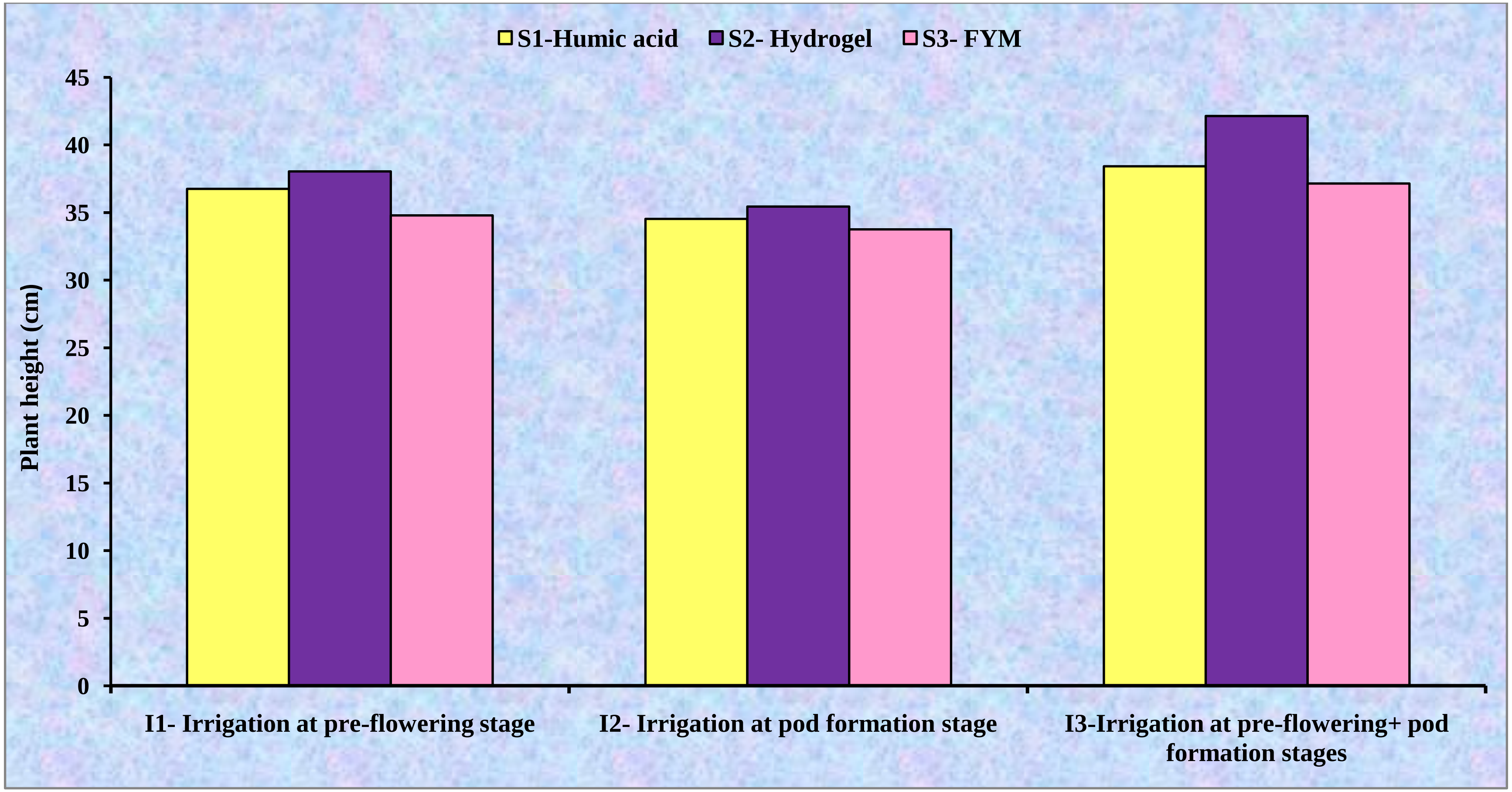


Fig. 4.1. Plant height (cm) of blackgram as influenced by irrigation schedules and soil amendments at harvest

4.2.3 Number of Branches Plant^{-1}

The data pertaining to number of branches recorded at 30, 45, 60 DAS and at harvest is presented in Table 4.3 indicated that number of branches increased gradually with increase in duration of the crop. Branches were not developed at 15 DAS. The influence of irrigation on number of branches plant^{-1} at all other crop growth stages (30, 45, 60 DAS and at harvest) was found to be significant. At 30 and 45 DAS more number of branches plant^{-1} 4.51 and 5.25 respectively were observed with irrigation given at I_3 (pre flowering + pod formation stages) which was significantly superior to I_2 (one irrigation at pod formation stage) and comparable with I_1 treatments (one irrigation at pre flowering stage). At 60 DAS and at harvest the highest number of branches in blackgram *viz.*, 5.73 and 5.93 were recorded with I_3.

The influence of soil amendments on number of branches plant^{-1} at all crop growth stages (30, 45, 60 DAS and at harvest) were noticed to be significant but soil application of hydrogel @ 2.5 kg ha^{-1} realized significantly more number of branches plant^{-1}(4.48, 5.17, 5.50 and 5.75) at 30, 45, 60 DAS and harvest, respectively compared to FYM @ 5 t ha^{-1} but comparable with humic acid @ 20 kg ha^{-1} at 30, 45, 60 DAS and harvest, respectively and less number of branches (4.15, 4.82, 5.12 and 5.36) were observed in the treatments those received FYM @ 5 t ha^{-1}. The interaction effect on number of branches plant^{-1} was found non significant.

This is due to the resultant effect of moisture availability at critical stages maintained the water potential and the net assimilation which transformed into vegetative growth *i.e.,* number of branches. Similar views were expressed by Dixit *et al*. (1993a), Lende and Patil (2017), Komal *et al*. (2018), Mondal *et al*. (2018), Jaybhay *et al.* (2019).

The increase in branches plant^{-1} was due to soil application of hydrogel @ 2.5 kg ha^{-1} might helped augmentation in crop growth due to its ability of retaining and release of water to maintain proper soil moisture in the rhizosphere which support better plant growth. (Anupama and Parmar 2012). A similar result was reported by Pradeep kumar and Rajkumara (2016), Singh *et al*. (2017), Ram *et al*. (2018), Ali *et al*. (2019), Suriyaprakash *et al*. (2019) and Santosh *et al*. (2020),

Table 4.3. Number of branches plant^{-1} of blackgram at different growth stages as influenced by irrigation schedules and soil amendments.

Treatments	**Number of branches plant^{-1}**			
Irrigation schedules (I)	**30 DAS**	**45 DAS**	**60 DAS**	**Harvest**
I_1- One irrigation at pre-flowering stage	4.29	5.05	5.18	5.45
I_2- One irrigation at pod formation stage	4.10	4.63	4.99	5.29
I_3- Two irrigations at pre-flowering and pod formation stages	4.51	5.25	5.73	5.93
SEm ±	0.07	0.09	0.15	0.12
CD (P=0.05)	0.25	0.30	0.53	0.41
CV%	5.89	6.30	10.07	7.31
Soil amendements (S)				
S_1 -Humic acid @ 20 kg ha^{-1}	4.27	4.95	5.28	5.55
S_2-Hydrogel @ 2.5 kg ha^{-1}	4.48	5.17	5.50	5.75
S_3- FYM @ 5 t ha^{-1}	4.15	4.82	5.12	5.36
SEm ±	0.08	0.08	0.08	0.16
CD (P=0.05)	0.24	0.23	0.25	0.25
CV%	6.53	5.34	5.36	5.20
Interaction (I x S)	NS	NS	NS	NS

4.2.4 Dry Matter Accumulation (kg ha^{-1})

Dry matter accumulation (kg ha^{-1}) of blackgram at different stages of crop growth was presented in Table 4.4 and depicted in Fig. 4.2. The data reveals that there is a progressive increase in dry matter accumulation with the age of the crop. Dry matter accumulation is significantly influenced by irrigation schedules and soil amendments at all stages of crop growth except at initial stage i.e at 15 DAS where the influence was found non significant.

At 30 and 45 DAS (513 and 770 kg ha^{-1}) highest dry matter accumulation was observed with I_3 which was significantly superior over I_2 but comparable with I_1 . At 60 DAS and at harvest higher dry matter production (2752 and 3399 kg ha^{-1}) was recorded with I_3 which was statistically superior over I_2 and I_1.

The influence of soil amendments on accumulation of dry matter was noticed to be significant at all crop growth stages except at 15 DAS. Soil application of hydrogel @ 2.5 kg ha^{-1} recorded maximum dry matter accumulation with 516, 755, 2630 and 3312 kg ha^{-1} at 30, 45, 60 DAS and at harvest respectively which is significantly superior to application of FYM 5 t ha^{-1} and on a par with soil application of humic acid @ 20 kg ha^{-1} treated plots. The minimum dry matter accumulation of 444, 686, 2364 and 2980 kg ha^{-1}, was recorded at 30, 45, 60 DAS and harvest respectively in the plots which received FYM @ 5 t ha^{-1}.

Irrigation schedules and soil amendments interaction effect on dry matter accumulation was observed to be non significant at all the stages of the crop growth.

The availability of soil moisture at critical growth stages of crop growth in I_3 when compared to only one irrigation at I_1 and I_2. Thus, it makes the sense clear that irrigation is imperative for crop growth and dry matter accumulation. These findings lead support with those of Lende and Patil (2017), Komal *et al*. (2018), Mondal *et al*. (2018) and Lakshmi *et al.* (2018).

Increased dry matter accumulation was due to soil application of hydrogel @ 2.5 kg ha^{-1} that led to increase in cell division and enlargement and that is mainly dependent on plant-water relations. Optimum moisture content in soil encourages better root development, proper translocation and uptake of nutrients in the soil by the plants, which support better plant growth and ultimately resuled in increased dry matter accumulation. (Anupama and Parmar 2012). Above outcomes are similar with the findings of Pradeep kumar and Rajkumara (2016), Singh *et al*. (2017 b), Kumar *et al*. (2019), Santosh *et al*. (2020).

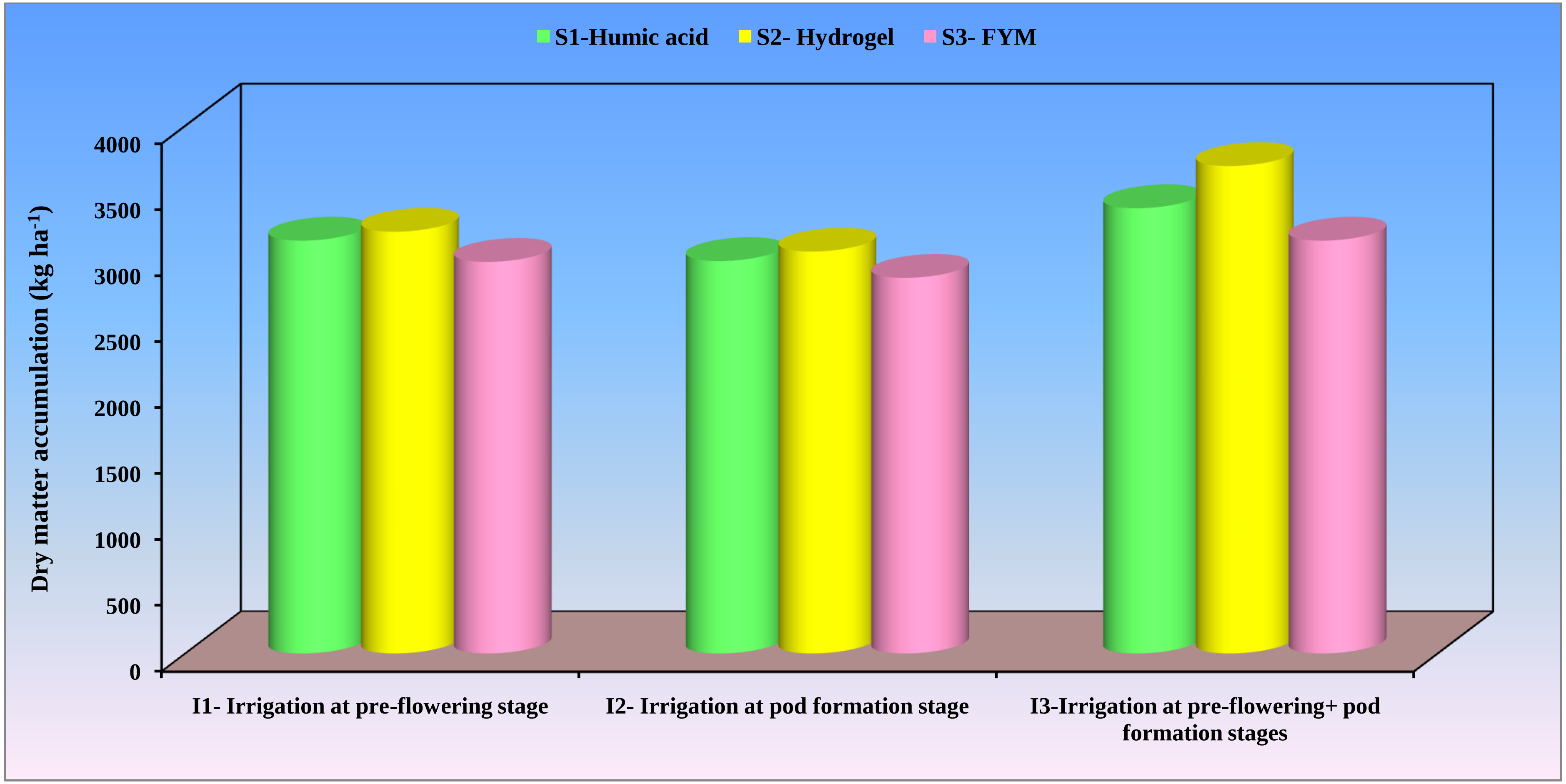


Fig. 4.2. Dry matter accumulation (kg ha^{-1}) of blackgram as influenced by irrigation schedules and soil amendments at harvest

Table 4.4. Dry matter accumulation (kg ha^{-1}) of blackgram at different growth stages as influenced by irrigation schedules and soil amendments

Treatments	**Dry matter accumulation (kg ha^{-1})**				
Irrigation schedules (I)	15 DAS	30 DAS	45 DAS	60 DAS	Harvest
I_1- One irrigation at pre-flowering stage	155	475	721	2450	3097
I_2- One irrigation at pod formation stage	152	466	685	2312	2955
I_3- Two irrigations at pre-flowering and pod formation stages	162	513	770	2752	3399
SEm ±	2.8	11.6	15.5	82.8	85.6
CD (P=0.05)	NS	40.4	53.8	286	296
CV%	6.2	8.3	7.4	11.46	9.4
Soil amendements (S)					
S_1 -Humic acid @ 20 kg ha^{-1}	156	493	723	2520	3159
S_2-Hydrogel @ 2.5 kg ha^{-1}	160	516	755	2630	3312
S_3- FYM @ 5 t ha^{-1}	153	444	698	2364	2980
SEm ±	2.3	10.9	12.1	42.2	55.9
CD (P=0.05)	NS	32	36	127	167
CV%	5.1	7.8	5.8	5.8	6.1
Interaction (I x S)	NS	NS	NS	NS	NS

4.3 YIELD ATTRIBUTES

4.3.1 Number of Clusters Plant^{-1}

Number of clusters plant^{-1} was significantly influenced by irrigation and soil amendments Table 4.5.

Maximum number of clusters plant^{-1} (3.8) was observed when irrigation was given at pre-flowering and pod formation stages (I_3) and minimum number of clusters plant^{-1} (3.2) was recorded in treatments which received one irrigation at pod formation stage (I_2).

The highest number of clusters plant^{-1} (3.6) was recorded in hydrogel treated plot which was on a par with humic acid treated plot . The plots those received FYM recorded the lowest number of clusters plant^{-1} (3.3).

Table 4.5 Number of clusters plant^{-1} of blackgram as influenced by irrigation schedules and soil amendments.

Number of clusters plant^{-1}				
Soil amendments (S)	**Irrigation schedules (I)**			
	I_1	I_2	I_3	**Mean**
S_1 -Humic acid @ 20 kg ha^{-1}	3.5	3.2	3.8	3.5
S_2-Hydrogel @ 2.5 kg ha^{-1}	3.6	3.3	3.9	3.6
S_3- FYM @ 5 t ha^{-1}	3.3	3.1	3.6	3.3
Mean	3.5	3.2	3.8	
	SEm±	**CD (p=0.05)**	**CV (%)**	
Irrigation schedules (I)	0.06	0.21	5.87	
Soil amendments (S)	0.05	0.16	5.32	
Interaction (I x S)	0.136	NS		

The interaction effect of irrigation treatments and soil amendments on number of clusters plant^{-1} was found non significant.

"The soil application of hydrogel and humic acid resulted in maintaining adequate content of moisture in soil inturn promotes better root development, appropriate movement and uptake of nutrients by the plant resulting in balanced availability of macro and micro nutrients at all stages by preventing their fixation in soil. So the nutrients have been effectively absorbed and translocated to the pods resulting in more no.of clusters plant^{-1}" Patil (2011). These are in confirmation with studies of Pradeep kumar and Rajkumara (2016), Singh *et al.* (2017b), Ram *et al.* (2018), Shikha *et al.* (2019) and Santosh *et al.* (2020).

4.3.2 Number of Pods Cluster^{-1}

Among the different main plot treatments presented in Table 4.6 showed that I_3 (two irrigations at pre-flowering and pod formation stages) recorded the highest number of pods cluster^{-1} (6.2) which is significantly superior over I_2 (5.5) and comparable with I_1 (5.9)

It is noteworthy to observe that, among the sub plots maximum number of pods cluster^{-1} was recorded with application of hydrogel @ 2.5 kg ha^{-1} (6.1). Minimum number of pods cluster^{-1} (5.6) were observed in FYM @ 5 t ha^{-1} treated plots.

Irrigation schedules and soil amendments interaction effect of on number of pods cluster^{-1} was found non significant.

This could be ascribed to the fact that moisture availability near rhizosphere increased the uptake of plant nutrients which resulted in better translocation of the photosynthates from source to sink. These results are in accordance with Dabhi *et al.* (1998), Basu and Bandyopadhyay (2009), Rao *et al.* (2016), Lende and Patil (2017), Komal *et al*. (2018), Lakshmi *et al.* (2018), Mondal *et al*. (2018) and Jaybhay *et al.* (2019).

Increase in the number of pods cluster^{-1} indicates better absorption of plant nutrients and higher photosynthetic activity resulting in more carbohydrate assimilation. Hydrogel application improves the water availability, this concurrently improves the nutrient uptake and photosynthetic activity thereby increases accumulation of dry matter production in the pod setting phase which might have improved the pod development and number of pods plant^{-1} and finally contributed for higher productivity. These observations were similar to the findings of Patil (2011), Pradeep kumar and Rajkumara (2016), Singh *et al.* (2017 b), Ram *et al.* (2018), Roy *et al.* (2019), Shikha *et al.* (2019) and Santosh *et al.* (2020),

Table 4.6 Number of pods $cluster^{-1}$ of blackgram as influenced by irrigation schedules and soil amendments.

Number of pods $cluster^{-1}$				
Soil amendments (S)	**Irrigation schedules (I)**			
	I_1	I_2	I_3	**Mean**
S_1 -Humic acid @ 20 kg ha^{-1}	5.9	5.5	6.1	5.8
S_2-Hydrogel @ 2.5 kg ha^{-1}	6.0	5.6	6.7	6.1
S_3- FYM @ 5 t ha^{-1}	5.7	5.4	5.9	5.6
Mean	5.9	5.5	6.2	
	SEm±	**CD (p=0.05)**	**CV (%)**	
Irrigation schedules (I)	0.11	0.36	6.18	
Soil amendments (S)	0.10	0.28	5.58	
Interaction (I x S)	0.176	NS		

4.3.3 Number of Seeds Pod^{-1}

Among the main plots I_3 recorded the highest number of seeds pod^{-1} (6.3) and the lowest was recorded in I_2 (6.0). It was noticed that the influence of irrigation treatments and soil amendments and their interaction on number of seeds pod^{-1} was found to be non significant Table. 4.7.

In resonance with the results, among the different sub plots, the highest number of seeds pod^{-1} was noticed in the plots those received hydrogel @ 2.5 kg ha^{-1} (6.3) and the lowest was recorded in the plots which received FYM @ 5 t ha^{-1} (6.0).

The increase in number of seeds pod^{-1} was due to increased uptake of nutrients and better translocation of nutrients from source to sink. These results are in conformity with those of Basu and Bandyopadhyay (2009), Rao *et al.* (2016), Lende and Patil (2017), Komal *et al*. (2018), Lakshmi *et al.* (2018), Mondal *et al*. (2018) and Jaybhay *et al.* (2019).

Table 4.7 Number of seeds pod^{-1} of blackgram as influenced by irrigation schedules and soil amendments.

	Number of seeds pod^{-1}			
Soil amendments (S)	**Irrigation schedules (I)**			
	I_1	**I_2**	**I_3**	**Mean**
S_1 -Humic acid @ 20 kg ha^{-1}	6.1	6.0	6.3	6.1
S_2-Hydrogel @ 2.5 kg ha^{-1}	6.3	6.0	6.5	6.3
S_3- FYM @ 5 t ha^{-1}	5.9	6.0	6.2	6.0
Mean	6.1	6.0	6.3	
	SEm±	**CD (p=0.05)**	**CV (%)**	
Irrigation schedules (I)	0.10	NS	5.68	
Soil amendments (S)	0.11	NS	6.26	
Interaction (I x S)	0.166	NS		

4.3.4 Test Weight (g)

Irrigation levels and soil amendments influence on 100 seed weight (g) of blackgram was observed to be significant but not by their interaction. Data pertaining to test weight of blackgram was represented in Table 4.9. The maximum mean test weight was recorded in I_3 (irrigation at pre-flowering + pod formation stages) (4.82 g) which was significantly superior to other irrigation treatments and the minimum was noticed in I_2 (4.23 g) . The maximum mean test weight was observed with hydrogel @ 2.5 kg ha^{-1} (4.73 g) which was comparable with humic acid @ 20 kg ha^{-1} (4.48g) and significantly superior to FYM @ 5 t ha^{-1} (4.21 g).

The increase in test weight in I_3 irrigation treatment may be because of better crop growth, efficient partitioning of dry matter and better translocation of photosynthates from source to the sink. On the other hand, the lowest test weight in I_2 is because of moisture stress leading to less movement of photosynthates bringing about wilted, shrivelled and under sized seeds. These results are similar with findings of Basu and Bandyopadhyay (2009), Pradeep kumar and Rajkumara (2016), Lende and Patil (2017), Komal *et al.* (2018), Lakshmi *et al.* (2018), Mondal *et al.* (2018) and Jaybhay *et al.* (2019).

Table 4.8 Test weight (100 seed weight) (g) of blackgram as influenced by irrigation schedules and soil amendments

Soil amendments (S)	Test weight (g)			
	Irrigation schedules (I)			
	I_1	I_2	I_3	Mean
S_1 -Humic acid @ 20 kg ha^{-1}	4.39	4.21	4.83	4.48
S_2-Hydrogel @ 2.5 kg ha^{-1}	4.65	4.51	5.02	4.73
S_3- FYM @ 5 t ha^{-1}	4.07	3.96	4.59	4.21
Mean	4.37	4.23	4.82	
	SEm±	**CD (p=0.05)**	**CV (%)**	
Irrigation schedules (I)	0.10	0.35	7.74	
Soil amendments (S)	0.09	0.27	6.91	
Interaction (I x S)	1.608	NS		

4.3.5 Seed Yield (kg ha^{-1})

The data representing the seed yield (kg ha^{-1}) is depicted in Table 4.9 and shown in Fig. 4.3 says that irrigation treatments and soil amendments influence on seed yield of blackgram was found to be significant.

The highest seed yield of 847 kg ha^{-1} was recorded with irrigation at I_3 (pre flowering+ pod formation stages) followed by I_1 (one irrigation at pre-flowering stage) and I_2 (one irrigation at pod formation stage) with 782 and 673 kg ha^{-1}, respectively. However, the increase in yield was significant with I_2 but comparable with I_1 treatment. The mean per cent increase in seed yield with I_3 and I_1 over I_2 was 20.5 % and 13.9 % respectively.

Among the soil amendments treatments, soil application of hydrogel @ 2.5 kg ha^{-1} proved to be better in increasing the seed yield (811 kg ha^{-1}) of blackgram and it was comparable with soil application of humic acid @ 20 kg ha^{-1} (772 kg ha^{-1}) and significantly superior over the treatments which received FYM @ 5 t ha^{-1} (720 kg ha^{-1}). The mean per cent increase in seed yield with hydrogel @ 2.5 kg ha^{-1} and humic acid @ 20 kg ha^{-1} over FYM @ 5 t ha^{-1} was 11.2 % and 7.2% respectively.

Irrigation schedules and soil amendments interaction effect on seed yield of blackgram was noticed non significant.

The increase in seed yield might be due to optimum soil moisture availability at critical stages of crop growth in I_3 treatment. Terminal heat and temperature extremities at later stages of crop growth during moisture stress especially at pre-flowering and pod formation stages may affect the productivity of blackgram, but the increase in seed yield might be due to optimum soil moisture availability at critical stages of crop growth by irrigation treatments and soil amendments. "Similar increase in seed yield of pulse crops (chickpea) with two irrigations at pre flowering and pod development stages was also reported by Munirathnam and Sangita (2009)". Similar results were noticed by Basu and Bandyopadhyay (2009), Lende and Patil (2017), Komal *et al*. (2018), Lakshmi *et al.* (2018), Mondal *et al*. (2018) and Jaybhay *et al.* (2019).

Table 4.9 Seed yield (kg ha^{-1}) of blackgram as influenced by irrigation schedules and soil amendments.

Seed yield (kg ha^{-1})				
Soil amendments (S)	**Irrigation schedules (I)**			
	I_1	I_2	I_3	Mean
S_1 -Humic acid @ 20 kg ha^{-1}	780	669	867	772
S_2-Hydrogel @ 2.5 kg ha^{-1}	845	689	900	811
S_3- FYM @ 5 t ha^{-1}	721	662	775	720
Mean	782	673	847	
	SEm±	CD (p=0.05)	CV (%)	
Irrigation schedules (I)	18	65	8.5	
Soil amendments (S)	18	54	8.2	
Interaction (I x S)	31	NS		

Hydrogel may have resulted in absorption/storage of moisture during the period of abundant supply *viz.* field capacity and release it during the time of moisture stress thereby with increased soil matric potential providing the crop with sufficient moisture supply during the entire vegetative and reproductive phases thereby

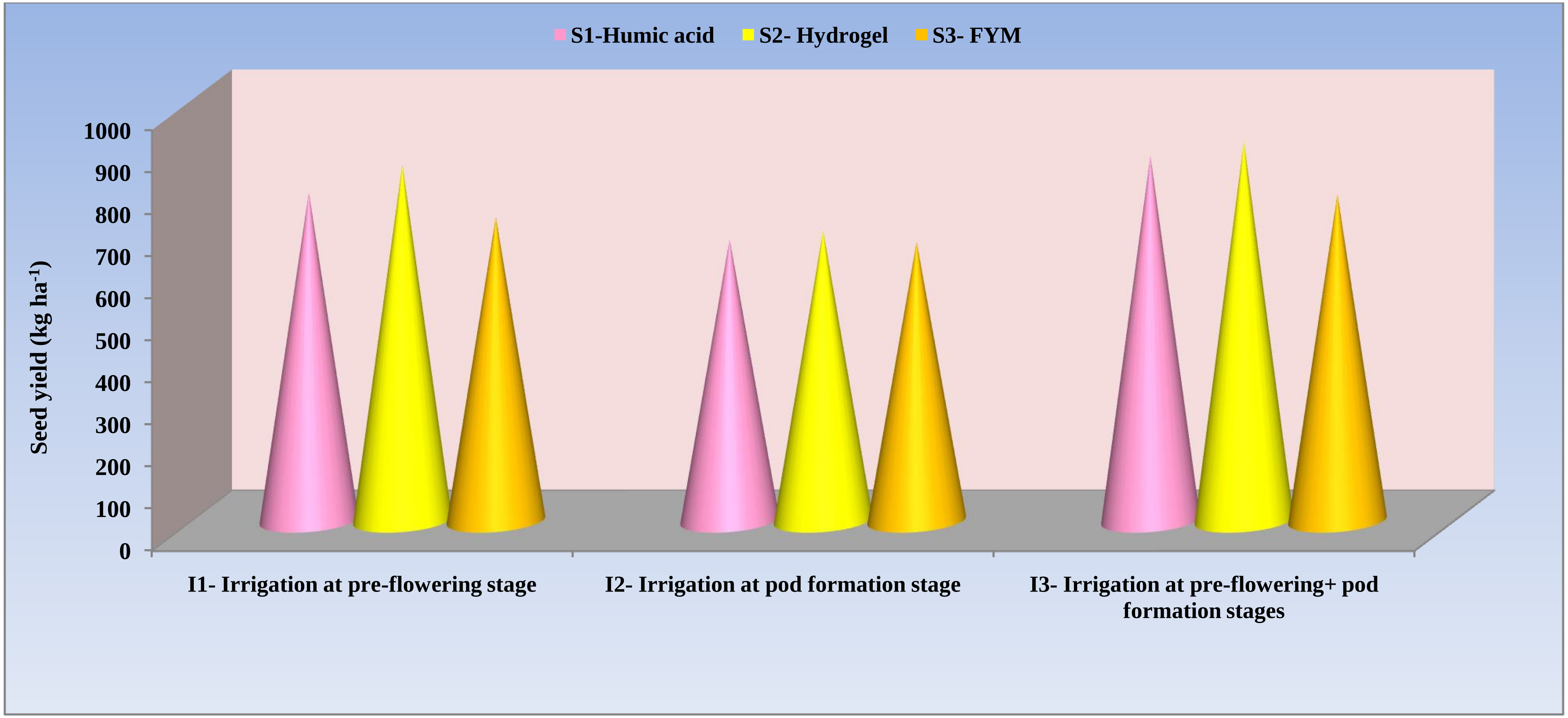


Fig. 4.3. Seed yield (kg ha^{-1}) of blackgram as influenced by irrigation schedules and soil amendments

augmenting the photosynthates accumlation in the crops which results in increased seed yield as well as yield attributes. These observations were similar to the findings of Koupai *et al.* (2008), Patil (2011), Narjary *et al.* (2012), Pradeep kumar and Rajkumara (2016), Singh *et al.* (2017), Ram *et al.* (2018), Bharat *et al.* (2019), Pal (2019), Roy *et al.* (2019), Shikha *et al.* (2019) and Santosh *et al.* (2020).

4.3.6 Haulm Yield (kg ha^{-1})

The data pertaining to haulm yield (kg ha^{-1}) is presented in Table 4.10 and depicted in Fig.4.4 showed that the impact of irrigation treatments on haulm yield was noticed to be significant.

The highest haulm yield of 1767 kg ha^{-1} was recorded with irrigation at I_3 (pre flowering+ pod formation stages) followed by I_1 (one irrigation at pre-flowering stage) and I_2 (one irrigation at pod formation stage) with 1665 and 1507 kg ha^{-1}, respectively which was significantly superior over I_2 and on a par with $I_{1.}$ The mean per cent increase in haulm yield with I_3 and I_1 over I_2 was 17.2 % and 10.4 % respectively.

The influence of soil amendments on halum yield was noticed to be significant. Among the soil amendments treatments, soil application of hydrogel @ 2.5 kg ha^{-1} recorded significantly higher haulm yield (1720 kg ha^{-1}) when compared to the treatment which received FYM @ 5 t ha^{-1} (1554 kg ha^{-1}) and comparable with treatments which received application of humic acid @ 20 kg ha^{-1} (1663 kg ha^{-1}). The mean per cent increase in haulm yield with hydrogel @ 2.5 kg ha^{-1} and humic acid @ 20 kg ha^{-1} over FYM @ 5 t ha^{-1} was 10.6 % and 7.01 % respectively.

Irrigation schedules and soil amendments interaction effect on haulm yield was found non significant

The increase in haulm yield with irrigation at critical stages might be accounted for highest vegetative growth and dry matter production. Similar findings were reported Munirathnam and Sangita (2009), Basu and Bandyopadhyay (2009), Lende and Patil (2017), Komal *et al*. (2018), Mondal *et al*. (2018) and Jaybhay *et al.* (2019), The application of soil amendments might have led to increased growth parameters such as leaf area and number of branches per plant which helped in higher accumulation of dry matter and ultimately lead to higher haulm yield. Further, the enhancement of haulm yield might be due to better soil physical properties and cation exchange capacity by soil amendments that enhanced supply and subsequent mobilization of nutrients to plant parts. Similar findings were reported by Pradeepkumar and Rajakumara (2016), Singh *et al.* (2017), Ram *et al.* (2018), Kumar *et al.* (2019), Nalia and Sengupta (2019) and Santosh *et al.* (2020).

Table 4.10. Haulm yield (kg ha^{-1}) of blackgram as influenced by irrigation schedules and soil amendments.

Haulm yield (kg ha^{-1})				
Soil amendments (S)	**Irrigation schedules (I)**			
	I_1	I_2	I_3	**Mean**
S_1 -Humic acid @ 20 kg ha^{-1}	1664	1512	1813	1663
S_2-Hydrogel @ 2.5 kg ha^{-1}	1755	1553	1853	1720
S_3- FYM @ 5 t ha^{-1}	1571	1458	1635	1554
Mean	1665	1507	1767	
	SEm±	CD (p=0.05)	CV (%)	
Irrigation schedules (I)	34	118	7.1	
Soil amendments (S)	29	87	6.1	
Interaction (I x S)	55	NS		

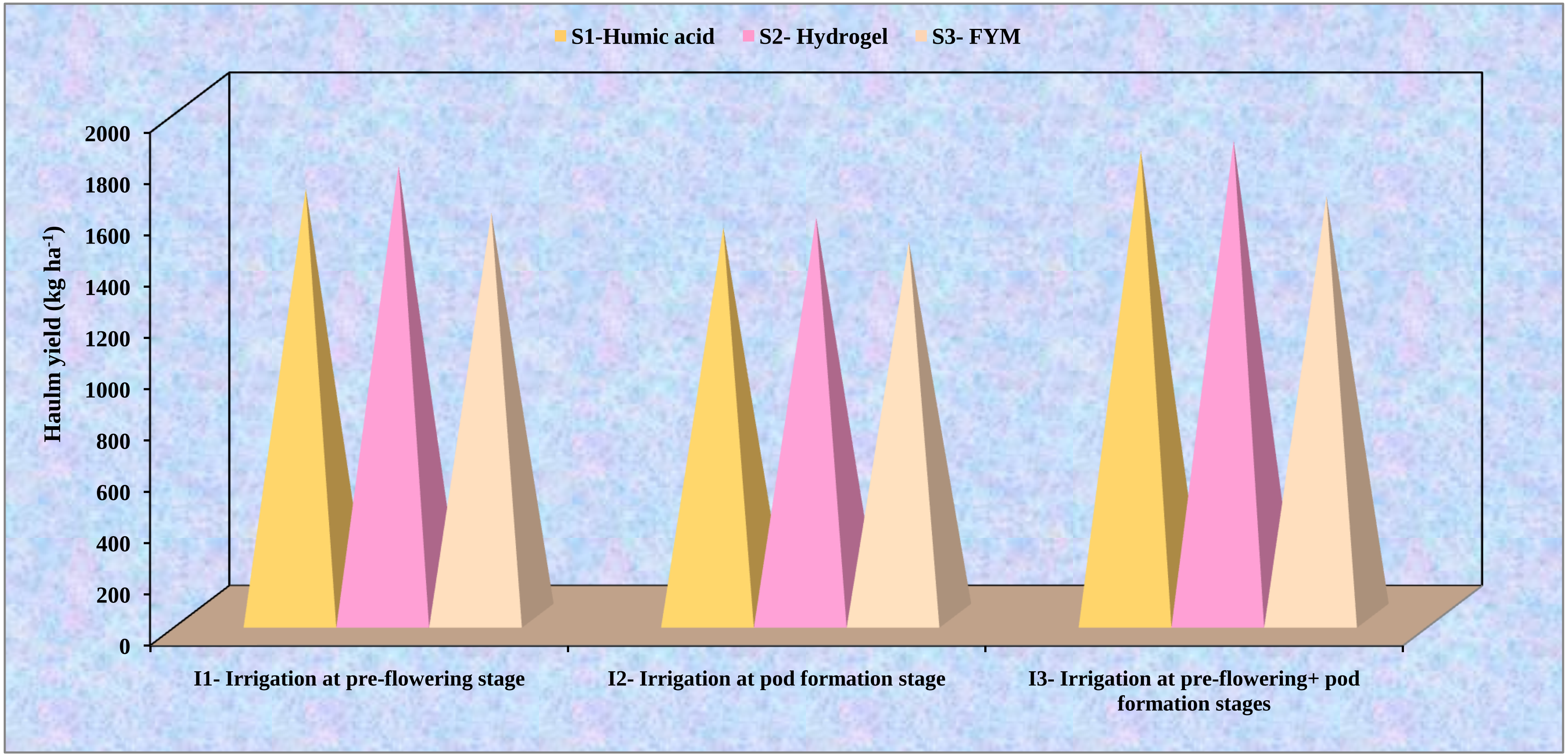


Fig. 4.4. Haulm yield (kg ha^{-1}) of blackgram as influenced by irrigation schedules and soil amendments

4.3.6 Biological Yield (kg ha^{-1})

The data pertaining to biological yield (kg ha^{-1}) is represented in Table 4.11. The impact of irrigation treatments on biological yield was found to be significant.

Irrigation at I_3 (pre flowering+ pod formation stages) recorded the highest biological yield of 2616 kg ha^{-1} followed by I_1 (one irrigation at pre-flowering stage) and I_2 (one irrigation at pod formation stage) with 2438 and 2194 kg ha^{-1}, respectively and it was significantly superior over I_2 and comparable with $I_{1.}$

The influence of soil amendments on biological yield was noticed to be significant. Among the soil amendments treatments, soil application of hydrogel @ 2.5 kg ha^{-1} recorded significantly higher biological yield (2533 kg ha^{-1}) and it was comparable with soil application of humic acid @ 20 kg ha^{-1} (2440 kg ha^{-1}). The plots those received FYM @ 5 t ha^{-1} recorded lowest haulm yield of 2275 kg ha^{-1} .

Irrigation schedules and soil amendments interaction effect on biological yield of blackgram was found non significant.

The increase in biological yield with irrigation at critical stages might be accounted for highest vegetative growth and dry matter production. comparative results were reported by Munirathnam and Sangita (2009), Basu and Bandyopadhyay (2009), Lende and Patil (2017), Komal *et al*. (2018), Mondal *et al*. (2018) and Jaybhay *et al.* (2019).

The application of soil amendments might have caused to increase in growth and yield parameters which ultimately lead to higher biological yield. Further the enhancement of biological yield might be due to the enhanced supply and subsequent mobilization of nutrients to plant parts. Similar to the findings were reported by Tyagi *et al.* (2015), Kumar *et al.* (2019), Pal (2019) and Nalia and Sengupta (2019).

Table 4.11 Biological yield (kg ha^{-1}) of blackgram as influenced by irrigation schedules and soil amendments.

Biological yield (kg ha^{-1})				
Soil amendments (S)	**Irrigation schedules (I)**			
	I_1	**I_2**	**I_3**	**Mean**
S_1 -Humic acid @ 20 kg ha^{-1}	2493	2195	2633	**2440**
S_2-Hydrogel @ 2.5 kg ha^{-1}	2551	2235	2813	**2531**
S_3- FYM @ 5 t ha^{-1}	2270	2152	2403	**2274**
Mean	**2447**	**2180**	**2614**	
	SEm±	**CD (p=0.05)**	**CV (%)**	
Irrigation schedules (I)	70	243	9.6	
Soil amendments (S)	53	155	7.6	
Interaction (I x S)	99	NS		

4.3.7 Harvest Index (%)

The influence of irrigation and soil amendments on harvest index of blackgram was noticed to be non significant. The perusal of data in Table 4.12 indicated that highest harvest index **(**32.40 %) was observed in the treatment which received two irrigations at pre flowering+ pod formation stages. Among the different sub plots, the highest value of harvest index in blackgram was recorded with Hydrogel @ 2.5 kg ha^{-1} (32.10 %).

Irrigation schedules and soil amendments interaction effect on harvest index of blackgram was also found non significant.

The increase in harvest index might be due to optimum availability of nutrients and soil moisture at critical stages of crop growth through irrigation treatments and soil amendments. This might be resulted in better translocation of assimilates from source to sink as was evidenced in terms of plant height, number of branches, dry matter accumulation and yield attributes. Similar findings were reported by Pradeep kumar and Rajkumara (2016), Ram *et al.* (2018), Ali *et al.* (2019) and Bharat *et al.* (2019).

Table 4.12 Harvest Index (%) of blackgram as influenced by irrigation schedules and soil amendments

Harvest Index (%)				
Soil amendments (S)	**Irrigation schedules (I)**			
	I_1	**I_2**	**I_3**	**Mean**
S_1 -Humic acid @ 20 kg ha^{-1}	31.50	30.42	32.25	31.60
S_2-Hydrogel @ 2.5 kg ha^{-1}	32.12	31.45	32.20	32.10
S_3- FYM @ 5 t ha^{-1}	31.21	30.51	31.80	31.60
Mean	31.95	30.87	32.40	
	SEm±	**CD (p=0.05)**	**CV (%)**	
Irrigation schedules (I)	0.71	NS	7.72	
Soil amendments (S)	0.49	NS	5.38	
Interaction (I x S)	0.99	NS		

4.4 NUTRIENT UPTAKE

4.4.1 Nitrogen

The data pertaining to nitrogen uptake by blackgram crop at maturity (Table 4.13) was significantly influenced by irrigation schedules and soil amendments but not by their interaction.

Higher uptake of nitrogen in the seed and haulm were recorded when irrigation was given at I_3 (pre flowering+ pod formation stages) (29.51 kg ha^{-1} and 63.01 kg ha^{-1} respectively) which was significantly superior over all other treatments and the lowest nitrogen uptake of seed and haulm were recorded in I_2 (one irrigation at pod formation stage). Irrigation at critical stages results in availability of adequate moisture in the soil which played an important role in minimizing leaching of a major part of nutrients , involving diffusion, mass flow and interception resulting in higher solubility of nutrients and higher uptake. Similar findings were reported by Swetha and Hussain (2017), Lakshmi *et al.* (2018), Dixit *et al.* (1993a), Srivastava and Srivastava (1994) and Arya *et al.* (2005).

The influence of soil amendments on seed and haulm uptake of nitrogen was found to be non significant. However application of humic acid @ 20 kg ha^{-1} recorded higher uptake of nitrogen in the seed and haulm (27.56 and 59.90 kg ha^{-1}) and the lowest seed and haulm uptake of nitrogen (25.75 and 56.58 kg ha^{-1}) were recorded in FYM @ 5 t ha^{-1}. The humic substances work on the metabolism of the plant and the effect is mainly exerted on the cell membrane functions and thus promoting nutrient uptake or plant growth and development by acting as a hormone-like substance. Kumar *et al.* (2017). Dhanasekaran (2011) also reported that the uptake of NPK by cotton was increased with increasing level of humic acid when applied with NPK.

The interaction effect of irrigation schedules and soil amendments on nitrogen uptake was found to be non significant.

4.4.2 Phosphorus

The influence of irrigation and soil amendments on phosphorus uptake was found to be significant (Table 4.14). Among the main plot treatments, irrigation at I_3 (pre flowering+ pod formation stages) recorded significantly the highest phosphorus uptake (7.40 and 14.60 kg ha^{-1}) in seed and haulm which was significantly superior to the rest of the irrigation treatments and the lowest phosphorus uptake (4.78 and 9.35 kg ha^{-1}) in seed and haulm were observed in I_2 (one irrigation at pod formation stage). Lakshmi *et al.*(2018) reported that increasing trend of irrigations significantly increased the nutrient uptake by blackgram. Similar findings were reported by Swetha and Hussain (2017) and Arya *et al.* (2005)

Among the sub plot treatments, humic acid @ 20 kg ha^{-1} recorded significantly the highest phosphorus uptake (6.50 and 13.32 kg ha^{-1}) in seed and haulm and the lowest phosphorus uptake (5.56 and 11.29 kg ha^{-1}) in seed and haulm were observed in FYM @ 5 t ha^{-1}. Humic acid likely increases P availability and uptake by inhibiting calcium phosphate (Ca-P) precipitation rates, forming phospho humates which could be easily assimilable by plants. Kumar *et al.* (2017). Dhanasekaran (2011) also reported that the uptake of NPK by cotton was increased with increasing level of Humic acid when applied with NPK.

The interaction effect of irrigation schedules and soil amendments on phosphorus uptake was found to be non significant.

4.4.3 Potassium

The highest uptake of potassium in the seed was recorded in I_3 (pre flowering+ pod formation stages) (15.70 kg ha^{-1}) compared to other irrigation schedules. The lowest uptake of potassium in the seed was recorded in I_2 (one irrigation at pod formation stage) (10.60 kg ha^{-1}). The highest uptake of potassium in the haulm was recorded in I_3 (pre flowering+ pod formation stages) (58.16 kg ha^{-1}) which was significantly superior over I_1 and I_2 . (Table 4.14)

The highest uptake of potassium in the seed was recorded with soil application of humic acid @ 20 kg ha^{-1} (14.40 kg ha^{-1}) which was significantly superior over application of FYM @ 5 t ha^{-1} and comparable with hydrogel @ 2.5 kg ha^{-1}. Humic acid attracts positive ions, forms chelates with micro nutrients and releases them slowly when required by plants thus improving availability and uptake by plants. Manzoor *et al.* (2014), Dhanasekaran (2011) and Kumar *et al.* (2017).

The interaction effect of irrigation levels and soil amendments on potassium uptake was found non significant.

Table 4.13 Nutrient uptake (kg ha^{-1}) of blackgram as influenced by irrigation schedules and soil amendments

Treatments	N Uptake (kg ha^{-1})		P Uptake (kg ha^{-1})		K Uptake (kg ha^{-1})	
Irrigation schedules (I)	**Seed**	**Haulm**	**Seed**	**Haulm**	**Seed**	**Haulm**
I_1- One irrigation at pre-flowering stage	26.62 (3.41)	58.33 (1.79)	5.93 (0.45)	12.67 (0.30)	13.52 (1.24)	51.66 (2.12)
I_2- One irrigation at pod formation stage	22.41 (3.21)	53.08 (1.68)	4.78 (0.41)	9.35 (0.26)	10.60 (1.21)	48.08 (1.99)
I_3- Two irrigations at pre-flowering and pod formation stages	29.51 (3.48)	63.01 (1.87)	7.40 (0.51)	14.60 (0.32)	15.70 (1.27)	58.16 (2.23)
SEm ±	0.68	1.66	0.15	0.35	0.35	0.85
CD (P=0.05)	2.18	5.73	0.53	1.21	1.23	2.93
CV%	8.19	9.86	8.77	9.88	9.25	5.57
Soil amendements (S)						
S_1 -Humic acid @ 20 kg ha^{-1}	27.56 (3.57)	59.90 (1.84)	6.50 (0.47)	13.32 (0.31)	14.40 (1.25)	54.25 (2.20)
S_2-Hydrogel @ 2.5 kg ha^{-1}	26.94 (3.41)	57.91 (1.69)	6.04 (0.45)	12.36 (0.29)	13.07 (1.24)	52.91 (2.17)
S_3- FYM @ 5 t ha^{-1}	25.75 (3.39)	56.58 (1.67)	5.56 (0.42)	11.29 (0.28)	12.35 (1.23)	50.75 (2.15)
SEm ±	0.68	0.98	0.17	0.34	0.33	0.83
CD (P=0.05)	NS	NS	0.52	1.02	0.99	2.48
CV%	8.89	5.83	9.93	9.69	8.67	5.48
Interaction (I x S)	NS	NS	NS	NS	NS	NS

4.5 SOIL MOISTURE STUDIES OF BLACKGRAM

4.5.1 Consumptive Use of Water (mm)

Irrigation and soil amendments impact on consumptive use of water was found significant. The data pertaining to consumptive use of water by blackgram presented in Table 4.14 and depicted in Fig. 4.5 revealed that irrigation at I_3 (pre flowering+ pod formation stages) recorded the highest consumptive use of water (226.5 mm) which was significantly superior over I_1 and I_2 . The highest consumptive use of water was recorded with hydrogel @ 2.5 kg ha^{-1} (193.6 mm) which was on a par with humic acid @ 20 kg ha^{-1} (189.1 mm) and significantly superior to FYM @ 5 t ha^{-1} (177.2 mm). The interaction effect of irrigation levels and soil amendment treatments on consumptive use of water was found to be non significant.

The increase in consumptive use of water might be due to optimum soil moisture availability at critical stages of crop growth led to increased uptake of nutrients which in turn helped in better growth and yield attributes. These results also corroborate the findings of Ravindran Nayar and Singh (1985), Gaur and Chaudhary (1993) and Koupai *et al* (2008).

Table 4.14. Consumptive use of water (mm) as influenced by irrigation schedules and soil amendments

Consumptive use of water (mm)				
Soil amendments (S)	**Irrigation schedules (I)**			
	I_1	**I_2**	**I_3**	**Mean**
S_1 -Humic acid @ 20 kg ha^{-1}	178.7	158.0	230.5	189.1
S_2-Hydrogel @ 2.5 kg ha^{-1}	183.1	162.2	236.1	193.6
S_3- FYM @ 5 t ha^{-1}	165.2	152.5	213.2	177.2
Mean	175.6	157.5	226.5	
	SEm±	**CD (p=0.05)**	**CV (%)**	
Irrigation schedules (I)	6	21	11.22	
Soil amendments (S)	4	13	8.34	
Interaction (I x S)	9	NS		

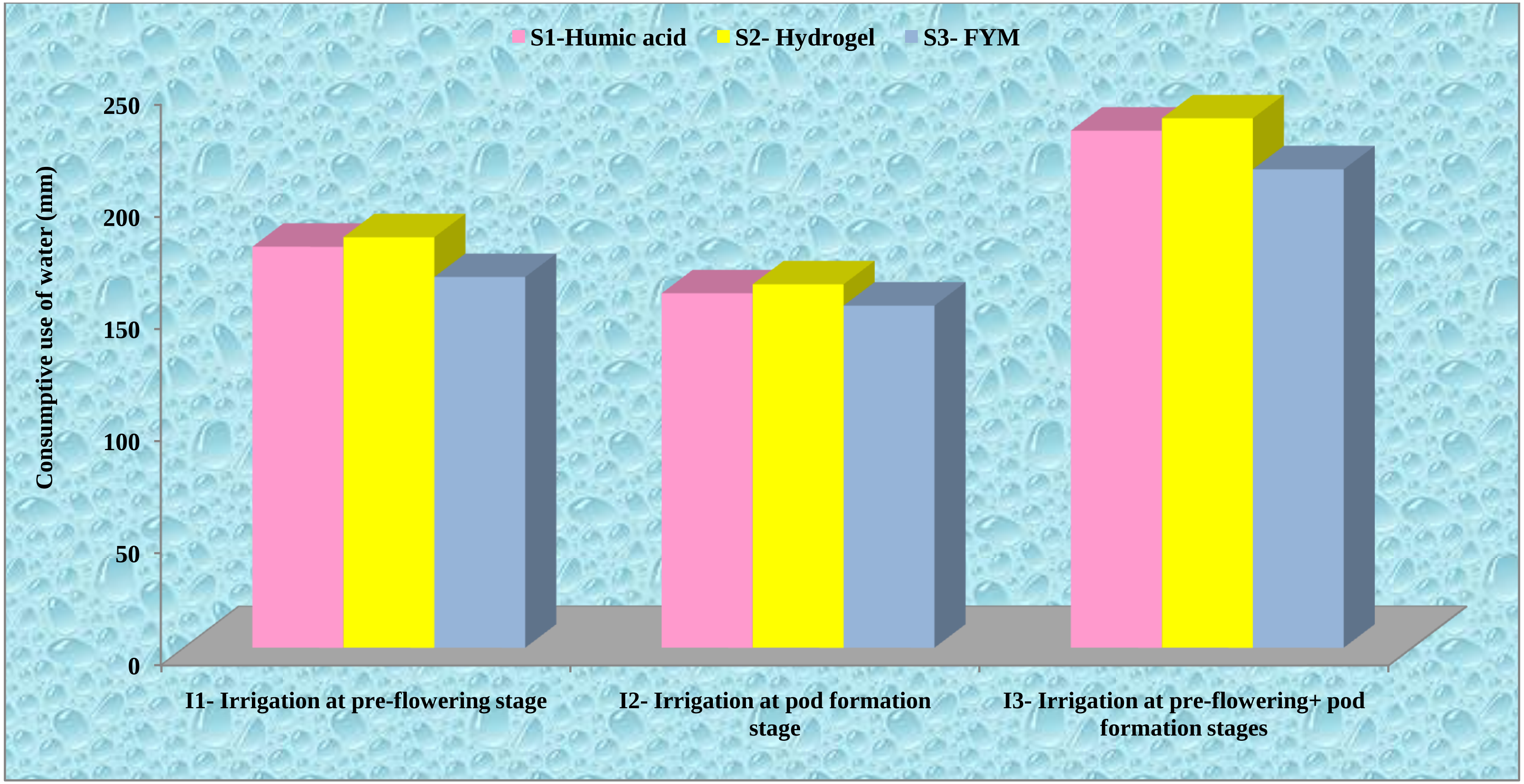


Fig. 4.5. Consumptive use of water (mm) of blackgram as influenced by irrigation schedules and soil amendments

4.5.2 Soil Moisture Use Rate (mm day^{-1})

Data pertaining to soil moisture use rate of blackgram presented in Table 4.15 and depicted in Fig. 4.5 revealed that plots which received irrigation at I_3 (pre flowering+ pod formation stages) recorded the highest soil moisture use rate (3.01 mm) and I_2 (one irrigation at pod formation stage) recorded the lowest moisture use rate (2.15 mm).

The highest soil moisture use rate was recorded in the plots those received Hydrogel @ 2.5 kg ha^{-1} (2.58 mm) which was on a par with Humic acid @ 20 kg ha^{-1} (2.50 mm).The lowest soil moisture use rate (2.41 mm) was recorded in FYM @ 5 t ha^{-1} .

The interaction effect of irrigation treatments and soil amendments on moisture use rate of blackgram, was found to be non significant. Similar results in chickpea were reported by Ravindran Nayar and Singh (1985) and Prabhakar and Saraf (1991).

Table 4.15. Soil moisture use rate (mm day^{-1}) as influenced by irrigation schedules and soil amendments

Soil moisture use rate (mm day^{-1})				
Soil amendments (S)	**Irrigation schedules (I)**			
	I_1	I_2	I_3	**Mean**
S_1 -Humic acid @ 20 kg ha^{-1}	2.32	2.12	3.07	2.50
S_2-Hydrogel @ 2.5 kg ha^{-1}	2.30	2.25	3.25	2.58
S_3- FYM @ 5 t ha^{-1}	2.17	2.15	3.10	2.41
Mean	2.26	2.15	3.01	
	SEm±	**CD (p=0.05)**	**CV (%)**	
Irrigation schedules (I)	0.07	0.24	9.64	
Soil amendments (S)	0.04	0.13	6.15	
Interaction (I x S)	0.09	NS		

4.5.3 Water use efficiency (kg ha mm^{-1})

The influence of irrigation schedules on water use efficiency of blackgram was found to be significant (Table 4.16). Among the different main plot treatments, I_1 (one irrigation at pre flowering stage) recorded the highest water use efficiency (4.42kg ha mm^{-1}) in blackgram which was significantly superior over I_3 (pre flowering+ pod formation stages) and on a par with I_2 (one irrigation at pod formation stages).

Among the sub plots, hydrogel @ 2.5 kg ha^{-1} recorded the highest water use efficiency (4.26 kg ha mm^{-1}). The treatments which received FYM @ 5 t ha^{-1} recorded the lowest water use efficiency of (4.01 kg ha mm^{-1}). However, influence of soil amendments on water use efficiency of blackgram was found non significant

Irrigation and soil amendments interaction effect on water use efficiency was found non significant.

Table 4.16. Water use efficiency (kg ha mm^{-1}) as influenced by irrigation schedules and soil amendments

Water use efficiency (kg ha mm^{-1})				
Soil amendments (S)	**Irrigation schedules (I)**			
	I_1	**I_2**	**I_3**	**Mean**
S_1 -Humic acid @ 20 kg ha^{-1}	4.30	4.42	3.70	4.13
S_2-Hydrogel @ 2.5 kg ha^{-1}	4.40	4.41	3.80	4.26
S_3- FYM @ 5 t ha^{-1}	4.31	4.30	3.52	4.01
Mean	4.42	4.31	3.70	
	SEm±	**CD (p=0.05)**	**CV (%)**	
Irrigation schedules	0.07	0.23	5.64	
Soil amendments	0.08	NS	6.91	
Interaction	0.13	NS		

Application of hydrogel to the soil increases both saturated and residual water content, water holding capacity and available water content, thus improving water use efficiency. This finding is in conformity with Koupai *et al.* (2008), Tyagi *et al.* (2015), Pradeep kumar and Rajkumara (2016) and Singh *et al.* (2017).

4.5.4 Soil Moisture Depletion Pattern

Soil moisture decreased with increase in depth of soil. (Table.4.17). The top layer of the soil 0-15 cm contributed nearly 45 to 55 percent of the total soil moisture utilized by crop. The maximum soil moisture depletion was recorded from top most layer which increased with increasing number of irrigations. Increase in moisture regimes leading to more root distribution in shallow depth that might have lead to higher percentage of moisture extraction from shallow depth compared to lower number of irrigations. The depletion of soil moisture from deeper layers under one irrigation at pod formation stage was more than two irrigation at pre-flowering and pod formation stages. This indicated that with less number of irrigations, deeper layers were subjected to more moisture depletion, since moisture stress under such conditions promotes extensive root growth in lower layers. Similar findings were reported by Gopal *et al.* (2015).

Hydrogel may have resulted in absorption/storage of moisture during the period of abundant supply *viz.* field capacity and release it during the time of moisture stress thereby with increased soil matric potential providing the crop with sufficient moisture supply during the crop growth period which results in increased moisture extraction from shallow depths than from the deeper layers (Fig 4.6) . These observations were similar to the findings of Koupai *et al.* (2008), Narjary *et al.* (2012).

Table 4.17. Soil moisture depletion pattern of blackgram as influenced by irrigation schedules and soil amendments

Treatments	Soil depth (cm)			
	0-15	15-30	30-45	45-60
I_1S_1	82.90 (45.2)	58.17 (32.5)	25.40 (11.2)	14.53 (8.12)
I_1S_2	85.27 (46.60)	60.82 (33.24)	26.49 (14.44)	13.67 (8.02)
I_1S_3	75.98 (44.31)	55.49 (32.01)	23.13 (14.02)	14.90 (8.43)
I_2S_1	72.35 (38.21)	52.43 (31.29)	21.87 (13.21)	14.34 (9.08)
I_2S_2	73.99 (39.50)	56.48 (32.40)	25.77 (13.44)	13.77 (8.50)
I_2S_3	71.84 (37.40)	48.30 (31.15)	20.79 (31.02)	14.91 (9.81)
I_3S_1	118.62 (53.2)	64.82 (34.63)	32.19 (17.04)	17.06 (7.42)
I_3S_2	122.32 (54.80)	65.34 (33.4)	36.40 (17.12)	17.11 (7.25)
I_3S_3	112.95 (53.5)	58.65 (34.11)	30.35 (16.60)	17.29 (7.68)

Values in parenthesis are per cent depletion of soil moisture

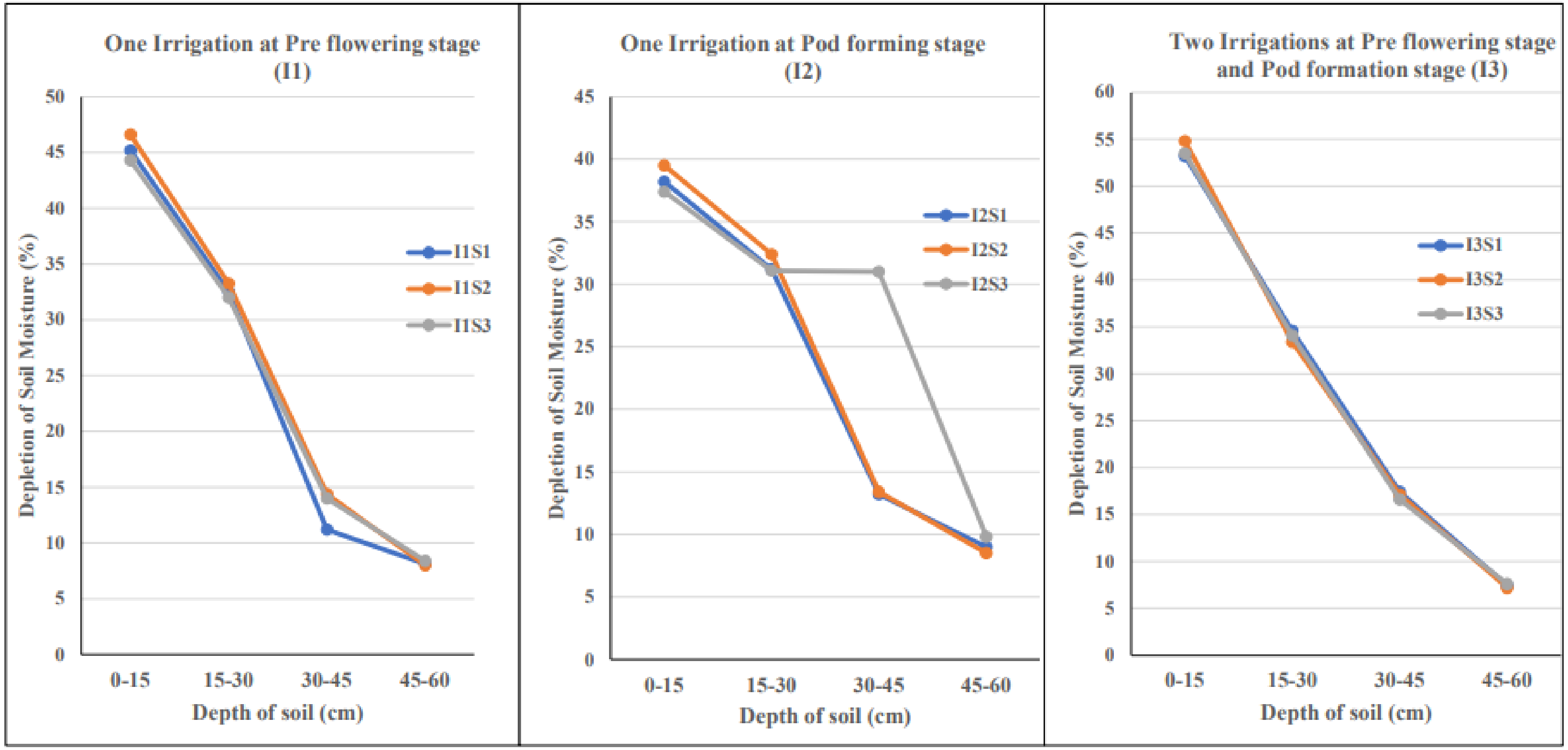


Fig 4.6. Soil moisture depletion pattern of blackgram as influenced by soil amendments at I_1, I_2, I_3 irrigations

4.6 ECONOMICS

The data on cost of cultivation, gross returns, net returns and BCR of blackgram with different irrigation schedules and soil amendments was presented in Table 4.18.

The highest gross returns (Rs.83, 160 /-) and net returns (Rs 54,195 /-) were recorded in the treatmental combination which received I_3S_2 *i.e.*, two irrigations (pre flowering and pod formation stages) along with soil application of hydrogel @ 2.5 kg ha^{-1}. The highest BCR (1.94) was also recorded in I_3S_2. The highest BCR was obtained in these treatments due to higher yield obtained over other treatments and increased irrigation level which in turn increased the net returns. The lowest gross returns (Rs.62,310/-) and net returns (Rs.31,180 /-) were recorded in the treatments which received I_2S_3 *i.e.*, the treatmental combination of one irrigation at pod formation stage along with soil application of FYM @ 5 t ha^{-1} . The lowest BCR (1.01) was also recorded in the plots those received I_2S_3. These results are in conformity with the results of Rao *et al.* (2016), Lende and Patil (2017). Similar result of improvement in the grain yield and net income with high BCR ratio due to application of hydrogel @ 2.5 kg ha^{-1} has been reported earlier by Singh *et al.* (2017) and Kumar *et al*. (2018)

Table 4.18. Cost of cultivation, gross returns, net returns and BCR of blackgram as influenced by irrigation schedules and soil amendments

Treatments	Cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	BCR
I_1S_1	26945	70180	43235	1.60
I_1S_2	27745	72780	45035	1.62
I_1S_3	31120	63810	32690	1.05
I_2S_1	27735	62550	34815	1.25
I_2S_2	27755	63540	35785	1.29
I_2S_3	31130	62310	31180	1.01
I_3S_1	27235	76050	48815	1.79
I_3S_2	28245	83160	54915	1.94
I_3S_3	31540	69840	38300	1.21

Input cost:

Cost of Seed : Rs.110.0 kg^{-1}

Urea : Rs.5.9 kg^{-1}

DAP : Rs.22.5 kg^{-1}

Humic acid : Rs. 55 kg^{-1}

Hydrogel : Rs. 800 kg^{-1}

FYM : Rs. 0.8 kg^{-1}

Labour cost : Rs. 250 day^{-1}

Output cost:

Price of blackgram seed: Rs.90 kg^{-1}

Summary & Conclusions

Chapter V

SUMMARY AND CONCLUSIONS

Blackgram (*Vigna mungo* L.) is one of the most important pulse crop and rich a source of proteins, energy, minerals and vitamins useful for the mankind. The productivity of blackgram is not adequate to satisfy the needs of the population. Hence, there is an urgent need for enhancement of the productivity of blackgram by proper agronomic management. In view of this, a field investigation entitled "Effect of Humic Acid and Hydrogel on Soil Moisture Retention and Productivity of *rabi* Blackgram (*Vigna mungo* L.)" was carried out on clay soils of Advanced Post Graduate Centre, Lam, Guntur during *rabi* 2019-20. The experiment was laid out in split-plot design replicated four times with three irrigation schedules *viz.*, one irrigation at pre-flowering stage (I_1), one irrigation at pod formation stage (I_2) and two irrigations each at pre-flowering and pod formation stages (I_3) as main plots and three soil amendment treatments *viz.*, soil application of Humic acid @ 20 kg ha^{-1} (S_1), Hydrogel @ 2.5 kg ha^{-1} (S_2), FYM @ 5 t ha^{-1} (S_3) as sub plots.

The results of the initial soil analysis indicated that the experimental soil was clay in texture, slightly alkaline in reaction with medium in organic carbon and low in available nitrogen and low in available phosphorus and medium in available potassium. The weather parameters favorably affected blackgram crop growth. However, the crop was suffered with minor incidence of YMV disease and maruca pest and proper plant protection measures were taken which resulted in average seed yields of blackgram. A total rainfall of 14.0 mm was received during the period of experimentation with two rainy days.

Irrigation schedules and soil amendments impact on initial and final plant population of blackgram was not significant.

Influence of irrigation and soil amendments on plant height was significant at all stages of crop growth but at 15 DAS the difference was found non significant. Significantly taller plants were observed with two irrigations at pre-flowering and pod formation stages at various crop growth stages of blackgram but at 30 and 45 DAS plant height was comparable with one irrigation at pre-flowering stage. Among different soil amendment treatments, soil application of hydrogel @ 2.5 kg ha^{-1} recorded significantly taller plants at 30, 45, 60 DAS and at harvest and are significantly superior to soil application of FYM @ 5 t ha^{-1} and comparable with soil application of humic acid @ 20 kg ha^{-1}

Number of branches plant^{-1} were significantly influenced by irrigation and soil amendments. The highest number of branches plant^{-1} were recorded with two irrigations at pre-flowering and pod formation stages at all the growth stages but at 30 DAS and 45 DAS number of branches plant^{-1} were comparable with one irrigation at pre-flowering stage. The lowest number of branches plant^{-1} were recorded when irrigation was given at pod formation stage at all stages of crop growth. Soil application of hydrogel @ 2.5 kg ha^{-1} increased the number of branches plant^{-1} which were comparable to soil application of humic acid @ 20 kg ha^{-1} and lowest values were noticed with FYM @ 5 t ha^{-1}.

The accumulation of dry matter at various growth stages showed that there is a gradual increase in dry matter accumulation with duration of the crop. The highest dry matter accumulation was recorded with two irrigations given at pre-flowering and pod formation stages but at 15 DAS difference was not noticed. The influence of soil amendments on dry matter accumulation of blackgram was found to be significant at all the growth stages of the crop except at 15 DAS. Application of hydrogel @ 2.5 kg ha^{-1} recorded significantly higher dry matter accumulation compared to FYM @ 5 t ha^{-1} and comparable with humic acid @ 20 kg ha^{-1}. The interaction effect of irrigation schedules and soil amendments on dry matter accumulation was found to be non significant at all the stages of crop growth.

The data recorded on yield attributes indicated that the influence of irrigation and soil amendments on number of clusters plant^{-1}, number of pods per cluster and test weight were found to be significant. But the significant difference in number of seeds pod^{-1} is not noticed. However, maximum number of yield attributes was recorded with two irrigations at pre-flowering and pod formation stages and minimum were recorded in one irrigation at pod formation stage. Among soil amendments, soil application of hydrogel @ 2.5 kg ha^{-1} recorded maximum yield attributing parameters which were comparable with soil application humic acid @ 20 kg ha^{-1} and minimum were recorded with FYM @ 5 t ha^{-1} .

The highest seed yield and haulm yield was recorded in two irrigations at pre-flowering and pod formation stages and it was significantly superior to one irrigation given at pod formation stage and comparable with one irrigation given at pre flowering stage. Soil application of hydrogel @ 2.5 kg ha^{-1} recorded the highest seed yield and haulm yield which was on a par with humic acid @ 20 kg $ha^{-1}$and the lowest seed yield was recorded with FYM @ 5 t ha^{-1}. Two irrigations at pre-flowering and pod formation stages recorded the highest biological yield and it was significantly superior to one irrigation given at pod formation stage and comparable with one irrigation given at pre-flowering stage. The influence of irrigation and soil amendments on harvest index of blackgram was found to be non significant.

The interaction effect of irrigation schedules and soil amendments on yield attributes, yield and harvest index of blackgram was found to be non significant.

Maximum N, P and K uptake was recorded in two irrigations at pre-flowering and pod formation stages. Nitrogen uptake was not influenced by soil amendments. Soil application of humic acid @ 20 kg ha^{-1} recorded maximum uptake of potassium and phosphorus but on a par with hydrogel @ 2.5 kg ha^{-1} and minimum was recorded with FYM @ 5 t ha^{-1} .

The consumptive use of water and daily soil moisture use rate were significantly affected by irrigation and soil amendments. The highest consumptive use and soil moisture use rate were recorded with two irrigations at pre-flowering and pod formation stages followed by one irrigation at pre-flowering stage and the lowest were recorded with one irrigation at pod formation stage. Among the soil amendments, soil application of hydrogel @ 2.5 kg ha^{-1} recorded the highest consumptive use and soil moisture use rate but on a par with humic acid @ 20 kg ha^{-1} .

Water use efficiency of blackgram was significantly influenced by irrigation and soil amendments. The highest water water use efficiency was recorded with one irrigation given at pre-flowering stage which was comparable with one irrigation at pod formation stage. The lowest water water use efficiency was recorded with two irrigations at pre-flowering and pod formation stages. The influence of soil amendments on water use efficiency of *rabi* blackgram was non significant.

The maximum soil moisture depletion was recorded from top most layer which increased with increasing number of irrigations. The depletion of soil moisture from deeper layers under one irrigation was comparatively more than the treatments where two irrigations were given at pre-flowering and pod formation stages.

The highest gross returns, net returns and benefit cost ratio were recorded when two irrigations were given at pre-flowering and pod formation stages and soil application of hydrogel @ 2.5 kg ha^{-1} .

From the above results, it can be concluded that

- The influence of irrigation schedules and soil amendments on growth, yield parameters, yield and nutrient uptake was found significant but their interaction was non significant. Irrigation given both at pre-flowering and pod formation stages recorded higher growth and yield attributing parameters of blackgram leading to a significant increase in seed and haulm yield due to sufficient soil moisture during critical stages of crop growth when compared to other irrigation

- Soil application of hydrogel @ 2.5 kg ha^{-1} was found more beneficial in increasing the growth, yield attributes and yield of blackgram and was comparable with soil application of humic acid @ 20 kg $ha^{-1}$and the lowest growth and yield parameters were observed in FYM @ 5 t ha^{-1} treated plots.

- The influence of irrigation and soil amendments on harvest index of blackgram was not significant.

- Maximum N, P and K uptake was recorded in two irrigations at pre-flowering and pod formation stages. Nitrogen uptake was not influenced by soil amendments. Soil application of humic acid @ 20 kg ha^{-1} recorded maximum uptake of potassium and phosphorus but on a par with hydrogel @ 2.5 kg ha^{-1} and minimum was recorded with FYM @ 5 t ha^{-1} .

- The highest water use efficiency was recorded in one irrigation at pre-flowering stage which was comparable with one irrigation at pod formation stage .The lowest was recorded with two irrigations at pre-flowering and pod formation stages. The influence of soil amendments on water use efficiency of blackgram was found to be non-significant.

- The highest gross, net returns and BCR were recorded with two irrigations at pre-flowering and pod formation stages along with soil application of hydrogel @ 2.5 kg ha^{-1}

- Overall the present study revealed that two irrigations at pre-flowering and pod formation stages and soil application of hydrogel @ 2.5 kg ha^{-1} recorded higher growth, yield and water use efficiency of *rabi* blackgram. However, humic acid @ 20 kg ha^{-1} was also showed comparable performance in clay soils of Lam, Guntur.

The present investigation was confined to short term field trial to study the response of irrigation schedules and soil amendments on growth and yield of *rabi* blackgram. However, the field trial needs to be repeated for few more years combined with laboratory assessment to draw valid conclusions and to give further recommendation to farmers.

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***Original not seen**

Note: The literature cited is in accordance with thesis guidelines formulated by Acharya N.G Ranga Agricultural University, Lam, Guntur, A.P.

Appendices

APPENDIX I

CALENDAR OF OPERATIONS

S.No.	Field operation	Date
1.	Land preparation and leveling	25.11.2019
2.	Layout ,irrigation channels	26.11.2019
3.	Basal application of fertilizers Urea, DAP	27.11.2019
4.	Soil application of Humic acid , Hydrogel and FYM and sowing of blackgram and irrigation	28.11.2019
5.	Pre-emergence application of Pendimethalin 30 % EC @ 750 g a.i ha^{-1}	29.11.2019
6.	Gap filling	2-12-2019
7.	Thinning	7.12.2019
8.	First hand weeding	12.12.2019
9.	Spraying of Acephate	13.12.2019
10.	Second hand weeding	27.12.2019
11.	Spraying of Acephate	28.12.219
12.	Irrigation given to I_1 and I_3 treatments at pre-flowering stage	01.01.2020
13.	Application of Flubendamide	9.01.2020
14.	Irrigation given to I_2 and I_3 treatments at pod formation stage	20.01.2020
15.	Application of chloranthraniliprole	23.01.2020
16.	Application of Flubendamide	03.02.2020
17.	Harvesting	21.02.2020
18.	Threshing	29.02.2020

Appendix-II

Daily E_{pan} (mm) values recorded at APGC, Lam during the crop growth period (28-11-2019 to 21-02-2019)

Date	E_{pan}	Date	E_{pan}	Date	E_{pan}
28-11-19	5.0	27-12-19	3.5	25-01-20	3.3
29-11-19	4.0	28-12-19	3.9	26-01-20	4.0
30-11-19	4.0	29-12-19	3.1	27-01-20	4.1
01-12-19	4.0	30-12-19	2.5	28-01-20	4.0
02-12-19	4.0	31-12-19	3.6	29-01-20	3.8
03-12-19	3.2	01-01-20	3.4	30-01-20	3.9
04-12-19	3.0	02-01-20	2.9	31-01-20	4.2
05-12-19	3.6	03-01-20	1.4	01-02-20	3.7
06-12-19	4.5	04-01-20	4.0	02-02-20	3.6
07-12-19	3.6	05-01-20	1.4	03-02-20	3.7
08-12-19	2.6	06-01-20	1.8	04-02-20	3.3
09-12-19	3.8	07-01-20	2.8	05-02-20	2.9
10-12-19	3.0	08-01-20	3.1	06-02-20	3.4
11-12-19	3.3	09-01-20	2.6	07-02-20	3.4
12-12-19	2.1	10-01-20	2.4	08-02-20	3.8
13-12-19	4.7	11-01-20	1.8	09-02-20	3.6
14-12-19	2.5	12-01-20	2.1	10-02-20	3.5
15-12-19	2.3	13-01-20	2.4	11-02-20	4.0
16-12-19	2.5	14-01-20	3.0	12-02-20	5.0
17-12-19	3.9	15-01-20	3.3	13-02-20	3.3
18-12-19	2.8	16-01-20	1.8	14-02-20	4.3
19-12-19	3.5	17-01-20	2.4	15-02-20	4.7
20-12-19	2.8	18-01-20	2.8	16-02-20	5.2
21-12-19	2.5	19-01-20	3.3	17-02-20	5.5
22-12-19	4.0	20-01-20	3.1	18-02-20	4.4
23-12-19	2.4	21-01-20	3.4	19-02-20	3.3
24-12-19	1.6	22-01-20	3.6	20-02-20	4.2
25-12-19	3.4	23-01-20	3.5	21-02-20	4.8
26-12-19	2.6	24-01-20	2.2		