

**EFFECT OF POST EMERGENCE
HERBICIDES ON GROWTH,
PHYSIOLOGICAL PARAMETERS AND
YIELD OF BLACKGRAM
(*Vigna mungo* (L.) Hepper)**

BY
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B.Sc. (Ag.)

**THESIS SUBMITTED TO THE
ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY
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FOR THE AWARD OF THE DEGREE OF**

**MASTER OF SCIENCE IN AGRICULTURE
(CROP PHYSIOLOGY)**

CHAIRPERSON: Dr. K. JAYALALITHA



**DEPARTMENT OF CROP PHYSIOLOGY
AGRICULTURAL COLLEGE, BAPATLA
ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY
GUNTUR, ANDHRA PRADESH**

2016

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(CROP PHYSIOLOGY)**



2016

CERTIFICATE

Ms. J. HARITHAVARDHINI has satisfactorily prosecuted the course of research and that the thesis entitled “**EFFECT OF POST EMERGENCE HERBICIDES ON GROWTH, PHYSIOLOGICAL PARAMETERS, AND YIELD OF BLACKGRAM [*Vigna mungo* (L.) Hepper]**” 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 the thesis or part there of has not been previously submitted by her for a degree of any university.

Place: Bapatla

Date:

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Associate Professor
Dept. of Crop Physiology

DECLARATION

I, **Ms. J. HARITHAVARDHINI**, hereby declare that the thesis entitled **“EFFECT OF POST EMERGENCE HERBICIDES ON GROWTH, PHYSIOLOGICAL PARAMETERS AND YIELD OF BLACKGRAM (*Vigna mungo (L.) Hepper*)”** submitted to the **Acharya N.G. Ranga Agricultural University** for the degree of **Master of Science in Agriculture** in the major field of **Crop Physiology** 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: Bapatla

Date:

(J. HARITHAVARDHINI)

I. D. No. BAM-14-18

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CERTIFICATE

This is to certify that the thesis entitled “**EFFECT OF POST EMERGENCE HERBICIDES ON GROWTH, PHYSIOLOGICAL PARAMETERS AND YIELD OF BLACKGRAM (*Vigna mungo* (L.) Hepper)**” submitted in partial fulfillment of the requirements for the degree of Master of Science in Agriculture in the major field of **Crop Physiology** of the Acharya N.G. Ranga Agricultural University, Guntur, is a record of the bonafide research work carried out by **MS. J. HARITHAVARDHINI** under my guidance and supervision. The subject of the thesis has been approved by the Student’s Advisory Committee.

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

Thesis approved by the Student Advisory Committee

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Date:

(J. Harithavardhini...)

ABSTRACT

Author : **J. HARITHAVARDHINI**

Title of the thesis : **EFFECT OF POST EMERGENCE
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Major Advisor : **Dr. K. JAYALALITHA**

Degree : **M.Sc (Ag)**

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Discipline : **Crop Physiology**

University : Acharya N.G. Ranga Agricultural University

Year of Submission : **2016**

The present investigation entitled “Effect of post emergence herbicides on growth, physiological parameters and yield of black gram [*Vigna mungo* (L.) Hepper]” was undertaken at Agricultural College Farm, Bapatla during *kharif*, 2015. The experiment was laid out in Randomised Block Design with ten treatments replicated thrice.

Post emergence herbicides viz., imazethapyr @ 50g and combined use of acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24%EC) @ 240 and 300g a.i ha⁻¹ applied at 15 and 25 DAS caused injury to blackgram plants in terms of stunting and yellowing/discoloration of leaves during initial stages i.e. 5 days after herbicide application (DAHA), indicating a condition of oxidative stress in blackgram due to herbicide injury. However, blackgram plants recovered quickly by 10 DAHA by possessing highest SOD activity (antioxidant defense enzyme) in the first five days after application and the phytotoxicity symptoms were disappeared by 40 DAS and ultimately no deleterious effect on the mature plants was observed in all the treatments, except acifluorfen sodium + clodinafop propargyl @ 300g a.i ha⁻¹ at 25 DAS (T₈), which caused severe stunting, discoloration and wilting of leaves at 5 DAHA and the symptoms remain unchanged upto maturity that adversely affected growth attributes and yield of blackgram.

Weed free treatment (i.e. hand weeding at 15 and 30 DAS) and post emergence application of acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24%EC) @ 240 and 300g a.i ha⁻¹ at 15 DAS recorded superior performance by increasing plant height, number of branches and leaf area over un weeded control and other treatments. These three treatments significantly reduced the weed population (i.e. both monocot and dicot weeds) and weed drymatter compared to un weeded control and other herbicidal treatments at 60 DAS and registered higher weed control efficiencies i.e. 83.0, 70.6 and 68.0 per cent, respectively. At harvest, total drymatter of blackgram plants was increased by 1.56, 1.54, 1.50 folds with weed free check and acifluorfen sodium + clodinafop propargyl @ 300 and 240g a.i ha⁻¹ applied at 15 DAS, respectively, over weedy check.

Photosynthetic pigments viz., chlorophyll a, chlorophyll b, total chlorophyll and carotenoid contents decreased in blackgram leaves during first 5 DAHA due to phytotoxicity of these herbicides. However, the blackgram plants recovered from the phytotoxicity of acifluorfen sodium + clodinafop propargyl and imazethapyr by 10 DAHA. Weed free check and acifluorfen sodium + clodinafop propargyl @ 300 and 240g a.i ha⁻¹ applied at 15 DAS increased the total chlorophyll content by 34.3, 28.7 and 27.2 per cent, respectively and carotenoid content by 10.3, 9.4, 8.7 per cent, respectively, over weedy check at 40 DAS (i.e. 25 DAHA). Higher SOD activity was recorded during first five days after application with acifluorfen sodium + clodinafop propargyl @ 300 and 240g a.i ha⁻¹ at 15 DAS, which helped in the mitigation of herbicide injury.

Weed free check and post emergence application of acifluorfen sodium + clodinafop propargyl @ 300 and 240g a.i ha⁻¹ at 15 DAS increased the yield attributes and seed yield of blackgram. These three treatments increased the seed yield by 77.6, 69.4 and 67.8 per cent, respectively, over unweeded control. Though, imazethapyr @ 50g ha⁻¹ at 15 and 25 DAS recorded significant increase in yield (25.3 and 29.9 percent, respectively) over weedy check, but these two treatments were inferior over the combined use of acifluorfen sodium + clodinafop propargyl @ 240 and 300g a.i ha⁻¹ at 15 DAS.

The highest benefit cost ratio was recorded with acifluorfen sodium + clodinafop propargyl @ 240g a.i ha⁻¹ (i.e. 1.59) and this was closely followed by acifluorfen sodium + clodinafop propargyl @ 300g a.i ha⁻¹ (i.e. 1.56). From this study, it can be concluded that post emergence application of acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24% EC) @ 240g a.i ha⁻¹ at 15 DAS is recommended for weed control in blackgram as it improved the growth, physiological parameters, photosynthetic pigments and yield of blackgram.

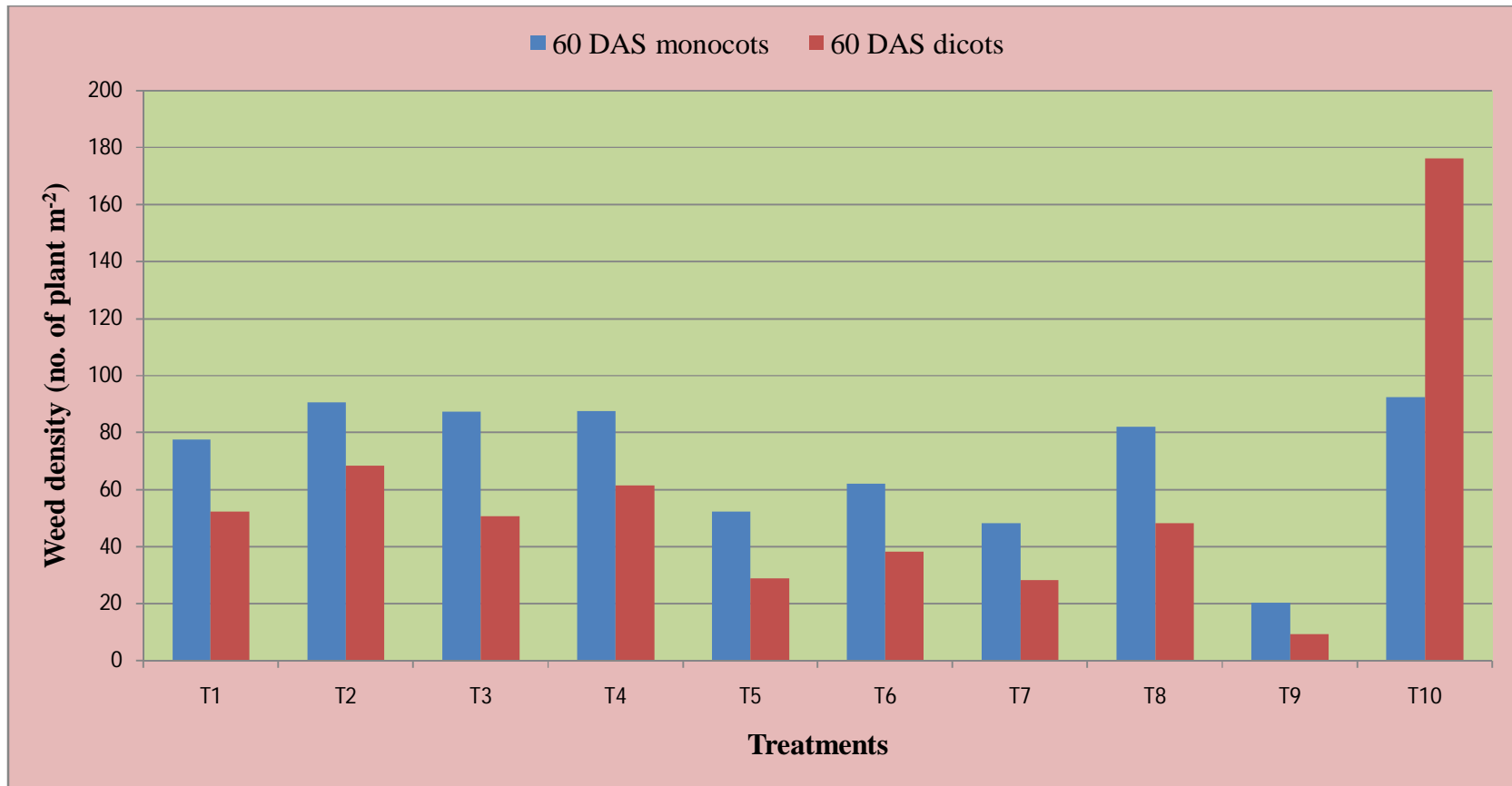


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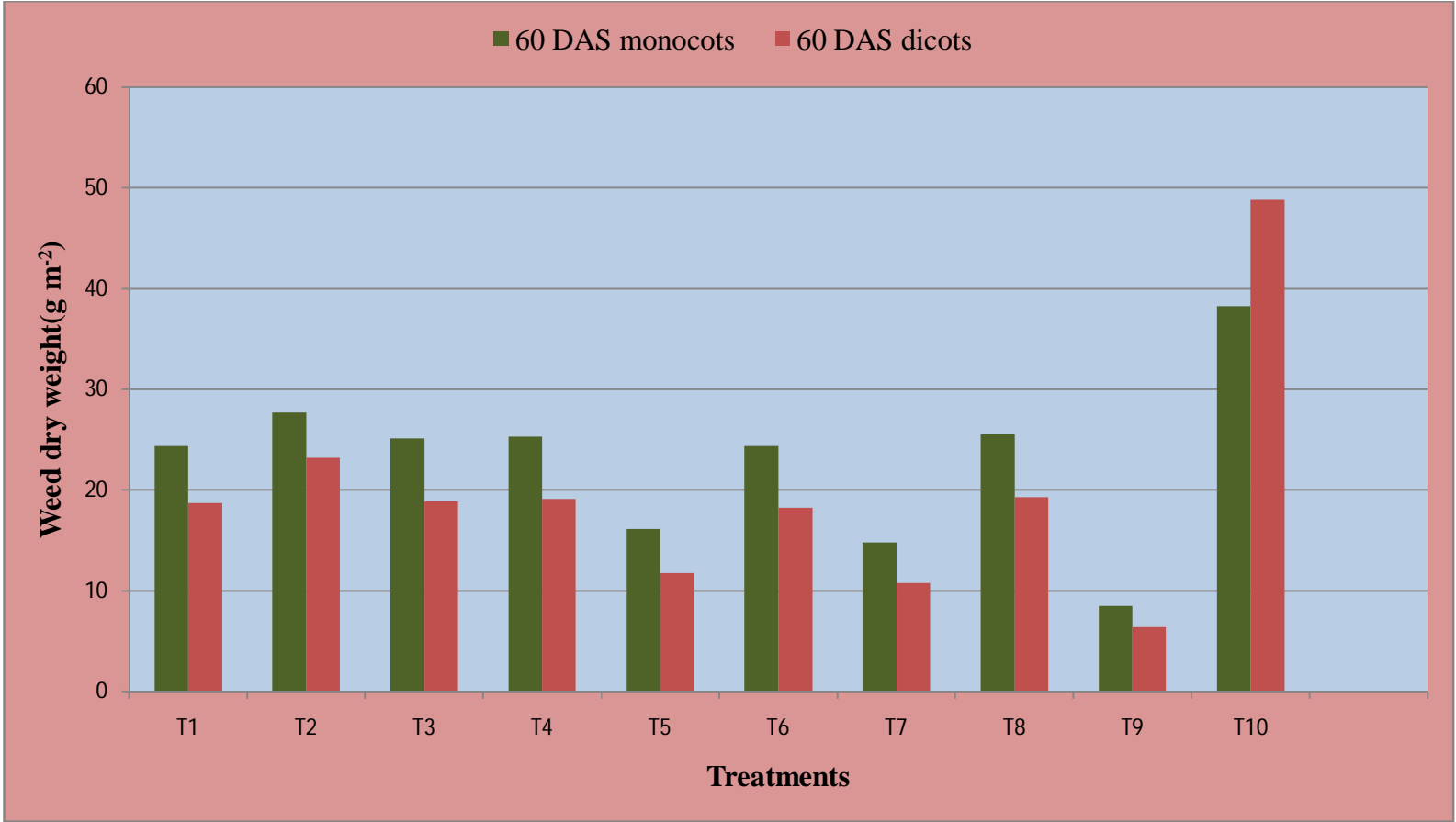


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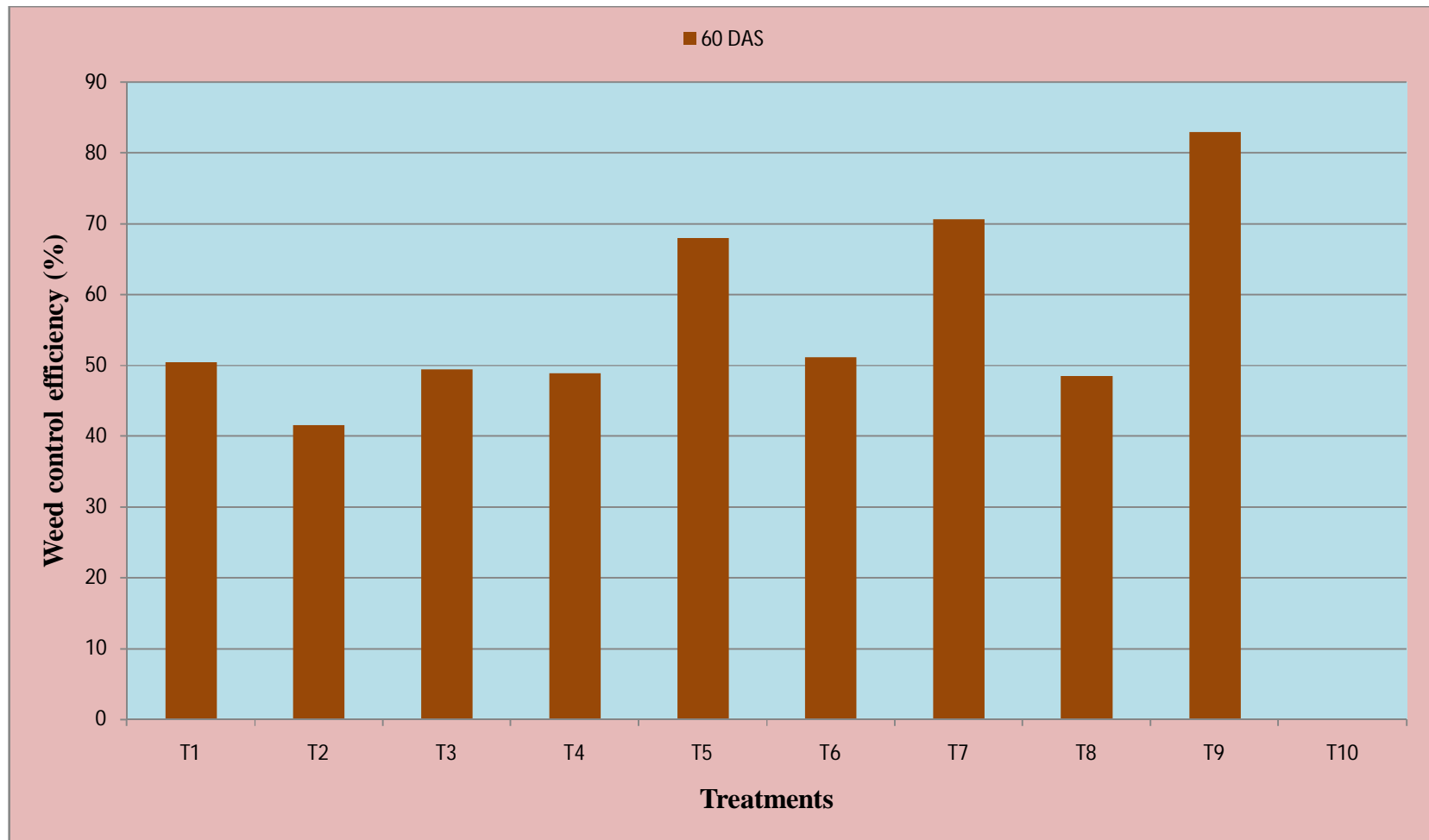


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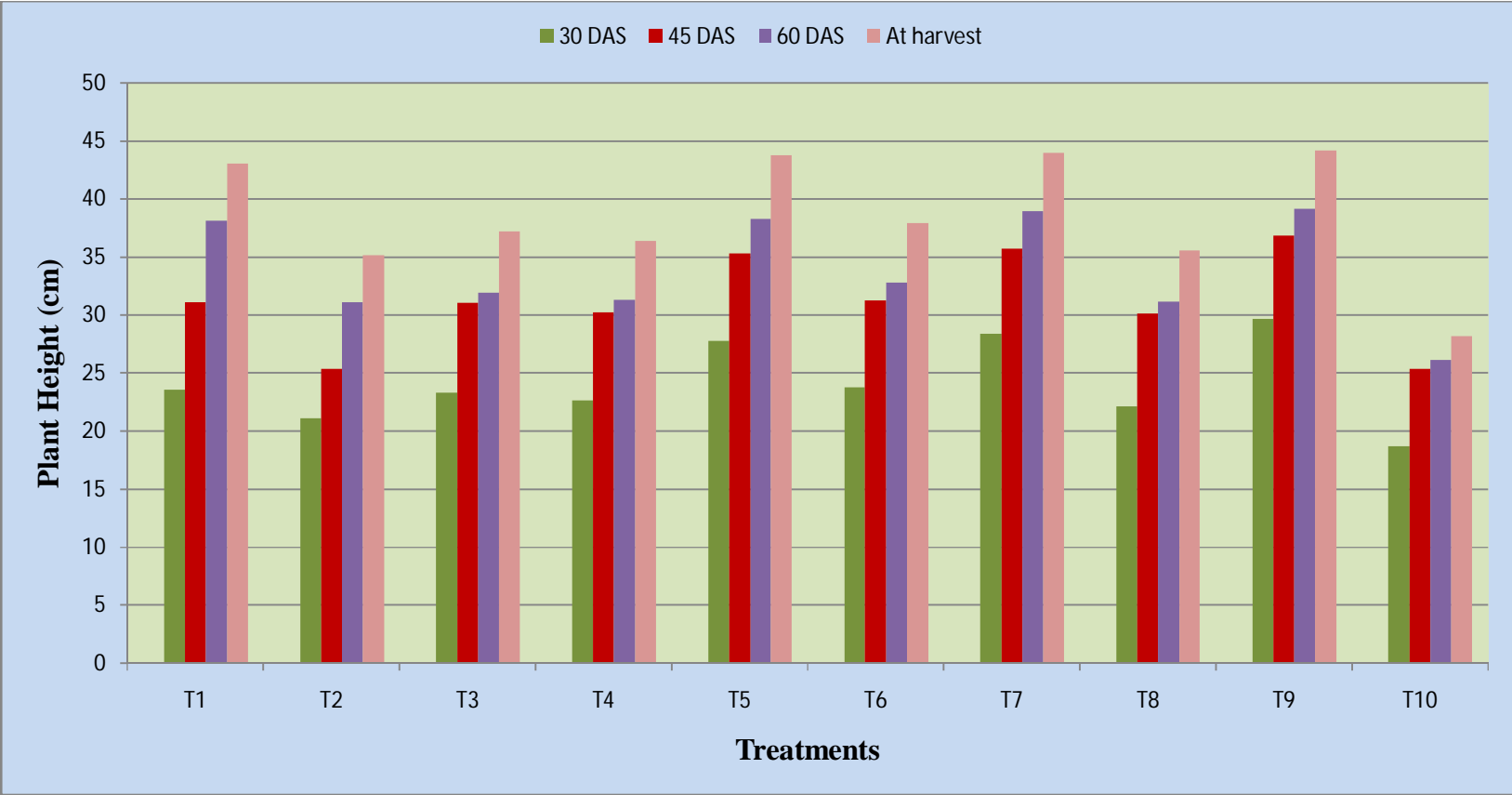


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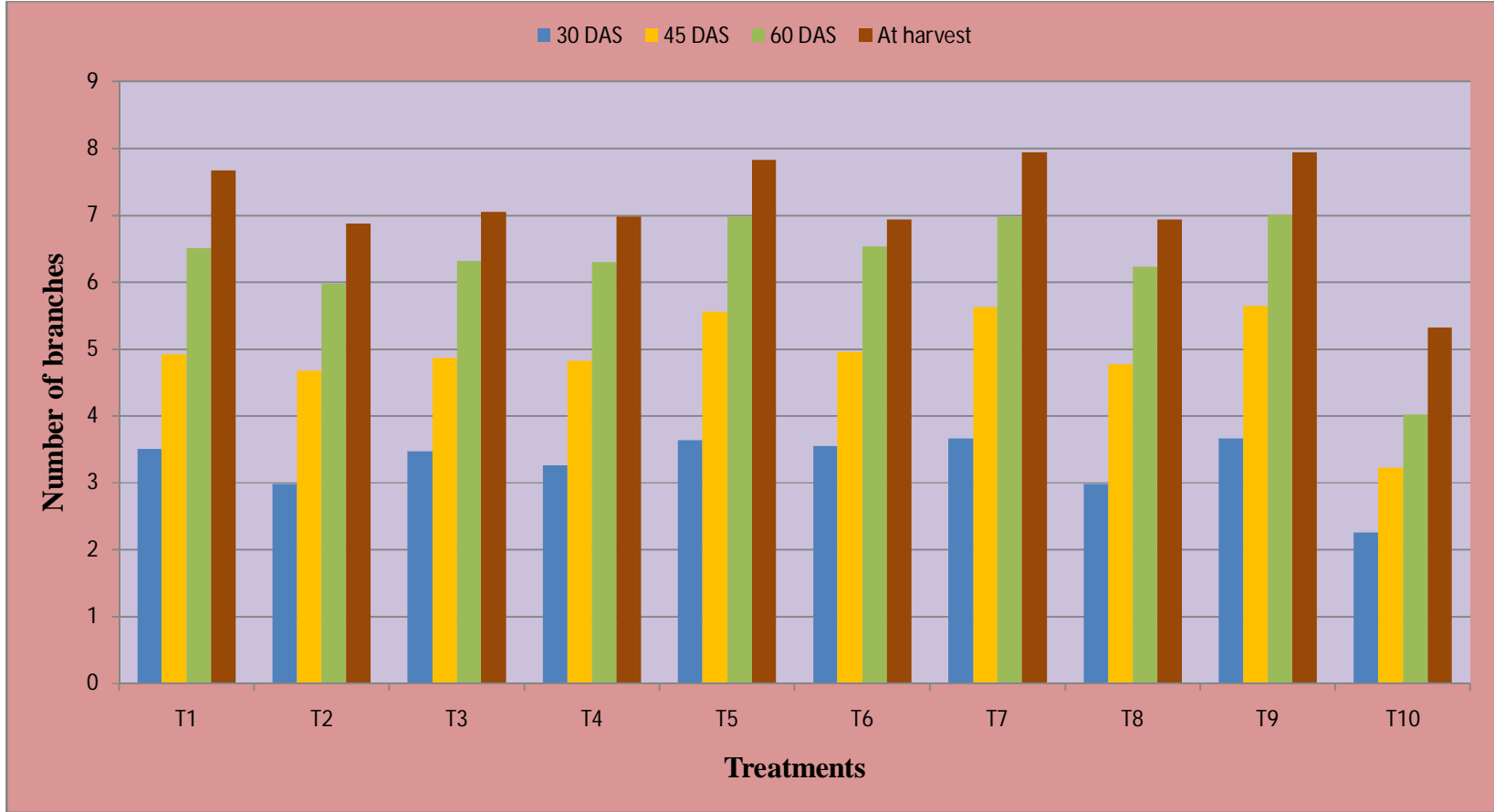


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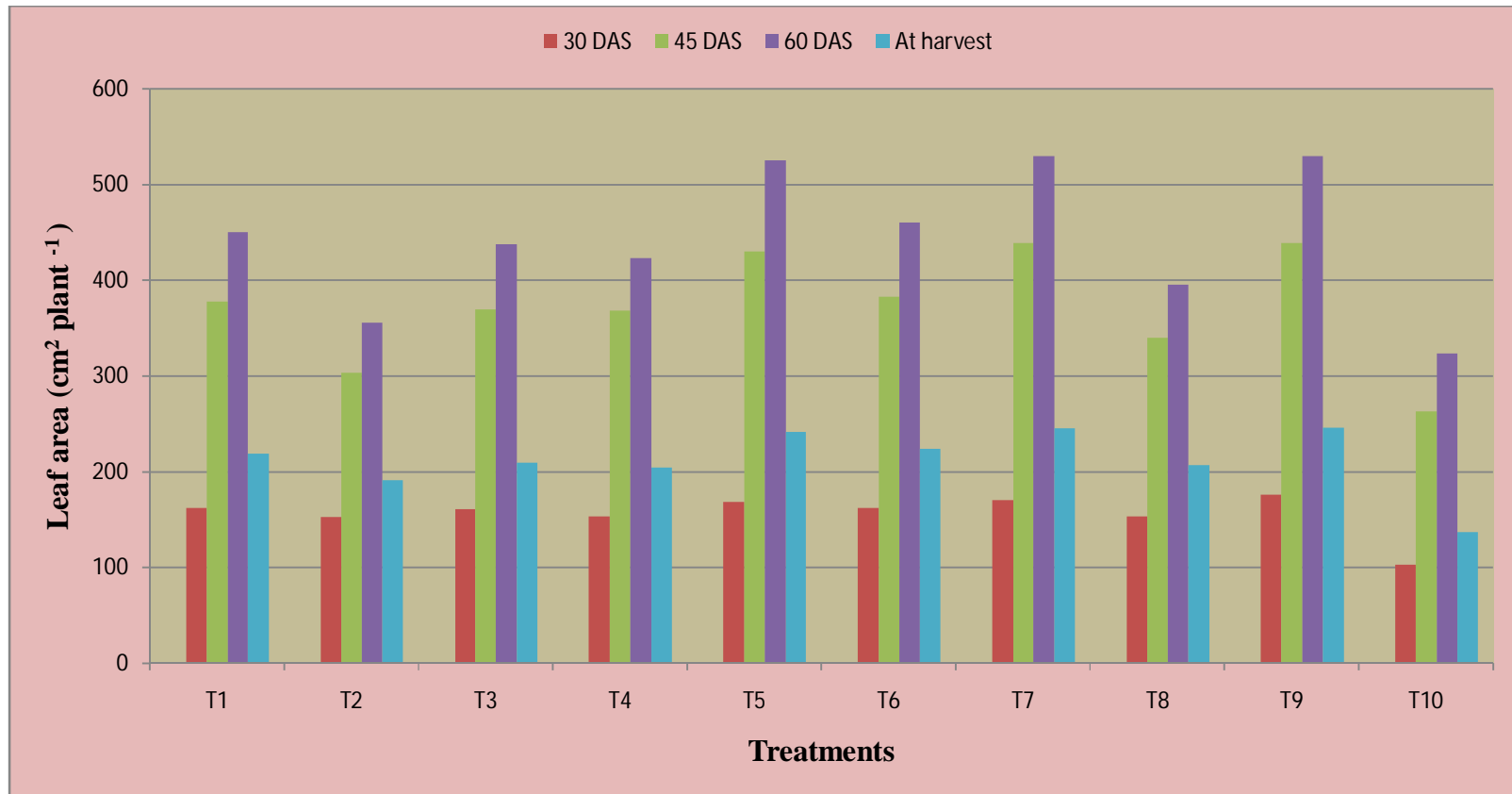


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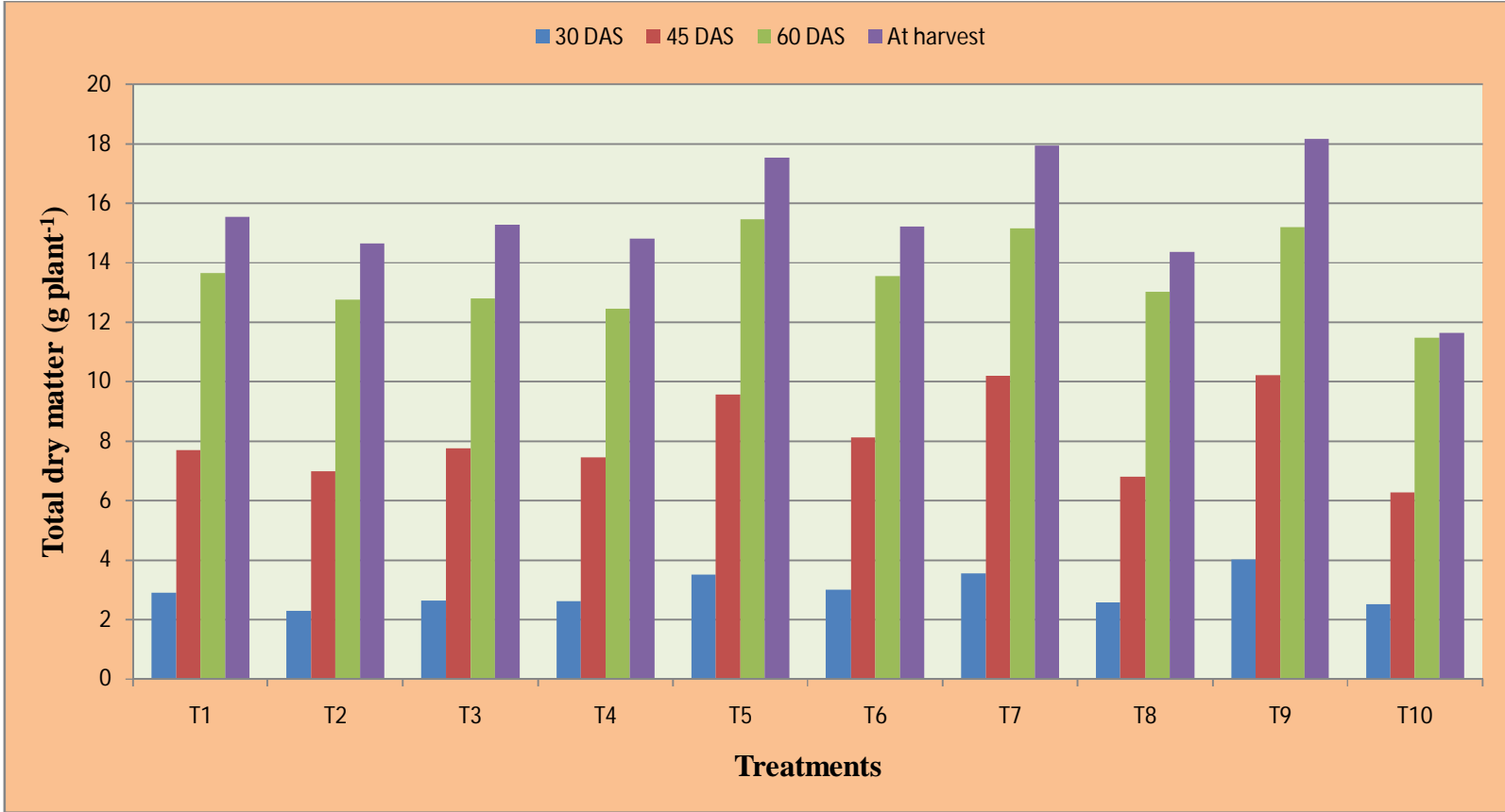


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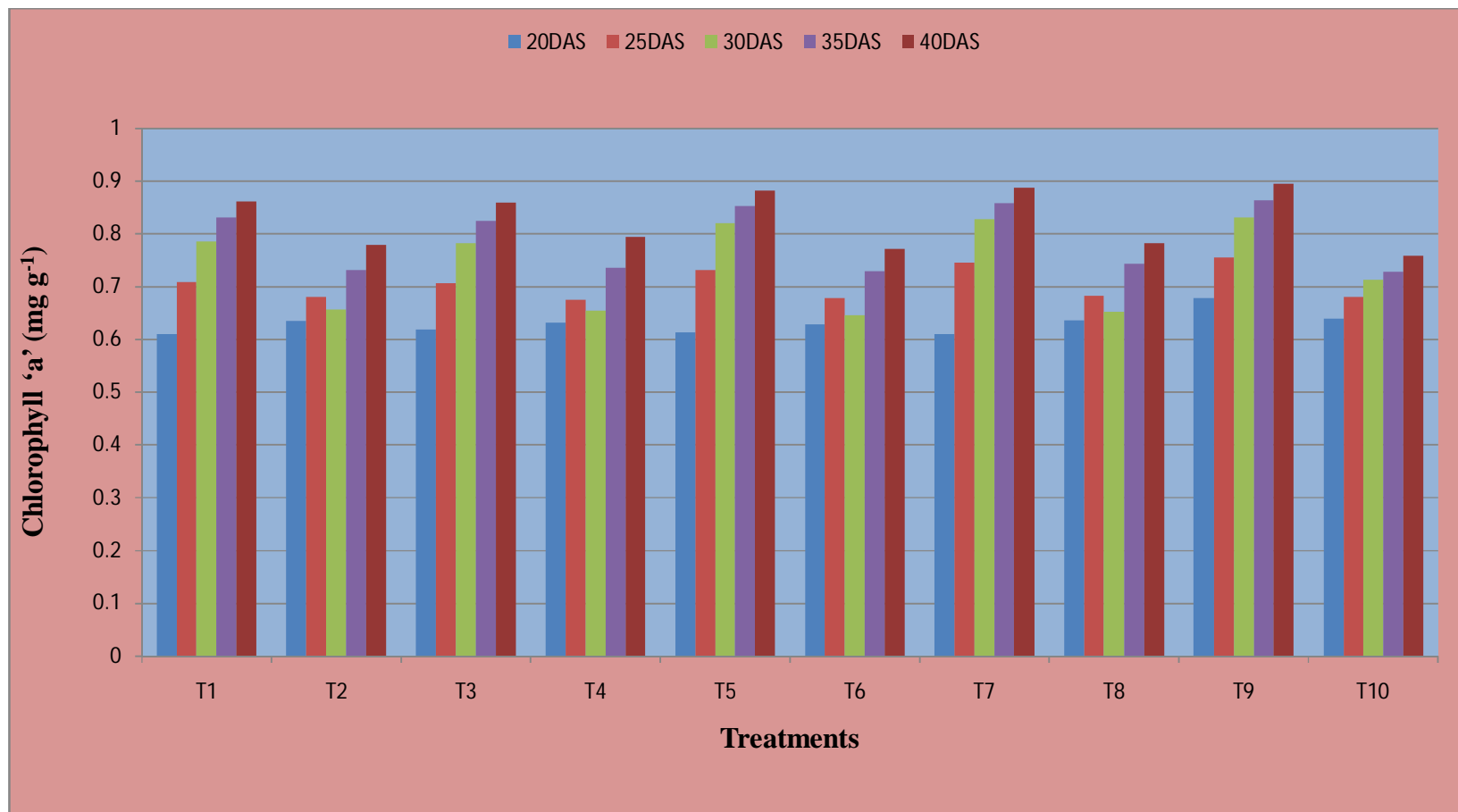


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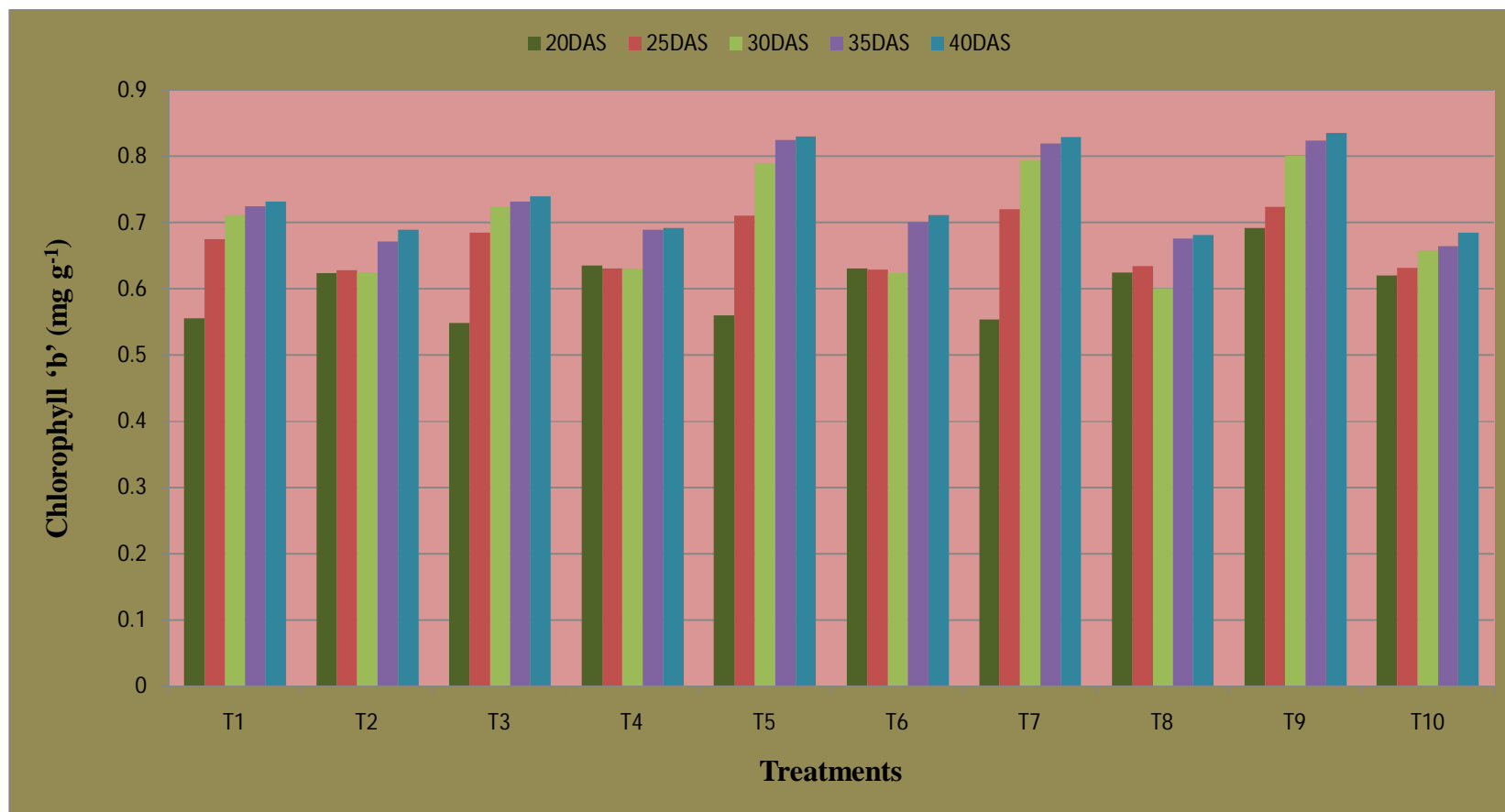


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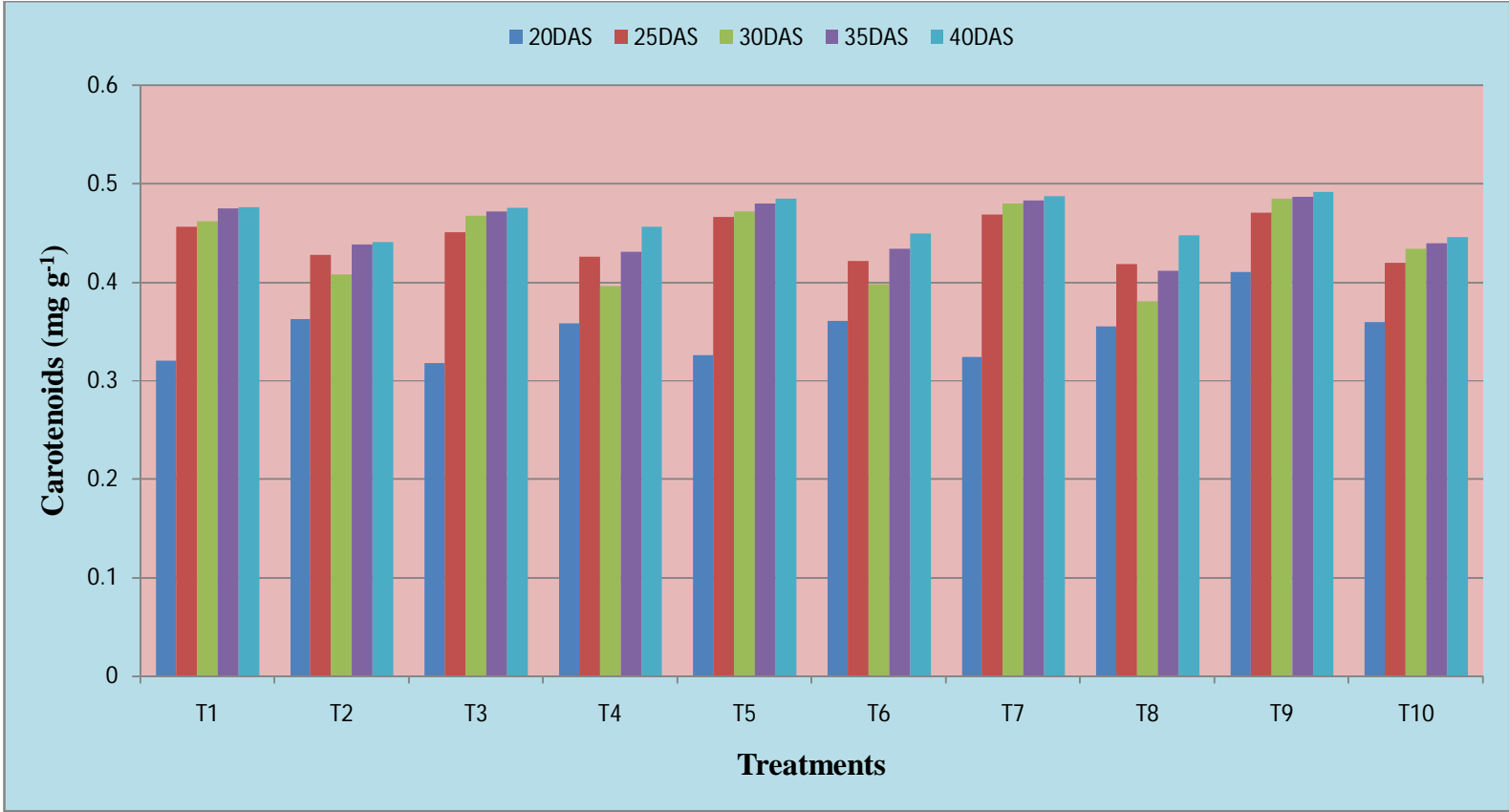


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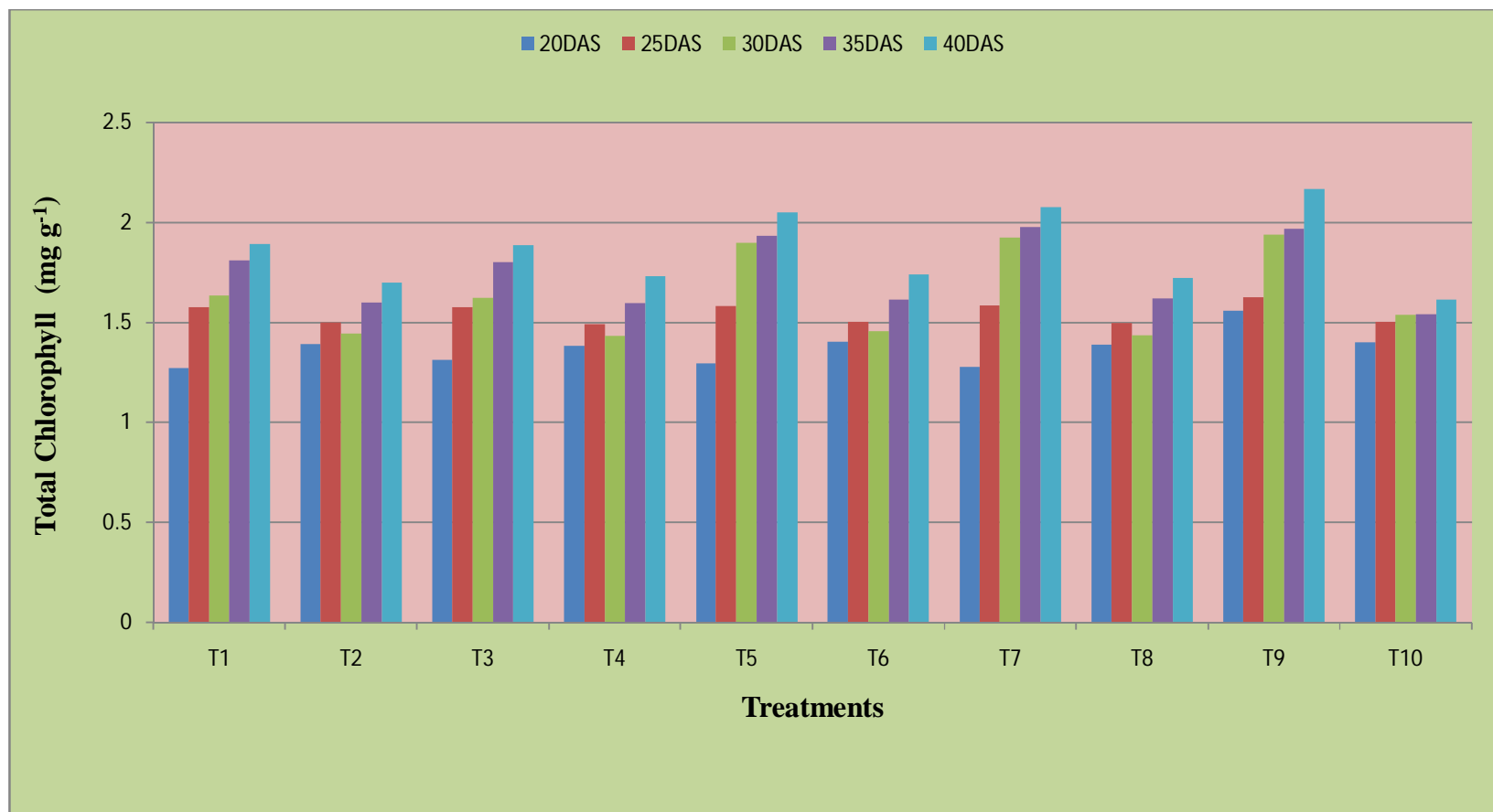


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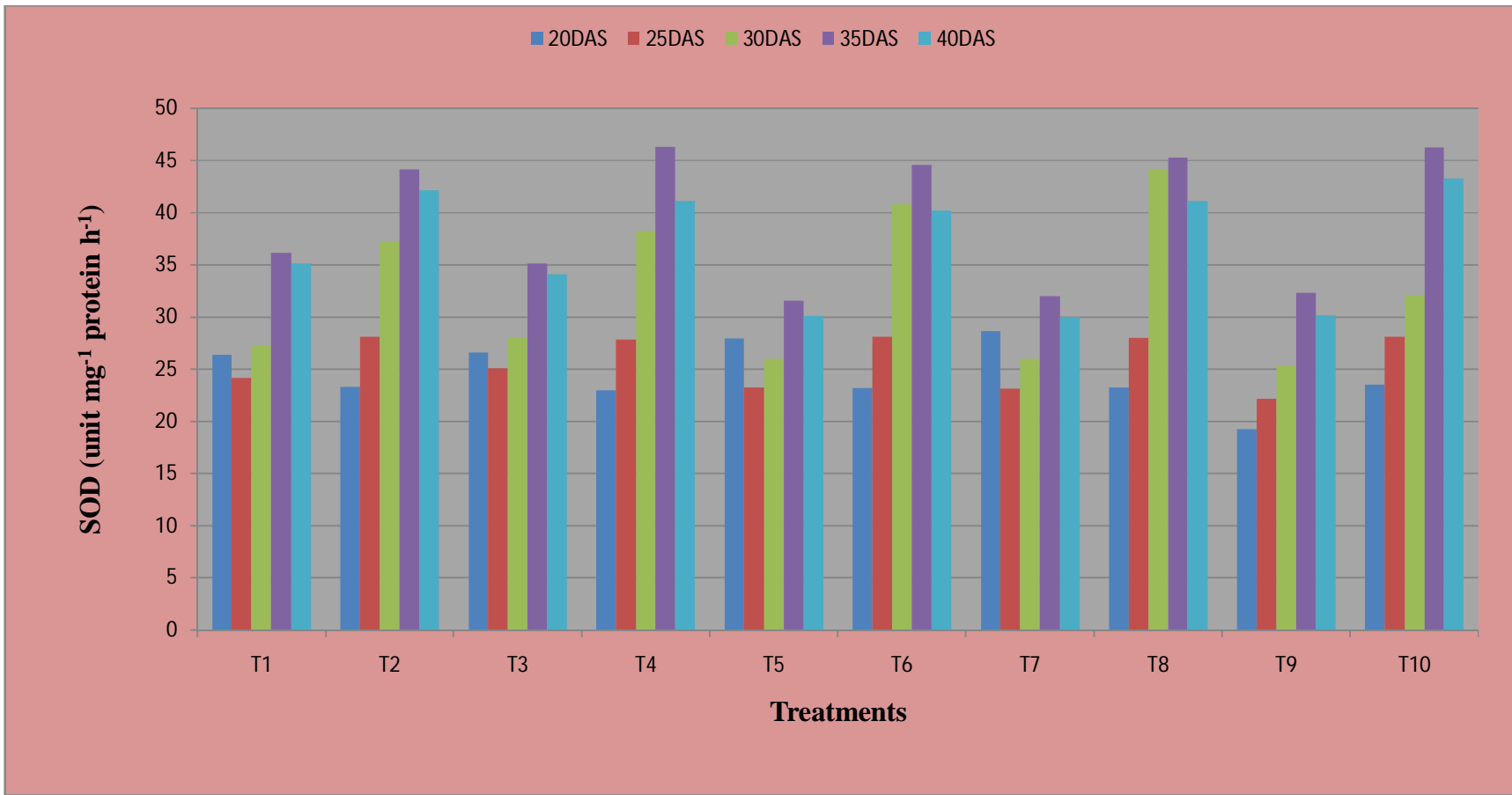


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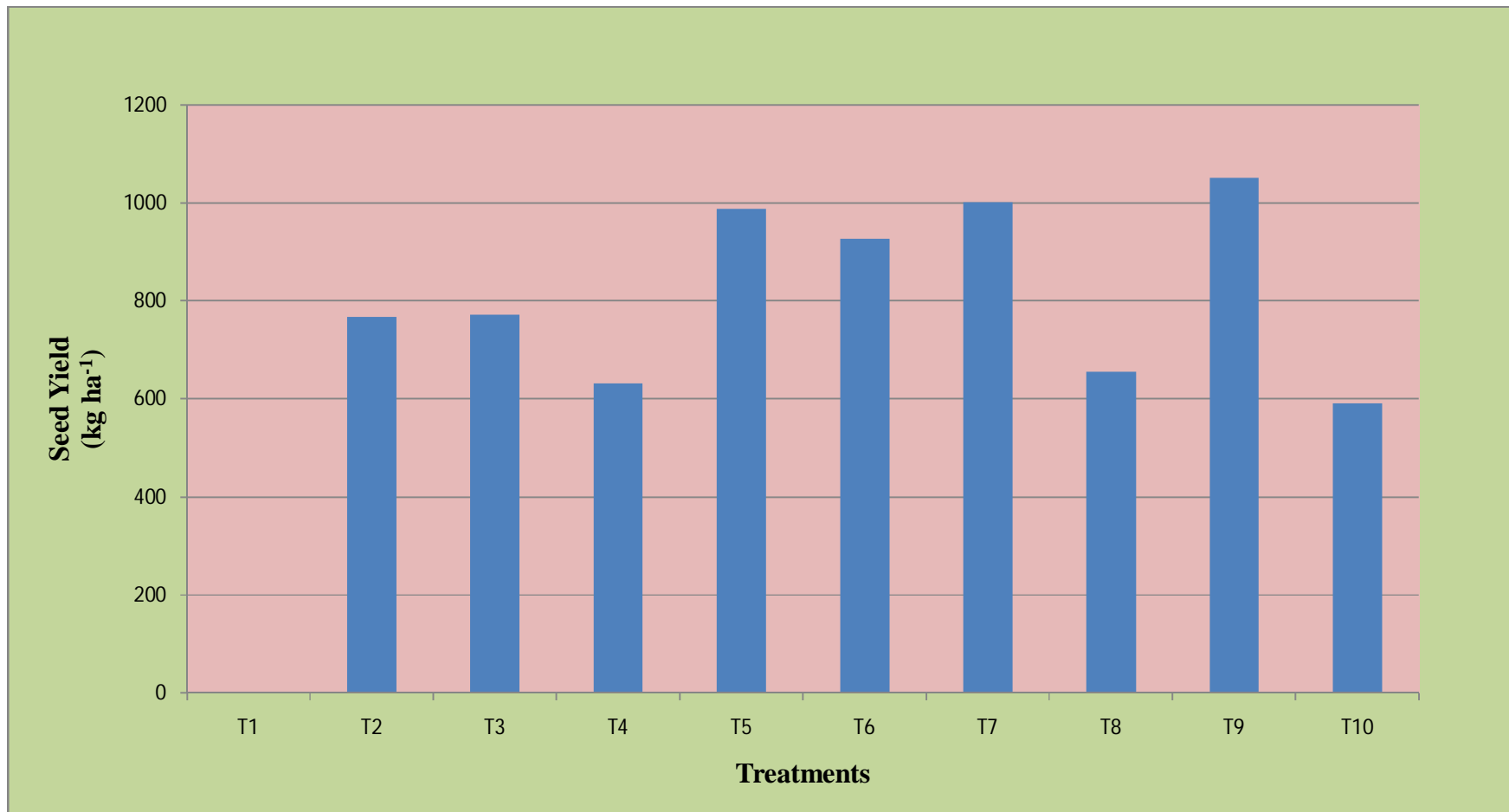


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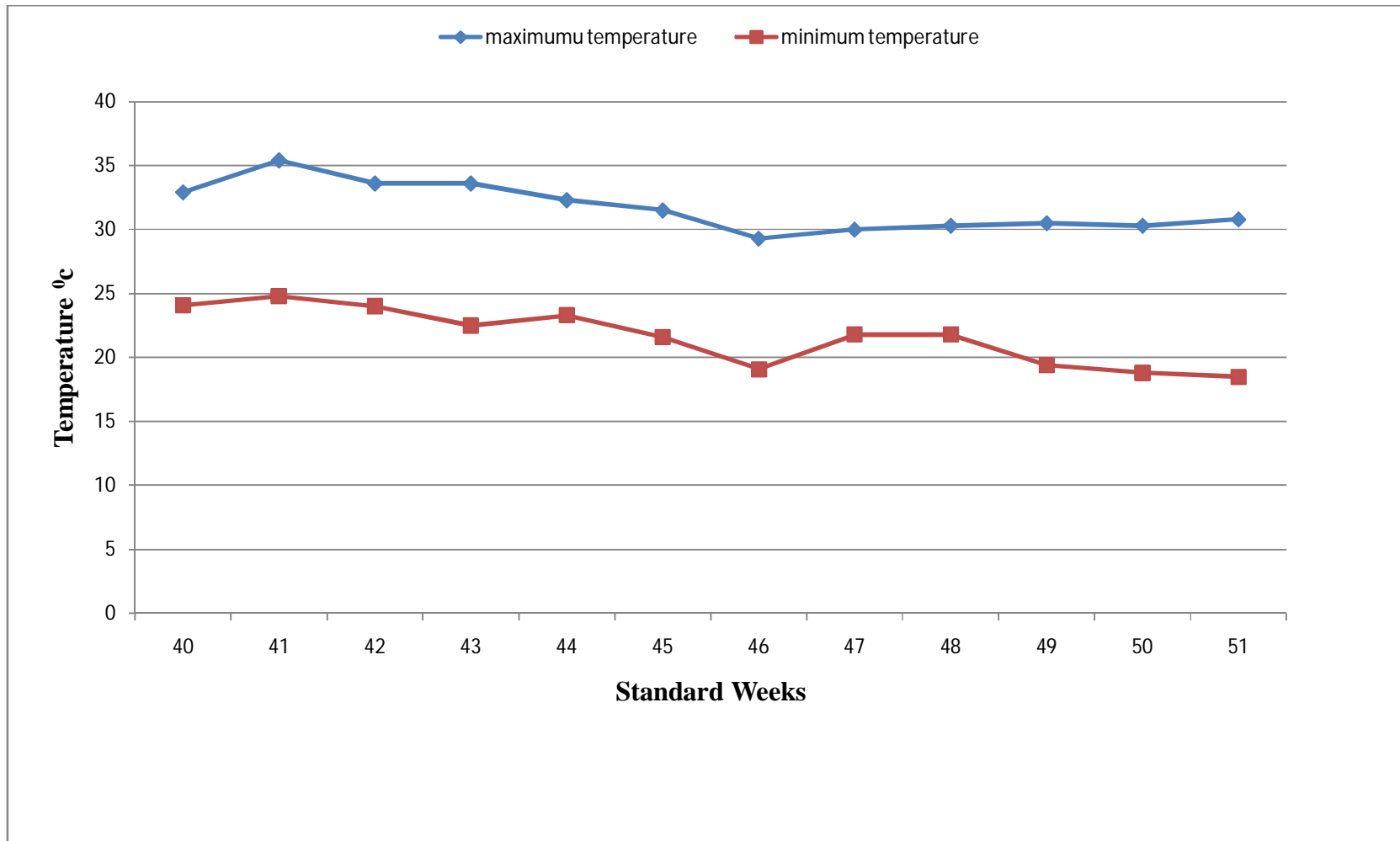


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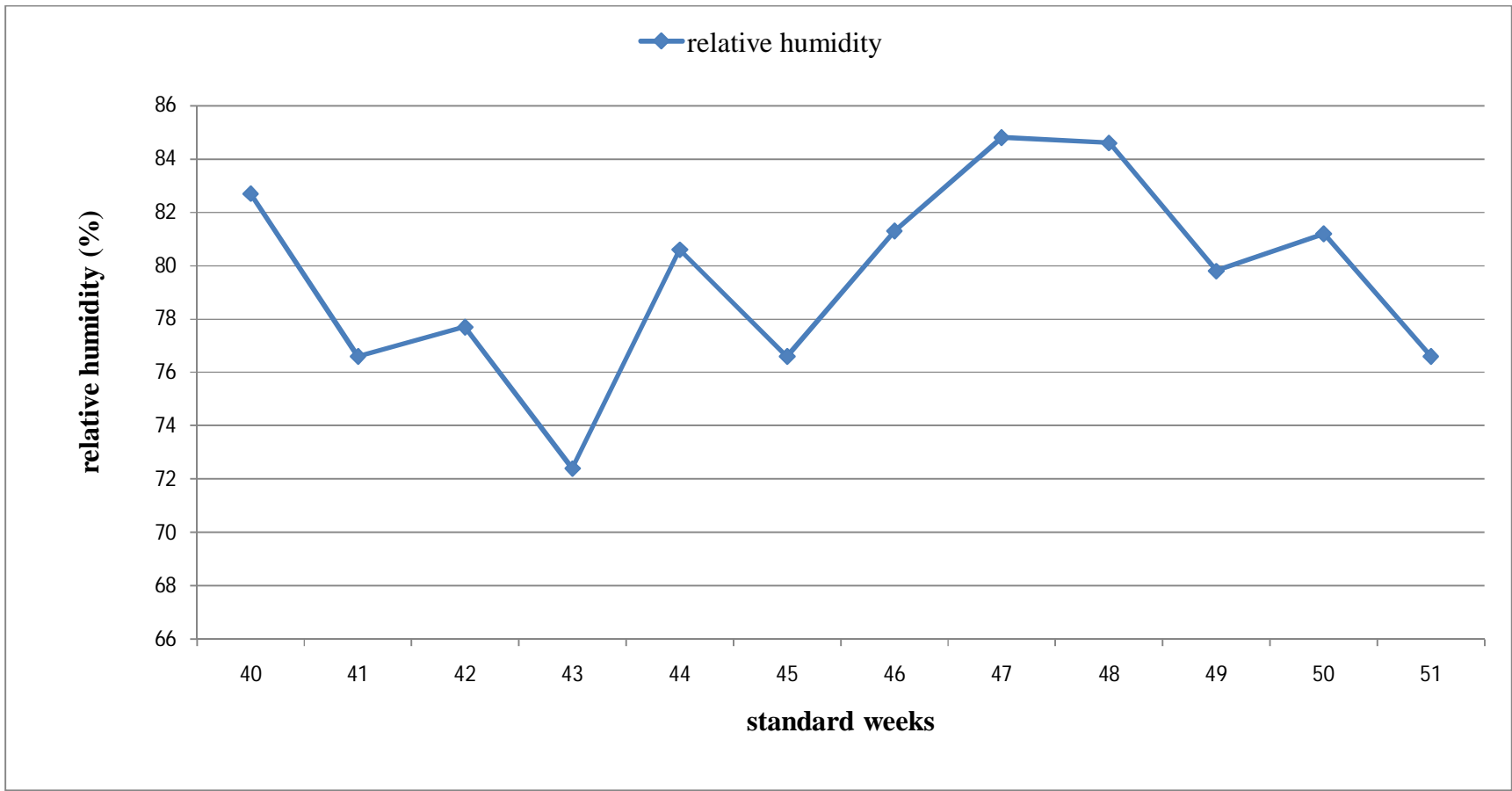


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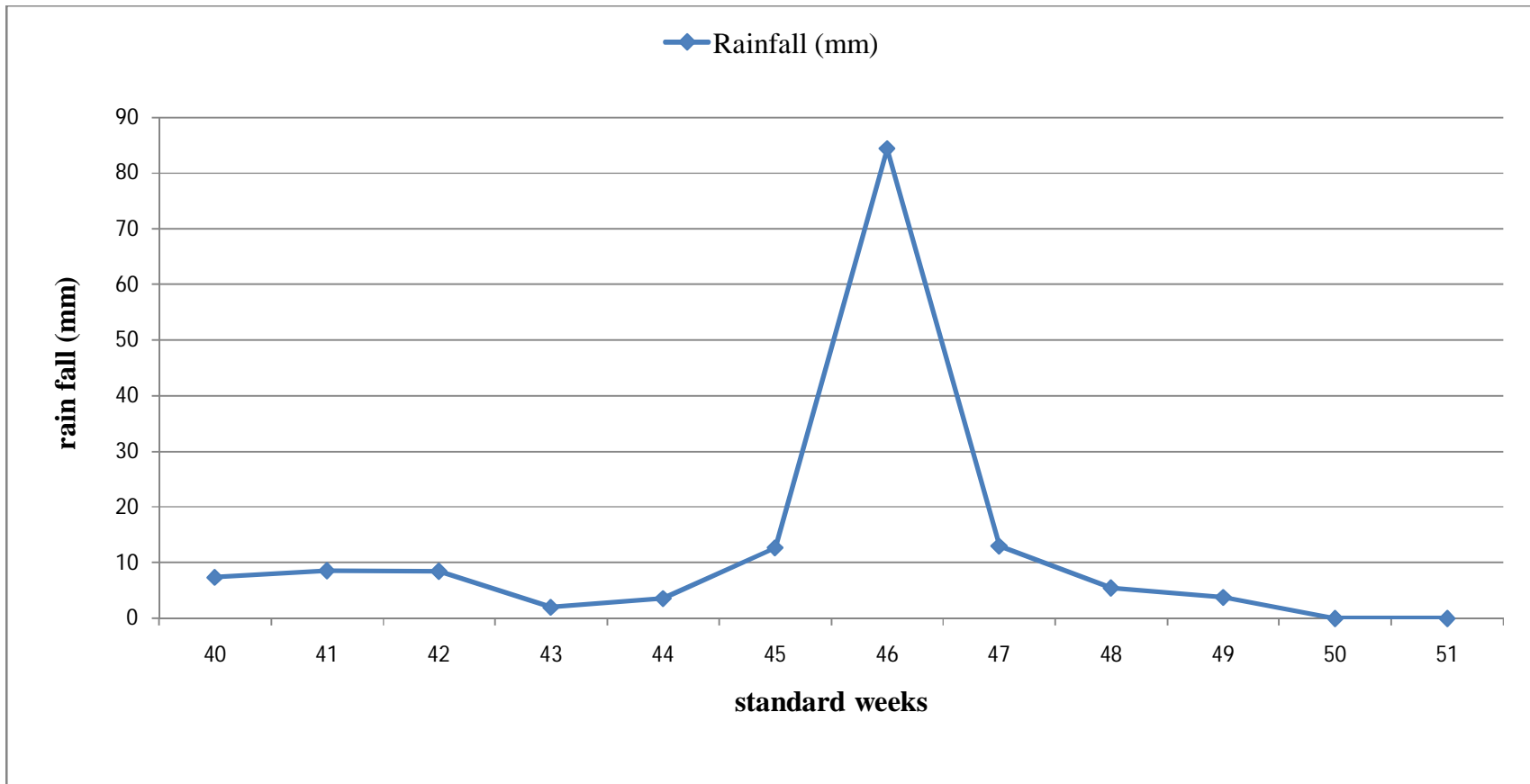


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Chapter I

INTRODUCTION

Pulses occupy a unique position in every system of Indian farming as a main, cover, green manure, catch and intercrop. These are the major source of dietary protein in the vegetarians and contribute about 14 per cent of total protein in an average Indian diet. Besides being a rich source of protein, they maintain soil fertility through biological nitrogen fixation in soil and thus play a vital role in sustainable agriculture.

Blackgram [*Vigna mungo* (L.) Hepper)] is an important legume crop cultivated worldwide in tropical and subtropical regions and is valued for high protein in its seeds. India is the largest producer and consumer of blackgram in the world. It is the fourth important pulse crop in India and second most important in Andhra Pradesh in terms of extent of cultivation. It is commonly known as urd, mush and mung in India, an important pulse crop next to greengram. It is cultivated mainly in Andhra Pradesh, Uttar Pradesh, Bihar, Madhya Pradesh and West Bengal in both *kharif* and *rabi* seasons.

In AP, blackgram is grown during *rabi* season in Krishna, Prakasam, Nellore, Guntur, East and West Godavari districts on receding soil moisture conditions. Rice- blackgram cropping system is famous in Guntur District of Andhra Pradesh, which ranks first in production. In *Kharif*, it is grown in 0.25 lakh ha, producing 0.17 lakh tonnes with a productivity of 676 kg ha⁻¹. In *Rabi*, it occupies 4.29 lakh ha, producing 3.39 lakh tonnes with a productivity of 790 kg ha⁻¹ (Department of Agriculture and Co-operation, Government of A.P, 2014-15). As a pulse crop, blackgram plays an important role in Indian diet. It contains about 26 per cent protein, 57 per cent carbohydrate and 1.2 per cent fat. It is a good source of phosphoric acid, calcium and vitamins like thiamine (B₁), riboflavin (B₂) and niacin (B₃), grown primarily for its protein rich seeds, used as dhal.

The protection of crops from weeds and other vegetation which inhibit crop growth is a constantly recurring problem in agriculture. Blackgram, being a short duration and initially slow growing, suffers heavily due to infestation of weeds. Depending upon intensity and nature of weed flora, an average yield reduction of 30-50 per cent has been reported due to weed competition (Mishra, 1997). *Echinochloa colona* alone, one of the major weed in blackgram, may reduce the seed yield to the extent of 49 per cent (Rao and Rao, 2003).

Control of weeds during critical period of crop weed competition is very important to avoid severe yield losses. The manual and mechanical methods of weed control, besides being less effective, are costly and time consuming. Moreover, many times labour is not available at the critical period of weed removal. Furthermore, weather conditions (rains) do not permit timely hand weeding due to wet field conditions. Delayed removal of weeds is not as effective in controlling weeds and obtaining higher yields as the timely removal of weeds. In such situations, herbicides offer most ideal, practical, effective and economical means of reducing early weed competition and crop production losses. Selective herbicides kill specific targets while leaving the desired crop relatively unharmed. Some of these act by interfering with the growth of the weed and are often synthetic “imitation” of plant hormones. The herbicides selectivity is based on the plant’s ability to rapidly metabolize the herbicide, forming non-phytotoxic compounds. However, there is a differential selectivity between species and the genetic makeup of the species or cultivar may determine varying degrees of tolerance or susceptibility to herbicides.

The use of herbicides, even in tolerant cultivars, can generate stress conditions, evidenced by the increase in phytotoxicity, which affects growth, development and productivity. The negative effect of stress is often mediated by the oxidative damage initiated by reactive oxygen species (ROS). The herbicides selectivity can be visually assessed by means of the phytotoxicity symptoms in plants, and also by the change in photosynthetic pigments, growth and yield parameters. Also, it is important to check the herbicides efficiency in the target weed control and the effects on productivity, as there are products that reduce crop productivity without visual symptoms and others that cause sharp injuries, but they allow the crop to fully express its productive potential.

Recently, some new post emergence herbicides viz., imazethapyr, acifluorfen sodium and clodinafop propargyl etc. are being marketed with the assurance of selective control of weeds in blackgram. Although these are recommended for blackgram, there are field reports of phytotoxicity in the crop after the application of imazethapyr, acifluorfen sodium and clodinafop propargyl. Currently, the information on the effect of these post-emergence herbicides on phytotoxicity, growth, photosynthetic pigments, antioxidant enzyme activity and yield of blackgram is scanty. Keeping this in view, this study is proposed to investigate the effect of post emergence herbicides viz., imazethapyr and acifluorfen sodium + clodinafop propargyl on growth, physiological parameters, phytotoxicity and yield of black gram with the following objectives.

- To find out the effect of imazethapyr and acifluorfen sodium + clodinafop propargyl on growth, photosynthetic pigments, antioxidant enzyme activity and phytotoxicity of blackgram.
- To find out the effect of imazethapyr and acifluorfen sodium + clodinafop propargyl on yield and yield attributes of blackgram.

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LIST OF SYMBOLS AND ABBREVIATIONS

@	:	At the rate of
$^{\circ}\text{C}$:	Degree Celsius
%	:	Per cent
CD (p=0.05%)	:	Critical Difference at 5 per cent level
a.i.	:	active in gradient
ANOVA	:	Analysis of Variance
B:C ratio	:	Benefit Cost ratio
CGR	:	Crop Growth Rate
cm	:	Centimeter
cm^2	:	Centimeter square
cm plant^{-1}	:	Centimeter per plant
CV	:	Coefficient of Variation
DAHA	:	Days after herbicide application
DAS	:	Days After Sowing
DAG	:	Days After Germination
dS m^{-1}	:	Desi Siemens per metre
EC	:	Electrical Conductivity
EC	:	Emulsifiable concentration
EPoE	:	Early post emergence
<i>et al.</i>	:	and others
etc.	:	And so on; and other people things
Fig.	:	Figure
g	:	gram
g ha^{-1}	:	Gram per hectare
g m^{-2}	:	Gram per meter square
g plant^{-1}	:	Gram per plant

h^{-1}	:	Per hour
ha^{-1}	:	hectare
i.e.	:	That is
K	:	Potassium
K_2O	:	Potassium oxide
$Kg\ ha^{-1}$:	Kilogram per hectare
Kg	:	Kilogram
Kg^{-1}	:	Per kilogram
km	:	kilometer
L^{-1}	:	Per Litre
LAI	:	Leaf area index
$L\ ha^{-1}$:	Litre per hectare
M	:	molar concentration
m	:	meter
m^{-2}	:	Per metre square
m^2	:	Square metre
Max	:	Maximum
$mg\ g^{-1}$:	Milligram per gram
ml	:	millilitre
$ml\ L^{-1}$:	Milliliter per litre
mm	:	Millimeter
Min	:	Minimum
min	:	minute
MOP	:	Murate of Potash
N	:	Nitrogen
nm	:	nanometers
No.	:	Number
$No.\ m^{-2}$:	Number per square metre

NS	:	Non-Significant
P	:	Phosphorus
P ₂ O ₅	:	Phosphorus penta oxide
pH	:	Potential of hydrogen ion concentration
PE	:	Pre emergence
PoE	:	Post emergence
PPI	:	Pre plant incorporation
ppm	:	Parts per million
q ha ⁻¹	:	Quintal per hectare
RBD	:	Randomized block design
RH	:	Relative humidity
ROS	:	Reactive oxygen species
rpm	:	Revolution per minute
Rs.	:	Rupees
Rs.ha ⁻¹	:	Rupees per hectare
SEM _⊥	:	Standard error of mean
SL	:	Soluble liquid
SOD	:	Superoxide dismutase
SSP	:	Single super phosphate
spp.	:	species
T	:	Treatment
viz.,	:	Namely
WCE	:	Weed control efficiency

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***Original not seen**

Note:The literature is cited as per the “Thesis Guidelines” prescribed by Acharya N G Ranga Agricultural University, Guntur.

Chapter III

MATERIAL AND METHODS

A field experiment was conducted to study the “Effect of post emergence herbicides on growth, physiological parameters, phytotoxicity and yield of Blackgram [*Vigna mungo* (L.) Hepper]” at Agricultural College Farm, Bapatla during *kharif* season of 2015. The methods of conducting experiment, materials and inputs used during the experiment action period are given in detail in this chapter under different heads.

3.1 EXPERIMENTAL SITE

The experiment was conducted in Northern Block, Field No. 28 of Agricultural College Farm, Bapatla, Guntur district, Andhra Pradesh. It is 9 km away from Bay of Bengal at an altitude of 5.49 m above mean sea level, 15⁰54' Northern latitude and 80⁰25' Eastern longitude.

3.2 WEATHER CONDITIONS

The weekly meteorological data recorded during the crop growth period i.e. from 5- 10- 2015 to 17- 12- 2015 are presented in Table 3.1 and depicted in Fig. 3.1, 3.2 and 3.3.

3.2.1 Temperature (°C)

The weekly mean maximum and minimum temperatures ranged from 29.3⁰C to 35.4⁰C and 18.5⁰C to 24.8⁰C, respectively, while the average maximum and minimum temperature during the crop growth period were 34.5⁰C and 23.6⁰C, respectively.

3.2.2 Relative Humidity (RH) (%)

The mean RH during the crop growth period ranged from 72.4 to 84.8 per cent with an average of 86.8 per cent.

**Table 3.1. Weekly meteorological data during the crop growth period
(05.10.2015 to 17.12.2015)**

Standard Weeks	Date and Month	Mean temperature (°C)		Mean Relative Humidity (%)	Rainfall (mm)
		Max	Min		
40	01 Oct - 07 Oct	32.9	24.1	82.7	7.4
41	08 Oct - 14 Oct	35.4	24.8	76.6	8.6
42	15 Oct - 21 Oct	33.6	24.0	77.7	8.5
43	22 Oct - 28 Oct	33.6	22.5	72.4	2.0
44	29 Oct - 04 Nov	32.3	23.3	80.6	3.6
45	05Nov - 11 Nov	31.5	21.6	76.6	12.7
46	12 Nov - 18 Nov	29.3	19.1	81.3	84.4
47	19 Nov - 25 Nov	30.0	21.8	84.8	13.0
48	26 Nov - 02 Dec	30.3	21.8	84.6	5.5
49	03Dec - 09 Dec	30.5	19.4	79.8	3.8
50	10 Dec - 16 Dec	30.3	18.8	81.2	-
51	17 Dec - 23 Dec	30.8	18.5	76.6	-
Total	-	-	-	-	149.5
Mean	-	34.5	23.6	86.80	-

3.2.3 Rainfall

The total amount of rainfall received during the crop period was 149.5 mm.

3.3 SOIL AND ITS CHARACTERISTICS

Initial soil sample from the experimental field was collected at random from 0 to 30 cm depth and a composite sample was analyzed for physical and physico-chemical properties. The results of the analysis (Table 3.2) indicated that the soil was clay loam in texture, slightly alkaline in reaction (pH 7.3), medium in organic carbon (0.52%), available nitrogen (190.3 kg ha^{-1}), available phosphorus (23.0 kg ha^{-1}) and available potassium (294.6 kg ha^{-1}).

3.4 Experimental Details

3.4.1 Design and Layout

The field experiment was laid out in a Randomised Block Design with ten treatments in three replications. The field layout plan is depicted in Fig. 3.4 and overall view of field experiment is depicted in Plate 1. The other details of the experiment are

Location	:	Agricultural College Farm, Bapatla
Crop	:	Blackgram [<i>Vigna mungo</i> (L.) Hepper]
Season	:	<i>kharif</i> , 2015
Design	:	Randomized Block Design
Treatments	:	Ten
Replications	:	3
Variety	:	PU-31
Plot size	:	4.2 m x 3 m
Spacing	:	30 x 10 cm
Date of sowing	:	05-10-2015.

Table 3.2. Soil sample analysis data of experimental plot before the initiation of experiment

S. No.	Particulars	Value	Method of Analysis
A)	Mechanical analysis		Bouyoucos Hydrometer method (Bouyoucos, 1962)
	Sand (%)	18.7	
	Silt (%)	41.6	
	Clay (%)	39.7	
	Textural class	Clay loam	
B)	Chemical analysis		
1	pH (1:2.5–soil water suspension)	7.3	Glass electrode method (Jackson, 1973)
2	EC (dS m ⁻¹)	0.32	Conductivity bridge (Jackson, 1973)
3	Organic carbon (%)	0.52	Walkley and Black's modified method (Walkley and Black, 1934)
4	Available nitrogen (kg N ha ⁻¹)	190.3	Alkaline permanganate method (Subbaiah and Asija, 1956)
5	Available phosphorus (kg P ₂ O ₅ ha ⁻¹)	23.0	Olsen's extractant method (Olsen <i>et al.</i> , 1954)
6	Available potassium (kg K ₂ O ha ⁻¹)	294.6	Neutral normal ammonium acetate method (Jackson, 1973)

3.4.2 Treatment details

T₁: Imazethapyr 10% EC @ 50g a.i ha⁻¹ at 15 DAS

T₂: Imazethapyr 10% EC @ 50g a.i ha⁻¹ at 25 DAS

T₃: Acifluorfen Sodium 16% EC + Clodinafop propargyl 8%EC
(24%EC)@180g a.i ha⁻¹ at 15 DAS

T₄: Acifluorfen Sodium 16% EC + Clodinafop propargyl 8%EC
(24%EC)@180 g a.i ha⁻¹ at 25 DAS

T₅: Acifluorfen Sodium 16% EC + Clodinafop propargyl 8%EC
(24%EC)@240g a.i ha⁻¹ at 15 DAS

T₆ Acifluorfen Sodium 16% EC + Clodinafop propargyl 8%EC
(24%EC) @ 240g a.i ha⁻¹ at 25 DAS.

T₇: Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC
(24%EC)@300g a.i ha⁻¹ at 15 DAS

T₈: Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC
(24%EC)@300g a.i ha⁻¹ at 25 DAS

T₉ : Weed free check (Hand weeding at 15and 30 DAS)

T₁₀: Un weeded control

3.5 VARIETAL DESCRIPTION

PU-31

Dwarf plant with dark green foliage. Semi erect and determinate growth habit having 3-4 basal branches. Leaves are trifoliate, narrow with lanceolate leaflets. Leaf and petioles are with violet pigmentation. Flowers are normal. Pods are hairy, short and stout with 4-6 seeds. Seeds are dull black, testa medium bold. Resistant to YMV. Suitable for summer season under rice fallows. Duration is 65-70 days. Yield potential is 12.5-15 q ha⁻¹.

3.6 FIELD OPERATIONS

The following field operations were carried out during the experimentation period.

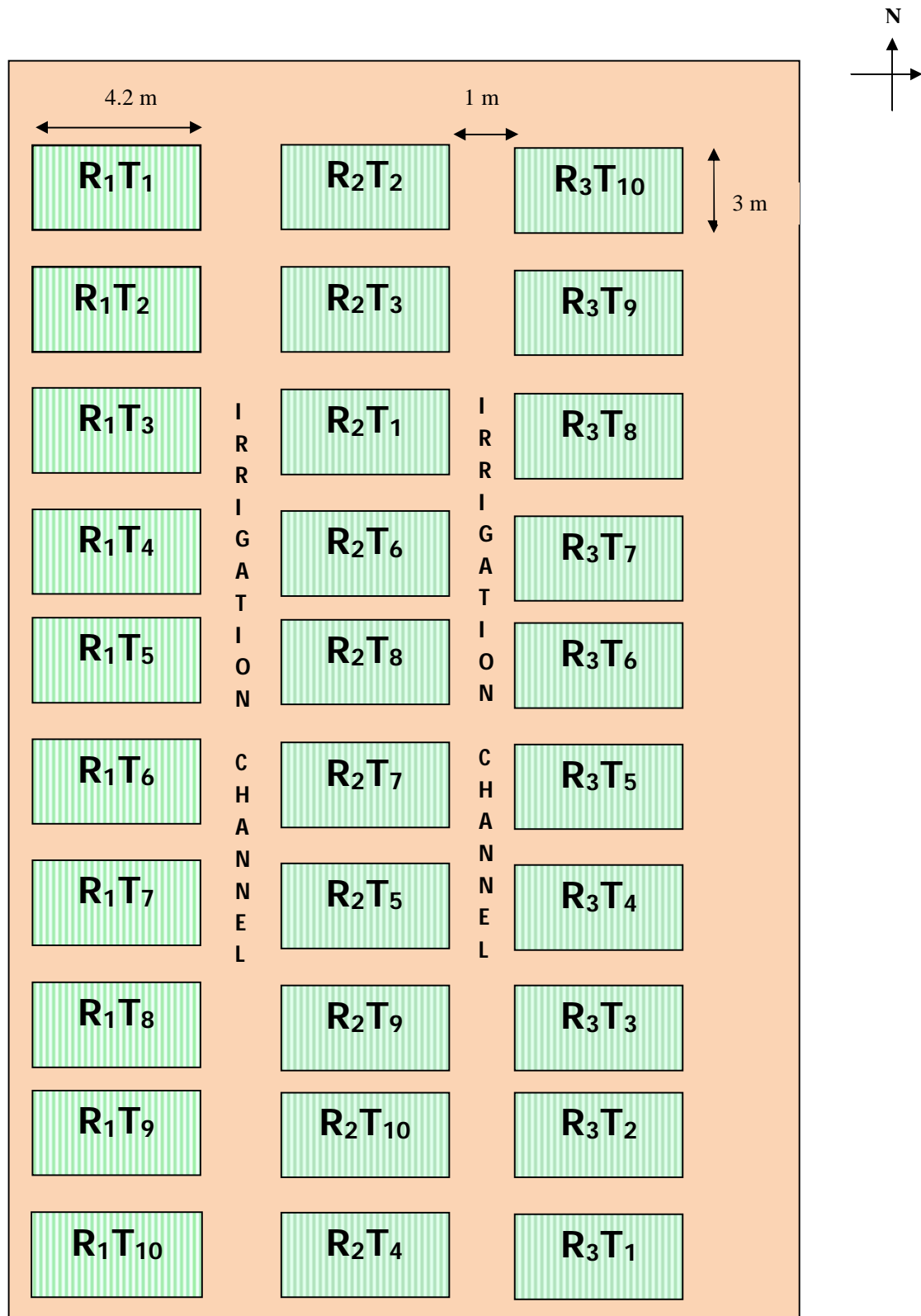


Fig. 3.4 Field layout plan of the experiment

3.6.1 Preparation of Land

The land was ploughed twice using a tractor drawn cultivar. Weeds and stubbles were removed and the field was levelled and later laid out into plots as per the design given in Fig 3.4.

3.6.2 Application of Fertilizers

Nitrogen and phosphorous were applied to the experimental plots @ 20 kg N ha⁻¹ in the form of urea and 50 kg P₂O₅ ha⁻¹ in the form of single super phosphate to the experimental plots before sowing of crop.

3.6.3 Seeds and Sowing

Blackgram, variety PU-31 was sown was on 05-10-2015 with a spacing of 30 cm between the rows and 10 cm between plants with in the row.

3.6.4 Thinning

After 10 days of sowing, seedlings were thinned out to maintain the interplant spacing of 30 x 10 cm and one plant per hill.

3.6.5 Hand Weeding

In weedy check weeds are allowed to grow throughout the crop growth period, where as in weed free check first hand weeding was done at 15 DAS followed by a second hand weeding at 30 DAS using hand hoes to remove weeds.

3.6.6 Herbicide Application

The post emergence herbicides viz., imazethapyr 10% EC @ 50 g a.i ha⁻¹ and acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24% EC) @ 180, 240 and 300 g a.i ha⁻¹ were sprayed at 15 and 25 DAS using knapsack sprayer fitted with flat fan nozzle at spray volume of 500 L ha⁻¹. The details of the herbicides used are presented in table 3.3.

3.6.7 Plant Protection Measures

All the crop protective measures were taken up regularly to prevent the incidence of pests and diseases. Monocrotophos @ 1.5 ml L⁻¹ was sprayed twice at 5 days interval from 30 DAS to prevent the attack of *Spodoptera* and *Heliothes* caterpillars.

3.6.8 Irrigation

Three irrigations were given to the crop i.e. at sowing, 20 DAS and at flowering stage.

3.6.9 Harvesting and Threshing

Harvesting was done from each net plot separately when the crop attained maturity, excluding the border rows. The crop was threshed after drying under sun and the seeds were collected plot wise, yield per net plot was recorded and finally yield ha⁻¹ was computed.

3.7 Collection of Experimental Data

Data were collected starting from 15 DAS to harvest by using the methods of non-destructive and destructive growth analysis. Five adjacent plants in a single row per each plot (excluding border rows) were selected and tagged (non destructive) for recording the data on morphological parameters. For destructive growth analysis, five adjacent plants in a single row per each plot (excluding border rows) were selected and dug out along with roots to record the observations for drymatter accumulation. Yield components and yield were estimated from the samples collected at the time of maturity.

3.7.1 Morphological Parameters

1. Plant height (cm)

The height of the five selected and tagged plants in each net plot was measured at 15, 30, 45 and 60 DAS and at harvest from the ground level to the apex of the main axis and the average is expressed as plant height. It was measured as cm plant⁻¹.

2. Number of branches

The number of branches per plant was worked out from the five plants selected and tagged for non-destructive measurement and the average was expressed as number of branches plant⁻¹.

3. Crop injury score

The phytotoxic effect of herbicides on blackgram was assessed at 20, 25, 30 and 35 DAS by using a simple rating scale of 0 to 10 (equal to 0 to 100%) is furnished in table 3.4 as suggested by Rao (2000).

3.7.2 Physiological Parameters

1. Leaf area (cm² plant⁻¹)

Leaves from the five adjacent plants sampled from each treatment in three replications were separated and leaf area was measured by using Leaf Area Meter (Model No. LP-80) and the average was expressed as leaf area plant⁻¹ in cm².

2. Drymatter accumulation (g plant⁻¹)

The total drymatter accumulation and its partitioning were estimated from the five adjacent plants sampled from each treatment in three replications and then separated into roots, stems, leaves and pods. The plant parts were dried to a constant weight in hot-air oven at 80°C for two days and the dry weights were recorded and expressed in g plant⁻¹.

3.7.3 Biochemical Parameters

Photosynthetic pigments (total chlorophyll, chlorophyll a, chlorophyll b and carotenoid contents) and superoxide dismutase activity (SOD) in leaves were estimated before herbicide application and 5, 10 and 15 DAHA.

1. Estimation of total chlorophyll and carotenoid content in leaves (mg g⁻¹ fresh weight)

Chlorophyll content in the leaves was estimated colorimetrically by dimethyl sulphoxide (DMSO) method as described by Hiscox and Stam (1979).

The leaf samples were collected, surface cleaned and cut in to small pieces. 300 mg of leaf sample was taken and immersed in stoppered test tubes containing 10 mL of pure dimethyl sulphoxide (DMSO). The test tubes containing sample + DMSO were kept in a hot air oven maintained at 60-65⁰ C for 3 hours. The optical densities of the supernatant liquid were taken at 480, 510, 645, 652 and 663 nm separately using Systronics Spectrophotometer (Model 105). The total chlorophyll, chlorophyll a, chlorophyll b and carotenoids were calculated by using the following formulae (Arnon, 1949).

$$\text{Chlorophyll a (mg g}^{-1}\text{)} = 12.7 (\text{D.663}) - 2.69 (\text{D.645}) \times \frac{V}{1000 \times W}$$

$$\text{Chlorophyll b (mg g}^{-1}\text{)} = 22.9 (\text{D. 645}) - 4.68 (\text{D. 663}) \times \frac{V}{1000 \times W}$$

$$\text{Carotenoids (mg g}^{-1}\text{)} = 7.6 (\text{D.480}) - 1.49 (\text{D.510}) \times \frac{V}{1000 \times W}$$

$$\text{Total chlorophyll (mg g}^{-1}\text{)} = \frac{\text{D. 652} \times 1000}{34.5} \times \frac{V}{1000 \times W}$$

Where,

D = Optical density

V = Final volume of DMSO

W = Fresh weight of sample taken

2. Estimation of superoxide dismutase (SOD) activity in leaves

Superoxide dismutase (SOD, EC 1.15.1.1) was assayed following the method as described by Dhindsa *et al.* (1981).

- Reagents :
- i. 1.50M Sodium carbonate (Na_2CO_3)
 - ii. 200 mM Methionine solution
 - iii. 2.25 mM Nitro blue tetrazolium solution (NBT)
 - iv. 3 mM Sodium- EDTA solution
 - v. 60 mM Riboflavin solution

Preparation of phosphate buffer (0.5 M; pH 7.5)

0.5M solution of monobasic potassium phosphate (K_2HPO_4) and dibasic potassium phosphate (KH_2PO_4) were prepared as follows.

Solution 'a' (K_2HPO_4): 3.4023g of salt was dissolved in distilled water and volume is made up to 50ml.

Solution 'b' (KH_2PO_4): 8.709g of salt was dissolved in distilled water and volume is made up to 100ml.

Now, the desired buffer solution is prepared by mixing 16ml of solution 'a' and 84 ml of solution 'b'. The pH of the buffer is adjusted by adding either of the solution using a pH meter. This solution is used for the extraction of enzyme from the plant material.

Extraction of enzyme

0.2g of fresh and cleaned leaf sample was homogenized in 10ml of 0.5M phosphate buffer containing 1% NEDD (1-naphthyl ethylenediamine dihydrochloride). The homogenate was then centrifuged at 4°C for 30min at 10,000 rpm. After centrifugation, the supernatant was stored for the enzyme assay and the pellet was discarded. SOD activity in the supernatant was assayed by measuring its ability to inhibit the photochemical reduction of NBT.

Enzyme assay

1.5ml buffer, 0.1ml of enzyme extract, 0.1ml of sodium carbonate, 0.1ml of NBT solution, 0.2ml of methionine solution, 0.1ml of EDTA solution and 1ml of double distilled water were taken in test tubes. 0.1ml of riboflavin solution is added just before illumination of reaction mixture. Blank 'A' with enzyme should be kept in dark where as blank 'B' without enzyme should be placed with sample test tubes 30 cm below a light source of two 15 watt inflorescence lamps for 10 min. reaction is stopped by switching off the light and tubes are covered with black cloth. The non-irradiated reaction mixture containing enzyme extract did not develop light blue color. Absorbance of samples along with blank 'B' is measured at 560 nm against the blank 'A'. Then the difference of per cent reduction in the color between blank 'B' and the sample is worked out.

50% reduction in the color is considered as one unit of enzyme activity and the activity is expressed in units of the enzyme per mg protein per hour.

% reduction in color between blank and

$$\text{SOD activity (unit mg}^{-1}\text{ protein h}^{-1}\text{)} = \frac{\text{Sample x dilution factor x 60}}{50 \times \text{incubation time x mg protein in sample}}$$

3.8 Yield Components and Yield

The observations pertaining to yield components and yield were taken at the time of harvest.

3.8.1 Number of pods per plant

The number of pods from the five plants tagged were counted and the average was expressed as number of pods plant⁻¹.

3.8.2 Number of seeds per pod

The number of seeds per pod was counted for the pods collected from five tagged plants and the mean value calculated.

3.8.3 100 seed weight (g)

A hand full of seeds were drawn at random from each treatment in three replications and weighed. Number of seeds constituting the sample was counted and from these values 100 seed weight was computed.

3.8.4 Seed yield (kg ha⁻¹)

Harvested plants were kept in the field for drying. After drying the pods, total pods from a plot were threshed and the resulted seed yield was calculated for a net plot area and it was computed to hectare and expressed as kg ha⁻¹.

3.9. OBSERVATIONS ON WEEDS

3.9.1 Weed density

The weeds were counted at 30 and 60 DAS in each plot from four randomly selected quadrants of 0.25 m² size. The total weed density was arrived by adding all the weed groups. Weed count was expressed as number m⁻². The data was subjected to square root transformation $\sqrt{X + 0.5}$ to normalize their distribution (Gomez and Gomez, 1984).

3.9.2 Weed dry weight

All the weeds present in the quadrant of 0.25 m² were collected from each plot at 30 and 60 DAS. The samples were shade dried initially followed by oven drying at 60 °C till a constant weight was obtained and weighed. Then the dry weight was computed in terms of g m⁻².

3.9.3 Weed control efficiency

Based on the weed drymatter recorded at 30 and 60 DAS weed control efficiency (WCE) was calculated using the following formula and expressed in per centage (AICRPWC, 1988).

$$\text{WCE (\%)} = \frac{DWC - DWT}{DWC} \times 100$$

Where,

WCE = Weed control efficiency

DWC = Dry weight of weeds in unweeded control plot

DWT = Dry weight of weeds in treated plot.

3.10 ECONOMICS

The economics of different treatments were calculated by considering the input costs and output prices prevailing at the time of the harvest.

$$\begin{aligned} \text{Gross returns} &= \text{value of the product in rupees} \\ &= \text{Yield in kg ha}^{-1} \times \text{Price per kg (Rs)} \end{aligned}$$

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

$$\text{Benefit cost ration (B:C)} = \frac{\text{Net returns}}{\text{Total cost of cultivation}}$$

3.11 STATISTICAL ANALYSIS

The data were analyzed statistically following analysis of variance (ANOVA) technique suggested by Panse and Sukhatme (1978) for randomized block design. The statistical hypothesis of equalities of treatment means was tested by F-test in ANOVA at 5 per cent level of significance. Critical difference was correlated at 5 per cent level of significance to compare different treatment means.

Table 3.4. Qualitative description of treatment effects on weeds and crop in the visuals cropping scale of 0 to 10

EFFECT	RATING	WEED	CROP DESCRIPTION
None	0	No control	No injury, normal
Slight	1	Very poor control	Slight stunting, injury or discoloration
	2	Poor control	Some stand loss, stunting or discoloration
	3	Poor to deficient control	Injury more pronounced but not persistent
Tolerate	4	Deficient control	Moderate injury, recovery possible
	5	Deficient to moderate control	Injury more persistent, recovery doubtful
	6	Moderate control	Near severe injury ,no recovery possible
Severe	7	Satisfactory control	Severe injury, stand loss
	8	Good control	Almost destroyed , a few plants surviving
Complete	9	Good to excellent control	Very few plants alive
	10	Complete control	Complete destruction

Table 3.3 Details of herbicides used in the experiment with their mode of action

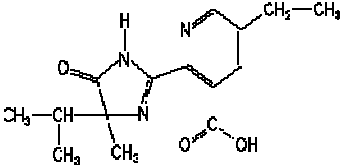
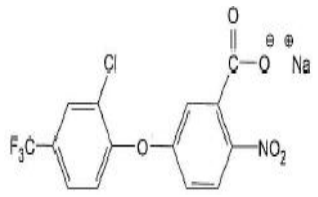
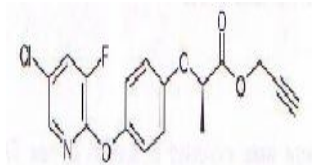
Particulars	Imazethapyr	Acifluofen sodium	Clodinafop propargyl
Trade name	Pursuit	Blazer	Topik-15
Chemical name	2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-5-ethyl-3-pyridinecarboxylic acid	[2-chloro-4-(trifluoromethyl)phenoxy]-2-nitrobenzoic acid	prop-2-ynyl (2R)-2-[4-(5-chloro-3-fluoropyridin-2-yl)oxyphenoxy]propanoate
Chemical family	Imidazolinones	Diphenylether	Aryloxyphenoxy-propionate 'FOPs'
Mode of action	Inhibition of acetolactate synthase	Inhibition of protoporphyrinogen oxidase (PPO)	Inhibition of acetyl CoA carboxylase (ACCase)
Molecular structure			

Table 4.1. Effect of post emergence herbicides on crop injury/ phytotoxicity of blackgram

TREATMENTS	% crop injury				
	20 DAS	25 DAS	30 DAS	35 DAS	40 DAS
T ₁ Imazethapyr 10% EC @ 50g a.i ha ⁻¹ at 15 DAS	10	10	0	0	0
T ₂ Imazethapyr 10% EC @ 50g a.i ha ⁻¹ at 25 DAS	0	0	10	10	0
T ₃ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@180g a.i ha ⁻¹ at 15DAS	0	0	0	0	0
T ₄ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@180 g a.i ha ⁻¹ at 25DAS	0	0	0	0	0
T ₅ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@240g a.i ha ⁻¹ at 15DAS	20	0	0	0	0
T ₆ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC(24%EC)@240g a.i ha ⁻¹ at 25DAS	0	0	20	0	0
T ₇ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@300g a.i ha ⁻¹ at 15DAS	30	0	0	0	0
T ₈ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC(24%EC)@300g a.i ha ⁻¹ at 25DAS	0	0	40	10	10
T ₉ Weed free check (Hand weeding at 15and 30 DAS)	--	--	--	--	0
T ₁₀ Un weeded control	--	--	--	--	0

0 : No injury

-- : No herbicide treatment

10% : Slight stunting and yellowing of leaves

20% : Some stand loss, stunting or discoloration

30%: injury more pronounced but not persistent

40%: Moderate injury, recovery possible

Table 4.2. Effect of post emergence herbicides on density of weeds (no. of plant m⁻²) of blackgram

TREATMENTS	Weed density (no. of plant m ⁻²)			
	30 DAS		60 DAS	
	MONOCOTS	DICOTS	MONOCOTS	DICOTS
T ₁ Imazethapyr 10% EC @ 50g a.i ha ⁻¹ at 15 DAS	42.1	20.8	77.5	52.2
T ₂ Imazethapyr 10% EC @ 50g a.i ha ⁻¹ at 25 DAS	46.8	41.3	90.5	68.4
T ₃ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@180g a.i ha ⁻¹ at 15DAS	42.4	30.2	87.2	50.7
T ₄ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@180 g a.i ha ⁻¹ at 25DAS	43.9	20.1	87.5	61.3
T ₅ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@240g a.i ha ⁻¹ at 15DAS	35.3	15.2	52.1	28.8
T ₆ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC(24%EC)@240g a.i ha ⁻¹ at 25DAS	40.3	32.3	62.1	38.2
T ₇ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@300g a.i ha ⁻¹ at 15DAS	28.1	11.2	48.1	28.2
T ₈ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC(24%EC)@300g a.i ha ⁻¹ at 25DAS	45.8	22.3	82.1	48.2
T ₉ Weed free check (Hand weeding at 15and 30 DAS)	0.0	0.0	20.1	9.3
T ₁₀ Un weeded control	66.9	130.5	92.5	176.3
SEm _±	3.0	2.0	4.4	3.7
CD	8.8	5.8	10.2	10.8
CV (%)	13.4	10.4	11.1	11.4

Table 4.3. Effect of post emergence herbicides on dry weight of weeds (g m⁻²) of blackgram

TREATMENTS	Weed dry weight(g m ⁻²)			
	30 DAS		60 DAS	
	MONOCOTS	DICOTS	MONOCOTS	DICOTS
T ₁ Imazethapyr 10% EC @ 50g a.i ha ⁻¹ at 15 DAS	13.87	16.56	24.37	18.73
T ₂ Imazethapyr 10% EC @ 50g a.i ha ⁻¹ at 25 DAS	16.81	20.32	27.68	23.18
T ₃ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@180g a.i ha ⁻¹ at 15DAS	14.61	18.76	25.16	18.87
T ₄ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@180 g a.i ha ⁻¹ at 25DAS	14.62	19.96	25.32	19.13
T ₅ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@240g a.i ha ⁻¹ at 15DAS	12.20	10.54	16.12	11.76
T ₆ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC(24%EC)@240g a.i ha ⁻¹ at 25DAS	13.17	15.74	24.35	18.21
T ₇ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@300g a.i ha ⁻¹ at 15DAS	8.69	9.37	14.78	10.78
T ₈ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC(24%EC)@300g a.i ha ⁻¹ at 25DAS	15.73	20.26	25.53	19.28
T ₉ Weed free check (Hand weeding at 15and 30 DAS)	0.00	0.00	8.48	6.35
T ₁₀ Un weeded control	20.82	36.78	38.26	48.78
SEm _±	0.915	1.014	1.826	1.217
CD	4.820	5.75	9.425	7.149
CV (%)	11.9	12.6	14.4	12.0

Table 4.4. Effect of post emergence herbicides on weed control efficiency of blackgram

TREATMENTS	Weed control efficiency (%)	
	30DAS	60 DAS
T ₁ Imazethapyr 10% EC @ 50g a.i ha ⁻¹ at 15 DAS	47.17	50.48
T ₂ Imazethapyr 10% EC @ 50g a.i ha ⁻¹ at 25 DAS	35.53	41.56
T ₃ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@180g a.i ha ⁻¹ at 15DAS	42.06	49.41
T ₄ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@180 g a.i ha ⁻¹ at 25DAS	39.96	48.93
T ₅ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@240g a.i ha ⁻¹ at 15DAS	60.52	67.96
T ₆ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@240g a.i ha ⁻¹ at 25DAS	49.80	51.10
T ₇ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@300g a.i ha ⁻¹ at 15DAS	68.64	70.63
T ₈ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@300g a.i ha ⁻¹ at 25DAS	34.51	48.51
T ₉ Weed free check (Hand weeding at 15and 30 DAS)	100	82.96
T ₁₀ Un weeded control	0	0
SEm _±	2.98	1.72
CD	9.02	5.20
CV (%)	8.90	7.80

Table 4.5. Effect of post emergence herbicides on plant height (cm) of blackgram

TREATMENTS	Plant height (cm)				
	15 DAS	30 DAS	45 DAS	60 DAS	At Harvest
T ₁ Imazethapyr 10% EC @ 50g a.i ha ⁻¹ at 15 DAS	18.52	23.56	31.16	38.19	43.12
T ₂ Imazethapyr 10% EC @ 50g a.i ha ⁻¹ at 25 DAS	19.93	21.12	25.42	31.14	35.21
T ₃ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@180g a.i ha ⁻¹ at 15DAS	18.80	23.32	31.08	31.98	37.23
T ₄ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@180 g a.i ha ⁻¹ at 25DAS	19.67	22.65	30.27	31.34	36.41
T ₅ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@240g a.i ha ⁻¹ at 15DAS	18.87	27.80	35.32	38.31	43.81
T ₆ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC(24%EC)@240g a.i ha ⁻¹ at 25DAS	18.68	23.82	31.28	32.84	37.96
T ₇ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@300g a.i ha ⁻¹ at 15DAS	19.68	28.40	35.72	39.01	44.01
T ₈ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC(24%EC)@300g a.i ha ⁻¹ at 25DAS	20.47	22.18	30.20	31.18	35.59
T ₉ Weed free check (Hand weeding at 15and 30 DAS)	19.32	29.72	36.90	39.21	44.20
T ₁₀ Un weeded control	19.64	18.71	25.40	26.18	28.23
SEm _±	0.977	2.045	1.594	2.071	1.838
CD	NS	4.076	5.736	5.254	5.462
CV (%)	8.7	13.8	9.3	10.9	8.3

Table 4.6. Effect of post emergence herbicides on number of branches of blackgram

TREATMENTS	Number of branches			
	30 DAS	45 DAS	60 DAS	AT HARVEST
T ₁ Imazethapyr 10% EC @ 50g a.i ha ⁻¹ at 15 DAS	3.51	4.92	6.51	7.68
T ₂ Imazethapyr 10% EC @ 50g a.i ha ⁻¹ at 25 DAS	2.98	4.68	5.98	6.88
T ₃ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@180g a.i ha ⁻¹ at 15DAS	3.47	4.87	6.32	7.05
T ₄ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@180 g a.i ha ⁻¹ at 25DAS	3.26	4.83	6.31	6.98
T ₅ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@240g a.i ha ⁻¹ at 15DAS	3.64	5.56	6.98	7.83
T ₆ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC(24%EC)@240g a.i ha ⁻¹ at 25DAS	3.55	4.96	6.54	6.94
T ₇ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@300g a.i ha ⁻¹ at 15DAS	3.66	5.63	6.99	7.94
T ₈ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC(24%EC)@300g a.i ha ⁻¹ at 25DAS	2.98	4.77	6.23	6.94
T ₉ Weed free check (Hand weeding at 15and 30 DAS)	3.66	5.65	7.01	7.94
T ₁₀ Un weeded control	2.26	3.23	4.02	5.32
SEm _±	0.03	0.180	0.165	0.149
CD	0.08	0.535	0.490	0.444
CV (%)	1.23	0.064	0.047	0.042

Table 4.7. Effect of post emergence herbicides on leaf area (cm² plant⁻¹) of blackgram

TREATMENTS	Leaf area (cm ² plant ⁻¹)				
	15 DAS	30 DAS	45 DAS	60 DAS	At Harvest
T ₁ Imazethapyr 10% EC @ 50g a.i ha ⁻¹ at 15 DAS	55.06	162.26	378.13	450.76	219.46
T ₂ Imazethapyr 10% EC @ 50g a.i ha ⁻¹ at 25 DAS	57.18	153.18	303.71	356.56	191.66
T ₃ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@180g a.i ha ⁻¹ at 15DAS	55.23	161.14	370.23	438.16	209.66
T ₄ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@180 g a.i ha ⁻¹ at 25DAS	53.33	153.66	368.66	423.52	204.37
T ₅ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@240g a.i ha ⁻¹ at 15DAS	53.33	169.18	430.26	526.18	242.15
T ₆ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC(24%EC)@240g a.i ha ⁻¹ at 25DAS	65.23	162.56	382.73	460.53	223.93
T ₇ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@300g a.i ha ⁻¹ at 15DAS	61.91	170.93	439.35	530.03	245.28
T ₈ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC(24%EC)@300g a.i ha ⁻¹ at 25DAS	62.00	153.48	340.03	395.86	207.63
T ₉ Weed free check (Hand weeding at 15and 30 DAS)	59.76	176.21	439.35	530.03	246.13
T ₁₀ Un weeded control	60.96	103.36	263.24	323.56	136.76
SEm _±	2.316	2.986	3.85	3.01	2.68
CD	NS	8.45	10.28	9.18	7.82
CV (%)	7.2	15.4	17.5	15.8	13.4

Table 4.8. Effect of post emergence herbicides on leaf dry matter (g plant⁻¹) of blackgram

TREATMENTS	Leaf dry matter (g plant ⁻¹)				
	15 DAS	30 DAS	45 DAS	60 DAS	At Harvest
T ₁ Imazethapyr 10% EC @ 50g a.i ha ⁻¹ at 15 DAS	0.30	2.31	3.20	6.43	5.09
T ₂ Imazethapyr 10% EC @ 50g a.i ha ⁻¹ at 25 DAS	0.30	1.65	2.75	5.97	4.99
T ₃ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@180g a.i ha ⁻¹ at 15DAS	0.27	2.02	3.38	6.41	4.81
T ₄ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@180 g a.i ha ⁻¹ at 25DAS	0.26	2.01	2.88	6.09	4.74
T ₅ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@240g a.i ha ⁻¹ at 15DAS	0.28	2.62	4.01	7.09	5.61
T ₆ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC(24%EC)@240g a.i ha ⁻¹ at 25DAS	0.27	2.39	3.23	6.90	4.68
T ₇ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@300g a.i ha ⁻¹ at 15DAS	0.30	2.67	4.24	7.12	5.87
T ₈ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC(24%EC)@300g a.i ha ⁻¹ at 25DAS	0.27	1.98	2.67	5.87	4.10
T ₉ Weed free check (Hand weeding at 15and 30 DAS)	0.26	3.03	4.18	7.12	5.90
T ₁₀ Un weeded control	0.27	1.92	2.33	5.37	4.01
SEm _±	0.010	0.153	0.200	0.370	0.299
CD	NS	0.454	0.595	1.098	0.889
CV (%)	6.3	12.5	11.1	10.1	10.8

Table 4.9. Effect of post emergence herbicides on stem dry matter (g plant⁻¹) of blackgram

TREATMENTS	Stem dry matter (g plant ⁻¹)				
	15 DAS	30 DAS	45 DAS	60 DAS	At Harvest
T ₁ Imazethapyr 10% EC @ 50g a.i ha ⁻¹ at 15 DAS	0.12	0.60	2.04	4.02	5.84
T ₂ Imazethapyr 10% EC @ 50g a.i ha ⁻¹ at 25 DAS	0.12	0.65	1.83	3.56	5.41
T ₃ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@180g a.i ha ⁻¹ at 15DAS	0.15	0.61	1.97	3.23	6.09
T ₄ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@180 g a.i ha ⁻¹ at 25DAS	0.15	0.60	2.31	3.16	6.05
T ₅ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@240g a.i ha ⁻¹ at 15DAS	0.15	0.89	2.40	4.52	6.94
T ₆ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC(24%EC)@240g a.i ha ⁻¹ at 25DAS	0.14	0.62	2.37	3.06	6.26
T ₇ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@300g a.i ha ⁻¹ at 15DAS	0.14	0.89	2.52	4.18	7.05
T ₈ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC(24%EC)@300g a.i ha ⁻¹ at 25DAS	0.13	0.61	1.72	3.74	5.90
T ₉ Weed free check (Hand weeding at 15and 30 DAS)	0.14	0.99	2.48	4.18	7.18
T ₁₀ Un weeded control	0.14	0.59	1.68	2.98	4.08
SEm _±	0.009	0.027	0.089	0.294	0.277
CD	NS	0.080	0.265	0.875	0.824
CV (%)	11.0	7.2	10.7	14.4	8.1

Table 4.10. Effect of post emergence herbicides on reproductive parts dry matter (g plant⁻¹) of blackgram

TREATMENTS	Reproductive parts dry Matter (g plant ⁻¹)		
	45 DAS	60 DAS	At Harvest
T ₁ Imazethapyr 10% EC @ 50g a.i ha ⁻¹ at 15 DAS	2.46	3.21	4.62
T ₂ Imazethapyr 10% EC @ 50g a.i ha ⁻¹ at 25 DAS	2.40	3.24	4.24
T ₃ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@180g a.i ha ⁻¹ at 15DAS	2.41	3.17	4.38
T ₄ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@180 g a.i ha ⁻¹ at 25DAS	2.27	3.21	4.03
T ₅ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@240g a.i ha ⁻¹ at 15DAS	3.15	3.85	4.98
T ₆ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC(24%EC)@240g a.i ha ⁻¹ at 25DAS	2.53	3.59	4.28
T ₇ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@300g a.i ha ⁻¹ at 15DAS	3.44	3.87	5.04
T ₈ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC(24%EC)@300g a.i ha ⁻¹ at 25DAS	2.42	3.42	4.38
T ₉ Weed free check (Hand weeding at 15and 30 DAS)	3.56	3.90	5.08
T ₁₀ Un weeded control	2.27	3.12	3.56
SEm±	0.037	0.080	0.212
CD	0.118	0.240	0.629
CV (%)	6.8	12.2	8.4

Table 4.11. Effect of post emergence herbicides on total dry matter (g plant⁻¹) of blackgram

TREATMENTS	Total dry matter (g plant ⁻¹)				
	15 DAS	30 DAS	45 DAS	60 DAS	At Harvest
T ₁ Imazethapyr 10% EC @ 50g a.i ha ⁻¹ at 15 DAS	0.42	2.91	7.70	13.66	15.55
T ₂ Imazethapyr 10% EC @ 50g a.i ha ⁻¹ at 25 DAS	0.41	2.30	6.98	12.77	14.64
T ₃ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@180g a.i ha ⁻¹ at 15DAS	0.40	2.63	7.76	12.81	15.28
T ₄ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@180 g a.i ha ⁻¹ at 25DAS	0.40	2.61	7.46	12.46	14.82
T ₅ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@240g a.i ha ⁻¹ at 15DAS	0.43	3.51	9.56	15.46	17.53
T ₆ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC(24%EC)@240g a.i ha ⁻¹ at 25DAS	0.41	3.01	8.13	13.55	15.22
T ₇ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@300g a.i ha ⁻¹ at 15DAS	0.43	3.56	10.20	15.17	17.96
T ₈ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC(24%EC)@300g a.i ha ⁻¹ at 25DAS	0.40	2.59	6.81	13.03	14.38
T ₉ Weed free check (Hand weeding at 15and 30 DAS)	0.40	4.02	10.22	15.20	18.16
T ₁₀ Un weeded control	0.41	2.51	6.28	11.47	11.65
SEm _±	0.021	0.179	0.396	0.560	0.769
CD	NS	0.531	1.176	1.663	2.286
CV (%)	9.0	10.9	9.8	7.8	8.8

Table 4.12. Effect of post emergence herbicides on chlorophyll 'a' content (mg g⁻¹) of blackgram leaves

TREATMENTS	Chlorophyll 'a' (mg g ⁻¹)					
	15DAS	20DAS (5 DAHA)	25DAS (10 DAHA)	30DAS (15 DAHA)	35DAS (20 DAHA)	40DAS (25 DAHA)
T ₁ Imazethapyr 10% EC @ 50g a.i ha ⁻¹ at 15 DAS	0.498	0.610	0.708	0.785	0.831	0.862
T ₂ Imazethapyr 10% EC @ 50g a.i ha ⁻¹ at 25 DAS	0.475	0.634	0.680	0.656	0.731	0.779
T ₃ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@180g a.i ha ⁻¹ at 15DAS	0.493	0.618	0.706	0.782	0.824	0.858
T ₄ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@180 g a.i ha ⁻¹ at 25DAS	0.498	0.631	0.675	0.654	0.735	0.793
T ₅ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@240g a.i ha ⁻¹ at 15DAS	0.491	0.613	0.731	0.820	0.852	0.882
T ₆ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC(24%EC)@240g a.i ha ⁻¹ at 25DAS	0.481	0.628	0.678	0.646	0.729	0.771
T ₇ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@300g a.i ha ⁻¹ at 15DAS	0.496	0.610	0.745	0.828	0.857	0.887
T ₈ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC(24%EC)@300g a.i ha ⁻¹ at 25DAS	0.497	0.635	0.682	0.652	0.742	0.782
T ₉ Weed free check (Hand weeding at 15and 30 DAS)	0.491	0.678	0.755	0.831	0.864	0.894
T ₁₀ Un weeded control	0.497	0.639	0.680	0.713	0.728	0.758
SEm _±	0.014	0.004	0.005	0.015	0.012	0.030
CD	NS	0.013	0.016	0.045	0.035	0.010
CV (%)	4.9	1.2	1.3	3.3	2.4	5.8

Table 4.13. Effect of post emergence herbicides on chlorophyll 'b' content (mg g⁻¹) of blackgram leaves

TREATMENTS	Chlorophyll 'b' (mg g ⁻¹)					
	15DAS	20DAS (5DAHA)	25DAS (10DAHA)	30DAS (15DAHA)	35DAS (20DAHA)	40DAS (25DAHA)
T ₁ Imazethapyr 10% EC @ 50g a.i ha ⁻¹ at 15 DAS	0.396	0.556	0.675	0.712	0.725	0.732
T ₂ Imazethapyr 10% EC @ 50g a.i ha ⁻¹ at 25 DAS	0.389	0.624	0.628	0.625	0.672	0.689
T ₃ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@180g a.i ha ⁻¹ at 15DAS	0.403	0.548	0.685	0.724	0.732	0.740
T ₄ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@180 g a.i ha ⁻¹ at 25DAS	0.397	0.635	0.631	0.631	0.689	0.692
T ₅ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@240g a.i ha ⁻¹ at 15DAS	0.398	0.560	0.711	0.789	0.825	0.830
T ₆ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC(24%EC)@240g a.i ha ⁻¹ at 25DAS	0.401	0.631	0.629	0.624	0.701	0.712
T ₇ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@300g a.i ha ⁻¹ at 15DAS	0.386	0.554	0.721	0.795	0.820	0.829
T ₈ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC(24%EC)@300g a.i ha ⁻¹ at 25DAS	0.398	0.625	0.634	0.601	0.676	0.682
T ₉ Weed free check (Hand weeding at 15and 30 DAS)	0.399	0.692	0.724	0.801	0.824	0.836
T ₁₀ Un weeded control	0.398	0.620	0.632	0.658	0.665	0.685
SEm _±	0.004	0.011	0.033	0.014	0.022	0.015
CD	NS	0.031	0.097	0.040	0.065	0.044
CV (%)	1.6	3.0	4.3	4.6	5.5	4.1

Table 4.15. Effect of post emergence herbicides on carotenoids content (mg g⁻¹) of blackgram leaves

TREATMENTS	Carotenoids (mg g ⁻¹)					
	15DAS	20DAS (5 DAHA)	25DAS (10 DAHA)	30DAS (15 DAHA)	35DAS (20 DAHA)	40DAS (25 DAHA)
T ₁ Imazethapyr 10% EC @ 50g a.i ha ⁻¹ at 15 DAS	0.068	0.321	0.456	0.462	0.475	0.477
T ₂ Imazethapyr 10% EC @ 50g a.i ha ⁻¹ at 25 DAS	0.063	0.363	0.428	0.408	0.439	0.441
T ₃ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@180g a.i ha ⁻¹ at 15DAS	0.066	0.318	0.451	0.468	0.472	0.476
T ₄ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@180 g a.i ha ⁻¹ at 25DAS	0.066	0.358	0.426	0.396	0.431	0.456
T ₅ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@240g a.i ha ⁻¹ at 15DAS	0.064	0.326	0.467	0.472	0.480	0.485
T ₆ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC(24%EC)@240g a.i ha ⁻¹ at 25DAS	0.066	0.361	0.422	0.398	0.434	0.450
T ₇ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@300g a.i ha ⁻¹ at 15DAS	0.066	0.324	0.469	0.480	0.483	0.488
T ₈ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC(24%EC)@300g a.i ha ⁻¹ at 25DAS	0.066	0.355	0.419	0.381	0.412	0.448
T ₉ Weed free check (Hand weeding at 15and 30 DAS)	0.063	0.411	0.471	0.485	0.487	0.492
T ₁₀ Un weeded control	0.065	0.360	0.420	0.434	0.440	0.446
SEm _±	0.001	0.006	0.004	0.004	0.009	0.002
CD	NS	0.018	0.013	0.013	0.027	0.007
CV (%)	3.5	1.6	1.8	1.8	3.5	1.0

Table 4.14 Effect of post emergence herbicides on total chlorophyll content (mg g⁻¹) of blackgram leaves

TREATMENTS	Total Chlorophyll (mg g ⁻¹)					
	15DAS	20DAS (5DAHA)	25DAS (10DAHA)	30DAS (15DAHA)	35DAS (20DAHA)	40DAS (25DAHA)
T ₁ Imazethapyr 10% EC @ 50g a.i ha ⁻¹ at 15 DAS	1.030	1.272	1.579	1.636	1.813	1.892
T ₂ Imazethapyr 10% EC @ 50g a.i ha ⁻¹ at 25 DAS	1.026	1.392	1.501	1.445	1.601	1.698
T ₃ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@180g a.i ha ⁻¹ at 15DAS	1.010	1.312	1.578	1.624	1.802	1.887
T ₄ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@180 g a.i ha ⁻¹ at 25DAS	1.034	1.382	1.492	1.431	1.598	1.732
T ₅ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@240g a.i ha ⁻¹ at 15DAS	0.996	1.294	1.582	1.899	1.934	2.052
T ₆ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC(24%EC)@240g a.i ha ⁻¹ at 25DAS	0.996	1.404	1.504	1.456	1.613	1.741
T ₇ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@300g a.i ha ⁻¹ at 15DAS	0.996	1.278	1.585	1.924	1.978	2.076
T ₈ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC(24%EC)@300g a.i ha ⁻¹ at 25DAS	0.986	1.389	1.498	1.436	1.623	1.724
T ₉ Weed free check (Hand weeding at 15and 30 DAS)	0.978	1.557	1.626	1.937	1.969	2.166
T ₁₀ Un weeded control	0.968	1.401	1.502	1.539	1.542	1.613
SEm _±	0.014	0.012	0.025	0.023	0.041	0.050
CD	NS	0.035	0.074	0.069	0.122	0.149
CV (%)	2.5	1.47	3.6	2.5	4.9	4.6

Table 4.16. Effect of post emergence herbicides on superoxide dismutase (SOD) (unit mg⁻¹ protein h⁻¹) of blackgram leaves

TREATMENTS	SOD (unit mg ⁻¹ protein h ⁻¹)					
	15DAS	20DAS (5DAHA)	25DAS (10DAHA)	30DAS (15DAHA)	35DAS (20DAHA)	40DAS (25DAHA)
T ₁ Imazethapyr 10% EC @ 50g a.i ha ⁻¹ at 15 DAS	16.70	26.42	24.16	27.19	36.12	35.12
T ₂ Imazethapyr 10% EC @ 50g a.i ha ⁻¹ at 25 DAS	18.30	23.32	28.10	37.18	44.18	42.14
T ₃ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@180g a.i ha ⁻¹ at 15DAS	17.20	26.58	25.10	28.01	35.13	34.13
T ₄ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@180 g a.i ha ⁻¹ at 25DAS	17.70	22.98	27.82	38.28	46.28	41.14
T ₅ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@240g a.i ha ⁻¹ at 15DAS	16.90	27.90	23.25	25.98	31.56	30.12
T ₆ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC(24%EC)@240g a.i ha ⁻¹ at 25DAS	17.80	23.18	28.10	40.76	44.56	40.18
T ₇ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@300g a.i ha ⁻¹ at 15DAS	16.80	28.61	23.14	26.01	31.98	30.01
T ₈ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC(24%EC)@300g a.i ha ⁻¹ at 25DAS	17.20	23.24	27.96	44.16	45.28	41.12
T ₉ Weed free check (Hand weeding at 15and 30 DAS)	17.50	19.26	22.13	25.32	32.30	30.13
T ₁₀ Un weeded control	0.065	23.48	28.12	32.10	46.24	43.26
SEm _±	0.168	0.365	0.730	0.843	0.365	0.365
CD	NS	1.085	2.19	2.505	1.085	1.085
CV (%)	5.0	2.7	4.4	4.2	1.5	2.3

Table 4.17. Effect of post emergence herbicides on yield components and yield of blackgram

TREATMENTS	No. of pods plant ⁻¹	No. of seeds Pod ⁻¹	Pod weight (g plant ⁻¹)	100 Seed weight (g)	Seed yield (kg ha ⁻¹)
T ₁ Imazethapyr 10% EC @ 50g a.i ha ⁻¹ at 15 DAS	23.4	3.4	15.55	3.81	740.74
T ₂ Imazethapyr 10% EC @ 50g a.i ha ⁻¹ at 25 DAS	19.2	3.5	14.64	3.95	768.25
T ₃ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@180g a.i ha ⁻¹ at 15DAS	25.6	4.2	15.28	4.34	771.60
T ₄ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@180 g a.i ha ⁻¹ at 25DAS	18.7	4.4	14.82	4.23	632.09
T ₅ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@240g a.i ha ⁻¹ at 15DAS	27.8	4.8	17.53	4.51	987.60
T ₆ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC(24%EC)@240g a.i ha ⁻¹ at 25DAS	24.6	4.3	15.22	4.18	925.90
T ₇ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@300g a.i ha ⁻¹ at 15DAS	28.9	4.9	17.96	4.92	1001.60
T ₈ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC(24%EC)@300g a.i ha ⁻¹ at 25DAS	23.4	4.1	14.38	4.53	655.50
T ₉ Weed free check (Hand weeding at 15and 30 DAS)	30.2	5.2	18.16	4.92	1050.20
T ₁₀ Un weeded control	18.2	3.0	11.65	3.59	591.23
SEm±	0.5	0.04	0.769	0.02	41.13
CD	1.5	0.12	2.286	0.06	123.4
CV (%)	2.8	2.05	8.8	1.01	11.6

Table 4.18. Economics of blackgram as influenced by different post emergence herbicides

TREATMENTS	Cost of cultivation (Rs ha ⁻¹)	Gross returns (Rs ha ⁻¹)	Net returns (Rs ha ⁻¹)	B:C Ratio
T ₁ Imazethapyr 10% EC @ 50g a.i ha ⁻¹ at 15 DAS	14477	29630	15153	1.04
T ₂ Imazethapyr 10% EC @ 50g a.i ha ⁻¹ at 25 DAS	14477	30730	16253	1.12
T ₃ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@180g a.i ha ⁻¹ at 15DAS	14837	30864	16027	1.08
T ₄ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@180 g a.i ha ⁻¹ at 25DAS	14837	25284	10447	0.70
T ₅ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@240g a.i ha ⁻¹ at 15DAS	15237	39501	24267	1.59
T ₆ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC(24%EC)@240g a.i ha ⁻¹ at 25DAS	15237	37036	21799	1.43
T ₇ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC (24%EC)@300g a.i ha ⁻¹ at 15DAS	15637	40064	24427	1.56
T ₈ Acifluorfen Sodium 16%EC + Clodinafop propargyl 8%EC(24%EC)@300g a.i ha ⁻¹ at 25DAS	15637	26220	10583	0.68
T ₉ Weed free check (Hand weeding at 15and 30 DAS)	17687	42008	24321	1.37
T ₁₀ Un weeded control	13637	23650	10012	0.73



Plate 1 General view of the experimental field

Chapter IV

RESULTS AND DISCUSSION

A field experiment was conducted during *kharif*, 2015 at Agricultural College Farm, Bapatla to study the “Effect of post emergence herbicides on growth, physiological parameters, phytotoxicity and yield of blackgram”. The means of observations recorded at successive stages of blackgram crop were presented in Tables. For the more clear expression of data, some of the parameters were figuratively/ diagrammatically represented. The results of the present investigation on blackgram influenced by different concentrations of post emergence herbicides applied are discussed in the following pages with reference to the data and the available authentic literature.

4.1 EFFECT ON CROP (PHYTOTOXICITY)

The results pertaining to phytotoxicity scoring (Table 4.1) ranged from no visible injury to slight stunting injury or crop yellowing i.e. discoloration, but no plants died from the herbicide treatments.

At 5 and 10 days after herbicide application (DAHA), imazethapyr 10% EC @ 50g a.i ha⁻¹ at 15DAS caused crop injury to the extent of 10 per cent resulting in slight stunting and yellowing/ discoloration of developing leaves without loss of crop stand. However, these symptoms were slowly recovered by 30 DAS (i.e. 15 DAHA).

Post emergence application of imazethapyr 10% EC @ 50g a.i ha⁻¹ at 25DAS caused crop injury to the extent of 10 per cent at 5 and 10 DAHA, the effect was negligible and at 15 DAHA, the blackgram plants recovered from phytotoxicity and the symptoms vanished by 40 DAS.

Naidu *et al.* (2012) reported that imazethapyr @ 150g a.i ha⁻¹ on blackgram caused crop injury to the extent of 40 per cent resulted in moderate stunted growth of seedlings and discoloration of developing leaves with partial

loss of crop stand, where as imazethapyr @ 200g a.i ha⁻¹ caused crop injury to the extent of 60 per cent resulted in severe stunted growth and discoloration with significant stand loss in blackgram. Similar results were reported by Rao *et al.* (2010), Kundu *et al.* (2011) and Rao and Rao (2002).

Post emergence application of acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24% EC) @ 180 g a.i ha⁻¹ at 15 and 25 DAS did not cause any crop injury, whereas acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24% EC) @ 240 g a.i ha⁻¹ at 15 and 25 DAS showed crop injury to the extent of 20 per cent resulting in stunting and discoloration of meristematic leaves at 5 DAHA, however plants recovered quickly by 10 DAHA and resumed normal growth.

Post emergence application of acifluorfen sodium + clodinafop propargyl @ 300 g a.i ha⁻¹ at 15 DAS recorded slight crop damage (rating = 30%) at 5 DAHA. At 10 DAHA, blackgram plants recovered from phytotoxicity and then the crop resumed to normal condition.

Acifluorfen sodium + clodinafop propargyl @ 300 g a.i ha⁻¹ at 25 DAS caused crop injury to the extent of 40 per cent resulting in severe stunting, discoloration and wilting of leaves at 5 DAHA. At 10 DAHA, though the effect was less and negligible (rating = 10%), stunted growth and discoloration continued till maturity which adversely affected growth attributes, chlorophyll content and yield of blackgram.

Rao (2005) reported that application of clodinafop propargyl @ 53 g a.i ha⁻¹ at 14 DAS caused initial injury to crop by showing pale yellow and tip burning. However, the crop completely recovered within two weeks after spray in rice.

Robert (1989) stated that acifluorfen exerts its major effect of phytotoxicity through toxic products formed following light activation, lipid peroxidation, activated by photosynthetic electron transport and tetrapyrrole accumulation. It affects growth and phenyl propanoid metabolism in soybean and spinach. Similar results were reported by Monks *et al.* (1993), Mathis *et al.* (1980) and South (1979).

From the present study, it is evident that post emergence application of acifluorfen sodium + clodinafop propargyl @ 300 g a.i ha⁻¹ at 25 DAS adversely affected the growth of blackgram and the symptoms remain unchanged upto maturity and reduced the growth and yield of blackgram, whereas acifluorfen sodium + clodinafop propargyl @ 300 g a.i ha⁻¹ at 15 DAS and 240 g a.i ha⁻¹ at 15 and 25 DAS resulted in slight injury to blackgram for about 5 days but the crop resumed normal condition by 10 days after herbicide application without showing any adverse effect on growth and yield of blackgram.

From the above findings, it can be stated that post emergence application of acifluorfen sodium + clodinafop propargyl @ 240 and 300 g a.i ha⁻¹ at 15 DAS showed phytotoxicity on blackgram plants, but toxic effect did not persist for long, it was moderate at early stage and gradually decreased. It had ultimately no deleterious effect on the mature plants.

4.2. EFFECT ON WEEDS

4.2.1 Weed density (no. of plants m⁻²)

The data recorded on density of weeds at 30 and 60 DAS is presented in Table 4.2 and graphically depicted in Fig.4.1. The major weed flora observed in experimental plot include both monocots (grassy weeds) and dicots (broad leaved weeds). The density of grassy weeds (viz., *Echinochloa colonum*, *Sorghum halopense*, *Cyperus rotundus*, *Cynodon dactylon* and *Digitaria sanguinalis*) was higher than the density of broad leaved weeds (viz., *Trianthema portulacastrum*, *Phyllanthus niruri*, *Celosia argentic*, *Aristolochia indica*, *Amaranthus viridis*, *Commelina bengalensis* and *Euphorbia hirta*).

Among different weed control treatments, at 30 DAS, weed free check (i.e. hand weeding at 15 and 30 DAS) recorded no weed population. At 60 DAS, it recorded significantly minimum number of grassy weeds (20.1 m⁻²) and broad leaved weeds (9.3 m⁻²) over un weeded control and other treatments. These results are in agreement with the findings of Singh *et al.* (2014) who reported that hand weeding done at 20 and 40 DAS reduced the weed density to the maximum extent over herbicidal treatments in groundnut.

Among the herbicidal treatments, post emergence application of acifluorfen sodium + clodinafop propargyl @ 300 g a.i ha⁻¹ at 15 DAS (T₇) recorded lower weed density (28.1 grassy weeds and 11.2 broad leaf weeds m⁻²) at 30 DAS and (48.1 grassy and 28.2 broad leaf weeds m⁻²) at 60 DAS, which was statistically at par with post emergence application of acifluorfen sodium + clodinafop propargyl @ 240 g a.i ha⁻¹ at 15 DAS and significantly superior to other herbicide treatments. Persistence of combined application of acifluorfen sodium and clodinafop propargyl for long period might have resulted in less weed population. Similar results were obtained by Jha *et al.* (2014).

Imazethapyr 10% EC @ 50g a.i ha⁻¹ at 15 and 25 DAS recorded significantly higher weed population compared to acifluorfen sodium + clodinafop propargyl @ 240 and 300 g a.i ha⁻¹ at 15 DAS and significantly superior over un weeded control at 30 and 60 DAS. This might be due to low dose of imazethapyr (50 g ha⁻¹) application could not able to control the weed population that lead to lesser growth of blackgram plants which in turn resulted lesser yield attributing characters in the later stages. Weedy check (T₁₀) recorded in the highest weed density (66.9 grassy and 130.5 broad leaf weeds m⁻²) at 30 DAS and (92.5 grassy and 176.3 broad leaf weeds m⁻²) at 60 DAS.

Such variations in the efficiency of different herbicides were because of their chemical structure and mode of action (Vyas and Jain, 2003; Kalpana and Velayutham, 2004). Asif *et al.* (2015) reported that significantly lower total weed density (15.00, 12.25 and 8.0 m⁻²) was found in carfentrazone-ethyl + clodinafop-propargyl + metsulfuron-methyl @ 550g a.i ha⁻¹ at 2, 4 weeks after spray and at harvest, respectively in wheat. These results are in line to those observed by Singh *et al.* (1996), Naseer *et al.* (2011) and Shehzad *et al.* (2012).

4.2.2 Weed Drymatter (g m⁻²)

The extent of drymatter production of weeds denotes the competition offered by them. During the crop growth period, higher the drymatter production by weeds greater is the competition between crop and weeds. The yield reduction of the crop was directly related to the drymatter production of weeds rather than density of weeds alone. The data recorded on drymatter accumulation

of weeds at 30 and 60 DAS is presented in Table 4.3 and graphically depicted in Fig. 4.2 revealed that all the weed control treatments significantly reduced the drymatter of weeds compared to weedy check.

In weed free check (T_9), hand weeding was done at 30 DAS, hence no weeds were observed in the plot and weed drymatter was not measured at 30 DAS. At 60 DAS, weed free check recorded significantly lower weed drymatter (8.48g - grasses and 6.35g-broad leaf weeds m^{-2}) over un weeded control and other herbicide treatments. This might be due to weed free condition achieved by hand weeding during critical period of crop growth. The above results were in tune with research findings of Singh *et al.* (2014) who reported that hand weeding done at 20 and 40 DAS reduced the weed drymatter to the maximum extent over herbicidal treatments in groundnut.

Lower weed drymatter was recorded at 30 and 60 DAS with post emergence application of acifluorfen sodium + clodinafop propargyl @ 300 g a.i ha^{-1} at 15DAS (T_7) which was statistically at par with post emergence application of acifluorfen sodium + clodinafop propargyl @ 240 g a.i ha^{-1} at 15DAS (T_5) and significantly superior to other herbicide treatments. Post emergence application of acifluorfen sodium + clodinafop propargyl 300 g ha^{-1} at 25 DAS was significantly inferior to 300 g ha^{-1} sprayed at 15 DAS by recording higher weed density and drymatter at 30 and 60 DAS. This is because, the period between first 15-30 DAS was found to be critical for weed competition in blackgram, hence weeds need to be removed during first 15-25 DAS for effective control and to promote good growth attributes of blackgram. In the treatment, where acifluorfen sodium + clodinafop propargyl at 300 g ha^{-1} was sprayed at 25 DAS it could not effectively control weed population because, by that time (25 DAS) weeds established well and created severe competition to blackgram for moisture and nutrients and ultimately resulted in lesser weed control efficiency compared to 300 g ha^{-1} sprayed at 15 DAS.

Imazethapyr at 50 g ha⁻¹ sprayed at 15 and 25 DAS recorded comparatively higher weed drymatter (i.e. both monocots and dicots) over acifluorfen sodium + clodinafop propargyl @ 300 g a.i ha⁻¹ at 15DAS. This was due to low rates of imazethapyr (50 g ha⁻¹) application that could not control the weed population.

In the present investigation, post emergence application of acifluorfen sodium + clodinafop propargyl @ 300 and 240 g a.i ha⁻¹ at 15DAS decreased the weed dry weight by 58.3 per cent (monocots), 74.5 per cent (dicots) and 41.4 per cent (monocots), 71.3 per cent (dicots), respectively over un weeded control at 30 DAS. At 60 DAS, acifluorfen sodium + clodinafop propargyl @ 300 g a.i ha⁻¹ at 15DAS reduced the drymatter of monocot weeds by 61.4 per cent and dicots by 77.9 per cent; and 240 g ha⁻¹ sprayed at 15 DAS reduced the dry weight of monocot weeds by 57.9 per cent and dicots by 75.9 per cent over weedy check. These results were in confirmation with the findings of Jha *et al.* (2014), who reported that combined use of clodinafop-propargyl 8% EC with Na-acifluorfen 16.5% SL @ 160 + 330g a.i ha⁻¹ was found superior in reducing weed drymatter compared to other treatments. Asif *et al.* (2015) reported that significantly lower total weed drymatter (4.76 g) was found with carfentrazone-ethyl + clodinafop-propargyl + metsulfuron-methyl @ 550g a.i ha⁻¹ in wheat at harvest.

Based on the above findings, among the herbicide treatments, acifluorfen sodium + clodinafop propargyl @ 240 and 300 g a.i ha⁻¹ sprayed at 15DAS was found superior in reducing weed density and drymatter by possessing higher weed control efficiency. Un weeded control registered significantly higher weed drymatter (grasses- 20.82g m⁻² and broad leaf weeds – 36.78g m⁻²) at 30 DAS and (38.26g m⁻²- grasses and 48.78g m⁻²-broad leaf weeds) at 60 DAS compared to other treatments.

It was evident from the present study, the combined use of acifluorfen sodium + clodinafop propargyl herbicides effectively controlled broad leaf weeds (dicots) than grassy weeds (monocots).

4.2.3 Weed Control Efficiency (WCE)

The data pertaining to weed control efficiency of different treatments are furnished in Table 4.4 and Fig. 4.3.

The highest weed control efficiency was noticed with two hand weedings treatment (83.0%). Among the different herbicides, post emergence application of acifluorfen sodium + clodinafop propargyl at 300 and 240g a.i ha⁻¹ sprayed at 15 DAS registered higher weed control efficiency (70.6 and 68.0%) respectively. This was due to greater reduction in weed biomass in these treatments which might have increased the weed control efficiency. Imazethapyr at 50g ha⁻¹ at 15 and 25 DAS recorded lower weed control efficiency (50.5 and 41.6%), respectively over high doses of acifluorfen sodium + clodinafop propargyl. Such variations in the efficiency of different herbicides were because of their chemical structure and mode of action (Vyas and Jain, 2003; Kalpana and Velayutham, 2004).

From the study, it is clear that the combined use of acifluorfen sodium 16% EC plus clodinafop propargyl 8% EC (24% EC) @ 300g a.i ha⁻¹ at 15 DAS was found superior to its other doses of 240 and 180g a.i ha⁻¹ in weed control efficiency.

4.3 MORPHOLOGICAL PARAMETERS

4.3.1 Plant Height (cm)

The data on the effect of post emergence herbicide sprays on height of blackgram plants recorded at 15 days interval from 15 DAS to harvest were presented in Table 4.5 and Fig. 4.4. In all the treatments, there was a gradual increase in plant height from 15 DAS to harvest. At 15 DAS, all the treatments were there was no significant difference in plant height with different herbicide doses. From 30 DAS onwards, significant differences were noted among the treatments.

At 30 and 45 DAS, weed free check (T₉) recorded significantly higher plant height (29.72 and 36.90 cm respectively) over un weeded control (T₁₀) and it was at par with combined use of acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24% EC) @ 300 g a.i ha⁻¹ at 15DAS (T₇-28.40 and 35.72 cm respectively) and acifluorfen sodium + clodinafop propargyl @ 240 g a.i ha⁻¹ at 15DAS (T₅-27.80 and 35.32 cm respectively) and significantly superior over other herbicidal treatments. All other herbicidal treatments were on par with

each other and higher over un weeded control (T₁₀). Weedy check (T₁₀) recorded lower plant height (18.71 and 25.40 cm) than other treatments at 30 and 45 DAS, respectively.

At 60 DAS, maximum plant height (39.21 cm) was recorded with weed free check (T₉) which was at par with combined application of acifluorfen sodium + clodinafop propargyl @ 300 g a.i ha⁻¹ at 15DAS (T₇- 39.01cm), acifluorfen sodium + clodinafop propargyl @ 240 g a.i ha⁻¹ at 15DAS (T₅-38.31 cm) and imazethapyr 10% EC @ 50g a.i ha⁻¹ at 15DAS (T₁-38.19 cm) and significantly superior to other herbicide treatments. Lower plant height (26.18 cm) was recorded with weedy check.

At harvest, hand weeding twice at 15 and 30 DAS (T₉) produced significantly higher plant height (44.20 cm) which was on a par with combined application of acifluorfen sodium + clodinafop propargyl @ 300 g a.i ha⁻¹ at 15DAS (T₇ -44.01cm), acifluorfen sodium + clodinafop propargyl @ 240 g a.i ha⁻¹ at 15DAS (T₅-43.81cm) and imazethapyr 10% EC @ 50g a.i ha⁻¹ at 15DAS (T₁-43.12 cm). All other herbicidal treatments were on par with each other and differed significantly with control. The un weeded control plot (T₁₀) recorded lower plant height (28.23 cm), obviously due to the effect of weeds at all stages of observation.

In the present investigation, plant height increased continuously from 15DAS to harvest, however the rate of increase was high during 30 to 60 DAS and then declined from 60DAS to harvest. At harvest, weed free check (T₉) and post emergence application of acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24% EC) @ 300 and 240 g a.i ha⁻¹ at 15DAS recorded higher performance by increasing plant height by 56.6, 55.9 and 55.2 per cent, respectively, over un weeded control (T₁₀). Hussain *et al.* (2015) reported maximum plant height in plots treated with clodinafop propargyl @ 300 g a.i ha⁻¹ at 21 DAS in wheat. Superior plant height in plots treated with clodinafop propargyl was also reported in chickpea by Sadiq *et al.* (2011). This might be due to less weed population, which reduced crop weed competition for soil

moisture, plant nutrients, solar radiation and space during active growth period resulting in better nutrient availability which helped in rapid cell development and facilitates luxurious crop growth in the above treatments.

It was evident from the present study, that the post emergence application of acifluorfen sodium + clodinafop propargyl @ 300 and 240g a.i ha⁻¹ at 15DAS is effective in increasing the height of blackgram compared to other herbicidal treatments.

4.3.2. Number of Branches Plant⁻¹

The data collected on number of branches of blackgram as influenced by post emergence herbicides are presented in Table 4.6 and Fig. 4.5. In all the treatments, there was a gradual increase in number of branches with advancement in age of the crop. Before spraying i.e. at 15 DAS no significant difference was observed among the treatments. From 30 DAS onwards, significant differences were noted among the treatments.

At 30, 45 and 60 DAS, weed free check i.e. two hand weedings at 15 and 30 DAS (T₉) recorded more number of branches (3.66, 5.65 and 7.01, respectively) which was found to be significantly superior over all other treatments, except the combined application of acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24% EC) @ 300 g a.i ha⁻¹ (T₇-3.66, 5.63 and 6.99) and 240 g a.i ha⁻¹ at 15 DAS (T₅-3.64, 5.56 and 6.98, respectively). However, these two treatments were at par with two hand weedings at 15 and 30 DAS (T₉) in producing branches. Less number of branches were recorded in un weeded control plots (T₁₀-2.26, 3.23 and 4.02) at 30, 45 and 60 DAS, respectively.

At harvest, post emergence application of acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24% EC) @ 300 g a.i ha⁻¹ at 15 DAS recorded more number of branches plant⁻¹ (T₇-7.94) and it was on a par with weed free check (T₉-7.94), acifluorfen sodium 16% EC + clodinafop propargyl 18% EC (24% EC) @ 240 g a.i ha⁻¹ at 15 DAS (T₅-7.83) and imazethapyr @ 50g a.i ha⁻¹ at 15DAS (T₁-7.68) and significantly superior to other treatments. The remaining treatments range between 6.88 to 7.05 and were significantly higher over control (T₁₀ - 5.32).

Number of branches increased from 30DAS to harvest due to increased plant height and production of secondary branches. At harvest, post emergence application of acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24% EC) @ 300 g a.i ha⁻¹ at 15DAS showed higher performance by producing more number of branches plant⁻¹ over control plants and this is on a par with weed free check. The increase in number of branches in this treatment (T₇) is 49.2 per cent compared to un weeded control (T₁₀).

The increased number of branches in these treatments (T₇ and T₉) could be due to weed free environment during active growth period resulting better nutrient availability which helps in rapid cell development that facilitated luxurious crop growth in these treatments. Hence, two hand weedings at 15 and 30 DAS and combined use of acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24% EC) @ 300 g a.i ha⁻¹ at 15 DAS found to be better in producing more number of branches plant⁻¹.

4.4. PHYSIOLOGICAL PARAMETERS

4.4.1 Leaf Area Plant⁻¹ (cm²)

The data on the leaf area of blackgram as influenced by post emergence herbicides are presented in Table 4.7 and Fig. 4.6. At 15 DAS, no significant differences were observed among the treatments with respect to leaf area. In all the treatments, there was a gradual increase in leaf area with advancement of age of the crop and decreased at maturity.

At 30 DAS, weed free treatment recorded higher leaf area plant⁻¹ (176.21 cm²) which was on a par with acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24% EC) @ 300g a.i ha⁻¹ at 15DAS (T₇.170.93cm²) and acifluorfen sodium + clodinafop propargyl @ 240 g a.i ha⁻¹ at 15DAS (T₅-169.18 cm²). The lower leaf area (103.36 cm²) was recorded in un weeded control treatment.

At 45 and 60 DAS, higher leaf area was recorded with combined application of acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24% EC) @ 300g a.i ha⁻¹ at 15DAS (T₇-439.35 and 530.03 cm²) and weed free treatment (T₉-439.35 and 530.03 cm²) which were on par with the application of acifluorfen sodium + clodinafop propargyl @ 240 g a.i ha⁻¹ at 15DAS (T₅-430.26 and 526.18 cm²), and significantly superior to other treatments. The remaining treatments were superior over control treatment. Un weeded control (T₁₀) recorded lower leaf area (263.24 and 323.56 cm²) at 45 and 60 DAS, respectively.

At harvest, hand weeding (15 and 30 DAS) recorded the highest leaf area (246.13 cm²) which was followed by acifluorfen sodium + clodinafop propargyl @ 300 g a.i ha⁻¹ at 15DAS (T₇-245.28 cm²) and acifluorfen sodium + clodinafop propargyl @ 240 g a.i ha⁻¹ at 15DAS (T₅-242.15cm²). These were at par with hand weeding treatment. The lowest leaf area was observed in weedy check (136.76 cm²) due to severe weed competition at all stages of crop growth.

In the present study, the increase in leaf area ranged between 10.2 to 63.8 % in all the weed control treatments over weedy check at 60 DAS. Post emergence application of acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24% EC) @ 300g a.i ha⁻¹ at 15DAS and weed free check increased the leaf area by 63.8 per cent over un weeded control. The increase in leaf area might be due to better weed control resulted in favourable environment to have higher nutrient uptake reflected on higher leaf area index (Sangeetha *et al.*, 2014). Imazethapyr application at 50 g ha⁻¹ sprayed at 15 and 25 DAS registered lesser leaf area compared to T₇ and T₅ treatments. This is due to lower rate of imazethapyr could not able to control weed infestation, weeds competed with blackgram and resulted in lesser leaf area.

From the present study, among different post emergence herbicides, acifluorfen sodium + clodinafop propargyl @ 300g a.i ha⁻¹ at 15DAS and weed free check (hand weeding at 15 and 30 DAS) were found promising with respect to leaf area of blackgram.

4.4.2 Partitioning of Drymatter (g plant⁻¹)

4.4.2.1 Leaf Drymatter

The data on leaf drymatter as affected by post emergence herbicides at different intervals are furnished in Table 4.8. A gradual increase in leaf drymatter of blackgram was observed from 15 to 60 DAS there after decreased gradually due to senescence of leaves. Significant differences were observed among the treatments from 30DAS to harvest. Before spraying i.e. at 15 DAS, all treatments did n't show any significant difference.

At 30 DAS, the amount of leaf drymatter ranged from 1.92 to 3.03 g plant⁻¹ in different treatments. Higher leaf drymatter was recorded by hand weeding treatment (T₉-3.03 g plant⁻¹) which was statistically at par with post emergence application of acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24%EC) @ 300g a.i ha⁻¹ at 15DAS (T₇-2.97 g plant⁻¹) and acifluorfen sodium + clodinafop propargyl @ 240 g a.i ha⁻¹ at 15DAS (T₅-2.62g plant⁻¹). Lesser leaf drymatter was recorded in un weeded control (T₁₀-1.92 g plant⁻¹).

At 45 DAS, among all the treatments, post emergence application of acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24%EC) @ 300g a.i ha⁻¹ at 15DAS registered higher leaf drymatter (T₇- 4.24 g plant⁻¹) and it was on a par with weed free check (T₉- 4.18 g plant⁻¹) and acifluorfen sodium + clodinafop propargyl @ 240 g a.i ha⁻¹ at 15DAS (T₅- 4.01g plant⁻¹). Weedy check (un treated) recorded lesser drymatter (T₁₀- 2.33g plant⁻¹) which was on a par with the treatments T₂, T₄, and T₈.

At 60 DAS, post emergence application of acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24%EC) @ 300g a.i ha⁻¹ at 15DAS (T₇) and weed free treatment (T₉) recorded higher leaf drymatter (7.12 g plant⁻¹) which were on par with all other herbicide treatments except imazethapyr 10% EC @ 50g a.i ha⁻¹ at 25DAS (T₂) and acifluorfen sodium + clodinafop propargyl @ 300g a.i ha⁻¹ at 25DAS (T₈). Lower leaf drymatter was recorded in un weeded control (T₁₀) i.e. 5.37 g plant⁻¹ which was on a par with the treatments T₂ and T₈.

At harvest, higher leaf drymatter was obtained in weed free treatment i.e. T₉ (5.90g plant⁻¹) followed by T₇ (5.87 g plant⁻¹), T₅ (5.61g plant⁻¹) and T₁ (5.09g plant⁻¹). Lower value was recorded in control (T₁₀ - 4.01 g plant⁻¹) which was on a par with the treatments T₃, T₄, T₆ and T₈.

In the present study, post emergence application of acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24%EC) @ 300, 240g a.i ha⁻¹ at 15DAS (T₇ and T₅) and weed free treatment (T₉-hand weeding at 15 and 30 DAS) exhibited better performance in increasing leaf drymatter by 32.6, 32.0 and 32.6 per cent respectively, over un weeded control at 60DAS. Other treatments increased the leaf drymatter in the range between 9.3 to 28.5 per cent. So considering economic benefit, it is better to go for post emergence application of acifluorfen sodium + clodinafop propargyl @ 240 and 300g a.i ha⁻¹ at 15DAS to increase leaf drymatter through effective removal of weeds during the critical period of crop weed competition in blackgram.

4.4.2.2 Stem drymatter (g plant⁻¹)

The stem drymatter as affected by post emergence herbicides at different intervals is presented in Table 4.9. A gradual increase in stem drymatter of blackgram was observed from 15 DAS to harvesting stage. At 15 DAS i.e. before herbicides spraying, no significant differences were observed among the treatments with respect to stem drymatter.

At 30 DAS, the variation in stem drymatter with different herbicidal treatments ranged between 0.59 to 0.99 g plant⁻¹. Higher stem drymatter was recorded in weed free check (T₉ - 0.99g plant⁻¹) followed by post emergence application of acifluorfen sodium 16% EC + clodinafop propargyl 8% (24% EC) @ 300g a.i ha⁻¹ at 15 DAS (T₇-0.89g plant⁻¹) and acifluorfen sodium + clodinafop propargyl @ 240 g a.i ha⁻¹ at 15DAS (T₅- 0.89g plant⁻¹). Lower stem drymatter was recorded in un weeded control (T₁₀ - 0.59g plant⁻¹), which was at par with the remaining treatments (T₁, T₂, T₃, T₄, T₆ and T₈).

At 45 DAS, plots treated with acifluorfen sodium + clodinafop propargyl @ 300 g a.i ha⁻¹ at 15DAS recorded higher stem drymatter (T₇- 2.52g plant⁻¹) than un weeded control (T₁₀- 1.68g plant⁻¹) and it was on a par with T₉ (2.48 g plant⁻¹), T₅ (2.40g plant⁻¹), T₆ (2.37g plant⁻¹) and T₄ (2.31g plant⁻¹).

At 60 DAS, post emergence application of acifluorfen sodium 16% EC + clodinafop propargyl 8% (24% EC) @ 240g a.i ha⁻¹ at 15 DAS recorded higher stem drymatter (T₅-4.52g plant⁻¹) which was at par with hand weeding treatment (T₉-4.18g plant⁻¹), acifluorfen sodium + clodinafop propargyl @ 300g a.i ha⁻¹ at 15DAS (T₇-4.18g plant⁻¹) and imazethapyr 10% EC @ 50g a.i ha⁻¹ at 15DAS (T₁-4.02g plant⁻¹), and significantly superior over other treatments. Lower stem drymatter was recorded in un weeded control (T₁₀) i.e. 2.98g plant⁻¹.

At harvest, higher stem drymatter was obtained in hand weeding treatment at 15 and 30 DAS i.e. T₉ (7.18 g plant⁻¹) followed by T₇ (7.05 g plant⁻¹) and T₅ (6.94 g plant⁻¹). Significantly lesser drymatter was observed in un weeded control (T₁₀-4.08 g plant⁻¹) than other treatments.

In the present study, weed free check (T₉) and post emergence application of acifluorfen sodium + clodinafop propargyl @ 300g a.i ha⁻¹ (T₇) and 240 g a.i ha⁻¹ (T₅) at 15DAS increased the stem drymatter by 3.10, 2.97 and 2.86g over un weeded control at harvest.

4.4.2.3 Reproductive parts drymatter (g plant⁻¹)

The data on dry weight of reproductive parts as affected by post emergence herbicide sprays from 45 DAS to harvest are presented in Table 4.10. A gradual increase in reproductive parts drymatter of blackgram was observed from 45 DAS to harvest.

At 45 DAS, twice hand weeding at 15 and 30 DAS (T₉-weed free check) produced significantly higher reproductive parts drymatter (3.56 g plant⁻¹) than the other treatments, which was on a par with post emergence application of acifluorfen sodium + clodinafop propargyl @ 300g a.i ha⁻¹ (T₇ -3.44 g plant⁻¹). The remaining treatments were on par with each other and significantly higher over un weeded control except, acifluorfen sodium + clodinafop propargyl @ 180g a.i ha⁻¹ at 25 DAS, which was at par with control (T₁₀). Lower reproductive parts drymatter was recorded in control treatment (T₁₀) i.e. 2.27 g plant⁻¹.

At 60DAS, higher reproductive parts drymatter was obtained in weed free check (T_9 -3.90g plant⁻¹). It was at par with post emergence application of acifluorfen sodium 16% + clodinafop propargyl 8% (24%) @ 300g a.i ha⁻¹ at 15DAS (T_7 - 3.87g plant⁻¹) and acifluorfen sodium + clodinafop propargyl @ 240 g a.i ha⁻¹ at 15DAS (T_5 -3.85 g plant⁻¹). Lesser value was recorded in un weeded control (3.12g plant⁻¹).

At harvest, higher reproductive parts drymatter was recorded in weed free treatment i.e. T_9 (5.08 g plant⁻¹) which was on a par with T_7 (5.04 g plant⁻¹), T_5 (4.98 g plant⁻¹) and T_1 (4.62 g plant⁻¹). The remaining treatments were on par with each other and significantly higher over un weeded control, except acifluorfen sodium + clodinafop propargyl @ 300 g a.i ha⁻¹ at 25DAS, which was at par with control (T_{10}). Lower value was recorded in control treatment (T_{10} -3.56g plant⁻¹).

From the data, it is evident that post emergence application of acifluorfen sodium + clodinafop propargyl @ 240, 300g a.i ha⁻¹ sprayed at 15 DAS and weed free check increased the drymatter of reproductive parts by 40.0, 41.6 and 42.7 per cent, respectively over un weeded control at harvest.

4.4.2.4 Total drymatter (g plant⁻¹)

The data on total drymatter of blackgram as affected by post emergence herbicide sprays at different intervals are furnished in Table 4.11 and Fig. 4.7. A gradual increase in total drymatter of blackgram plants was observed from 15 DAS to harvest. Before spraying i.e. at 15 DAS, all treatments did n't show any significant difference.

At 30 DAS, higher amount of drymatter accumulation was observed in hand weeding treatment (T_9 -4.02g plant⁻¹) which was statistically at par with post emergence application of acifluorfen sodium 16% EC + clodinafop propargyl 8%EC (24%)EC @ 300g a.i ha⁻¹ at 15DAS (T_7 -3.56g plant⁻¹) and acifluorfen sodium + clodinafop propargyl @ 240g a.i ha⁻¹ at 15DAS (T_5 -3.51g plant⁻¹). Un weeded control recorded lesser drymatter accumulation (T_{10} -2.51g plant⁻¹). All other treatments are on par with control.

At 45 DAS, weed free plots registered higher amount of drymatter (10.22 g plant⁻¹) which was on a par with T₇ (10.20g plant⁻¹) and T₅ (9.56g plant⁻¹). The remaining treatments were on par with each other and significantly higher over un weeded control except T₂ and T₈, which were at par with control. Un weeded control (T₁₀) recorded lesser drymatter i.e. 6.28 g plant⁻¹ at 45 DAS.

At 60 DAS, post emergence application of acifluorfen sodium + clodinafop propargyl @ 240g a.i ha⁻¹ at 15DAS recorded higher total drymatter (T₅- 15.46 g plant⁻¹) followed by weed free check (T₉- 15.20g plant⁻¹) and acifluorfen sodium + clodinafop propargyl @ 300g a.i ha⁻¹ at 15DAS (T₇- 15.17g plant⁻¹). All other treatments are on par with un weeded control except post emergence application of imazethapyr 10% EC @ 50g a.i ha⁻¹ at 15DAS (T₁) and acifluorfen sodium + clodinafop propargyl @ 240g a.i ha⁻¹ at 25DAS (T₆) which were significantly superior over un weeded control. Weedy check recorded lesser drymatter (11.47 g plant⁻¹) at 60 DAS.

At harvest, weed free check (T₉) registered higher amount of total drymatter (18.16 g plant⁻¹) which was statistically at par with T₇ (17.96g plant⁻¹) and T₅ (17.53g plant⁻¹), and significantly superior over control and other treatments. Un weeded control accumulated lesser drymatter (11.65 g plant⁻¹) due to severe weed competition. All other treatments were significantly higher over control.

Total drymatter production and its partitioning are the key factors in determining the economic yield of the crop. In the present study, two hand weedings at 15 and 30 DAS (weed free check) and post emergence application of acifluorfen sodium + clodinafop propargyl @ 300 and 240g a.i ha⁻¹ at 15DAS increased the total drymatter of blackgram 55.9, 54.2 and 50.5 per cent, respectively, over un weeded control. These three treatments significantly reduced the weed population by 78, 48 and 43.7 per cent (monocot weeds) 95, 84 and 83.7 per cent (dicot weeds), and weed drymatter by 77.8, 61.4 and 57.9 per cent (monocot weeds); and 87, 77.9 and 75.9 per cent (dicot weeds) respectively, over un weeded control at 60 DAS (Table 4.1 and 4.2). This better

weed control resulted in favourable environment to have higher nutrient uptake reflected on higher leaf area index and better source sink relationship for accumulating higher drymatter. On the other hand, un weeded control recorded lower total drymatter due to severe weed competition at all stages of crop growth. Whereas imazethapyr @ 50 g a.i ha⁻¹ at 15 and 25 DAS increased the total drymatter of blackgram by 33.5 and 25.7 per cent, respectively, over un weeded control and decreased the total drymatter by 15.5 and 22.7 per cent, respectively, over higher doses of acifluorfen sodium + clodinafop propargyl i.e. 300g a.i ha⁻¹ at 15 DAS. This is due to lower dose of imazethapyr (i.e. 50 g ha⁻¹) at 15 and 25 DAS could not able to control the weed population, which resulted in higher weed drymatter in these plots and ultimately recorded lesser drymatter of blackgram.

The above results were in tune with research findings of Jha *et al.* (2012) in soybean crop. He reported that weed free check produced significantly higher plant dry weight of 17.46g plant⁻¹ over weedy check (5.53g plant⁻¹) and combined use of clodinafop propargyl 8% EC + Na-acifluorfen 16.5 SL @ 100 + 206.2 g a.i ha⁻¹ recorded significantly more plant dry weight. Such beneficial effects of herbicides on plant dry weight may be due to effective weed control and minimizing the crop weed competition resulting in better plant growth (Chandel and Saxena, 2001). Rao (2005) also reported that post emergence application of clodinafop propargyl @ 53g ha⁻¹ applied at 14 DAS recorded higher dry weight of rice seedlings at 30 DAS.

It is evident from the present study that post emergence application of acifluorfen sodium 16 % EC + clodinafop propargyl 8 % EC (24 % EC) @ 240 and 300 g a.i ha⁻¹ at 15 DAS were found superior by maintaining higher leaf area and biomass production through effective weed control in blackgram. Hand weeding twice at 15 and 30 DAS also recorded similar performance with the above herbicide sprays.

4.5 PHOTOSYNTHETIC PIGMENTS

4.5.1 Chlorophyll a

The influence of post emergence herbicides on chlorophyll a content of blackgram leaves is presented in Table 4.12 and Fig. 4.8. The data pertaining to chlorophyll a content were collected at 5, 10, 15, 20 and 25 days after herbicide application (DAHA). At 15 DAS i.e. before spraying, no significant differences were observed among the treatments.

At 20 DAS (i.e. 5 DAHA), the treatments (viz., T₁, T₃, T₅, and T₇) where post emergence herbicides were sprayed at 15 DAS showed significant decrease in chlorophyll a content in blackgram leaves over un weeded control and other herbicidal treatments. Among the herbicides, sprayed at 15 DAS, acifluorfen sodium + clodinafop propargyl at 300 g a.i ha⁻¹ (T₇) and imazethapyr at 50g ha⁻¹ (T₁) recorded lesser chlorophyll a content (0.610 mg g⁻¹) followed by acifluorfen sodium + clodinafop propargyl @ 240 g a.i ha⁻¹ (T₅- 0.613 mg g⁻¹) and acifluorfen sodium + clodinafop propargyl @ 180g a.i ha⁻¹ (T₃- 0.618 mg g⁻¹). In these treatments, except imazethapyr at 50g ha⁻¹, the content of chlorophyll a was reduced gradually as the concentration of acifluorfen sodium + clodinafop propargyl increased from 180 to 300g a.i ha⁻¹. This is due to higher concentration of acifluorfen sodium + clodinafop propargyl at 240 to 300g a.i ha⁻¹ caused crop injury to the extent of 20 to 30 per cent, which resulted in stunting and discoloration of leaves at 20 DAS. Imazethapyr at 50g ha⁻¹ sprayed at 15 DAS also caused chlorosis/discoloration of leaves resulted in lower chlorophyll a content in blackgram leaves. Weed free check recorded higher chlorophyll a content (T₉- 0.678 mg g⁻¹) over un weeded control (T₁₀- 0.639 mg g⁻¹). The treatments T₂, T₄, T₆, and T₈ are at par with un weeded control.

At 25 DAS (i.e.10 DAHA), higher values of chlorophyll a were obtained with two hand weedings (0.755 mg g⁻¹) and acifluorfen sodium + clodinafop propargyl at 300 g a.i ha⁻¹ applied at 15 DAS (0.745 mg g⁻¹). This is due to quick recovery of blackgram plants from the phytotoxicity of acifluorfen sodium +

clodinafop propargyl and the crop resumed to normal condition by 10 days after herbicide application. The treatments T₅, T₁ and T₃ also recorded significantly higher chlorophyll a values compared to un weeded control. Remaining weed control treatments were at par with weedy check. Weedy check recorded lesser chlorophyll a content (0.680 mg g⁻¹).

At 30 DAS, acifluorfen sodium + clodinafop propargyl at 240, 300 and 180 g a.i ha⁻¹ and imazethapyr at 50g ha⁻¹ applied at 25 DAS recorded significantly lesser chlorophyll a contents compared to un weeded control. This is due to phytotoxicity of these herbicides which caused chlorosis of leaves. Higher chlorophyll a content was recorded with two hand weedings at 15 and 30 DAS (0.831 mg g⁻¹) followed by post emergence application of acifluorfen sodium + clodinafop propargyl at 300 g a.i ha⁻¹ at 15 DAS (0.828 mg g⁻¹) and 240 g ha⁻¹ at 15 DAS (0.820 mg g⁻¹).

At 35 and 40 DAS, weed free check recorded significantly higher chlorophyll a content (0.864 mg g⁻¹ and 0.894 mg g⁻¹, respectively) which was statistically at par with acifluorfen sodium + clodinafop propargyl at 300 g a.i ha⁻¹ at 15 DAS (0.857 mg g⁻¹ and 0.887 mg g⁻¹, respectively) and significantly superior over other treatments. Weedy check recorded lesser chlorophyll a content (0.728 and 0.758 mg g⁻¹) at 35 and 40 DAS respectively. The remaining herbicidal treatments were at par with weedy check at 40 DAS.

4.5.2 Chlorophyll b

The data pertaining to the influence of post emergence herbicides on chlorophyll b content of blackgram leaves are presented in Table 4.13 and Fig. 4.9. Before herbicides spraying i.e. at 15 DAS, significant differences were not noted among the treatments.

At 20 DAS, among the herbicidal treatments, acifluorfen sodium + clodinafop propargyl at 300, 240 and 180 g a.i ha⁻¹ and imazethapyr at 50g ha⁻¹ sprayed at 15 DAS significantly decreased the chlorophyll b content (0.554, 0.548, 0.560 and 0.556 mg g⁻¹, respectively) over un weeded control

(0.620 mg g⁻¹). This might be due to phytotoxicity of these herbicides at initial stages of crop growth. Remaining treatments were at par with weedy check. Weed free check recorded the highest chlorophyll b content (0.692 mg g⁻¹) compared to other treatments.

The contents of chlorophyll b in blackgram leaves at 10 days after herbicide application (i.e. at 25 DAS) were generally comparable among the treatments. The highest chlorophyll b content was recorded with weed free treatment (0.730 mg g⁻¹). Remaining weed control treatments were at par with un weeded control, which recorded the lowest chlorophyll b content (0.632 mg g⁻¹).

At 30 DAS, post emergence application of acifluorfen sodium + clodinafop propargyl @ 300g a.i ha⁻¹ sprayed at 25 DAS recorded the lowest chlorophyll b content (T₈ - 0.601 mg g⁻¹) compared to other treatments. This is due to higher dose of acifluorfen sodium + clodinafop propargyl (300g ha⁻¹) exhibited phytotoxicity on blackgram at 30 DAS. Weed free check recorded the highest chlorophyll content (0.801 mg g⁻¹) which was statistically at par with acifluorfen sodium + clodinafop propargyl at 300 and 240g a.i ha⁻¹ at 15 DAS (0.795 mg g⁻¹ and 0.789 mg g⁻¹, respectively). This is due to recovery of blackgram plants from acifluorfen sodium + clodinafop propargyl phytotoxicity, which were sprayed at early stages of crop growth (i.e. at 15 DAS). The treatments T₂, T₄, and T₆ are on par with un weeded control and T₁ and T₃ are superior over control in recording chlorophyll b content.

At 35 and 40 DAS higher chlorophyll b content was obtained with two hand weedings treatment (0.824 mg g⁻¹ and 0.836 mg g⁻¹, respectively) and it was statistically at par with the application of acifluorfen sodium + clodinafop propargyl @ 240 (0.825 mg g⁻¹ and 0.830 mg g⁻¹, respectively) and 300g a.i ha⁻¹ at 15 DAS (0.820 mg g⁻¹ and 0.829 mg g⁻¹, respectively). Weedy check recorded lesser chlorophyll b content (0.665 and 0.685 mg g⁻¹) at 35 and 40 DAS, respectively, and it was at par with the remaining herbicidal treatments i.e. T₂, T₄, T₆ and T₈. The treatments T₁ and T₃ recorded superior values of chlorophyll b over control.

4.5.3 Total chlorophyll (mg g^{-1})

The data pertaining to the total chlorophyll content of blackgram leaves as influenced by post emergence herbicides are furnished in Table 4.14 and Fig. 4.10. At 15 DAS i.e. before spraying, significant differences were not observed among the treatments.

At 5 DAHA (i.e. at 20 DAS), imazethapyr at 50g ha^{-1} and acifluorfen sodium + clodinafop propargyl at 300, 240 and 180g a.i ha^{-1} sprayed at 15 DAS recorded lesser total chlorophyll content (1.272 , 1.278 , 1.294 and 1.312 mg g^{-1} , respectively) over un weeded control (1.401 mg g^{-1}). These results indicated that the effect of post emergence herbicides on total chlorophyll content followed a dose-dependent manner, i.e. the content of total chlorophyll was reduced gradually as the concentration of acifluorfen sodium + clodinafop propargyl increased from 180 to 300 g a.i ha^{-1} during early stages of crop growth i.e. at 20 DAS. This is due to phytotoxicity of these herbicides during initial stages. Weed free check recorded the highest total chlorophyll content (1.557 mg g^{-1}) over other weed control treatments. The treatments T_2 , T_4 , T_6 and T_8 were on par with control.

At 25 DAS, weed free check recorded higher total chlorophyll content (1.626 mg g^{-1}) which was statistically at par with post emergence herbicides acifluorfen sodium + clodinafop propargyl at 300, 240 and 180 and imzethapyr 50 g a.i ha^{-1} sprayed at 15 DAS (1.585 , 1.582 , 1.578 and 1.579 mg g^{-1} , respectively). Though, these herbicides caused injury to blackgram plants at their respective concentrations during initial stages, but the crop recovered at later growth stages and increased the total chlorophyll content significantly. The remaining weed control treatments were statistically at par with un weeded control.

In the treatments, where herbicides acifluorfen sodium + clodinafop propargyl were applied at 25 DAS @ 180, 240 and 300 g a.i ha^{-1} and imzethapyr at 50 g ha^{-1} significantly reduced the total chlorophyll content compared to the

control. This is due to phytotoxicity exhibited by these herbicides at their respective concentrations at 30 DAS. Highest total chlorophyll content was recorded with hand weeding at 15 and 30 DAS treatment (1.937 mg g^{-1}) which was statistically at par with 240 and 300 g a.i ha^{-1} of acifluorfen sodium + clodinafop propargyl applied at 15 DAS (1.924 and 1.899 mg g^{-1} , respectively).

At 35 and 40 DAS, higher total chlorophyll content was obtained with weed free check (1.969 and 2.166 mg g^{-1} , respectively). Among the post emergence herbicides, acifluorfen sodium + clodinafop propargyl at 300 and 240 g a.i ha^{-1} at 15 DAS recorded significantly total chlorophyll contents (1.978 and 2.076 ; 1.934 and 2.052 mg g^{-1} at 35 and 40 DAS, respectively) and these were statistically at par with weed free check and superior over other herbicidal treatments. Un weeded control recorded lesser total chlorophyll content (1.542 and 1.613 mg g^{-1}) and it was statistically at par with T_2 , T_4 , T_6 and T_8 treatments. The treatments T_1 and T_3 are superior over un weeded control in recording total chlorophyll content at 35 and 40 days after sowing. Shaban *et al.* (2004) reported that higher values of chlorophyll a, chlorophyll b, carotenoids and total pigments were obtained with hand weeding and clodinafop propargyl at 225 or 315 g a.i ha^{-1} .

In all the treatments, there was a gradual increase in total chlorophyll content from 15 to 40 DAS. In the present study, weed free check and acifluorfen sodium + clodinafop propargyl at 300 and 240 g a.i ha^{-1} applied at 15 DAS increased the total chlorophyll content of blackgram leaves by 34.3, 28.7 and 27.2 per cent, respectively, over un weeded control at 40 DAS. Regarding the results obtained in the present investigation, it was found that these herbicide treatments (T_5 and T_7 treatments) have caused phytotoxicity only at 5 DAHA (i.e. during initial stages) and the blackgram plants recovered at later growth stages and maintained higher chlorophyll a, b and total chlorophyll contents. The treatment with acifluorfen sodium + clodinafop propargyl at 300 g a.i ha^{-1} applied at 25 DAS (T_8) showed damage to the blackgram crop up to 40 DAS (i.e. up to 15 DAHA) and recorded lesser total chlorophyll content compared to other herbicidal treatments.

4.5.4 Carotenoid content (mg g⁻¹)

The data pertaining to the influence of post emergence herbicides on carotenoid content of blackgram leaves are presented in Table 4.15 and Fig. 4.11. Before spraying i.e. at 15 DAS, significant differences were not observed among the treatments.

At 20 DAS, post emergence application of acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24% EC) @ 180, 240 and 300 g and imazethatyr @ 50 g a.i ha⁻¹ applied at 15 DAS recorded lesser carotenoid content in blackgram leaves (0.318, 0.326, 0.324 and 0.321 mg g⁻¹, respectively) when compared to control (0.360 mg g⁻¹) and other treatments. This might be due to phytotoxicity of these herbicides during first five days after herbicide application. The reduction of the carotenoid contents can cause oxidative stress due to the oxidative degradation of chlorophylls and rapid destruction of thylakoid membranes by excessive ROS generation, resulting in tissue discoloration, necrosis, desiccation and death (Kim et al., 2004). Weed free check recorded higher carotenoid content (0.411 mg g⁻¹), which is significantly superior over un weeded control and other treatments. The treatments i.e. T₂, T₄, T₆ and T₈ were at par with control.

At 25 DAS, highest carotenoid content was obtained with two hand weedings treatment (0.471 mg g⁻¹). Among the post emergence herbicides, acifluorfen sodium + clodinafop propargyl @ 300 and 240 g a.i ha⁻¹ applied at 15 DAS recorded higher carotenoid contents (0.469 and 0.467 mg g⁻¹), which were statistically at par with weed free check and superior over un weeded control and other weed control treatments. The increase in carotenoid content in these treatments is due to the recovery of blackgram plants from the herbicide stress by 10 DAHA (i.e. at 25 DAS). Increased contents of carotenoids exert an antioxidant function in chloroplasts due to its ability to remove ROS (Reactive oxygen species) that are formed during herbicide stress (Kim *et al.*, 2004). Weedy check recorded lowest carotenoid content (0.420 mg g⁻¹) and it was statistically at par with T₂, T₄, T₆ and T₈ treatments. This is due to severe

competition of weeds with blackgram for moisture, nutrients, light and space which might have created oxidative stress in blackgram, that resulted decrease in carotenoid content.

At 30 DAS, there was a reduction in carotenoid content with acifluorfen sodium + clodinafop propargyl @ 180,240 and 300 g a.i ha⁻¹ at 25 DAS (0.396, 0.398 and 0.381 mg g⁻¹, respectively) compared to control and other treatments. This is due to phytotoxicity of these herbicides during first five days after application which caused oxidative degradation of chlorophylls and carotenoids. Whereas acifluorfen sodium + clodinafop propargyl at 300 and 240 g a.i ha⁻¹ at 15 DAS registered higher carotenoid contents (0.480 and 0.472 mg g⁻¹) which were statistically at par with weed free check (0.485 mg g⁻¹) and significantly superior over un weeded control (0.434 mg g⁻¹). Imazethapyr @ 50 g ha⁻¹ at 15 DAS recorded superior value (0.462 mg g⁻¹) over control.

At 35 and 40 DAS, post emergence herbicides viz., acifluorfen sodium + clodinafop propargyl @ 300 and 240 g a.i ha⁻¹ applied at 15 DAS recorded higher carotenoid contents (0.483, 0.488 mg g⁻¹; and 0.480, 0.485 mg g⁻¹, respectively) which were statistically at par with weed free check (0.487 and 0.492 mg g⁻¹, respectively) and significantly superior over un weeded control (0.440 and 0.446 mg g⁻¹, respectively) and other treatments. Whereas the treatments viz., T₂, T₄, T₆ and T₈, where the herbicides were applied at 25 DAS recorded lesser carotenoid contents compared to T₁, T₃, T₅ and T₇ treatments. This is due to quick recovery of blackgram plants from the herbicide injury and resulted increase in the content of carotenoids in the later case.

Hence, in the present study, among the post emergence herbicides, acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24% EC) @ 240 and 300 g a.i ha⁻¹ at 15 DAS were found superior by recording higher carotenoid content in blackgram leaves which might have imparted tolerance to herbicides injury in terms of higher antioxidative properties. These treatments increased the carotenoid contents by 8.7 and 9.4 per cent, respectively, over unweeded control.

4.6 SUPEROXIDE DISMUTASE (SOD) ACTIVITY IN BLACKGRAM LEAVES

The data pertaining to SOD activity in blackgram leaves as affected by post emergence herbicides are presented in Table 4.16 and Fig 4.12. At 15 DAS i.e., before spraying, no significant differences were noted among the treatments.

At 20 DAS (i.e. 5DAHA), the highest SOD activity was detected with acifluorfen sodium + clodinafop propargyl @ 300 g a.i ha⁻¹ at 15 DAS (28.61 units mg⁻¹ protein h⁻¹) followed by 240 g ha⁻¹ at 15 DAS (27.90 units mg⁻¹ protein h⁻¹), when compared to the control and other treatments. The highest SOD activity in blackgram leaves due to herbicide treatments is an indicative of increased detoxification of reactive oxygen species which are produced in response to stress caused by these herbicides at early stages of crop growth. Treatments with the herbicide clodinafop have induced oxidative stress in wheat, maize and rye plants (Lukatkin *et al.*, 2013). SOD is an important antioxidant defense enzyme and occurs in various sub cellular compartments, catalysing the dismutation of O₂^{•-} (superoxide radicals) into O₂ and H₂O₂ (Gill and Tuteja, 2010), providing plant protection and tolerance to herbicides. Agostinetto *et al.* (2016) reported that there was an increased SOD activity in wheat plants exposed to clodinafop herbicide at 5 days after spraying the herbicide compared to control and other treatments. Weed free check recorded lowest SOD activity (19.26 units mg⁻¹ protein h⁻¹) because of no weed competition (i.e. no stress). Weedy check recorded higher values of SOD (23.48 unit mg⁻¹ protein h⁻¹) and it was at par with T₂, T₄, T₆ and T₈ treatments. This is due to the competition of weeds with blackgram for moisture, nutrients, light and space which might have resulted oxidative stress in blackgram.

At 25 DAS, lower SOD activity was observed with acifluorfen sodium + clodinafop propargyl at 300 and 240 g a.i ha⁻¹ and imazethapyr at 50 g ha⁻¹ applied at 15 DAS (23.14, 23.25 and 24.16 units mg⁻¹ protein h⁻¹, respectively), which were statistically at par with weed free check (22.13 units mg⁻¹ protein h⁻¹), and significantly lower than control (weedy check) and other treatments.

This might be due to the recovery of blackgram plants from the herbicide injury through the lesser generation of ROS, especially of $O_2^{\cdot-}$ (superoxide anions). Weedy check recorded highest SOD activity due to weed competition and it was at par with T_2 , T_4 , T_6 and T_8 treatments

At 30 DAS, among the post emergence herbicides, acifluorfen sodium + clodinafop propargyl @ 300, 240 and 180 g a.i ha⁻¹ and imazethapyr at 50 g ha⁻¹ sprayed at 25 DAS recorded higher SOD activity than other weed control treatments. The higher SOD activity in blackgram plants during the first five days after herbicide application has been correlated with tolerance to oxidative stress. Whereas acifluorfen sodium + clodinafop propargyl @ 300 and 240 g and imazethapyr @ 50 g a.i ha⁻¹ at 15 DAS recorded SOD activity at par with weed free check, due to complete recovery of blackgram plants, an indication of no stress.

At 35 and 40 DAS, weedy check (T_{10}) recorded highest SOD activity (46.28 and 43.26 units mg⁻¹ protein h⁻¹, respectively). This might be due to stress created due to weed competition in blackgram which increased the activation of SOD enzyme, indicating greater generation of ROS, especially of $O_2^{\cdot-}$ which serves as a substrate for SOD. Among the post emergence herbicides, acifluorfen sodium + clodinafop propargyl @ 300 g a.i ha⁻¹ applied at 25 DAS recorded higher SOD activity (46.24 and 42.14 units mg⁻¹ protein h⁻¹, respectively) followed by 240 g a.i ha⁻¹ 25 DAS (45.28 and 41.14 units mg⁻¹ protein h⁻¹, respectively). In these treatments, injury due to these herbicides continued up to 40 DAS (i.e. 15 days after herbicide application) and an increased activation of SOD was observed, which may represent a condition of oxidative stress that finally resulted in lesser growth attributes and yield. Whereas, acifluorfen sodium + clodinafop propargyl @ 240 and 300 g a.i ha⁻¹ applied at 15 DAS recorded SOD activity (31.56 and 30.01 units mg⁻¹ protein h⁻¹) and (31.98 and 30.12 units mg⁻¹ protein h⁻¹) similar to that of weed free check (32.30 and 30.13 units mg⁻¹ protein h⁻¹), respectively at 35 and 40 DAS. This might be due to quick recovery of blackgram from the herbicide stress and the crop resumed to normal condition by 25 DAS, which resulted in the lesser generation of ROS, and hence lesser activation of SOD enzyme.

The effects of post emergence herbicides, acifluorfen sodium + clodinafop propargyl @ 240 and 300 g a.i ha⁻¹ applied at 15 DAS on the SOD activity (i.e. antioxidant activity) seem to be more evident in the first five days after application, indicating a condition of oxidative stress in blackgram due to herbicide injury. But by 25 DAS, the crop recovered from the herbicide stress and exhibited lesser SOD activity compared to un weeded control and other treatments, indicating lesser oxidative stress in blackgram. From this study, it can be concluded that initially, acifluorfen sodium + clodinafop propargyl @ 240 and 300 g a.i ha⁻¹ at 15 DAS caused oxidative stress (up to 20 DAS), but the blackgram crop recovered the negative condition afterwards and exhibited superior performance in terms of growth and yield.

4.7 YIELD ATTRIBUTES AND YIELD

Yield is a phenomenon, being the end product of a number of growth processes which in turn are affected by environmental factors throughout the life of the plant. Each of the yield parameters was explained separately under this section. Fetching greater harvestable yield is the ultimate purpose of growing crops. Yield parameters in blackgram includes, number of pods per plant, number of seeds per pod, pod weight (g plant⁻¹), 100 seed weight (g) and seed yield (kg ha⁻¹). The data pertaining to the influence of post emergence herbicides on yield and yield components of blackgram are presented in Table 4.17.

4.7.1 Number of Pods per Plant

The data on number of pods per plant as influenced by post emergence herbicide sprays are furnished in Table 4.17. The different weed control treatments produced significantly more number of pods than weedy check, except imazethapyr at 50g ha⁻¹ and acifluorfen sodium + clodinafop propargyl at 180g ha⁻¹ sprayed at 25 DAS, which were at par with weedy check.

The highest number of pods per plant was recorded with weed free check (T₉ -30.2) which had minimum weed competition. Among the herbicidal treatments, post emergence application of acifluorfen sodium 16% EC +

clodinafop propargyl 8% EC (24% EC) @ 300g a.i ha⁻¹ at 15 DAS recorded higher number of pods per plant (28.9) which was statistically at par to its 240g ha⁻¹ at 15 DAS (T₅ - 27.8) and significantly superior over other treatments. The positive effect on yield attributes in these treatments was due to better crop growth and drymatter production due to better weed control. Weedy check resulted in lowest number of pods per plant (T₁₀ - 18.2) due to heavy infestation of weeds. Reduction in yield and yield attributes was mainly due to high plant-weed competition for light, space, moisture and nutrients (Kalpana and Velayutham, 2004).

In the present study, different weed control treatments increased the number of pods per plant from 2.7 to 65.9 percent compared to weedy check. The highest increase in number of pods per plant was observed with weed free check (65.9%) followed by acifluorfen sodium + clodinafop propargyl at 300g ha⁻¹ at 15DAS (58.8%) compared to un weeded control.

4.7.2 Number of Seeds per Pod

The data pertaining to the influence of post emergence herbicides on number of seeds per pod are presented in Table 4.17.

The highest number of seeds per pod (5.2) was recorded under hand weeding twice at 15 and 30 DAS over other treatments. Among different post emergence herbicides, acifluorfen sodium + clodinafop propargyl at 300 and 240g a.i ha⁻¹ at 15 DAS recorded higher number of seeds per pod i.e., 4.9 and 4.8, respectively, and were significantly superior over other herbicidal treatments. Un weeded control recorded lower number of seeds per pod (T₁₀ - 3.0).

4.7.3 Pod Weight (g plant⁻¹)

The data on pod weight of blackgram as affected by post emergence herbicide sprays at harvest are presented in Table 4.17.

Higher pod weight was recorded in weed free treatment i.e. T₉ (5.08 g plant⁻¹) which was on a par with T₇ (5.04 g plant⁻¹), T₅ (4.98 g plant⁻¹) and T₁ (4.62 g plant⁻¹). The remaining treatments were on par with each other and significantly higher over un weeded control, except acifluorfen sodium + clodinafop propargyl @ 300 g a.i ha⁻¹ at 25DAS, which was at par with control (T₁₀). Lower value was recorded in control treatment (T₁₀-3.56g plant⁻¹).

From the data, it is evident that post emergence application of acifluorfen sodium + clodinafop propargyl @ 240, 300g a.i ha⁻¹ at 15DAS and weed free check increased the pod weight by 40.0, 41.6 and 42.7 per cent, respectively over un weeded control.

4.7.4 100 Seed Weight (g)

The data pertaining to the variation in test weight (100 seed weight) of blackgram in response to post emergence herbicidal sprays at harvest are furnished in Table 4.17.

The data regarding 100-seed weight indicated that there was significant increase in seed weight due to weed control treatments. The maximum 100-seed weight observed was 4.92g versus control (3.59g) as a result of combined application of acifluorfen sodium +clodinafop propargyl (300g a.i ha⁻¹) at 15 DAS. This treatment is at par with weed free check and superior over other herbicidal treatments. The increase in 100-seed weight was possibly due to better growth and development of crop plants which resulted in more seed weight assimilation. Other herbicidal treatments recorded 100-seed weight in the range of 3.81 to 4.53g.

In the present study, T₇ and T₉ treatments increased the 100-seed weight by 37 percent over un weeded control.

4.7.5 Seed Yield (kg ha⁻¹)

The data pertaining to seed yield of blackgram as affected by different post emergence herbicide sprays are presented in Table 4.17 and Fig 4.17. The different weed control treatments produced significantly more seed yield than

weedy check, except post emergence application of acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24% EC) @ 180g (T₄) and 300g a.i ha⁻¹ (T₈) at 25 DAS, which were at par with control.

The highest seed yield was recorded with weed free check (T₉ – 1050.20 kg ha⁻¹), where yield attributes were also higher. Among different herbicides, post emergence application of acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24% EC) @ 300g a.i ha⁻¹ at 15 DAS recorded higher seed yield (T₇ – 1001.60 kg ha⁻¹) which was statistically at par to its 240g ha⁻¹ at 15 DAS (T₅ – 987.60kg ha⁻¹) due to better yield attributes. These two treatments were at par with weed free check. This significant increase in yield due to these treatments may be because of reduced crop-weed competition at critical stages as reflected by significantly low weed population and drymatter, resulting in better accumulation of photosynthates. Remaining herbicidal treatments (i.e. T₁, T₂, T₃, and T₆) were significantly superior over un weeded control. Weedy check (T₁₀) recorded lowest seed yield (591.23 kg ha⁻¹) due to heavy infestation of weeds.

In the present study, weed control treatments increased the seed yield of blackgram by 6.9 to 77.6 percent over weedy check. The treatments T₉, T₇ and T₅ increased the seed yield by 77.6, 69.4 and 67.8 per cent, respectively, over un weeded control. All the growth attributes, drymatter production and yield contributing characters were higher in these treatments. This might be due to least weed population and weed drymatter, which reduced crop weed competition for soil moisture, plant nutrients, solar radiation and space during active growth period resulting better nutrient availability, helped in rapid cell development that facilitated luxurious crop growth in these treatments. Similar results were also reported by Jha *et al.* (2014) in soybean. They stated that the combined use of clodinafop propargyl 8% EC + Na acifluorfen 16.5% SL @ 80 + 165g a.i ha⁻¹ and 100 + 206.2g a.i ha⁻¹ at 20 DAS gave significantly more seed yield in soybean.

Though imazethapyr at 50g ha⁻¹ at 15 and 25 DAS recorded significant increase in yield (25.3 and 29.9 percent, respectively) over un weeded control, but these two treatments were inferior over acifluorfen sodium + clodinafop propargyl at 240 and 300g a.i ha⁻¹ sprayed at 15 DAS. This is due to lesser weed control efficiency recorded with T₁ and T₂ treatments (50.5 and 41.6% respectively) over T₅ and T₇ treatments (70.6 and 68.0% respectively).

From the above findings, among the post emergence herbicides, it is evident that the application of acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24% EC) at 240 and 300g a.i ha⁻¹ sprayed at 15 DAS were found superior in increasing the seed yield of blackgram. Though these herbicides showed phytotoxicity (slight stunting and chlorosis of leaves) at its higher doses of 240 and 300g ha⁻¹ during initial stages (i.e. at 20 DAS), but the crop recovered and resumed to normal condition by possessing highest SOD activity (i.e. antioxidant defense system) during the first five days after herbicide application which helped in the mitigation of stress effects of these herbicides. In addition to this, these two treatments reduced the weed density and drymatter to a greater extent and recorded higher weed control efficiency, which resulted in increased drymatter production and seed yield in blackgram.

4.8 ECONOMICS

The data on the effect of post emergence herbicides on economics of blackgram was presented in Table 4.18.

Among the various weed control treatments, weed free check (T₉) recorded the highest gross returns (Rs. 42008) which was followed by post emergence application of acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24% EC) @ 300g a.i ha⁻¹ at 15 DAS (T₇- Rs.40064) and acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24% EC) @ 240g a.i ha⁻¹ at 15 DAS (T₅- Rs.39504). Remaining treatments recorded higher gross returns over un weeded control. The lowest gross returns (Rs.23649) were recorded in weedy check (T₁₀) due to unchecked weed growth, which causes severe crop-weed competition resulting in decreased yield in blackgram.

The highest net returns (Rs.24427) was observed with post emergence application of acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24% EC) @ 300g a.i ha⁻¹ at 15 DAS (T₇) followed by weed free check (T₉) and acifluorfen sodium + clodinafop propargyl @ 240g a.i ha⁻¹ at 15 DAS (T₅) with net returns of Rs. 24321 and 24267, respectively. In treatment T₇, lower cost of herbicide decreased the cost of cultivation there by increased the net returns, whereas in T₉ higher cost of labour increased the cost of cultivation leads to the decreased net returns. Even though T₆, T₂, T₃, T₁,T₈ and T₄ treatments were recorded better net returns than weedy check (T₁₀ - Rs. 10012), they were inferior compared to T₇, T₉ and T₅.

The highest benefit cost ratio (1.59) was recorded with acifluorfen sodium + clodinafop propargyl @ 240g a.i ha⁻¹ at 15 DAS (T₅), this was closely followed by acifluorfen sodium + clodinafop propargyl @ 300g a.i ha⁻¹ at 15 DAS (T₇) with 1.56 and hand weeding at 15 and 30 DAS (T₉) with 1.37 indicating the cost effectiveness of herbicides, whereas in T₉ highest cost involved in hand weeding was not compensated by the net returns resulting in lower returns per rupee invested. These results were supported by Jha *et al.* (2014).

Chapter II

REVIEW OF LITERATURE

Among the pulses, blackgram is one of the most important and extensively cultivated pulses crop. Weed management is an important key factor for enhancing the productivity of blackgram as it is having slow initial growth, encourages heavy weed infestation during early crop growth stage. The weeds compete for nutrients, water, light and space with crop plants during early growth period. Yield losses in blackgram due to weeds have been estimated to range between 30-50% (Bhan and Singh, 1991).

The critical period of crop – weed competition in blackgram crop is from 15 to 45 DAS (Vats and Sawhney, 1980). The current trends and further development of intensive agriculture are likely to seek the help of herbicides as an effective tool for weed management.

Recently some post emergence herbicides are begun marketed with the assurance of selective control of weeds in blackgram. Few post emergence herbicides like imazethapyr, acifluorfen sodium etc. are found to control both broad leaved and grassy weeds and mixed application of these herbicides is usually recommended for effective weed control in soybean crop (Jha *et al.*, 2014). Despite being selective herbicides and possess better weed control efficiency, their phytotoxic action on desired crops is reported in the literature.

The information available on the effect of these post emergence herbicides on phytotoxicity, growth, physiological parameters and yield of pulse crops and cereals were reviewed in this chapter and presented under relevant heads as follows.

Imazethapyr: It is a selective systemic herbicide and belongs to imidazolinone group.

Mode of action: Growth inhibition by imidazolinone herbicides begins within a few hours after application and injury symptoms usually appear one to two weeks later. Meristematic areas become chlorotic followed by slow foliar chlorosis and necrosis. Imazethapyr controls wide spectrum of annual broad leaved and grass weeds (Rao, 2000).

Imazethapyr is an imidazolinone herbicide, which is absorbed by both roots and shoots and can be applied as preplant incorporation (PPI), pre emergence (PE) and post emergence (PoE). Imazethapyr can control annual broadleaf and grass weeds including *Abutilon theophrasti* (velvet leaf), *Amaranthus retroflexus* (red root pigweed), *Chenopodium album* (common lambsquarters), *Sinapis arvensis* (wild mustard), *Ambrosia artemisiifolia* (common ragweed), *Solanum ptycanthum* (Eastern black nightshade), *Polygonum convolvulus* (wild buckwheat) and other *Polygonum spp* (Soltani *et al.*, 2013).

Acifluorfen sodium: It is a selective contact diphenyl ether herbicide

Mode of action: The herbicide acifluorfen causes strong photo-oxidative destruction of pigments and lipids in sensitive plant species. This herbicide is effective for control of broad leaved weeds with same effect on grasses in soybean, peanut, peas and rice. Despite being a selective herbicide, its phytotoxic action or phytotoxicity on desired crop is reported in the literature.

Clodinafop propargyl: It belongs to aryloxyphenoxy herbicide group.

Mode of action: It inhibits the enzyme acetyl CoA carboxylase which is essential for lipid biosynthesis. Growth of susceptible grass species ceases within 48 hours after application. It controls only annual grass weeds and it has no effect on dicot weeds.

Clodinafop propargyl as post emergence spray @ 30-60 g a.i ha⁻¹ effectively controlled wild oat in winter wheat and the application is best when the grasses are at tillering stage (Raffle and Flush 1992).

2.1 EFFECT OF POST-EMERGENCE HERBICIDES ON MORPHOLOGICAL PARAMETERS

Plant height is one of the morphological parameter influenced by the application of post emergence herbicides.

Jayalalitha and Rao (2003) reported that significant increase in leaf area of blackgram was recorded with imazethapyr @ 62.5 and 75.0 g a.i. ha⁻¹ over weedy check and were on a par with weed free treatment at 60 DAS.

Hand weeding at 20 and 40 DAS improved plant growth significantly followed by imazethapyr @ 75 g a.i ha⁻¹ (Kushwah and Vyas, 2006) in soybean.

Kachhadiya *et al.* (2009) reported that post emergence application of imazethapyr @ 0.050 kg ha⁻¹ at 30-35 DAS recorded significantly higher values of growth characters viz., plant height, plant spread, number of branches per plant and yield attributes in chickpea.

Sadiq *et al.* (2011) reported that application of clodinafop propargyl @ 0.2 kg a.i ha⁻¹ recorded maximum plant height due to lesser weed competition in wheat.

Wadafale *et al.* (2011) stated that application of imazethapyr @ 75 g a.i ha⁻¹ at 15 DAS + 1 hoeing and 1 hand weeding at 35 DAS improved the growth characters viz., plant height, number of leaves plant⁻¹, leaf area index and number of branches plant⁻¹ in soybean.

Basu *et al.* (2012) registered highest plant height with imazethapyr @ 150 g a.i ha⁻¹ at 30 and 60 DAS in soybean.

Soltani *et al.* (2013) stated that imazethapyr applied as PPI, PRE and POST @ 37.5, 75 and 150 g a.i ha⁻¹ caused no decrease in plant height of kidney or white bean compared to weed free control.

Sangeetha *et al.* (2014) studied the efficiency of early post emergence herbicides and integrated weed management methods in soybean for two years. The results of the pooled data revealed that the plant height and drymatter production during both the years showed a significantly marked variation across weed control treatments. EPoE (early post emergence) application of imazethapyr @ 100 g ha⁻¹ + earthing up at 45 DAS registered taller plants followed by EPoE of imazethapyr @ 200 g ha⁻¹ + earthing up at 45 DAS.

Sasikala *et al.* (2014) observed that the post emergence application of imazethapyr @ 100 g ha⁻¹ at 15 DAS increased the plant height and crop growth parameters viz., LAI and CGR next to fenoxaprop-p-ethyl and cyhalofop butyl in blackgram. A similar effect on growth parameters by the application of imazethapyr was also reported by Vasuki (2001) in soybean.

Maximum plant height was observed in plots treated with clodinafop propargyl @ 300 g a.i. ha⁻¹ at 21 DAS in wheat (Hussain *et al.*, 2015).

2.2 EFFECT OF POST EMERGENCE HERBICIDES ON PHYSIOLOGICAL PARAMETERS

Photosynthesis is the basic physiological process determining the total drymatter production (TDMP). Crop should produce optimum drymatter for good yield. Total drymatter production has a direct relationship with crop productivity.

Rao (2005) conducted an experiment to study the effect of pre and post emergence herbicides on *Echinochloa spp.* control in rice nursery. He stated that post emergence application of clodinafop propargyl @ 53 g ha⁻¹ applied at 14 DAS recorded higher dry weight of rice seedlings at 30 DAS and it was on par with the herbicides fenoxaprop-p-ethyl and cyhalofop butyl.

Wadafale *et al.* (2011) investigated the effect of some new post emergence herbicides on weed and plant growth parameters of soybean. He stated that application of imazethapyr @ 75 g a.i. ha⁻¹ at 15 DAS + 1 hoeing and 1 hand weeding at 35DAS were found superior in recording the maximum plant drymatter.

Gupta *et al.* (2012) reported that post emergence application of imazethapyr @ 20 g ha⁻¹ at 30 DAG resulted in significant improvement in dry weight plant⁻¹ than the other treatment combinations and weedy check in chickpea.

Naidu *et al.* (2012) investigated the bioefficacy and economics of herbicides against weeds of blackgram grown in rice fallow. They reported that imazethapyr @ 150 g a.i ha⁻¹ at 15 DAS recorded higher crop drymatter accumulation compared to unweeded check.

Jha *et al.* (2014) studied the influence of post emergence herbicides on weeds, nodulation, yield of soybean and soil properties. The results of the study revealed that imazethapyr 10% SL @ 100 g a.i ha⁻¹ recorded the highest plant dry weight compared to clodinafop propargyl 8% EC @ 160 g a.i ha⁻¹, acifluorfen sodium 20% SL @ 206.2 g a.i ha⁻¹ alone and weedy check and it was at par with weed free check. They further reported that the combined use of clodinafop propargyl 8% EC + acifluorfen sodium 16.5% SL @ 100 + 206.2 g a.i ha⁻¹ recorded significantly more plant dry weight than their 80 + 165 g a.i and 160 + 330 g a.i ha⁻¹ doses.

Sangeetha *et al.*, 2014 reported that weed control treatments positively influenced the drymatter production of soybean at different growth stages. At 20 days after herbicide application (DAHA), EPOE application of imazethapyr @ 100 g ha⁻¹ + earthing up at 45 DAS recorded higher drymatter production compared to imazethapyr @ 200 g ha⁻¹ + earthing up at 45 DAS and hand weeding on 25 and 45 DAS in soybean.

Sasikala *et al.* (2014) conducted a field experiment to evaluate different methods of sowing and post emergence herbicides for efficient weed control in zero till sown rice fallow blackgram during *rabi* season of two consecutive years. The results of the study indicated that, among different weed management practices, post emergence application of imazethapyr @ 100 g ha⁻¹ increased the crop growth parameters viz., leaf area index, crop growth rate, net assimilation

rate and total drymatter production next to fenoxaprop-p-ethyl and cyhalofop butyl. A similar effect on growth parameters by the application of imazethapyr was also reported by Vasuki (2001) in soybean.

2.3 EFFECT OF POST EMERGENCE HERBICIDES ON BIOCHEMICAL PARAMETERS

Alonge (2000) studied the effects of pre-emergence and post-emergence applications of four rates of imazaquin (0.00, 0.15, 0.30 and 0.45 kg a.i ha⁻¹) on the growth, leaf chlorophyll and grain yield of soybean cv.SAMSOY2. The results of the study revealed that pre and post emergence application of imazaquin showed a strong tendency to reduce the concentration of chlorophyll a and total chlorophyll at three and five WAP, respectively. This study showed that inhibition of soybean leaf chlorophyll concentration was transient and that soybean plants require about six weeks for complete recovery from imazaquin phytotoxicity.

Shaban *et al.* (2004) reported that higher values of chlorophyll a, chlorophyll b, carotenoids and total pigments were obtained with the application of clodinafop propargyl at 135 g a.i ha⁻¹ in wheat cultivar Giza 164.

Chandi *et al.* (2006) conducted an experiment to evaluate the effects of herbicides on chlorophyll, sugar content and quality parameters of *durum* wheat (*Triticum durum* Desf.) cultivars. Post emergence application of clodinafop @ 60 and 70 g ha⁻¹ was done at 35 and 45 days after sowing. The Chlorophyll and total sugar contents decreased when sampling was delayed from 10 to 30 days after herbicide spray.

Hall *et al.* (2008) conducted an experiment to study the resistance pattern and antioxidant enzyme profiles of protoporphyrinogen oxidase (PROTOX) inhibitor-resistant transgenic rice. He stated that protoporphyrinogen oxidase (PROTOX) inhibitors, acifluorfen, oxyfluorfen, carfentrazone-ethyl and oxadiazon reduced the chlorophyll content in leaves of wild-type (WT) rice but had minimal or no effect on transgenic rice line M₄. The WT rice had higher

activities of superoxide dismutase, catalase, ascorbate peroxidase and glutathione reductase than M_4 after treatment with PROTOX inhibitors. However, the induction in antioxidant activity in WT was not enough to overcome the toxic effects of a PROTOX inhibitor, so the plant eventually died.

Meng *et al.* (2008) studied the effect of two diphenylether herbicides on growth and nitrogen metabolism of peanut at the seedling stage. The effect of acifluorfen on groundnut growth was shown to exert a fairly strong inhibitory rate, and the inhibitory rate of fresh weight and dry weight were 32.85% and 30.00%. Acifluorfen application reduced the contents of chlorophyll than those of the control.

Hoseiny *et al.* (2011) conducted an experiment to study the effect of herbicide imazethapyr (1M) on chickpea seed germination. This study was carried out by using imazethapyr (1M) with five concentrations (0.5, 1, 2.5, 5, and 10 ppm) of 1M along with control under hydroponic conditions. He observed a significant decrease in chlorophyll pigment content with an increase in concentration of the herbicide in chickpea seedlings.

Lanjuan *et al.*, 2014 studied the effect of clodinafop propargyl emulsifiable concentration on antioxidative enzymes activity in leaves of seedlings of different wheat cultivars. The results of the study showed that MDA content was increased by 56.4% in the leaf of Ningmai 16 (sensitive cultivar) and chlorophyll content was decreased by 68.6% at 15 days after treatment with 120 mg L^{-1} concentration of clodinafop propargyl, at the same time, SOD, POD and GSTs activities were increased by 130.7, 123.0 and 23.3%, respectively. MDA content was increased by 32.0% in yangmai 15 (moderately sensitive cultivar), chlorophyll content and SOD activity were not increased significantly, while POD and GSTs activity was increased by 29.8% and 28.3%, respectively. Under the same treatment, the content of chlorophyll and MDA were changed invisibly in Huaimai 23 (tolerant cultivar) the activities of SOD and POD were increased by 226.0 and 63.9%, respectively GSTs activity was not increased significantly. The results suggested that tolerant wheat cultivars could enhance their antioxidant abilities to reduce the damage of herbicides stress. So there were significant differences in antioxidative activities among wheat varieties with different tolerance to clodinafop propargyl.

Ghatari and Roozbahani (2015) evaluated the chemical and mechanical weed control methods and their effects on photosynthetic pigments and grain yield of kidney bean. They stated that the effects of interaction between herbicide application and one cultivation for traits of carotenoids, chlorophyll a, chlorophyll b and total chlorophyll content were significant at 1%, and grain yield at the 5% probability levels.

Xin-an *et al.*, 2015 studied the effects of imazethapyr residue on physiological indices of succeeding crop of rape seed. He reported that the imazethapyr residue in the field inhibited the plant height and reduced the content of chlorophyll, increased the content of MDA and changed the activities of antioxidant enzymes. The activity of SOD and CAT was decreased and the activity of POD was increased with imazethapyr residue in the field.

Hajebi *et al.* (2016) undertaken a work to study the herbicides tank-mixes effects on weeds and productivity and profitability of chilli (*Capsicum annum* L.) under conventional and zero tillage. He observed that the pre-emergence tank-mix application of pendimethalin 0.75 kg ha⁻¹ + imazethapyr 0.075 kg ha⁻¹ resulted in significantly higher weed control efficacy (>86%) and leaf chlorophyll content but lower ascorbate peroxidase activity.

2.4 EFFECT OF POST EMERGENCE HERBICIDES ON CROP PHYTOTOXICITY

Phytotoxic means harmful or lethal to plants. Phytotoxicity is the degree to which a chemical or other compound is toxic to plants. Phytotoxic effects range from slight burning or browning of leaves to death of the plant. Sometimes the damage appears as leaf cupping, crinkling and speckling, distorted leaves, fruit, flowers or stems. Damage symptoms vary with the herbicide and the type of plant that has been affected. Generally, herbicides are non-phytotoxic to the crop because of their selectivity.

South (1979) reported that post emergence treatment of acifluorfen sodium @ 1.1 kg a.i ha⁻¹ recorded injury to slash pine seedlings when applied at 30 days after sowing. A post emergence treatment of 0.3 to 0.6 kg a.i ha⁻¹ did not reduce seedling vigour of slash or long leaf pine.

Mathis *et al.* (1980) reported that acifluorfen sodium at 0.125 to 1lb/acre + 0.25% Ag-98 wetter caused slight to moderate injury to soybean immediately following application of acifluorfen but the crop recovered within 14 days.

Robert (1989) stated that acifluorfen exerts its major effect of phytotoxicity through toxic products formed following light activation, lipid peroxidation, activated by photosynthetic electron transport and tetrapyrrole accumulation. Acifluorfen affects growth and phenyl propanoid metabolism in soybean and spinach.

Monks *et al.* (1993) reported that post emergence application of chlorimuron at 7 g a.i ha⁻¹ + acifluorfen at 140 g a.i ha⁻¹ control complex of weed species such as common cocklebur, common lambsquarters, common rag weed and morning glory species in soybean and soybean injury was less than 20% with this treatment at 10 days after application and was not apparent at 30 days after application.

Gaikwad and Pawar (2001) conducted a field experiment to study the bioefficacy and phytotoxicity of herbicides in soybean. He reported that the higher dose of imazaquin (240 g a.i. ha⁻¹) adversely affected yield contributing characters, which reflected in low yield of soybean because of phytotoxic effect.

Rao *et al.* (2002) observed negligible crop injury at the lowest rate i.e.50 g a.i. ha⁻¹ of imazethapyr spray in rice fallow blackgram with slight stunting of crop plants. The intensity of crop injury increased with increasing rate of imazethapyr i.e.75 g a.i. ha⁻¹ showed the maximum stunting, dark leaves and reduced leaf area expansion.

Crop injury increased with increasing rates of imazethapyr i.e. 50, 62.5 and 75.0 g a.i ha⁻¹ and the injury recorded on visual rating scale as 1, 2 and 4, respectively in rice fallow blackgram (Rao and Rao, 2002).

Jayalalitha and Rao (2003) found that imazethapyr at all four doses i.e. 37.5, 50.0, 62.5 and 75.0 g a.i. ha⁻¹ caused initial crop injury to blackgram but the crop recovered by 15 DAS.

Rao and Rao (2003) observed that post-emergence application of clodinafop propargyl @ 37.5 to 75.0 g ha⁻¹ at 20 DAS did not show any symptoms of crop injury to blackgram. However, imazethapyr at 62.5 g ha⁻¹ applied at 15 DAS initially caused stunted growth of blackgram seedlings and recovered by 15 days after application.

Rao (2005) conducted an experiment to study the effect of pre and post emergence herbicides on *Echinochloa spp.* control in rice nursery. Results revealed that post emergence application of clodinafop propargyl 53 g ha⁻¹ caused initial injury to rice, but crop recovered by 30 DAS. The visual rating on phytotoxicity of herbicides recorded at seven DAT indicated that post emergence application of clodinafop propargyl @ 53 g ha⁻¹ at 14 DAS caused initial injury to crop by showing pale yellow, tip burning etc. However, the crop completely recovered within two weeks after spray.

Singh and Punia (2007) reported that post emergence application of clodinafop propargyl (40 to 70 g ha⁻¹) at 45 DAS exhibited 20 to 53 percent crop injury in barley at two weeks after application, however, plants recovered later and no crop injury was observed at eight weeks after application.

Rao *et al.* (2010) stated that post emergence application of imazethapyr @ 50 g ha⁻¹ at 20 DAS resulted in slight injury to blackgram for about a week and then the crop resumed to normal condition.

Kundu *et al.* (2011) undertook a field experiment to assess the bio-efficacy of imazethapyr against predominant weeds in soybean and the crop safety at different doses of imazethapyr (75, 100, 125 and 150 g a.i ha⁻¹ at 10 DAS). He concluded that among the herbicidal treatments higher level of imazethapyr i.e. 150 g ha⁻¹ at 10 DAS showed the better suppression of all predominant weeds throughout crop growing season and also recorded high herbicide efficiency index, but produced relatively lower yield than imazethapyr @ 125 g ha⁻¹ at 10 DAS and also showed delay maturity due to its phytotoxicity effect on soybean crop.

Naidu *et al.* (2012) reported that post-emergence application of imazethapyr @ 150 g a.i ha⁻¹ at 15 DAS on blackgram caused crop injury to the extent of 40 percent resulted in moderate stunted growth of seedling and discoloration of developing leaves with partial loss of crop stand where as imazethapyr @ 200 g a.i ha⁻¹ at 15 DAS caused crop injury to the extent of 60 percent resulted in severe stunted growth and discoloration with significant stand loss in blackgram.

Goud *et al.* (2013) reported that application of higher dose of imazethapyr @ 100 g a.i ha⁻¹ at 25 DAS and 35 DAS significantly reduced the plant height, branches plant⁻¹, pods plant⁻¹, seed weight plant⁻¹ and root nodules over lower dose of herbicides (50g a.i ha⁻¹). The results pertaining to phytotoxicity scoring ranged from no visible injury to slight stunting injury or crop yellowing i.e. discoloration, but no plants died from the treatment in chick pea.

Asif *et al.* (2015) conducted a field experiment to evaluate and optimize the best dose of newly formulated mixture of carfentrazone ethyl + clodinafop propargyl + metsulfuron methyl for effective weed control in wheat. The results of the study revealed that lowest number of spike bearing tillers of wheat was recorded in treatment receiving the carfentrazone ethyl + clodinafop propargyl + metsulfuron methyl @ 550 g a.i ha⁻¹ at 35 DAS compared to 500g a.i ha⁻¹. This was probably due to its phytotoxic action on crop at higher concentration of herbicide mixtures.

2.5 EFFECT OF POST EMERGENCE HERBICIDES ON WEEDS

South (1979) stated that acifluorfen sodium provided effective post emergence control of broad leaf weeds and it did not show residual activity comparable to that of oxyfluorfen.

Mathis *et al.* (1980) reported that acifluorfen sodium at 0.125 to one lb/acre + 0.25% Ag-98 wetter on soybean effectively controlled *sesbania*, *crotalaria*, morning glory, *amaranthus*, *physalis* and *xanthium* weeds.

Monks *et al.* (1993) reported that post emergence application of chlorimuron at 7 g a.i ha⁻¹ + acifluorfen at 140 g a.i ha⁻¹ controlled complex weed species such as cocklebur, lambsquarters, rag weed and morning glory species in soybean.

Rao and Rao (2003) reported that post-emergence application of clodinafop propargyl at 52.5 to 75.0 g ha⁻¹ recorded the highest per cent of weed control efficiency (from 89 to 94%) which was on a par with hand weeding at 25 DAS in blackgram.

Rao (2005) stated that application of post emergence herbicide clodinafop propargyl @ 53 g ha⁻¹ at 14 DAS recorded higher weed control efficiency (WCE) of 85 to 89 percent in rice nursery.

Tambe *et al.* (2005) conducted an experiment to study the performance of different herbicides against weeds in *kharif* groundnut. He reported at two hand weedings at 15 and 30 DAS followed by imazapic 24% AS @ 500 ml ha⁻¹ applied as pre emergence (two days after sowing) was found effective for controlling weeds in *kharif* groundnut.

Kushwah and Vyas (2006) reported that hand weeding twice at 20 and 40 DAS followed by imazethapyr @ 75 g a.i ha⁻¹ application in soybean recoded the lowest weed drymatter.

Tiwari *et al.* (2006) conducted a field experiment to study the effect of soil solarisation and herbicides on weed control in soybean. He stated that the maximum weed control efficiency was recorded under soil solarization for 45 days followed by imazethapyr at 100 g ha⁻¹ at 20 DAS (applied as early post emergence at 2-3 leaf stage of weeds).

Khogali and Idris (2014) reported that imazethapyr at 0.01 and 0.02 kg a.i ha⁻¹ applied immediately after sowing as pre emergence treatment resulted in good to excellent control of broad leaved weeds throughout the growing season of snap bean.

Sharma *et al.* (2007) reported that post emergence application of clodinafop propargyl @ 75 g a.i ha⁻¹ with sequential application of pendimethalin @ 0.75 g a.i ha⁻¹ (pre- emergence) followed by clodinafop propargyl @ 45 g a.i ha⁻¹ (post emergence) at 45 DAS significantly reduced the total weed drymatter and count and were statistically at par with hand weeding twice in Gobhi sarson.

Bibi *et al.* (2008) reported that clodinafop propargyl @ 0.04 kg a.i ha⁻¹ at 35 DAS in wheat exhibited the best performance with minimum weed density and weed fresh biomass as compared to weedy check.

Veeraputhiran *et al.* (2008) reported that post emergence application of imazethapyr @ 90 g a.i ha⁻¹ at 21 days after sowing recorded lower weed density, weed dry weight in blackgram compared to unweeded control.

Rao *et al.* (2010) stated that pre emergence sand mix application of pendimethalin 1.0 kg followed by sequential application of imazethapyr 50 g a.i ha⁻¹ at 20 DAS recorded higher weed control efficiency (WCE) of 70% at 60 DAS in blackgram.

Ali *et al.* (2011) reported that imazethapyr @ 100 g ha⁻¹ at 15-20 DAS was most effective in minimizing weed infestation and recorded significantly less dry weight of weeds in green gram.

Kundu *et al.* (2011) observed that the maximum suppression of all the weed density, weed biomass and highest weed control efficiency were obtained with hand weeding done at 20 and 40 days after sowing and closely followed by the treatment with imazethapyr @ 150 g a.i ha⁻¹ and imazethapyr 125 g a.i ha⁻¹, respectively in soybean.

Sadiq *et al.* (2011) reported that application of clodinafop propargyl @ 0.2 kg a.i ha⁻¹ at 3-4 leaf stage of chickpea recorded significantly lesser weed density compared to weedy check.

Wadafale *et al.* (2011) stated that application of imazethapyr @ 75 g a.i. ha⁻¹ at 15 DAS + one hoeing and one hand weeding at 35 DAS were found more effective in controlling weeds throughout growth period in soybean.

Bera *et al.* (2012) worked on bio-efficacy and phytotoxicity of new molecule herbicides for weed management in soybean. He reported that UPH-203 @ 100.0 g ha⁻¹ + Na- Acifluorfen 10% SL @ 206.2 g ha⁻¹ decreased the weed population of grasses, sedges and broadleaf weeds and their dry weights over untreated control.

A field experiment was conducted to study the effect of imazethapyr on weed control and yield in chickpea under *kandi* belt of low altitude sub tropical zone of Jammu. Post emergence application of imazethapyr @ 20 g a.i ha⁻¹ at 30 DAG resulted in significant reduction in total weed density and weed biomass (Gupta *et al.*, 2012)

Naidu *et al.* (2012) investigated the bioefficacy and economics of herbicides against weeds of blackgram grown in rice fallow. He reported that post emergence application of imazethapyr @ 200 g a.i ha⁻¹ and 150 g a.i ha⁻¹ at 15 DAS significantly reduced the density and dry weight of weeds in blackgram.

Shehzad *et al.* (2012) reported that clodinafop propargyl @ 60 g a.i ha⁻¹ applied after first irrigation in wheat at tillering stage was found to be the most effective in reducing the weed population as well as biomass with maximum mortality after 15 days of herbicides application (DAHA) as compared to weedy check.

Goud *et al.* (2013) studied the efficacy of imazethapyr and quizalofop-ethyl herbicides on growth and yield of chickpea. The results of the study revealed that the application of imazethapyr @ 100 g ha⁻¹ at 25 and 35 DAS recorded lowest dry weight of weeds at all the growth stages of chickpea. However, imazethapyr was effective against annual broad leaf weeds and grass weeds.

Jha *et al.* (2014) conducted an experiment to study the influence of post emergence herbicides on weeds and yield of soybean. He stated that imazethapyr 10% SL @ 100 g a.i. ha⁻¹ showed maximum weed control efficiency and minimum weed index and it was comparable with clodinafop-propargyl 8% EC + Na-acifluorfen 16.5% SL @ 100 + 206.2 g a.i. ha⁻¹.

Asif *et al.* (2015) reported that post emergence application of carfentrazone ethyl + clodinafop propargyl + metsulfuron methyl @ 500 g ha⁻¹ at 35 DAS was proved to be the best in reducing weed density in wheat.

Hussain *et al.* (2015) stated that post emergence application of clodinafop propargyl @ 300 g a.i. ha⁻¹ at 21 DAS was quite effective to control the weed density and weed biomass present in wheat fields.

2.6. EFFECT OF POST EMERGENCE HERBICIDES ON YIELD ATTRIBUTES AND YIELD

Jayalalitha and Rao (2003) reported highest number of pods plant⁻¹ in imazethapyr treated plots @ 62.5 and 75.0 g a.i. ha⁻¹ and were on a par with weed free check. No significant difference was observed in number of seeds pod⁻¹. The highest rate of imazethapyr 75.0 g a.i. ha⁻¹ recorded significantly more test weight.

Tambe *et al.* (2005) conducted an experiment to study the performance of different herbicides against weeds in *khariif* groundnut. He reported that the higher dry pod yield was obtained with two hand weedings at 15 and 30 DAS followed by application of imazapic 24% AS at 500 ml/ha as pre emergence (two days after sowing) over control treatment.

Kushwah and Vyas (2006) worked on the efficacy of herbicides against weeds in rainfed soybean. He observed that the hand weeding at 20 and 40 DAS followed by imazethapyr @ 75 g ha⁻¹ significantly increased the yield.

Mahadevappa *et al.* (2007) studied the relative efficacy of trifluralin and imazethapyr for weed control in lucerne. He stated that early post emergence application of imazethapyr @ 0.2 kg a.i ha⁻¹ successfully checked the sprouting of cuscuta which resulted increase in yield of lucerne.

Sharma *et al.* (2007) reported that post emergence application of clodinafop propargyl @ 75g a.i ha⁻¹ with sequential application of pendimethalin @ 0.75g a.i ha⁻¹ (pre- emergence) followed by clodinafop propargyl @ 45 g a.i ha⁻¹ (post emergence) at 45 DAS gave the highest yield which was comparable to hand weeding twice in Gobhi sarson .

Bibi *et al.* (2008) investigated effect of planting density and post emergence herbicides in wheat. She reported that clodinafop propargyl @ 0.04 kg a.i ha⁻¹ at 35 DAS recorded maximum grain yield and number of tillers in wheat.

Veeraputhiran *et al.* (2008) reported that post emergence application of imazethapyr @ 90 g a.i ha⁻¹ at 21 days after sowing recorded higher growth, yield and yield attributes in blackgram compared to un weeded control.

Rao *et al.* (2010) stated that post emergence application of imazethapyr @ 50 g ha⁻¹ at 20 DAS recorded significantly the highest seed yield in blackgram due to reduced weed growth.

Ali *et al.* (2011) reported that maximum yield of green gram can be achieved with the application of imazethapyr 100 g ha⁻¹ at 15-20 days after sowing in green gram.

Sadiq *et al.* (2011) reported that application of clodinafop propargyl @ 0.2 kg a.i ha⁻¹ at 2-3 leaf stage of chickpea significantly increased the yield compared to weedy check.

Gupta *et al.* (2012) reported that post emergence application of imazethapyr @ 20 g ha⁻¹ at 30 DAG gives significant improvement in yield attributing characters viz., no. of pods plant⁻¹, no. of seeds pod⁻¹, seed index and seed yield of chick pea than other treatment combinations and weedy check.

Jha *et al.* (2014) studied the influence of post emergence herbicides on weeds and yield of soybean. He stated that imazethapyr 10% SL @ 100 g a.i. ha⁻¹ gave the highest grain yield and straw yield and it was comparable with clodinafop propargyl 8% EC + Na-acifluorfen 16.5% SL with 100 + 206.2 g a.i. ha⁻¹, respectively.

Naidu *et al.* (2012) studied the bio-efficacy and economics of herbicides against weeds of blackgram grown in rice fallow. He reported that imazethapyr @ 150 g a.i ha⁻¹ at 15 DAS recorded maximum number of pods plant⁻¹.

Shehzad *et al.* (2012) reported that maximum spike bearing tillers, number of grains per spike, 1000 grain weight, straw yield and grain yield were obtained with clodinafop propargyl at 60 g a.i ha⁻¹ which was applied after first irrigation at tillering stage in wheat.

Kundu *et al.* (2011) investigated the bio-efficacy of imazethapyr on predominant weeds of soybean. He reported that the application of imazethapyr @ 125 g ha⁻¹ at 10 DAS recorded the highest yield of soybean.

Goud *et al.* (2013) stated that the highest yield attributes, *viz.*, branches plant⁻¹, pods plant⁻¹, seed weight/plant and 100 seed weight were recorded with the application of imazethapyr @ 75 g ha⁻¹ at 25 and 35 DAS, respectively over other herbicide treatments in chick pea.

Reddy *et al.* (2013) studied bio-efficacy and phytotoxicity of imazethapyr on the predominant weeds in soybean. He reported that higher economic yields can be achieved in soybean with imazethapyr 10% SL at 100 g ha⁻¹ at three DAS due to effective control of weeds.

The highest pod yield was achieved by applied immediately after sowing as pre- emergence treatment mixture of pendimethlin at 0.50 and 0.75 kg a.i/ fed and imazethapyr at 0.01 and 0.02 kg a.i/fed, which gave yield comparable to the hand weeded control reported by Khogali and Idris (2014).

Sangeetha *et al.* (2014) worked on the efficiency of early post emergence herbicides and integrated weed management methods in soybean and their residual effect on succeeding crops. She reported that application of imazethapyr @ 100 g a.i ha⁻¹ at 45 DAS recorded higher grain yield.

Singh *et al.* (2014) reported that the combined application of imazethapyr at lower rate 100 g a.i ha⁻¹ with chlorimuron 24 g a.i ha⁻¹ paralyzed the weed growth significantly to that of hand weeding twice and attained the superior values of yield attributes as well as higher pod and haulm yield over rest of the treatments.

Asif *et al.* (2015) reported that herbicide application increased yield and yield components of wheat by controlling weeds. Application of carfentrazone ethyl + clodinafop propargyl + metsulfuron methyl @ 500 g ha⁻¹ at 35 DAS produced significantly higher number of spike bearing tillers, grains spike⁻¹, 1000 grain weight and grain yield.

Chavan *et al.* (2015) studied the influence of chemical weed management on yield attributes, yield and economics of soybean. He stated that weed free check recorded high number of pods plant⁻¹ which was at par with imazethapyr @ 75 g a.i ha⁻¹ applied at 10-15 DAS.

Hussain *et al.* (2015) investigated the efficacy of different post emergence herbicides in controlling weeds in wheat. He stated that application of clodinafop propargyl @ 300 g a.i. ha⁻¹ effectively controlled weeds which increased crop growth and yield.

Jakhar *et al.* (2015) observed that the highest grain yield was obtained in weed free treatment that showed statistical equivalence with imazethapyr at 100 g a.i ha⁻¹ applied at 20 DAS in soybean.

Chapter V

SUMMARY AND CONCLUSIONS

The present investigation entitled “Effect of post emergence herbicides on growth, physiological parameters and yield of blackgram” was undertaken at Agricultural College Farm, Bapatla during *kharif*, 2015. The experiment was laid out in a Randomised Block Design with three replications and ten treatments viz., post emergence application of imazethapyr 10% EC @ 50g a.i ha⁻¹ at 15DAS (T₁), imazethapyr 10% EC @ 50g a.i ha⁻¹ at 25DAS (T₂), acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24% EC) @ 180g a.i ha⁻¹ at 15DAS (T₃), acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24% EC) @ 180g a.i ha⁻¹ at 25DAS (T₄), acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24% EC) @ 240g a.i ha⁻¹ at 15DAS (T₅), acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24% EC) @ 240g a.i ha⁻¹ at 25DAS (T₆), acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24% EC) @ 300g a.i ha⁻¹ at 15DAS (T₇), acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24% EC) @ 300g a.i ha⁻¹ at 25DAS (T₈), Weed free check (Hand weeding at 15 and 30 DAS) (T₉) and Un weeded control (T₁₀). The results are summarized below.

Post emergence application of imazethapyr 10% EC @ 50g a.i ha⁻¹ at 15 and 25 DAS caused crop injury to the extent of 10 per cent resulting in slight stunting and yellowing/discoloration of developing leaves at 5 and 10 days after herbicide application (DAHA), the effect was negligible at 15 DAHA, blackgram plants recovered from phytotoxicity and the symptoms disappeared by 40DAS.

Combined use of acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24% EC) @ 180g a.i ha⁻¹ at 15 and 25 DAS did not cause crop injury, whereas these herbicides at its higher doses i.e. 240 and 300 g ha⁻¹ sprayed at 15 DAS showed crop injury to the extent of 20 and 30 per cent, respectively,

resulted in stunting and discoloration of meristematic leaves at 5 DAHA, indicating a condition of oxidative stress in blackgram due to herbicide injury. However, blackgram plants completely recovered by 10 DAHA by possessing highest SOD activity (antioxidant defense enzyme activity) in the first five days after application and the toxic effects did not persist for long and ultimately no deleterious effect on the mature plants was observed.

Acifluorfen sodium + clodinafop propargyl @ 300g a.i ha⁻¹ at 25 DAS caused 40 percent crop injury resulted in severe stunting , discoloration and wilting of leaves at 5 DAHA and the symptoms remain unchanged upto maturity which adversely affected growth attributes, chlorophyll content and yield of blackgram.

Weed free check and post emergence application of acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24% EC) @ 300 and 240 g a.i ha⁻¹ at 15 DAS recorded superior performance by increasing the plant height by 56.6,55.9 and 55.2 per cent, respectively, over un weeded control at harvest. Acifluorfen sodium + clodinafop propargyl @ 300g a.i ha⁻¹ at 15 DAS and two hand weedings treatment (at 15 and 30 DAS) increased the number of branches by 49.2 per cent compared to weedy check at maturity.

All the weed control treatments increased the leaf area, which ranged between 10.2 to 63.8 per cent over weedy check at 60 DAS. Post emergence application of acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24% EC) @ 300 and 240 g a.i ha⁻¹ at 15 DAS and weed free treatment increased the leaf area by 63.8 and 62.6 per cent over control . Imazethapyr application at 50 g ha⁻¹ at 15 and 25 DAS registered lesser leaf area compared to acifluorfen sodium + clodinafop propargyl @ 300 and 240 g a.i ha⁻¹ at 15 DAS.

At 60 DAS, post emergence application of acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24% EC) @ 300 , 240 g a.i ha⁻¹ at 15 DAS and weed free treatment (i.e. hand weeding at 15 and 30 DAS) exhibited better performance in increasing leaf drymatter by 32.6, 32.0 and 32.6 per cent

respectively, over un weeded control. Weed free check and the combined use of acifluorfen sodium + clodinafop propargyl @ 300 and 240 g a.i ha⁻¹ at 15 DAS increased the stem drymatter by 3.10, 2.97 and 2.86g over un weeded control at harvest. Maximum increase in the drymatter of reproductive parts was observed with weed free treatment (42.7 per cent) followed by the combined use of acifluorfen sodium + clodinafop propargyl at 300 (41.6 per cent) and 240 g a.i ha⁻¹ (40.0 per cent) sprayed at 15 DAS compared to un weeded control.

Two hand weedings at 15 and 30 DAS (weed free check) and post emergence application of acifluorfen sodium + clodinafop propargyl @ 300 and 240 g a.i ha⁻¹ at 15 DAS increased the total drymatter by 1.56, 1.54 and 1.50 folds, respectively, over un weeded control at harvest. These three treatments significantly reduced the weed population by 78, 48 and 43.7 per cent (monocot weeds) and 95, 84 and 83.7 per cent (dicot weeds) and weed drymatter by 77.8, 61.4 and 57.9 per cent (monocot weeds) and 87, 77.9 and 75.9 per cent (dicot weeds), respectively, over un weeded control at 60 DAS and registered higher weed control efficiencies i.e. 83, 70.6 and 68 per cent, respectively.

Imazethapyr at 50 g ha⁻¹ sprayed at 15 and 25 DAS recorded comparatively higher weed drymatter (i.e. both monocots and dicots) over acifluorfen sodium + clodinafop propargyl @ 300 and 240 g a.i ha⁻¹ at 15 DAS. This is due to low rates of imazethapyr application (50 g ha⁻¹) at 15 and 25 DAS could not able to control the weed population which resulted in lesser weed control efficiency (i.e. 50.5 and 41.6 per cent), respectively.

Combined use of acifluorfen sodium + clodinafop propargyl @ 300g a.i ha⁻¹ sprayed at 25 DAS is significantly inferior to its 300g ha⁻¹ sprayed at 15 DAS by recording higher weed density and drymatter at 30 and 60 DAS as it could not effectively controlled weed population, because by that time (i.e. spraying at 25 DAS), the weeds established well and created severe competition to blackgram for moisture and nutrients and ultimately resulted lesser weed control efficiency (48.5 per cent) compared to 300g ha⁻¹ sprayed at 15 DAS (70.6 per cent).

Photosynthetic pigments viz., chlorophyll a, chlorophyll b and total chlorophyll contents decreased in blackgram leaves during first five days after herbicide application due to phytotoxicity of these herbicides. However, the blackgram plants recovered from the phytotoxicity of acifluorfen sodium plus clodinafop propargyl and imazethapyr by 10 days after herbicide application i.e. by 25DAS. Weed free check and acifluorfen sodium + clodinafop propargyl @ 300 and 240 g a.i ha⁻¹ applied at 15 DAS increased the total chlorophyll content by 34.3, 28.7, and 27.2 per cent, respectively, over un weeded control at 40 DAS, whereas acifluorfen sodium + clodinafop propargyl @ 300g a.i ha⁻¹ applied at 25 DAS showed damage to the blackgram crop upto 40 DAS (i.e. upto 15 DAHA) and recorded lesser total chlorophyll content.

A reduction in carotenoid content in blackgram leaves was recorded during first five days after herbicide application in all the weed control treatments, except weed free check, indicating a condition of oxidative stress in blackgram plants due to herbicide injury, which caused oxidative degradation of chlorophylls and resulted in tissue discoloration and necrosis. But by 15 DAHA, acifluorfen sodium + clodinafop propargyl @ 300 and 240 g a.i ha⁻¹ increased the carotenoid content in blackgram leaves by 9.4 and 8.7 per cent, respectively, over weedy check due to the recovery of blackgram plants from herbicide injury, which might have imparted tolerance to herbicide stress in terms of higher antioxidative properties (i.e. higher carotenoid content).

The effect of post emergence herbicides, acifluorfen sodium + clodinafop propargyl @ 240 and 300 g a.i ha⁻¹ applied at 15 DAS on the superoxide dismutase activity (i.e. antioxidant enzyme activity) seem to be more evident in the first five days after application, indicating a condition of oxidative stress in blackgram due to herbicide injury. These herbicides increased the SOD activity by 44.9 and 48.5 per cent, respectively, over weed free check (i.e. no herbicide stress), and by 18.8 and 21.8 per cent, respectively, over unweeded control at 20 DAS. But by 40 DAS, the crop recovered from these herbicides stress and exhibited SOD activity similar to that of weed free check (i.e. no herbicide stress) and lesser than un weeded control and other herbicidal treatments, which

were applied at 25 DAS. Un weeded control recorded higher SOD activity upto 40 DAS due to the competition of weeds with blackgram for moisture, nutrients, light and space which might have resulted oxidative stress in blackgram.

Different weed control treatments increased the number of pods per plant from 2.7 to 65.9 per cent compared to weedy check. Weed free check and post emergence application of acifluorfen sodium + clodinafop propargyl @ 300 and 240 g a.i ha⁻¹ at 15 DAS increased the pods per plant by 65.9, 58.8 and 52.7 per cent, respectively, over un weeded control. The highest number of seeds per pod (5.2) was recorded under hand weeding twice at 15 and 30 DAS, followed by post emergence application of acifluorfen sodium + clodinafop propargyl @ 300 (4.9) and 240 (4.8) g a.i ha⁻¹ at 15 DAS.

Post emergence application of acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24% EC) @ 240, 300 g a.i ha⁻¹ at 15 DAS and weed free treatment increased the pod weight by 40.0, 41.6 and 42.6 per cent , respectively, over un weeded control. There was a significant increase in 100 seed weight (test weight) due to weed control treatments. The maximum 100- seed weight observed was 4.92g versus control (3.50g) as a result of combined application of acifluorfen sodium + clodinafop propargyl @ 300 g a.i ha⁻¹ at 15 DAS and this treatment is at par with weed free check (4.92 g) and superior over other herbicidal treatments. These two treatments increased the 100- seed weight by 37 per cent over un weeded control.

All the weed control treatments increased the seed yield of blackgram by 6.9 to 77.6 per cent over weedy check. Weed free check and post emergence application of acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24% EC) @ 300 and 240 g a.i ha⁻¹ at 15 DAS increased the seed yield by 77.6, 69.4 and 67.8 per cent, respectively, over un weeded control. Though, imazethapyr @ 50 g ha⁻¹ at 15 and 25 DAS recorded significant increase in yield (25.3 and 29.9 per cent, respectively) over un weeded control, but these two treatments were inferior over the combined use of acifluorfen sodium + clodinafop propargyl at 240 and 300g a.i ha⁻¹ at 15 DAS.

Conclusion

Among the post emergence herbicides, the combined use of acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24%) EC @ 300 and 240g a.i ha⁻¹ at 15 DAS recorded higher weed control efficiencies by reducing weed density and drymatter to a maximum extent during critical period of crop-weed competition in blackgram which might have helped in recording higher growth attributes i.e. more number of branches, leaf area and drymatter accumulation,

Though these herbicides at its higher doses i.e. 240 and 300 g ha⁻¹ at 15 DAS caused phytotoxicity during initial stages (i.e. first five days after herbicide application), the toxic effects did not persist for long, gradually decreased and the crop resumed to normal condition by 15 days after herbicide application by possessing higher antioxidative properties in terms of higher total chlorophyll, carotenoid pigments and superoxide dismutase activity, which helped in the mitigation of herbicide injury.

Apart from this, these two treatments also possessed higher yield attributes and yield. Though, the yield and growth attributes are maximum in the twice hand weeded plot, but it involves higher labour cost and increased the cost of cultivation, which lead to decreased net returns. The highest benefit cost ratio was recorded with acifluorfen sodium + clodinafop propargyl @ 240g a.i ha⁻¹ (i.e. 1.59) and this was closely followed by acifluorfen sodium + clodinafop propargyl @ 300g a.i ha⁻¹ (i.e. 1.56).

From this study, it can be concluded that post emergence application of acifluorfen sodium 16% EC + clodinafop propargyl 8% EC (24% EC) @ 240g a.i ha⁻¹ at 15 DAS is recommended for weed control in blackgram as it improved the growth, physiological parameters, photosynthetic pigments and yield of blackgram.