Bio-efficacy of cyhalofop-butyl 10 per cent EC against weeds in direct-sown rice (*Oryza sativa* L.) and their residual effect on mustard (*Brassica juncea* L.)

काशी हिन्दू विश्वविद्यालय
BANARAS HINDU UNIVERSITY

THESIS
SUBMITTED IN PARTIAL FULFILMENT OF THE
REQUIREMENTS FOR AWARD OF
Master of Science (Agriculture)
in
Agronomy

Supervisor
Prof. J.K. Singh

Submitted by
Amit Kumar Yadav

DEPARTMENT OF AGRONOMY
INSTITUTE OF AGRICULTURAL SCIENCES
BANARAS HINDU UNIVERSITY
VARANASI- 221 005
INDIA

Examination Roll No. 19412AGR001 2021 Enrollment No. 417411

काशी हिन्दू विश्वविद्यालय
BANARAS HINDU UNIVERSITY

Department of Agronomy
Institute of Agricultural Sciences
Banaras Hindu University
Varanasi - 221005

Prof. J. K. Singh
Professor
Mobile No. 094503 47087
E-mail jksinghbhu3@gmail.com
Fax 0542-2368993

Ref. No. ……………….. **Date:…..-09-2021**

CERTIFICATE

To
The Joint Registrar (Academic),
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Varanasi-221 005 (India)

Through: **The Head**, Department of Agronomy,
Institute of Agricultural Sciences,
BHU, Varanasi, 221 005.

Sir,

I have great pleasure in forwarding the thesis entitled **"Bio-efficacy of cyhalofop-butyl 10 per cent EC against direct-sown rice (*Oryza sativa* L.) and their residual effect on mustard (*Brassica juncea* L.)"** submitted by **Mr. Amit Kumar Yadav**, (**Examination Roll No. 19412AGR001; Enrolment No. 417411)** in partial fulfillment of the requirements for the degree of **Master of Science (Agriculture)** in **Agronomy**, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (U.P.) and placing on record that he has completed the requisite residential requirements as contained in the statutes of the university.

I certify that the entire scheme of investigation presented herein was planned and carried out solely by the candidate under my guidance and supervision. The data presented in thesis, to the best of my knowledge and belief, are genuine and original.

Thanking you,

Yours faithfully,

Forwarded by

(J. K. Singh)
Supervisor

Head

BHU
capital of knowledge

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VARANASI - 221 005 INDIA

2021

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MEMBER	**Dr. M. K. Singh** **Professor** Department of Agronomy Institute of Agricultural Sciences, BHU, Varanasi.
MEMBER	**Dr. P. K. Sharma** **Professor** Department of Soil Science and Agril. Chemistry Institute of Agricultural Sciences, BHU, Varanasi.

EXTERNAL EXAMINER

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Date: ...09-2021
Place: *Varanasi*

(Amit Kumar Yadav)

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LIST OF ABBREVIATIONS

%	-	Percentage
°C	-	Degree centigrade
@	-	at the rate of
`	-	Rupees
a.i.	-	Active ingredient
B: C	-	Benefit: Cost
CD	-	Critical difference
cm	-	Centimeter
DAS	-	Days after sowing
dS m^{-1}	-	deci Siemen per meter
DSR	-	Direct-sown rice
e.g.	-	for example (exempli *gratia*)
EC	-	Emulsion Concentrate
et al.	-	and others (*et alibi*)
etc.	-	and so forth (*et cetera*)
Fig.	-	Figure
g	-	Gram
ha	-	Hectare
i.e.	-	That is (*id est*)
K	-	Potassium
kg ha^{-1}	-	kilogram per hectare
kg	-	kilogram
m	-	meter
M.S.S.	-	Mean sum of square
Max.	-	Maximum
mg	-	milligram
Mha	-	Million hectare
Min.	-	Minimum
MSL	-	Mean Sea Level
N	-	Nitrogen
No.	-	Number
NS	-	Non-significant
P	-	Phosphorus
ppm	-	Part per million
R.H.	-	Relative humidity
SEm	-	Standard error of mean
Spp.	-	Species
t ha^{-1}	-	tonnes per hectare
Viz.	-	Namely (*videlicet*)

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Chapter I

INTRODUCTION

Rice (*Oryza sativa* L.) is a staple food for more than 60 per cent of the world's population and plays an important role in the world's economic and social stability. After China, India is the world's second largest producer of rice. Rice is grown on 160.6 million ha of land worldwide, with a total production of 490.3 million tonnes in 2015-2016. **(FAO, 2016)**. Rice cultivation area in India is approximately 43.78 million ha, with a total production of 121.46 million tonnes in 2020-2021. **(Directorate of Economics & Statistics, 2020-2021)**. Uttar Pradesh is the second-largest rice-growing state in the country, after West Bengal, with an area of about 5.87 million ha and a production of 15.52 million tonnes and a productivity of 2.7 t ha^{-1}, respectively. **(Directorate of Economics & statistics, 2019-20)**. Rice is the most important cereal crop in the world **(Ashraf *et al*., 2006),** with more than half of the human population relying on it for daily sustenance **(Chauhan and Johnson, 2011)**. It is the primary source of income and employment for more than 100 million Asian households. To keep up with population growth, the world's rice demand is expected to rise by 25% from 2001 to 2025, making meeting ever-increasing rice demand in a sustainable manner with diminishing natural resources a major challenge **(Singh *et al*., 2016)**.

In Asia, 58.6 per cent of rice growing land is irrigated, 32.1 per cent is rainfed lowland, 6.7 per cent is upland, and 2.6 per cent is deep water cultivation. Thus, among the four rice ecosystems, irrigated rice is the most important system in terms of both area coverage and production. Irrigated rice accounts for more than half of global rice area and meets more than 75 per cent of global rice demand **(FAO, 2007)**. Unfortunately, due to water scarcity, this most important rice ecosystem is becoming increasingly endangered, threatening global food security **(Singh *et al*., 2016)**. In many Asian countries, including India, increased production costs, farm worker shortages, higher wages, and decreased groundwater availability have resulted in the transition from traditional paddy nursery transplanting to dry direct seeding of rice

(Mahajan *et al.*, 2013). Direct seeded rice requires only 34% of the total farm workers required and saves 29% of the total cost of the transplanted crop **(Ho and Romli, 2000).** It also allows for the early establishment of successful wheat crops, lowers methane emissions, and ensures higher profits in areas with guaranteed water supply **(Balasubramanian and Hill, 2000).**

Weeds are a major biotic stress to rice production in direct seeded systems because they increase production costs and cause yield loss. Weeds reduce rice yield by 40-100 per cent in direct seeded rice **(Choubey *et al.*, 2001)**. Weed growth reduced grain yield by up to 53 and 74% in wet seeded rice, respectively **(Ramzan, 2003)**. **Remington and Posner (2000)** conducted research on weed control in rice cultivation in Gambia and discovered that every day delay in weeding causes a 25 kg ha^{-1} decrease in crop yield in direct cultivation.

Given the foregoing, there is a need to manage weeds during critical crop-weed competition periods using either physical methods or herbicides. Manual weeding has traditionally been the most common method of weed control due to the alleged abundance of farm workers at low wages. However, the situation is changing fast. There are many areas where the non-availability of farm workers during peak periods of farm operations, the tediousness and time-consuming nature of manual operation, and unfavourable weather conditions force a delay in weeding operation, resulting in crop losses. Furthermore, manual weeding in rice is not only expensive and difficult, but also time consuming due to the morphological similarity of grass type weeds and the rice crop, particularly during early growth stages. Further cultural and mechanical methods are less effective due to the possibility of weed seed escape and regeneration, as well as the continued germination of weed seeds buried in the soil.

In India, a number of herbicides have been developed for weed control in rice, but none of them can be used alone to control a wide range of weeds in rice effectively and economically. Furthermore, the herbicides currently available for rice have a limited selectivity range, and the weed species that compete with rice may shift as a result of long-term use of a specific herbicide. As a result, continuous development and evaluation of new herbicide chemistry is critical to mitigating emerging problems of weed shift and herbicide resistance in weeds. Furthermore, sequential/mixed herbicide application appears to be more promising than individual herbicide application. cyhalofop-butyl is a post-emergence herbicide used to control a broad range of weeds, particularly broad leaf infesting rice. However, literature on its use in direct seeded rice, either alone or in combination with other rice herbicides, is limited and scarce.

Keeping these facts in view, the current investigation, titled "**Bio-efficacy of cyhalofop-butyl 10 per cent EC against weed in direct-sown rice (*Oryza sativa* L.) and their residual effect on mustard (*Brassica juncea* L.)**" was carried out during the rainy (*kharif*) season of 2020 at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh (India), with the following objectives:

i) To evaluate the bio-efficacy of cyhalofop butyl 10% EC against weeds

ii) To evaluate the phytotoxicity of cyhalofop-butyl 10% EC in rice

iii) To find out relative economics of the treatment

iv) Effect on succeeding crop growing in same field/ plot in the coming season.

REVIEW OF LITERATURE

In this chapter, an effort has been made to present a concise and coherent picture of the progress made thus far on various aspects related to the current investigation. The available information and literature are reviewed under the various head and subheads based on the different experimental variable information of the current project. Major emphasis has been given on the work pertaining to the present research work entitled "**Bio-efficacy of cyhalofop-butyl 10 per cent EC against weeds in direct-sown rice (*Oryza sativa* L.) and their residual effect on mustard (*Brassica juncea* L.)**".

2.1 Dry-seeded rice weed flora

The following weed species observed in the experimental field were *Echinochloa colona, Digitaria marginata, Dactyloctenium aegyptium, Ageratum conyzoides, Commelina benghalensis, Cyanotis axillaris, Croton bonplandianum, Spilanthus acmella*, *Acanthospermum hispidum, Mollugo disticha, Phyllanthus niruri, Celosia argentea*, *Protulaca oleraceae*, *Aeschynomene indica*, *Cyperus rotundus* and *Cyperus esculentus* **(Sunil *et al*., 2010).**

A field experiment conducted in West Bengal during the *Kharif* seasons revealed that weed flora during the experiment, grasses like *Cynodon dactylon* and *Echinochloa colona* emerged, as did sedges like *Cyperus rotundus, Cyperus iria*, and *Fimbristylis miliacea*, and broadleaf weeds like *Ludwigia parviflora*, *Ageratum conyzoides*, *Spilanthes paniculata*, and *Enhydra fluctuans*. **(Maity *et al.*, 2011).**

During *Kharif*, a field experiment at G.B Pant University of Agriculture and Technology in Pantnagar discovered that the major weed flora that emerged was During both years, *Echinochloa colona* was the dominant weed species in the experimental site, followed by *Commelina benghalensis* and *Caesulia axillaris* among non-grasses and *Cyperus rotundus* among sedges. **(Kumar *et al.*, 2012).**

Conducting experiments in silty clay soil in Kerala, observed that major weed flora in experimental site indicated that sedges were the predominant nongrassy weeds present in the experimental field were *Fimbristylis miliacea*, *Cyperus difformis*, *Cyperus iria and Schenoplectus pungens* among the sedges and *Monochoria vaginalis*, *Ludwigia perennis* and *Sphenoclea zeylanica* were the dominant broadleaf weeds species present in the field. On an average, total non-grassy weed population at 30 DAS comprised of broadleaf weeds (9.69%) and sedges (90.31%). At 60 DAS, total non-grassy weed population comprised of broadleaf weeds (13.22%) and sedges (86.78%) **(Raj *et al*., 2013).**

Singh (2013) Conducted field experiments in Varanasi and observed that at 40 days after sowing, the major weeds infesting the experimental field were, *Cynodon dactylon* (6.2%), *Dactyloctenum aegypticum* (2.2%), *Echinochloa colona* (20.3%), *Echinochloa crusgalli* (5.9%), *Leptochloa chinenis* (1.7%) among grasses. *Ammannia baccifera* (1.9%), *Caesulia axillaries* (4.5%), *Commelina benghalensis* (6.1%), *Physalis minima* (6.3%), *Eclipta alba* (3.3%), *Euphorbia hirta* (5.1%), *Phyllanthus niruri* (12.6%), *Ludwigia spp.* (1.3%), *Trianthema monogyna* (3.8%) among broadleaf weeds and *Cyperus difformis* (5.4%) among Sedges.

Menon *et al*. (2014) It has been observed that the grasses *Echinochloa colona*, *Echinochloa crusgalli*, *Echinochloa stagnina* and *Leptochloa chinensis* were the most common weed species discovered in the experimental plot. Broadleaf weeds included *Ludwigia perennis*, *Lindernia crustacea*, *Monochoria vaginalis*, *Sphaeranthes indicus* and *Alternanthera sp.*, and sedges included *Fimbristylis mileacea*, *Cyperus iria* and *Cyperus difformis.*

The main weed flora observed in the experimental field included *Echinochloa crusgalli* (15.8%), *Ecinochloa colona* (23.8%), *Leptochloa chinensis* (18.4%), *Ammania baccifera* (14.8%), *Caesulia axillaris* (10.3%), *Cyperus rotundus* (8.9%) and others (8.7%) in rice crop **(Joshi *et al*., 2015).**

Weed infestation is a significant biotic constraint in rice production. Rice communities are infested with a diverse weed flora colonised by aquatic, semi-aquatic and terrestrial weeds are grown under the variety of conditions, cropping sequences, tillage and irrigation regimes. Approximately 350 species have been reported as rice weeds with grasses ranking first in terms of posing a serious problem **(Singh *et al*., 2016).**

A recent survey conducted in 2014 indicated that during earlier years of DSR adoption, typical rice weeds dominate the weed flora but after more than two years of continuous adaption weed flora shifts towards aerobic grasses. *Echinochloa sp*. Have been the dominant weed of PTR in Punjab but weed flora in DSR tends to be more diverse including typical rice and non-rice weeds and these weeds emerge in several flushes during the growing season **(Bhullar *et al*., 2016).**

Ghosh *et al*. (2017) Conducted field experiments in Varanasi and observed that emerged during experimentation, the dominant weeds associated with rice were *Echinochloa colona* L., *Echinochloa crus-galli* L., *Beauv, Cyperus iria* L., *Cynodon dactylon* L., Pers, *Caesulia axillaris* and *Commelina benghalensis* L. However, other weed flora consists of *Phyllanthus niruri* L., *Eclipta alba* (L.) and *Physalis minima.*

Singh *et al.* (2017) reported that the weed flora in DSR was dominated by *Cyperus difformis, Cyperus rotundus, Leptochloa chinensis, Echinochloa glabrescens, Eclipta alba* and *Ammania spp.*

Jannu *et al*. (2017) Conducted field experiments in Hyderabad and observed that the weed flora associated with experimental crop included of grasses such as *Echinochloa colona, Echinochloa crusgalli, Cynadon dactylon* and *Digitaria sangunalis, sedges viz; Cyperus rotundus* and *Cyperus difformis and broad leaf weeds viz; Phyllanthus niruri, Physalis minima, Alternanthra sessillis, Commelina bengalensis, Digera arvensis, Celosia argentina, Parthinium hysterophorus* and *Eclipta alba.* Among these, broadleaf weeds are dominant weeds followed by sedges and grasses in dry seeded rainfed rice.

The major weed flora observed in the experimental field consisted of six grasses species, five of broadleaf weeds and one sedge. The grassy weeds were

Cynodon dactylon, *Echinochloa colona*, *Echinochloa crus-galli*, *Brachiari aramosa,Eleusine indica,* and *Dactyloctenium aegyptium*. *Cyperus rotundus* was only sedge and *Boerhavia diffusa, Euphorbia hirta*, *Alternanthera sessilis*, *Trianthema portulacastrum*, *Digera arvensis* and *Physalis minima* were the broadleaf weeds **(Patel *et al*., 2018).**

Menon (2019) Conducted field experiments in Kerala observed that the major weed flora of the field included *Echinochloa crus-galli* and *Ludwigia perennis*. *Hydrolea zeylanica*, *Phyllanthus niruri*, *Eclipta alba* and *Scoparia dulcis* were minor weeds. At 30 DAS, weed density was not affected by treatments except in the case of *Echinochloa crus-galli* and *Eclipta alba.*

Saravanane (2020) Observed that the experimental field was infested with a diverse weed flora consisting of grasses, sedges, and broad-leaved weeds. Analyses of relative density revealed that *Echinochloa colona* was the most common weed species (86.12 per cent) in the experimental field, followed by *Fimbristylis miliaceae* (7.93 per cent) and *L. chinensis* (3.28 per cent).

Sen *et al.* (2021) Reported that the major Weed flora under unweeded situation (UWC) comprised of *Echinochloa crus-galli* L. and *Leptochloa chinensis* L. among grassy weeds. *Eclipta alba L*., *Digera arvensis*, and *Trianthema portulacastrum L*. among broadleaf weeds and *Cyperus rotundus L*. and *Cyperus iria L*. among sedges. Weed flora composition differed greatly across the treatments having herbicides with different site-specific modes of action. Grassy weeds were more dominant constituting about (66.0% – 91.8%) of total weed dry weight across the treatments, followed by broadleaf weeds (5.1% – 15.3%) and sedges (2.8% – 19.0%).

2.2 Loss caused due to weeds in direct seeded rice

Globally, actual rice yield losses due to pests have been estimated at 40%, of which weeds have the highest loss potential (32%). The worldwide estimated loss in rice yield from weeds is around 10% of the total production **(Oerke and Dehne, 2004).**

Actual weed losses due to pest have been estimated to be 40%, with weeds causing the greatest loss (32%), globally **(Rao *et al*., 2007).**

Weeds are a major constraint to aerobic rice production systems because dry tillage, alternate wetting and drying conditions promote germination and growth of weeds, resulting in grain yield losses of 50-90 per cent **(Mishra and Singh, 2007).**

According to **Mahajan *et al*. (2009),** unchecked weed growth reduced crop yield by up to 57% in puddled transplanted rice and 82% in DSR.

Yield loss is affected by several factors, including associated weed flora, degree of infestation, rice ecosystem, growing season, cultivar raised, and cultural and management practises used. On average, yield loss due to weed competition ranges from 15% to 20%, but in severe cases, it can exceed 50% **(Hasanuzzaman *et al*., 2009).**

The absence of a size differential between crop and weeds, as well as the suppressive effect of standing water on weed emergence and growth during crop emergence, are the primary causes of the weed problem in dry-seeded systems. **(Chauhan *et al*., 2012).**

Weed competition can cause yield losses of up to 100% in DSR if weeds are not controlled throughout the season. The critical weed-free period in DSR ranges from 11.8 to 83.2 days after sowing, which is longer than the critical weed-free period in puddle transplanted rice **(Singh *et al*., 2014).**

This constraint also impedes the widespread adoption of aerobic rice because weeds and rice seeds germinate at the same time, resulting in severe crop-weed competition **(Mewada *et al*., 2016).**

2.3 Critical period of crop weed competition

Johnson *et al*. (2004) reported that Weed control until 38 DAS in the wet season and 32 DAS in the dry season resulted in a weed-free situation in a dry-seeded irrigated rice field and increased rice yield in the Senegal River delta during the dry season.

Weeds caused the most damage because they competed with crops for growth factors such as nutrients, soil moisture, light, space, and so on **(Walia, 2006).**

Azmi *et al*. (2007) It was reported that the critical period for weed control in DSR under mixed weed infestation ranged from 12 to 60 DAS.

Begum *et al*. (2008) According to the predicted logistic and gompertz curves, the critical period for controlling rice weed *Fimbristlis miliacea* in direct seeded rice was between 14 and 28 DAS.

Weed control that is effective during the early stages of rice growth (0 to 40 DAS) may aid in increasing DSR productivity **(Maity and Mukherjee, 2008).**

Singh (2008) reported that, it is critical to reduce crop-weed competition in DSR during the early stages of the crop before it forms a closed leaf canopy.

Sunil *et al*. (2010) observed that season-long weed competition in DSR may cause yield reduction up to 80%.

The elimination of the practice of maintaining about a 5 cm depth of standing water, which would otherwise keep weed growth at bay, and the emergence of weed seedlings earlier or concurrently with crop seedlings under DSR cultivation methods have significantly increased the risk of severe crop-weed competition, ultimately resulting in heavy yield losses **(Choudhary and Suri, 2013).**

Rana *et al*. (2016) reported that *Echinochloa colona* was the most competitive weed, followed by *Aeschynomene indica* and *Panicum dichotomiflorum*.

Crop-weed competition in DSR is more severe than in transplanted rice. The severity of competition is determined not only by competing species, but also by their density, duration, and the soil's fertility status **(Raj and Syriac, 2017).**

2.4 Evaluation of herbicides for weed control in direct seeded rice

Weed control is one of the most important factors in the successful production of direct seeded rice because the soil is exposed during the early stages of rice growth. Aerobic soil conditions and dry tillage practises, in addition to alternate wetting and drying, favour the germination and growth of highly competitive weeds. Furthermore, the lack of water control inherent in dry seeded culture reduces the efficacy of all weed control methods, especially herbicides.

There are a number of herbicides recommended for effective control of weed flora in transplanted rice throughout the rice-wheat system of India. But, under direct seeded rice, weeds are a serious problem causing severe losses to crop leading to even total crop failure. No such herbicides have been recommended so far which controls broad spectrum of weeds very efficiently. Hence, performance of different herbicides alone and with combination was evaluated in the present study and review of literature is presented here under.

2.4.1 Effect of Cyhalofop-butyl on weed

Kumar and Rana, (2013) conducted field experiments in Palampur reported that Bispyribac 30 g ha-1 behaving statistically alike with its different doses (20 and 25 g ha^{-1}) and with farmer's practice, and cyhalofop butyl followed by (*fb*) 2, 4-D resulted in significantly lower count of *Echinochloa colona.*

Permeela *et al*. (2014) from Kole lands of Thrissur, Kerala reported that Weed population was lowest at 60 DAS in bispyribac sodium, cyhalofop-butyl fs Almix, and fenoxaprop p-ethyl fs Almix due to broad spectrum action.

Kailkhura *et al*. (2015) at Pantnagar reported that Herbicidal combinations of pre-emergence application of pendimethalin 1000 g/ha *fb* post-emergence application of bispyribac-sodium 25 g $ha^{-1}$and post-emergence application of readymix of penoxsulam + cyhalofop-butyl 135 g ha^{-1} were found to be the most effective in controlling weed infestation with the highest weed control efficiency.

Mishra *et al*. (2016) from OUAT, Bhubaneswar reported that Hand weeding produced the least amount of weed biomass (4.5 g m^{-2}), followed by fenoxaprop + (chororimuron + metsulfuron), cyhalofop-butyl + (chlorimuron + metsulfuron), bispyribac-sodium, and fenoxaprop + ethoxysulfuron at 5.7, 7.8, 9.8 gm^{-1}, respectively.

Jacob *et al*. (2017) In Kerala reported that *L. chinensis* was not present in the fenoxaprop-p-ethyl treatment at 30 DAS, and cyhalofop butyl had the lowest weed dry weight of 11.6 kg ha^{-1}. Weed control efficiency (WCE) was highest with fenoxaprop-p-ethyl, then cyhalofop-butyl, and lowest with bispyribac-sodium.

Jannu *et al*. (2017) was conducted at agricultural college farm, Rajendranagar, Hyderabad, reported that Cyhalofop-butyl + (Chlorimuron –ethyl + Metsulfuron methyl) @ 90+20 g ha^{-1} was found to be effective in controlling various weeds and yielded a higher WCE of 82.13 per cent in direct seeded rainfed rice.

Singh *et al*. (2017) at Pantnagar reported that the minimum density and biomass of *E. colona* and *E. crus-galli* were recorded with the application of cyhalofop-butyl at 90 g ha^{-1}, which was comparable to its lower doses of 80 (both sponsor sample and standard check) and 75 g ha^{-1}.

Patel *et al*. (2018) at Gujarat reported that pretilachlor 1250 g ha^{-1} as PE *fb* bispyribac-sodium salt 50 g ha^{-1} at 30 DAS, pretilachlor 1250 g ha^{-1} as PE *fb* cyhalofop-butyl 100 g ha^{-1} at 30 DAS, pyrazosulfuron-ethyl 25 g ha^{-1} as PE *fb* bispyribac-sodium salt 50 g ha^{-1} at 30 DAS and pyrazosulfuron-ethyl 25 g ha^{-1} as PE *fb* cyhalofop-butyl 100 g ha^{-1} at 30 DAS were found equally effective and recorded significantly lower dry weight of weeds at 40 DAS and harvest.

Singh *et al*. (2019) at Haryana reported that at 1 WAT, cyhalofop-butyl+penoxsulam sprayed at 25 DAS had least control of *E. japonica* followed by *D. aegyptium*.

Joshi *et al*. (2019) at Pantnagar reported that during both years, sole rice had the lowest total weed density and dry weight (pendimethalin *fb* cyhalofop-butyl *fb* 1 hand-weeding at 45 DAS/DAP), followed by inter-cropping rice with brahmi in paired (2 :1) ratio along with pendimethalin 1 kg ha^{-1} *fb* cyhalofop-butyl 100g/ha *fb* 1 hand-weeding at 45 DAS.

Sen *et al*. (2020) form IARI, New Delhi reported that Sequential applications of pendimethalin (1.0 kg ha^{-1}) *fb* ready-mix of penoxsulam + cyhalofop-butyl (130 g ha^{-1}) resulted in the lowest grassy weed dry weight at 60 DAS (30 g m^{-2}) and harvest (41.7 g m^{-2}) and the highest WCI (87.6 per cent).

2.4.2 Effect of Cyhalofop-butyl on yield attributes and yields of rice

Permeela *et al*. (2014) from Kole lands of Thrissur, Kerala reported that this yield was statistically comparable to cyhalofop-butyl fs Almix (5.8 Mg ha^{-1}) and fenoxaprop p-ethyl fs Almix (5.8 Mg ha^{-1}) with WCEs of 88 and 90%, respectively.

Kailkhura *et al*. (2015) at Pantnagar reported that the highest grain yield (6.42 t ha^{-1}) was obtained with a pre-emergence application of pendimethalin 1000 g ha^{-1} followed by a post-emergence application of bispyribac-sodium 25 g ha^{-1}. This was comparable to the post-emergence application of a readymix of penoxsulam + cyhalofop-butyl at 135 g ha^{-1} (6.32 t ha^{-1}).

Mishra *et al*. (2016) from OUAT, Bhubaneswar reported that among the various chemical control methods, fenoxaprop + (chororimuron + metsulfuron) yielded significantly higher grain yield (3.23 t ha^{-1}) than cyhalofop-butyl + (chlorimuron + metsulfuron) and bispyribac sodium, with grain yields of 3.23 and 3.07 t ha^{-1}and 3.07 t ha^{-1}.

Jacob *et al*. (2017) In Kerala reported that the hand-weeded control plot produced the highest grain yield of 6.46 t ha^{-1}, followed by fenoxaprop-p-ethyl (5.88 t ha^{-1}) and cyhalofop-butyl (5.46 t ha^{-1}), and the unweeded control produced the lowest yield of 4.07 t ha^{-1}.

Singh *et al*. (2017) at Pantnagar reported that the application of Cyhalofop-butyl at 90 g ha^{-1} resulted in the highest grain yield (4.21 and 4.29 t ha^{-1}), which was comparable to the other herbicidal treatments except for its lower dose of 65 g ha^{-1}.

Jannu *et al*. (2017) was conducted at agricultural college farm, Rajendranagar, Hyderabad, reported that among the early post-emergence herbicides, application of cyhalofop-butyl + (chlorimuron-ethyl+ metsulfuron-methyl) @ 90+20 g ha^{-1} produced grain yield comparable to hand weeding (at 20 and 40 DAS).

Patel *et al*. (2018) In Gujarat reported that significantly higher grain (2.0 and 1.9 t ha^{-1}, respectively) and straw (4.5 and 4.1 t ha^{-1}, respectively) yields were recorded in plots treated with pretilachlor 1250 g ha^{-1} or pyrazosulfuron-ethyl 25 g ha^{-1} as PE *fb* bispyribac-sodium salt 50 g ha^{-1} at 30 DAS.

Joshi *et al*. (2019) at Pantnagar reported that during both the years, a single stand of rice produced significantly more grain yield, which was followed by additive and replacement series in both 1:1 and 2:1 ratio, as well as pendimethalin *fb* cyhalofop-butyl *fb* 1 hand-weeding at 45 DAS/DAP.

Sen *et al*. (2020) form IARI, New Delhi reported that among the herbicide treatments, pendimethalin *fb* penoxsulam + cyhalofop-butyl produced the highest rice grain yield (3.92 t ha^{-1}) and harvest index (38.0 per cent).

2.4.3 Effect of Cyhalofop-butyl on economics

Kumar and Rana, (2013) The highest net profit rupee-1 invested was obtained by cyhalofop butyl *fb* metsulfuron methyl.

Permeela *et al*. (2014) from Kole lands of Thrissur, Kerala reported that an economic analysis of rice cultivation reveals that spraying cyhalofop-butyl followed by almix is the best option for high returns (Rs.67,090 ah^{-1}) and a B-C ratio of 1.8.

Mishra *et al*. (2016) from OUAT, Bhubaneswar reported that despite the fact that hand weeding produced the highest yield, the net return and B-C ratio in herbicidal treatments such as fenoxaprop + (chororimuron + metsulfuron), cyhalofop-butyl + (chlorimuron + metsulfuron), fenoxaprop + ethoxysulfuron, and bispyribac-sodium were higher than in hand weeding.

Jacob *et al*. (2017) In Kerala reported that an economic analysis of rice cultivation revealed that the use of fenoxaprop-p-ethyl provided the best B-C ratio (2.1).

Jannu *et al*. (2017) was conducted at agricultural college farm, Rajendranagar, Hyderabad, reported that cyhalofop-butyl + (chlorimuron-ethyl+metsulfuron-methyl) @ 90+20 g ha^{-1}] was found economically beneficial weed control practice and recorded the maximum BCR (2.22) over two hand weedings treatment (2.08).

Joshi *et al*. (2019) at Pantnagar reported that during both the years, the treatment pendimethalin *fb* cyhalofopbutyl *fb* 1 hand-weeding at 45 DAS/DAP in alternate (1: 1) rice and brahmi ratio yielded the highest net returns and benefit-cost ratio.

Sen *et al*. (2020) form ICAR-IARI, New Delhi reported that despite lower gross returns (by 7501.5 Rs. ha^{-1} or 10.3 per cent), the latter herbicide treatment (i.e., pendimethalin *fb* penoxsulam + cyhalofop-butyl) provided 13.4 per cent and 31.4 per cent higher net returns over UWC (NRUWC) and gross benefit-cost over WFC, respectively, due to higher grain yield and lower weed control costs in this treatment.

2.4.4 Effect of Fenoxaprop-p-ethyl on weeds

Abraham *et al*. (2012) Reported from Kerala that all the doses of fenoxaprop resulted significant reduction in the count of *Echinochloa* spp. at 30 days after spraying in both the years of study. The weed dry matter production also showed a similar trend.

Jacob *et al*. (2014) conducted a field experiment at Aappad-Pullu Kole lands, Kerala concluded that at 60 DAS, the weed dry weight increased six-fold in the unweeded control plots, while the fenoxaprop-p-ethyl treated plots had the lowest dry weight, followed by cyhalofop butyl.

Mahajan and Chauhan, (2015) from Punjab Agricultural University, Ludhiana reported that the tank mix application of azimsulfuron plus bispyribac plus fenoxaprop resulted in the lowest total weed density (5 plants m^{-2} in 2013 and 3 plants m^{-2} in 2014).

Ali *et al*. (2015) at Faisalabad reported that at 30 and 45 DAS, the application of bispyribac-sodium 25 g a.i. ha^{-1}, followed by fenoxaprop-p-ethyl 1406 g a.i. ha^{-1} (T_5), was more effective (>85 per cent) in minimising total weed dry biomass.

Bhulllar *et al*. (2016) From Punjab Agricultural University, Ludhiana reported that the tank mixture of fenoxaprop and ethoxysulfuron improved control of *Echinochloa crus-galli* and *Echinochloa colona* by 43-69% compared to fenoxaprop alone, whereas the tank mixture of azimsulfuron and fenoxaprop was antagonistic and reduced control of *Leptochloa chinensis* by 86% compared to fenoxaprop alone.

Aparna *et al*. (2017) In Kerala reported that application of both cyhalofop butyl and fenoxaprop-p-ethyl at the four-leaf stage was found to be less effective in *Echinochloa colona*, with more than 60% seedling survival. Fenoxaprop-p-ethyl performed better at the weed's eight leaf stage, with a seedling survival rate of 40%, implying that application at this stage would be more effective.

A field experiment was conducted in clayey loam soil by **Saleem *et al*. (2018)** during *Kharif* season of 2016 at Rice Research Institute, Kala Shah Kaku, Lahore, observed that Pre-emergence application of pendimethalin, along with sprays of fenoxaprop-P-ethyl and bispyribac sodium at 22 (days after sowing) DAS reduced the weed population from 125 m^{-2} to 11.50 m^{-2}.

An experiment was conducted at Students' Farm of College of Agriculture, CCS Haryana Agricultural University; by **Singh *et al*. (2018)** observed that Pre-emergence application of pendimethalin 1000 g/ha *fb* post emergence application of fenoxaprop 67 g/ha with lowest weed density, weed dry weight and highest WCE provided excellent control of *L. chinensis* in direct seeded rice.

A experiment was conducted in Kerala the soil was sandy loam in texture and has a pH of 5.84. observed that Fenoxaprop-pethyl + ethoxysulfuron had significantly lower weed control efficiency, which was likely due to its inability to effectively control *Echinochloa crus-galli*, **Menon, (2019).**

Sekhar *et al*. (2020) In Kerala reported that during both the years, dry matter production of *L. chinensis* was lower when fenoxaprop-p-ethyl was applied alone at 60 g ha^{-1} and cyhalofop-butyl was applied alone at 80 g ha^{-1}compared to their tank mix combination with bispyribac-sodium at 25 g ha^{-1}.

Field experiment was conducted at the Research farm of Bidhan Chandra Krishi Viswavidyalaya, West Bengal, by **Kundu *et al*. (2020)** reported that among the herbicides tested, the treatment plot with bis pyribac sodium 10 per cent SC (250 ml ha-1) had the lowest weed density of Echinochloa colona throughout the growing period (1.82 and 3.11 g m -2 for 30 DAA and 45 DAA, respectively) and was significantly comparable to the fenoxaprop-p-ethyl 9.3 per cent EC (625 ml ha-1) treated plot.

2.4.5 Effect of fenoxaprop-p-ethyl on yield attributes and yields of rice

Abraham *et al*. (2012) In Kerala reported that the highest grain yield was in the plots sprayed with fenoxaprop at 60.38 g ha^{-1} (4050 kg ha^{-1}) followed by hand weeded control (3900 kg ha^{-1}) and the standard check cyhalofop (3800 kg ha^{-1}). Fenoxaprop at 60.38 g ha^{-1} and cyhalofop 62.5g ha^{-1} recorded significantly higher straw yields also.

Jacob *et al*. (2014) conducted a field experiment at Alappad-Pullu Kole lands, Kerala concluded that the best treatments for grain yield were fenoxaprop-p-ethyl (5.88 mg ha^{-1}) and cyhalofop butyl (5.46 mg ha^{-1}) with the unweeded control yielding 4.07 mg ha^{-1}.

Mahajan and Chauhan, (2015) From Punjab Agricultural University, Ludhiana reported that the highest grain yield was recorded in the plots treated with the tank mix of azimsulfuron plus bispyribac plus fenoxaprop (7.23 t ha^{-1} in 2013 and 7.86 t ha^{-1} in 2014).

Ali *et al*. (2015) at Faisalabad reported that the highest number of total tillers (421) were observed in the T3 treatment, where bispyribac-sodium and fenoxaprop-p-ethyl were applied at 25 and 937 g a.i. ha^{-1}, respectively.

Bhullar *et al*. (2016) From Punjab Agricultural University, Ludhiana reported that rice grain yield ranged from 6.2 to 7.7 t ha^{-1} in plots treated with pendimethalin followed by post-emergence bispyribac or a tank-mix of fenoxaprop ethoxysulfuron, compared to 5.3-5.6 t ha^{-1} in pendimethalin alone.

Meher *et al*. (2018) Reported from Cuttack (Odisha), among the treatments, the weed-free plot (T_{11}) produced the most effective tillers (385.00 m^{-2}), which is comparable to fenoxaprop-p-ethyl 6.7 per cent EC (w/w) + ethoxysulfuron 15 per cent WDG (w/w) @ (50+15) g ha^{-1}. Further, the weed-free (T_{11}) (5.23 t ha-1) proved significantly superior in terms of grain yield, but was found to be equivalent to v Fenoxaprop-p ethyl 6.7 per cent EC (w/w) + Ethoxysulfuron 15 per cent WDG (w/w) @ (50+15) g ha-1 (T_4).

Sekhar *et al*. (2020) In Kerala reported that during both the years, tank mix combination of bispyribac-sodium with fenoxaprop-p-ethyl at 25 + 60 g ha^{-1} (4.76 and 5.30 t ha^{-1}) and cyhalofop-butyl at 25 + 80 g ha^{-1} (4.37 and 5.14 t ha^{-1}) and ready-mix combination of penoxsulam + cyhalofop-butyl at 150 g ha^{-1} treated plots recorded statistically similar grain yield (4.55 and 5.36 t ha^{-1}) to the plots kept weed free throughout the season (4.93 and 5.47 t ha^{-1}).

Field experiment was conducted by **Kundu *et al*. (2020)** at the Research Farm of Bidhan Chandra Krishi Viswavidyalaya, West Bengal, reported that bispyribac-sodium applied at a rate of 250 ml ha^{-1} produced significantly higher grain yields than fenoxaprop-p-ethyl applied at a rate of 625 ml ha^{-1} and bispyribac-sodium 10 per cent SC applied at a rate of 200 ml ha^{-1}, but the treatments were statistically dissimilar.

2.4.6 Effect of Fenoxaprop-p-ethyl on economics

Jacob *et al*., 2014 conducted a field experiment at Alappad-Pullu Kole lands, Kerala concluded that according to an economic analysis of rice cultivation, the highest B-C ratio (2.1) was found in fenoxaprop-p-ethyl.

Ali *et al*., 2015 at Faisalabad reported that among various treatments, T3 (bispyribac sodium + fenoxaprop-p-ethyl at 25 and 937 g a.i. ha^{-1}, respectively) gave maximum paddy yield (3.80 t ha^{-1}) and recorded highest net income Rs. 83,006 ha^{-1}.

Mahajan and Chauhan, 2015 at the research farm of Punjab Agricultural University, Ludhiana reported that the additional costs due to herbicide treatments ranged from 24.6 to 60.4 USD ha^{-1}, with pendimethalin being the cheapest and plots treated with a tank mixture of azimsulfuron, bispyribac, and fenoxaprop being the most expensive due to the lowest weed biomass in these plots.

2.4.7 Effect of Oxyfluorfen on Weeds

Ramachandiran and Balasubramanian, (2012) On 30 DAS (T_6), a post-emergence mixture of fenoxaprop + (chlorimuron + metsulfuron) reduced total weed density to 18.00 m^{-2}. This was followed by the application of pre-emergence oxyfluorfen and post-emergence 2,4-D on 30 DAS (T_{10}) and a post-emergence mixture of fenoxaprop + ethoxysulfuron on 30 DAS (T_9).

A field experiment conducted by **Poddar *et al.* (2014)** at BCKV's Kalyani C-Block Farm in Mohanpur, West Bengal, reported that at 15 DAA, the treatment oxyfluorfen @ 400 g h^{-1} reduced the weed population to 39.67 m^{-2}, whereas it was 107.51 m^{-2} in un-weeded plots. At 30 DAA, similar trends were observed.

A field experiment was conducted by **Upasani and barla, (2014)** at Agronomical Research Farm of Birsa Agricultural University, Ranchi reported that

Application of pyrazosulfuron25 g ha 3-7DAS (T_1) being similar to azimsulfuron 50DF 35 g ha 35 DAS (T_7) and oxyfluorfen 23.5 EC 300 g +2,4-D 80% 500 g ha^{-1} (T_{10}) at 30 and 60 DAS and also fenoxaprop 1 9.3% 30DAS 60 g ha $^{-1}$ at 60 DAS (T_4) recorded significantly reduced weed dry matter accumulation by weeds compared to rest of the treatments

A field experiment was conducted during the *Kharif* season at Agricultural Research Station, Vadgaon Maval, Pune, Maharashtra to find out the second-best treatment was pre-emergence application of oxyfluorfen 0.150 kg/ha and post-emergence application of metsulfuron-methyl 10% + chlorimuron-ethyl 0.004 kg/ha having lowest weight of dry matter of weed (22.77 g m^{-2}) with higher weed control efficiency (91.08%) and lower weed index (2.96). The highest weed biomass was recorded in unweeded check, **Kashid *et al*. (2015).**

A field experiment was conducted during *Kharif* season 2018 at Instructional cum Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.). reported that the weed-free treatment resulted in the significantly highest plant height, which was statistically superior to all other treatments. However, it was comparable to two-hand weeding at 15 and 30 DAS and oxyflourfen 20 DF@ 240 g a.i. ha^{-1} treatments, **Sumit *et al*. (2020)**

2.4.8 Effect of Oxyfluorfen on yield attributes and yields of rice

A field experiment conducted by **Poddar *et al.* (2014)** at BCKV's Kalyani C-Block Farm in Mohanpur, West Bengal, reported that as the treatment oxyfluorfen @ 400 g h^{-1} showed the maximum control of weed, the ultimate reflection of this treatment was at the highest grain yield i.e. 1.99 t ha^{-1}.

A field experiment was conducted by **Upasani and barla, (2014)** at Agricultural Research Farm of Birsa Agricultural University, Ranchi reported that application of pyrazosulfuron 25 g ha^{-1} 3-7 DAS (T_1) being on par with pretilachlor-S 50% 750 g ha^{-1} 0-5 DAS (T_2), and oxyfluorfen 23.5 EC 300 g +2,4-D 80% 500 g ha^{-1}

(T_{10}) recorded 49.04 and 73.23 per cent significantly higher grain and straw yield compared to the mean grain yield recorded by rest of the treatments.

A field experiment was conducted by **Kashid *et al*. (2015)** during the *Kharif* season at Agricultural Research Station, Vadgaon Maval, Pune, Maharashtra to find out the weed-free treatment yielded the highest grain and straw yields of paddy (5.71 t $ha^{-1}$and 6.55 t ha^{-1}, respectively). It was comparable to a pre-emergence application of oxyfluorfen 0.150 kg ha^{-1} and a post-emergence application of metsulfuron-methyl + chlorimuron-ethyl 0.004 kg ha^{-1} in terms of grain yield (5.53 t ha^{-1}) and straw yield (6.38 t ha^{-1}).

A field experiment was conducted by **(Sumit *et al*., 2020)** during *Kharif* season 2018 at Instructional cum Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) reported that the weed free treatment produced the highest grain yield (54.75 q ha-1) and was significantly superior to all other treatments, followed by two hand weeding at 15 and 30 DAS (53.91 q ha^{-1}) and oxyflourfen 20 DF @ 240 g a.i. ha (53.91 q ha^{-1}).

2.4.9 Effect of Oxyfluorfen on economics

A field experiment was conducted by **Upasani and barla, (2014)** at Agronomical Research Farm of Birsa Agricultural University, Ranchi reported that Maximum net return (pooled Rs 35,192 ha^{-1}) and B-C ratio (pooled 2.81) were recorded with application of pyrazosulfuron 25g ha^{-1} 3-7 DAS (T_1) being on par with pretilachlor-S 50% 750 g ha^{-1} 0- 1 5 DAS (T_2), and oxyfluorfen 23.5 EC 300 g +2,4-D 2 80% 500 g ha^{-1} (T_{10}) compared to rest of the treatment during both the years as well in pooled.

A field experiment was conducted by **Kashid *et al*. (2015)** during the *Kharif* season at Agricultural Research Station, Vadgaon Maval, Pune, Maharashtra to find out the treatment of preemergence application of oxyfluorfen 0.150 kg ha^{-1} and postemergence application of metsulfuron-methyl + chlorimuron-ethyl 0.004 kg ha^{-1}

yielded the highest net returns (57,063 ha^{-1}) and B:C ratio (2.3), which was comparable to the weed free treatment (54,390 ha^{-1}).

A field experiment was conducted by **Sumit *et al.* (2020)** during *Kharif* season 2018 at Instructional cum Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.). reported that the highest net return (Rs. 54,619 ha^{-1}) was observed with preemergence application of oxyflourfen 20 DF @ 240 g a.i.ha1, followed by two hand weeding at 15 and 30 DAS (Rs 53,143 ha^{-1}) and oxyflourfen 20 DF @ 480 g a.i. ha^{-1} (Rs. 47,093 ha^{-1}). The highest B-C ratio (2.41) was obtained with oxyflourfen 20 DF @ 240 a.i. ha^{-1}, followed by oxyflourfen 20 DF @ 480 g a.i. ha^{-1} (2.17) and two hand weeding at 15 and 30 DAS (2.10).

Chapter III

MATERIALS AND METHODS

The present experiment entitled, "**Bio-efficacy of cyhalofop-butyl 10 per cent EC against weeds in direct-sown rice (*Oryza sativa* L.) and their residual effect on mustard (*Brassica juncea* L.)**" was conducted at the Agricultural Research Farm of Institute of Agricultural Sciences, Banaras Hindu University during the *Kharif* (rainy) seasons of 2020. The details of materials used, experiment procedures followed and various techniques adopted during the experimentation have been presented in this chapter

3.1 Experimental site

The experiment was carried out at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. It is located in the South Eastern part of Varanasi at $25^{0}18'$ N Latitude, $83^{0}03'$ E longitude and at an altitude of 75.7 meters above the mean sea level in the Northern Gangetic alluvial plains. The experiment was laid out in field number A/14 of Research Farm. The experimental site was homogeneously fertile with even topography and uniform textural make up as well as adjoining the main irrigation channel connecting the farm tube well for quick, regular and timely irrigation. A proper drainage facility was also provided in order to remove excess water during the experimental period.

3.2 Climate and weather

Varanasi has a subtropical climate that is frequently subjected to weather extremes, such as extremely hot summers and extremely cold winters. The temperature begins to rise in the middle of February and reaches its peak in May or the middle of June. The coldest time of year is between the last week of December and the first week of January. The maximum temperature ranged from 23°C to 40.6°C, while the minimum temperature ranged from 5.0°C to 24.5°C. The normal time for the onset of monsoon in this zone is the third week of June and lasts until the end of September, though it can sometimes last until the first week of October. The area occasionally experiences cyclonic rains during winter seasons *i.e.* December to

February. The months of March to May are generally dry. The average annual rainfall in this region is 1081.6 mm, with 845.5 mm falling during the rainy season. The annual rainfall distribution is as follows: 87.33 per cent during the rainy season from June to September (monsoon season), and 12.67 per cent during the post-rainy season (9.8 per cent from October to February and 2.8 per cent from March to May). The average annual potential evapotranspiration (PET) is 1525 mm. The mean relative humidity is 88%, which rises to 91 per cent from July to September and falls to 39% from the end of April to early June. The meteorological data during the experimental period for the years were recorded week wise from the meteorological observatory of the Research Farm, and presented in Table 3.1 and graphically show in Figure. 3.1.

3.2.1 Rainfall (mm)

The total rainfall received during the experimentation year of 2020 was 733.2 The maximum rainfall of 118.6 mm was recorded during week number 28 (July 09-15), while the minimum was 6 mm in week number 29 (July 16-22).

3.2.2 Temperature

The average temperature at the time of sowing was 28.4 °C. The mean maximum temperature ranged between 30.7 and 33.7°C, During the crop period while the mean minimum temperature ranged between 22 and 28.2°C, gradually decreasing from mid-October onward.

3.2.3 Relative humidity

The relative humidity increased from July to September and then gradually decreased until November. Relative humidity remained above 92 per cent for the majority of crop growth, and was in the 79-87 per cent range up until September, before dropping to 73 per cent in the first week of November.

3.2.4 Evaporation (mm)

The daily evaporation rate was minimum (2.6 mm) in week no. 38 (Sep 17-23) and maximum (3.7) in week no.29 and 37 (June 25-01) and (Sep 10-17) respectively, during crop growth period.

Table 3.1: Weekly meteorological data during the period of experiment (*Kharif*, 2020-2021)

2020 year	Standard Meteorological Week	Weather parameters					
		Relative Humidity (%)		Temperature (°C)		Total Rainfall (mm)	Evaporation mm
		(Max.)	(Min.)	(Max.)	(Min.)		
June 25-01	26	91	66	31.3	25.5	105.8	3.7
July 02-08	27	93	74	33.3	26.7	74.4	2.9
09-15	28	87	73	33.7	26.8	118.6	3.4
16-22	29	88	76	32.6	28.2	6.0	2.8
23-29	30	90	69	33.5	27.3	103.4	3.2
30-05	31	93	83	30.7	27.6	31.3	2.8
Aug 06-12	32	91	73	32.6	28.0	8.6	3.2
13-19	33	92	75	33.1	27.6	109.6	3.6
20-26	34	92	83	31.3	26.9	10.6	3.1
27-02	35	89	84	32.3	27.0	8.6	3.1
Sep 03-09	36	88	79	32.2	23.4	39.2	3.6
10-16	37	90	73	31.7	23.5	6.0	3.7
17-23	38	92	86	31.9	22.0	30.5	2.6
24-30	39	87	74	33.3	24.3	55.0	3.0
Oct 01-7	40	91	73	32.2	23.7	26.0	3.2
08-14	41	88	65	33.6	24.5	0.0	3.5
15-21	42	90	59	34.1	24.4	0.0	3.0
22-28	43	90	62	32.4	21.1	32.4	2.2
29-04	44	78	40	30.3	16.6	30.3	2.3
Nov 05-11	45	90	48	29.6	13.9	0.0	2.1
12-18	46	89	54	25.0	18.1	0.0	2.2
19-25	47	91	48	26.3	12.5	13.2	1.9
26-02	48	92	43	26.3	11.1	0.0	1.6
Dec 03-09	49	93	53	27.7	12	0.0	1.2
10-16	50	93	64	23.9	14.8	3.6	1.4
17-23	51	91	59	20.5	7.5	0.0	1.3
24-31	52	94	49	22.3	7.8	0.0	1.2
Jan 01-07	01	90	54	25.4	12.3	0.0	1.1
08-14	02	92	59	21.7	13.0	0.0	1.6
15-21	03	95	65	19.4	8.1	0.0	1.0
22-28	04	95	71	17.5	9.2	0.0	1.0
29-04	05	96	46	22.5	7.3	0.0	1.25
Feb 05-11	06	91	50	24.6	10.8	0.6	1.7
12-18	07	90	37	28.4	12.4	0.0	1.9
19-25	08	85	41	29.0	13.7	0.0	2.6
26-04	09	79	34	30.7	15.4	0.0	3.8
March 05-11	10	88	36	32.7	17.0	0.0	4.5

3.3 Cropping history of experimental field

A study of the previous year's cropping scheme provides insight into the field's general fertility and crop production trend. In the experimental field, a continuous rice-wheat rotation had been practised for the previous five years (Table 3.2). This has resulted in a progressive decline in soil fertility after each rotation.

Table 3.2: Cropping history of the experimental field

Year	*Kharif*	*Rabi*
2015-2016	Rice	Wheat
2016-2017	Rice	Wheat
2017-2018	Rice	Wheat
2018-2019	Rice	Wheat
2019-2020	Rice	Wheat
2020-2021	Experimental plot	Mustard

3.4 Soil and analysis

The experimental field's soil is typical Indo-Gangetic alluvium (entisol), which is deep flat, well drained, and has moderate soil fertility. To evaluate the native fertility status of the field, random soil samples from two places from each plot was collected as per the methodology of **Black *et al*. (1965)** from a depth of 0-30 cm soil samples from the experimental field with the help of the screw auger prior to the experimentation. All of the technical precautions required for standard soil sampling were taken. The tagged samples were then brought to the laboratory, where they were air-dried, ground, and sieved through a 20 mm mesh. The processed and prepared samples were analysed for soil physical and chemical properties. The result thus obtained is presented in Table 3.3. The soil at the experimental site was sandy clay loam in texture, deep, well drained, moderately fertile with low available nitrogen, medium available phosphorus and potassium, and neutral reaction.

3.5 Experimental design and layout

The experiment was set up in a randomised block design, with herbicide rates assigned to different plots at random. The treatment was repeated three times in each herbicide dose.

The details of layout plan and treatment are presented in Table 3.3 (a&b) and depicted in fig. 3.2.

Table 3.3: Physico-chemical properties of the soil

Particulars	Value	Rating	Method	Reference
1. Mechanical analyses				
Sand (%)	49.89	Sandy clay loam	Hydrometer	Bouyoucos (1962)
Silt (%)	26.71			
Clay (%)	23.40			
Textural class			Textural triangle	Black *et al.* (1965)
2. Physical constants				
Bulk density (Mg m^{-3})	1.43		Core sampler	Black *et al.* (1965)
Particle density (Mg m^{-3})	2.65		Pycnometer	
3. Chemical analyses				
Organic carbon (%)	0.33	Low	Wet digestion method	Walkley and Black's (1934)
Available N (kg ha^{-1})	176	Low	Alkaline potassium permanganate	Subbiah & Asija (1956)
Available P_2O_5 (kg ha^{-1})	23.43	Medium	0.5 *M* $NaHCO_3$ extractable	Olsen *et al.* (1954)
Available K_2O (kg ha^{-1})	207	Medium	Flame photometer method	Jackson (1973)
*p*H (1:2.5 soil: water suspension)	7.32	Neutral	Glass electrode digital *p*H meter	Sparks (1996)
Electrical conductivity (1:2.0 soil: water suspension) dS m^{-1} at 25°C)	0.31	Normal	Systronics electrical conductivity meter	Sparks (1996)

Table 3.4(a): Details of the layout plan

1.	Design of experiment	Randomized block design (RBD)
2.	Number of treatment	8
3.	Number of replication	3
4.	Total number of plots	24
5.	Block border	1.0 m
6.	Plot border	1.0 m
7.	Gross plot size	5.0 m × 4.0 m
8.	Net plot size	4.0 × 3.0
9.	Width of main irrigation channel	1.0 m
10.	Width of main irrigation channel	1.0 m
11.	Row spacing	15.0 cm

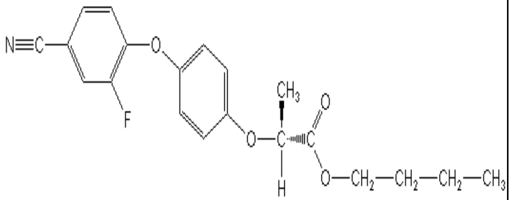
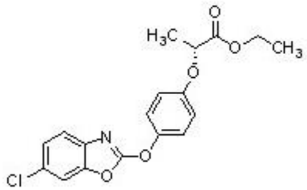
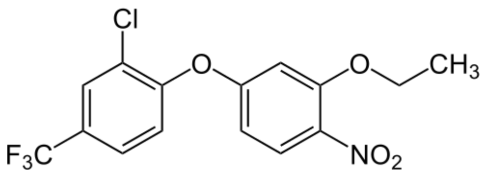
Table 3.4(b): Details of the treatment

T.No.	**Treatments**	**Dosage (ml a.i./ ha)**	**Dilution in water (litre/ ha)**
1.	Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	500
2.	Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	500
3.	Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	500
4.	Cyhalofop-butyl 10% EC (Market sample)	75.0	500
5.	Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	500
6.	Oxyfluorfen 23.5% EC (Market sample)	152.8	500
7.	Hand weeding at 20 & 40 DAS	-	-
8.	Untreated control (weedy check)	-	-
9.	Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample) [Only for phytotoxicity studies]	1600	500

R_1		R_2		R_3
T_7		T_1		T_4
T_2		T_4		T_7
T_6		T_7		T_1
T_8		T_3		T_6
T_1	**Irrigation channel**	T_2	**Irrigation channel**	T_5
T_4		T_6		T_8
T_5		T_8		T_3
T_3		T_5		T_2
T_9		T_9		T_9

Figure 3.2 Layout details of experimental field

Table 3.5: Herbicides used in experimental plot

Herbicide used	Common name	IUPAC Name	Molecular formula	Structural formula	Formulation
Cyhalofop-butyl	Cyhalofop-butyl	Butyl (2*R*)-2-[4-(4-cyano-2-fluorophenoxy)phenoxy]propanoate	$C_{20}H_{20}FNO_4$		10 EC
Fenoxaprop-p-ethyl	Fenoxaprop-p-ethyl	Ethyl (2*R*)-2-[4-[(6-chloro-1,3-benzoxazol-2-yl)oxy]phenoxy]propanoate	$C_{18}H_{16}ClNO_5$		6.7 EC
Oxyfluorfen	Oxyfluorfen	2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene	$C_{15}H_{11}ClF_3NO_4$		23.5 EC

3.6 Variety used

The rice variety “HUR 1304” was developed at the Banaras Hindu University in Varanasi, Uttar Pradesh (India). It is a semi-dwarf variety with a plant height of 95-100 cm, medium grains, slender leaves, and a growing season of 110 days. Average yield production of 4127-4251 kg ha^{-1}, grown in irrigated conditions in Uttar Pradesh and Bihar.

3.7 Agronomic practices

The detail of cultural operation done starting from field preparation to harvesting of the crop is given in Table 3.6.

Table 3.6: Field operational programme during crop season

S.No.	Nature of operation	Date
1.	Field operation	22.06.2020
2.	Layout	23.06.2020
3.	Sowing	25.06.2020
4.	Herbicide application	
	(a) Cyhalofop butyl	13.07.2020
	(b) Oxyfluorfen	13.07.2020
	(c) Fenoxaprop-p-ethyl	13.07.2020
5.	Fertilizer application	
	(a) Basal (50%N+full P_2O_5+full K_2O)	25.06.2020
	(b) First top dressing (25 % nitrogen)	16.07.2020
	(c) Second top dressing (25% nitrogen)	14.08.2020
6.	Harvesting	07.10.2020
7.	Threshing and winnowing	06.12.2020

3.7.1 Application of Fertilizer

A uniform dose of 120 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1} were applied in all the plots in the form of urea, DAP, MOP respectively. Full dose of Phosphorus, potash and half dose of nitrogen were applied as basal application and rest amount of Nitrogen was top dressed in two equal split doses at tillering and panicle initiation stage.

3.7.2 Application of herbicides

After determining the total amount of herbicides required per plot, the required amount of herbicides were carefully measured and dissolved in the appropriate volume of water. Herbicides were applied using a Knapsack sprayer with a flat fan nozzle after preparation. Pre-emergence herbicides were applied immediately following crop sowing, and post-emergence herbicides were applied 18 days later. Herbicides were sprayed in each plot in a consistent pattern.

3.7.3 Seed Rate and Sowing

3.7.3.1 Direct seeding

The seeds were sown in the furrow opened by "Kudali" using 100 kg seed ha^{-1}.

3.7.4 Irrigation

Irrigation was provided at each critical stage when a lack of moisture was observed in the soil due to a lack of a break in the monsoon.

3.7.5 Harvesting

The crop was harvested when the majority of the panicles turned golden yellow. Harvesting was done manually with a sickle. Each plot was harvested separately and carefully bundled and tagged. It was then brought to the threshing floor separately and allowed to dry in the sun for three days to achieve the optimum moisture for threshing.

3.7.6 Threshing

After sun drying, the bundles were weighed using a spring balance, and the total biomass was recorded. The bundles were then threshed separately by hand by labourers using sticks. The grain from each plot was collected, cleaned, and weighed to determine the grain yield kg per plot. The yield obtained was converted to kg ha^{-1} for presentation of results.

3.8 Studies on Weeds

At 30, 45, 60, and 75 DAS, observations on weed flora composition, population, and dry matter accumulation by different weed species were made. Weed samples were collected from each plot using a quadrate (0.25 m^2). The collected samples were analysed for weed population and dry matter accumulation by various weed species. The weed population is represented by the number m^{-2}.

3.8.1 Weed density

Weed associated with crop was detected in the experimental area at 30, 45, 60, and 75 DAS. Weeds were counted in groups of four quadrates of 0.25 m2 in each plot at random. The number of weeds was counted, and the results were recorded in m^{-2} units. The weed density was subjected to the square root of transformation, i.e. $\sqrt{X+0.5}$.

3.8.2 Dry matter of weeds

Weeds enclosed in quadrates were removed and sundried from each polt. After sun drying, samples were dried in an oven at 70°C for 48 hours to achieve a constant dry weight. The obtained dry weight was recoded in g 0.25 m^2 and converted to g m^{-2}.

3.8.3 Weed control efficiency

The weed control efficiency was calculated and expressed as a percentage based on the difference in dry matter production between the treated and control plots **(Mani *et al*., 1973).**

$$\text{WCE (\%)} = \frac{\text{DMC-DMT}}{\text{DMC}} \times 100$$

Where, WCE = weed control efficiency (%)

DMC = Dry weight of weeds in untreated plot (g)

DMT = Dry weight of weeds in treated plot (g)

3.9 Studies on Crop

3.9.1 Growth attributes

Biometric observations on crop growth characters were recorded from the marked area of the net plot at 30, 60 and 90 DAS, and harvest stage in order to assess the probable relationship between various growth attributes and crop yield. The following are the primary indices for rice during various growth periods and at maturity:

3.9.1.1 Plant height (cm)

At 30, 60 and 90 DAS and harvest stage, the height of five marked plants from each plot was measured from the ground level to the upper most leaf tip. The height was measured from ground level to neck node level and expressed in centimetres as the average plant height.

3.9.1.2 Number of tillers plant^{-1}

The number of tillers was counted per plant, per border row on either side of each plot, or in terms of number per plant.

3.9.1.3 Dry matter of Rice

Border rows of one metre selected plants were taken from each plot for recording dry weight off the crop. These samples were sun dried before being transferred to a hot air oven and dried at 70 °C for hours to obtain a consistent dry weight of plant, which is expressed in g/meter row.

3.9.2 Yield attributes

At maturity, observations on yield attributing characters, such as number of panicles m^{-2}, number of grains per panicle, and dry weight of one thousand grains (test weight), panicles length (cm), panicles weight, grain yield and straw yield were recoded.

3.9.2.1 Number of panicles m^{-2}

The number of panicles in the two quadrates were counted at maturity and express in number of panicles squared per meter.

3.9.2.2 Number of grains panicle^{-1}

The grains of ten randomly selected panicles were counted, and the mean value was expressed as the average number of grains per panicle.

3.9.2.3 Test weight (1000 grain weight)

A thousand grains were randomly selected from each plot's grain sample and their weight was recorded in grammes.

3.9.2.4 Panicle length (cm)

Ten panicles from the tagged plants were harvested separately, and the length of each panicle was measured in centimetres from the node of the panicle to the apex of the panicle.

3.9.2.5 Panicle weight (g)

The grains from each panicle of the ten tagged plants were collected and weighed on an electric weighing balance. The panicle^{-1} grain weight was recorded, and the mean was calculated.

3.9.2.6 Grain yield

After threshing each plot separately, the grains were cleaned and the weight in kg per plot was recorded. At 14 per cent moisture content, this was converted to kg and expressed as grain yield kg ha^{-1}.

3.9.2.7 Straw yield

Grain yield was subtracted from each plot's bundle weight to calculate straw yield. The obtained weight was converted to quintal per hectare.

3.10 Relative Economics

The relative economics of various treatments were calculated using the mean value of the yield. The cost of input and the price of produce at the Agricultural Research Farm, B.H.U., were considered when calculating the cost of different treatments, which were expressed as net returns and Benefit-Cost ratio.

3.10.1 Gross income (` ha^{-1})

Gross returns (` ha^{-1}) were calculated by converting the harvest into monetary terms at the prevailing market rate during the course of the studies for each treatment.

3.10.2 Net returns (` ha^{-1})

The net return was calculated by subtracting the total cost of cultivation from the gross income.

Net return (`) = Gross income (`) – Total cost of cultivation (`)

3.10.3 Benefit-cost (B:C)

The benefit: cost ratio was calculated with the help of following formula:

$$\text{Benefit-cost} = \frac{\text{Net returns (`)}}{\text{Total cost of cultivation (`)}}$$

3.11 Chemical analysis

3.11.1 Soil analysis

Before sowing the crop, soil samples were collected from each plot at a depth of 0-15 cm. The available nitrogen, phosphorus, and potassium were measured using the standard method.

3.11.1.1 Available nitrogen

The alkaline potassium permanganate method was used to determine available nitrogen (Subbiah and Asija, 1956). The method entails distilling the soil with an alkaline potassium permanganate solution and determining the ammonia liberated by titration against sulphuric acid (0.02N).

3.11.1.2 Available phosphorus

The Olsen's method (Olsen *et al.*, 1954) was used to determine available-P in soil. The soil was extracted using 0.5 *M* NaHCO3 in this method (pH 8.5). Ascorbic acid solution was used to develop colour in five millilitres of extract. After waiting 10 minutes, the intensity of the blue colour was measured using a spectrophotometer at 660 nm.

3.11.1.3 Available potassium

Shaking for 30 minutes, five grammes of soil were extracted with a neutral normal ammonium acetate solution (pH 7.0). Jackson's flame photometric method was used to determine the potassium content of the extract (1973).

3.11.2 Chemical analysis of plant

Plant material was collected at harvest for chemical analysis of plant samples. The samples were thoroughly cleaned by repeated washing followed by 0.1N HCl solutions. Finally, all of the samples were washed with double distilled water. After drying in the shade, the samples were placed in a hot air oven at 60 10 C for 48 hours. After drying samples were weighed and grinded in Willey’s Mill as per treatment separately and stored in butters paper covers. Samples were then subjected to chemical analysis for nitrogen, phosphorous, potassium.

3.11.2.1 Nitrogen

Jackson's modified Kjeldahal methods were used to estimate N content in grain and straw (1973). Uptake and removal were calculated by the following formula:

$$\text{Nitrogen uptake (kg ha}^{-1}\text{)} = \frac{\text{Nitrogen content (\%)} \times \text{dry matter / yield (ka/ha)}}{100}$$

3.11.2.2 Phosphorus

The phosphorus content of grain and straw was determined using Jackson's Vandomolybdo phosphoric yellow colour method (1973). Uptake and removal were calculated by the following formula:

$$\text{Phosphorus uptake (kg ha}^{-1}\text{)} = \frac{\text{Phosphorus content (\%)} \times \text{dry matter / yield (ka/ha)}}{100}$$

3.11.2.3 Potassium

Potassium was estimated using a Flame photometer, as described by Jackson (1973). The potassium in grain and straw was multiplied by their dry matter. Uptake and removal were calculated by the following formula:

$$\text{Potassium uptake (kg ha}^{-1}) = \frac{\text{Potassium content (\%)} \times \text{dry matter / yield (ka/ha)}}{100}$$

3.12 Statistical analysis

The data was organised using a randomised block design (RBD). The data collected from the various characters under investigation were analysed using the analysis of variance method described by **Gomez and Gomez (1984).** For each character, an analysis of variance (ANOVA) table was created in the following manner.

Source of variation	**Df**	**SS**	**MSS**	**F Cal**	**F tab (5%)**
Replication	(r-1) =2				
Treatment	(t-1) =7				
Error	(r-1) (t-1) =14				
Total	23				

Standard error and critical values were calculated in order to compare the mean value of treatment. For standard error, critical difference, and coefficient of variation estimations, the following formula was used.

(a) $SEm\pm = \sqrt{EMS/r}$

(b) $C.D. = SEm\pm \times \sqrt{2} \times t_{error}$ d.f.at 5%

(c) $C.V.(\%) = \sqrt{EMS}/GM$

Where,

R = Number of replication,

t = Number of treatment,

d.f. = Degree of freedom,

C.D. = Critical difference,

S.S. = Sum of square,

M.S.S = Mean sum of square,

EMS = Error mean square,

C.V. = Coefficient of variance,

SEm± = Standard error of mean

EXPERIMENTAL FINDINGS

The present investigation entitled "**Bio-efficacy of cyhalofop-butyl 10 per cent EC against weeds in direct-sown rice (*Oryza sativa* L.) and their residual effect on mustard (*Brassica juncea* L.)**" was conducted during *kharif* season of 2020-2021 at the Agricultural Research Farm, Institute of Agricultural sciences, Banaras Hindu University, Varanasi, Uttar Pradesh (India). In this chapter, an attempt has been made to ascertain the degree of variation in weeds and rice crop at different stages of crop growth and development due to influence of weed control treatments.

Observations on the type of weed flora, population of important weed species, and dry weight were made at 30, 45, 60, and 75 DAS. Rice characteristics were recorded at 30, 60, and 90 days after sowing, as well as at harvest. At harvest, yield attributes that have a direct bearing on grain and straw yield were recorded.

The experimental data were statistically analysed, and the results were presented in this chapter through tables and figures as needed.

4.1 Studies on weed

4.1.1 Weed flora

The weed flora present in the experimental field from 2020 to 2021 was collected, identified, and classified as grasses, sedges, and broad-leaved weeds, as shown in Table 4.1. (a).

The critical analysis of data presented in table showed that among the grasses *cynodon dactylon* (L.) pers, *Echinochloa colona* (L.) Link and *Echinnochloa crusgalli* (L.) Beauv were the predominant weeds, whereas among sedges *Cyperus irria* (L.), *Cyperus rotundus* (L.), *Cyperus haspan* (L.) and in broad-leaved weeds, *Lindernia crustacea* (L.) F. Muell, *Lindernia procumbens* (Krock.) philcox, *Eclipta alba* L. Hassak, *Phyllanthus niruri* L, *Spilanthes acmella* auct.non L, *Paspalum conjugatam* were dominant weeds in years.

4.1.2 Density of *Echinochloa spp.*

The relevant data on the average population of *Echinochloa (colonum+crusgalli)* as affected by herbicides were recorded on 30, 45, 60, and 75 DAS and are presented in Table 4.2.

The data reveals that the density of *Echinochloa spp.* under the application of different herbicidal treatments statistically did not influence at 30 and 45 DAS. Further, at 60 DAS lower weed density was recorded under the application of cyahlofop-butyl 10% EC (Best Crop Sc LLP sample) @ 75.0 ml a.i. followed by fenoxaprop-p-ethyl 6.7% EC (market sample) @ 54.5 ml a.i. ha^{-1}. It was significantly superior over the weedy check. At 75 DAS lower weed density was recorded under the application of cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 80.0 ml a.i. ha^{-1} followed by Fenoxaprop-p-ethyl 6.7% EC (market sample) @ 54.5 ml a.i. ha^{-1}. However, it was significantly superior over the weedy check and oxyfluorfen 23.5% EC (market sample) @ 152.8 ml a.i. ha^{-1}.

4.1.3 Density of *Cynodon dactylon*

The data pertaining to the density of *Cynodon dactylon* per square meter presented in Table 4.3.

A perusal of data revealed that application of herbicidal treatments statistically did not influence on density of *cynodon dactylon* at all the dates of observation.

4.1.4 Density of *Cyperus haspan*

The data pertaining to the density of *Cyperus haspan* per square meter are presented in Table 4.4.

An inspection of the data revealed that population of *Cyperus haspan* under the application of different herbicidal treatments statistically did not influence at all the dates of observation.

4.1.5 Density of *Cyperus irria*

The data pertaining to the density of *Cyperus irria* per square meter are presented in Table 4.5.

A perusal of data revealed that the density of *Cyperus irria* at 30 and 45 DAS application of various herbicidal treatments statistically did not influence. At 60 DAS application of Fenoxaprop-p-ethyl 6.7% EC (market sample) @ 54.5 ml a.i. ha^{-1} reduced the density of *Cyperus irria* followed by Oxyfluorfen 23.5% EC (market sample) @152.8 ml a.i. ha^{-1} over weedy check. At 75 DAS application of cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 80.0 ml a.i. ha^{-1} lower weed density was recorded followed by cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 85.0 ml a.i. ha^{-1}, Oxyfluorfen 23.5% EC (market sample) @ 152.8 ml a.i. ha^{-1}. It was significantly superior over the weedy check.

4.1.6 Density of *Cyperus rotundus*

The data pertaining to the density of *Cyperus rotundus* per square meter are presented in Table 4.6.

A perusal of data revealed that the density of *Cyperus rotundus* under the application of different herbicidal treatments statistically did not influence at all the dates of observation but later stage at 60 and 75 DAS lower weed density was recorded under the application of cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 75.0 ml a.i. ha^{-1}. It was significantly superior over the weedy check.

4.1.7 Density of *Lindernia crustacea*

The data pertaining to the density of *Lindernia curstacea* per square meter are presented in Table 4.7.

A perusal of data revealed that the density of *Lindernia curstacea* under the application of different herbicidal treatments statistically did not influence at all the dates of observation.

4.1.8 Density of *Lindernia procumbens*

The data pertaining to the density of *Lindernia procumbens* per square meter are presented in Table 4.8.

A perusal of data revealed that the density of *Lindernia procumbens* under the application of different herbicidal treatments statistically did not influence at all the dates of observation.

4.1.9 Density of *Eclipta alba*

The relevant data pertaining to the density of *Eclipta alba* under different treatments are presented in Table 4.9.

A perusal of data revealed that the density of *Eclipta alba* under the application of different herbicidal treatments statistically did not influence at all the dates of observation.

4.1.10 Density of *Phyllanthus niruri*

The relevant data pertaining to the density of *Phyllanthus niruri* under different treatments are presented in Table 4.10.

A perusal of data revealed that the density of *Phyllanthus niruri* under the application of different herbicidal treatments statistically did not influence at all the dates of observation. But at 60 DAS, the application of cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 85.0 ml a.i. ha^{-1} followed by cyhalofop-butyl 10% EC (market sample) @ 75.0 ml a.i. ha^{-1}, oxyfluorfen 23.5% EC (market sample) @ 152.8 ml a.i. ha^{-1} were statistically at par with each other and recorded lower weed density over the weedy check.

4.1.11 Density of *Spilanthes acmella*

The relevant data pertaining to the density of *Spilanthes acmella* under different treatments are presented in Table 4.11.

A perusal of data revealed that the density of *Spilanthes acmella* under the application of different herbicidal treatments statistically did not influence at all the dates of observation. However, at 60 DAS significantly lower the weed density was recorded under the application of cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 80.0 ml a.i. ha^{-1} followed by cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 85.0 ml a.i. ha^{-1} and oxyfluorfen 23.5% EC (market sample) @ 152.8 ml a.i. ha^{-1} over the weedy check.

4.1.12 Density of *Pasplam conjugatam*

The data related to density of *Pasplam conjugatam* recorded in rice field at different stages of observation as affected by different herbicidal treatments is presented in Table 4.12.

A perusal of data revealed that the density of *Paspalum conjugatum* at 30 and 45 DAS application of different herbicidal treatments statistically did not influence. At 60 and 75 DAS lower weed density was recorded under the application of cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 75.0 ml a.i. ha^{-1}. It was significantly superior over the weedy check and Oxyfloufen 23.5% EC (market sample) @ 152.8 ml a.i. ha^{-1}.

4.2 Weed dry matter (g m^{-2})

The accumulation of dry matter by various weeds increased with the progression of growth stages; data on weed dry matter at various dates of observation as influenced by various treatments are presented in Table (4.13-4.23)

4.2.1 Dry matter of *Echinochloa spp*

The relevant data on the dry matter of *Echinochloa (colonum+crusgalli)* as affected by herbicides were recorded on 30, 45, 60, and 75 DAS and are presented in Table 4.13.

The data reveals that the total weed dry matter of *Echinochloa* spp. under the application of different herbicidal treatments statistically did not influence at 30 and 45 DAS. Further, at 60 DAS lower dry matter was recorded under the application of cyahlofop-butyl 10% EC (Best Crop Sc LLP sample) @ 75.0 ml a.i. followed by fenoxaprop-p-ethyl 6.7% EC (market sample) @ 54.5 ml a.i. ha^{-1}. It was significantly superior over the weedy check. At 75 DAS lower weed dry matter was recorded under the application of cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 80.0ml a.i. ha^{-1} followed by Fenoxaprop-p-ethyl 6.7% EC (market sample) @ 54.5 ml a.i. ha^{-1}. It was significantly superior over the weedy check and oxyfluorfen 23.5% EC (market sample) @ 152.8 ml a.i. ha^{-1}.

4.2.2 Dry matter of *cynodon dactylon*

The data pertaining to the dry matter of *Cynodon dactylon* per square meter presented in Table 4.14.

A perusal of data revealed that application of herbicidal treatments statistically did not influence on dry matter of *cynodon dactylon* at all the dates of observation.

4.2.3 Dry matter of *Cyperus haspan*

The data pertaining to the dry matter of *Cyperus haspan* per square meter are presented in Table 4.15.

An inspection of the data revealed that dry matter of *Cyperus haspan* under the application of different herbicidal treatments statistically did not influence at all the dates of observation.

4.2.4 Dry matter of *Cyperus irria*

The data pertaining to dry matter of *Cyperus irria* per square meter are presented in Table 4.16.

A perusal of data revealed that dry matter of *Cyperus irria* at 30 and 45 DAS application of various herbicidal treatments statistically did not influence. At 60 DAS application of fenoxaprop-p-ethyl 6.7% EC (market sample) @ 54.5 ml a.i. ha^{-1} reduced the dry weight of Cyperus irria followed by oxyfluorfen 23.5% EC (market sample) @ 152.8 ml a.i. ha^{-1} over weedy check. At 75 DAS application of cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 80.0 ml a.i. ha^{-1} was recorded lower dry matter followed by cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 85.0ml a.i. ha^{-1}, oxyfluorfen 23.5% EC (market sample) @152.8 ml a.i. ha^{-1}. It was significantly superior over the weedy check.

4.2.5 Dry matter of *Cyperus rotundus*

The data pertaining to dry matter of *Cyperus rotundus* per square meter are presented in Table 4.17.

A perusal of data revealed that dry matter of *Cyperus rotundus* under the application of different herbicidal treatments statistically did not influence at all the dates of observation but later stage at 60 and 75 DAS lower dry matter was recorded under the application of cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 75.0 ml a.i. ha^{-1}. It was significantly superior over the weedy check.

4.2.6 Dry matter of *Lindernia crustacea*

The data pertaining to dry matter of *Lindernia crustacea* per square meter are presented in Table 4.18

A perusal of data revealed that dry matter of *Lindernia crustacea* under the application of different herbicidal treatments statistically did not influence at all the dates of observation.

4.2.7 Dry matter of *Lindernia procumbens*

The data pertaining to dry matter of *Lindernia procumbens* per square meter are presented in Table 4.19.

A perusal of data revealed that dry matter of *Lindernia procumbens* under the application of different herbicidal treatments statistically did not influence at all the dates of observation.

4.2.8 Dry matter of *Eclipta alba*

The relevant data pertaining to dry matter of *Eclipta alba* under different treatments are presented in Table 4.20.

A perusal of data revealed that dry matter of *Eclipta alba* under the application of different herbicidal treatments statistically did not influence at all the dates of observation.

4.2.9 Dry matter of *Phyllanthus niruri*

The relevant data pertaining to dry matter of *Phyllanthus niruri* under different treatments are presented in Table 4.21.

A perusal of data revealed that dry matter of *Phyllanthus niruri* under the application of different herbicidal treatments statistically did not influence at all the dates of observation. However, at 60 DAS the application of cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 85.0 ml a.i. ha^{-1} followed by cyhalofop-butyl 10% EC (market sample) @ 75.0 ml a.i. ha^{-1}, oxyfluorfen 23.5% EC (market sample) @ 152.8 ml a.i. ha^{-1} was recorded lower dry matter significantly over the weedy check.

4.2.10 Dry matter of *Spilanthes acmella*

The relevant data pertaining to dry matter of *Spilanthes acmella* under different treatments are presented in Table 4.22.

A perusal of data revealed that dry matter of *Spilanthes acmella* under the application of different herbicidal treatments statistically did not influence at all the dates of observation. But except at 60 DAS significantly lower the dry matter was recorded under the application of cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 80.0ml a.i. ha^{-1} followed by cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 85.0 ml a.i. ha^{-1} and oxyfluorfen 23.5% EC (market sample) @ 152.8 ml a.i. ha^{-1} over the weedy check.

4.2.11 Dry matter of *Paspalum conjugatam*

The data related to dry matter of *Pasplam conjugatam* recorded in rice field at different stages of observation as affected by different herbicidal treatments is presented in Table 4.23.

A perusal of data revealed that dry matter of *Paspalum conjugatum* at 30 and 45 DAS application of different herbicidal treatments statistically did not influence. At 60 and 75 DAS lower dry matter was recorded under the application of cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 75.0 ml a.i. ha^{-1}. It was significantly superior over the weedy check and oxyfloufen 23.5% EC (market sample) @ 152.8 ml a.i. ha^{-1}.

4.3 Weed control efficiency (%)

The data associated to weed control efficiency are directly proportional to crop yield. The data regarding weed control efficiency as influenced periodically by different treatments are presented in Table (4.24-4.34)

4.3.1 Weed control efficiency (%) of *Echinochloa* spp.

Critical analysis of data revealed that all the herbicidal treatments were significantly affected the *Echinochloa* spp (4.24). It is evident from the data that at 45, 60, and 75 DAS, the maximum weed control efficiency (84.91, 86.71 and 93.97%, respectively) was recorded under application of cyhalofop-butyl 10% EC 85.0 ml a.i. ha^{-1} (Best Crop Sc LLP sample). However, application of cyhalofop-butyl 10% EC proved superior to fenoxaprop-p-ethyl and oxyfluorfen irrespective of the dates of observation.

Critical analysis of data Table (4.25-4.34) exhibited not satisfactory result by the application of herbicidal treatments on weed control efficiency in respect to *Cynodon dactylon, Cyperus haspan, Cyperus rotundus, Cyperus irria, Lindernia crustacea, Lindernia procumbens, Eclipta alba, Phyllanthus niruri, Spilanthes acmella, Paspalum conjugatam*.

4.4 Growth Parameter

4.4.1 Plant height (cm)

The data pertaining to the mean plant height of rice as influenced by treatment at dates of observation are presented in Table 4.35

It is evident from the Table 4.35 that plant height of rice did not influence by the treatments at 30 and 60 DAS. Further, at 90 DAS and at harvest higher plant height was recorded with the application of cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 75.0 ml a.i. ha^{-1} which was statistically at par cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 85.0 ml a.i. ha^{-1} and cyhalofop-butyl 10% EC (market sample) @ 75.0 ml a.i. ha^{-1}. However, it was significantly superior over the weedy check.

4.4.2 Number of tillers per running meter

The data pertaining to number of tillers per running meter rice at various dates of observations as influenced by different treatments are presented in (Table 4.36)

A perusal of data clearly indicated that the application of cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 85.0 ml a.i. ha^{-1} was recorded higher number of leaves per plant at all the dates of observation. but statistically being at par with application of fenoxaprop-p-ethyl 6.7% (market sample) @ 54.5 ml a.i. ha^{-1} at 30 DAS. At 60 and 90 DAS number of tillersper running meter did not influence by the herbicidal treatments.

4.4.3 Crop dry matter (g/m)

The data pertaining to the dry matter accumulation per meter row length of rice as influenced by different treatments are presented in (Table 4.37).

Dry matter accumulation of plant was increased with the advancement of crop age up to harvest. At 30 DAS it was non-significant due to the application of treatment. At 60 and 90 DAS more dry matter accumulation per running meter was recorded with post-emergence application of cyhalofop-butyl 10% EC (Best Crop Sc

LLP sample) @ 75.0 ml a.i. ha^{-1}. However, the minimum dry matter accumulation by the crop was recorded in the untreated control (weedy check) and all the weed control treatments were significantly superior to untreated control.

4.4.4 Number of leaves per plant

The data pertaining to the number of leaves per plant of rice as influence by different treatments are presented in Table 4.38.

The maximum number of leaves per plant was recorded at 90 DAS under the application of cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 75.0 ml a.i. ha^{-1}. It was statistically at par with rest of the herbicidal treatments. However, it was non-significance at 30 and 60 DAS.

4.5 Yield attributes

Yield attributing characters like plant height, effective number of panicles, and panicle length, number of grains per panicle, fresh weight of panicle and test weight showed positive correlation with yield. It is shown in (Table 4.39).

4.5.1 Number of panicles per square meter

A critical analysis of data clearly indicates that there was significant variation in effective number of tillers (m^{-2}) due to different treatments. The maximum number of effective tillers was observed under hand weeding. Further, among the herbicidal treatments, the higher number of effective tillers under the post-emergence application of cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 75.0 ml a.i. ha^{-1} (239 m^{-2}) which was significantly higher over the weedy check and all the other treatments. It was statistically at par with cyhalofop-butyl 10% (Best Crop Sc LLP sample) @ 80.0 ml a.i. ha^{-1}.

4.5.2 Number of grains per panicle

The data on average number of grains per panicle as influenced by herbicidal treatments are presented in (Table 4.39).

A perusal of data shows a significant variation in number of grains per panicle.Among herbicidal treatments, the application of cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) **@** 75.0 ml a.i. ha^{-1} was recorded the maximum number of grains per panicle.

4.5.3 Panicle length (cm)

It can be revealed from data presented in Table 4.39 that the length of panicle shows non significance effect of different treatments. However, the longest panicles length (21.5 cm) in hand weeding which was closely followed by cyhalofop butyl 10% EC (market sample) @ 75.0 ml a.i. ha^{-1} (21.2 cm).

4.5.4 Panicle weight (g)

The data showing the effect of different treatment on panicle weight are presented in Table 4.39. It is clear from the table that the higher panicle weight was recorded with the application of cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 85.0 ml a.i ha^{-1} over the weedy check but being at par with cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 75.0 ml a.i ha^{-1} followed by cyhalofop-butyl 10% EC (market sample) @ 75.0 ml a.i ha^{-1} and fenoxaprop-p-ethyl 6.7% EC (market sample) @ 54.2 ml a.i. ha^{-1}.

4.5.5 Test weight (g)

A critical study of the data presented in Table 4.39 revealed that the maximum test weight recorded with the application of cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 75.0 ml a.i. ha^{-1}. It was statistically at par with doses of cyhalofp-butyl 10 % EC (Best Crop Sc LLP sample) @ 80.0 ml a.i. ha^{-1}, 85.0 ml a.i. ha^{-1}, cyhalofp-butyl 10 % EC (market sample) @ 75.0 ml a.i. ha^{-1} and significant higher over the weedy check.

4.5.6 Grain yield (kg ha^{-1})

Grain yield of rice was significantly influenced by different treatments. the higher grain yield (3692 kg ha^{-1}) was recorded under the application of cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 75.0 ml a.i. ha^{-1}. It was statistically at par with the application of doses cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 80.0 ml a.i. ha^{-1}, 85.0 ml a.i. ha^{-1}. The magnitude in increase in grain yield by the application of cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 75.0 ml a.i. ha^{-1} 39.5 per cent over the control (weedy check).

4.5.7 Straw yield (kg ha^{-1})

The data on straw yield is presented in Table 4.39 It was revealed that the application of cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 75.0 ml a.i. ha^{-1} showed superiority over all the herbicidal treatments in respect of straw yield. It remained at par with the rest of doses cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 80.0 ml a.i. ha^{-1}, 85.0 ml a.i. ha^{-1} which was significantly higher over the weedy check. The per cent increase in straw yield by the application of cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) 75.0 ml a.i. ha^{-1} as post-emergence over the untreated control (weedy check) was 40.0.

4.6 Crop phytotoxicity (%)

Visual phytotoxicity recorded at 7, 10, 20, 30 and 45, 60 days after spraying. Based on 1-10 scale where: 1=0-10%, 2=11-20%, 3=21-30%, 4=31-40%, 5=41-50%, 6=51-60%, 7=61-70%, 8=71-80%, 9=81-90%, 10=91-100% indicated that there was no phytotoxicity of any the treatments on the rice crop.The application of cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) 75.0 ml a.i. ha^{-1} either of the doses and Fenoxaprop-p-ethyl 6.7% w/w EC at 54.5 ml a.i. ha^{-1} (market sample) exhibited injury on tips or surface of leaf at 10 and 20 of treatment application DTA and necrosis at 30 and 60 DTA on rice. However, wilting, vein clearing, necrosis, epinasty and hyponasty did not appear on rice by the application of herbicidal treatments during different dates of observation,

4.7 N P K content in grain and straw

Application of the treatment did not influence the content of NPK in grain and straw (Table 4.41).

4.8 Nutrient uptake by crop

The data of pertaining of nitrogen, phosphorus and potassium uptake by grain and straw of various treatments presented in (Table 4.42).

4.9.1 Nitrogen uptake by grain and straw (kg ha^{-1})

All the weed management practices exhibited significantly higher nitrogen uptake by grain and straw over the untreated plot (weedy check). The treatment oxyfluorfen @ 23.5% (market sample) followed by cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 75.0 ml a.i. ha^{-1} recorded more nitrogen uptake by grain. Further, application of cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 75.0 ml a.i. ha^{-1} observed higher nitrogen uptake by straw as compared to the other herbicidal treatment. However, the lowest nitrogen uptake was noted from the untreated plots (weedy check).

4.9.2 Phosphorus uptake by grain and straw (kg ha^{-1})

The data revealed that significantly higher phosphorus uptake by grain observed by application of cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 75.0 ml a.i. ha^{-1}. However, the lowest phosphorus uptake by grain was noted from the untreated plots (weedy check). Further phosphorus uptake by straw did not influence by the treatment.

4.9.3 Potassium uptake by grain and straw (kg ha^{-1})

Among the herbicidal treatments, potassium uptake by grain shown significant effect of weed management practices. Under the herbicidal treatments higher potassium uptake was under application of cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) 75.0 ml a.i. ha^{-1}. it was at par with rest of the dosage herbicidal treatment except cyhalofop-butyl 10% EC (market sample) @ 75.0 ml a.i. ha^{-1}. The lowest potassium uptake was noted from the untreated plots (weedy check), Further, potassium uptake by straw did not influence by the treatment.

4.10 Relative economics

Data on total cost of cultivation, gross income, net income and B-C ratio as influenced by weed control treatments have been embodied in (Table 4.43). The cost of cultivation of different treatment has been appended in Appendix-I and II.

4.10.1 Cost of cultivation

Data on cost of cultivation of different weed control treatments have been embodied in (Table 4.45). Cost of cultivation was higher for weed free treatment (Rs. 53,892/- ha^{-1}) due to more Farm workers used in weeding and minimum under weedy check.

4.10.2 Gross income

A perusal of data in Table 4.45 revealed that control of weeds through different weed control treatments increased the gross income significantly over the weedy check. Because of higher grain and straw yield, weed less with cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 75.0 ml a.i. ha^{-1} was recorded higher gross income as compared to rest of the treatments.

4.10.3 Net returns

Weed control treatments resulted in significantly higher net return over the weedy check. The higher net return was recorded in the treatments of cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 75.0 ml a.i. ha^{-1} (Rs 69,198/- ha^{-1}) and minimum was recorded under the weedy check (Rs 40,044/- ha^{-1}).

4.10.4 Benefit-cost ratio

The benefit-cost ratio (B: C) was highest under cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 75.0ml a.i. ha^{-1} (1.5). The lowest benefit-cost ratio was obtained the weedy check (0.97).

4.11 Observation of succeeding crop (Mustard)

4.11.1 Crop germination percentage

There were not significance differences on crop germination percentage of among the treatments applied in preceding rice crop. Table (4.44).

4.11.2 Plant height (cm)

Plant height of mustard at harvest was recorded the maximum (193.13) with cm the application of cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 75.0 ml a.i. ha^{-1} among the herbicidal treatment.

4.11.3 Yield attributes and yield

The residual effect of different treatments applied in preceding rice crop was tested in succeeding yield of mustard crop, regarding this data of different yield attributing character were analysed, and found that there was not significance differences in number of siliqua $plant^{-1}$, length of siliqua, 1000-seed weight and grain yield. However, no. of primary branch and no. of secondary branch higher under the application of fenoxaprop-p-ethyl 6.7% EC (market sample) @ 54.5 ml a.i. ha^{-1}. Number of siliquae on main shoot (per shoot) on recorded higher under application of cyhalofop-bytul 10% EC (Best Crop Sc LLP sample) @ 80.0 ml a.i. ha^{-1} applied in preceding rice crop over rest of the treatments.

Table 4.1(a): Weed flora of the experimental field during experiment

Weeds	**Botanical name**	**Common name**	**Family**
Grasses	*Cynodon dactylon* (L.) Pers	Doob grass	Poaceae
	Echinochloa colona (L.) Link	Senwai/dhenhari	Poaceae
	Echinochloa crusgalli (L.) Beauv	Shyma ghas	Poaceae
Sedges	*Cyperus irria* L.	Bhada	Cyperaceae
	Cyperus haspan L.	Haspan flatsedge	Cyperaceae
	Cyperus rotundus L.	Purple nutsedge	Cyperaceae
Broad-leaved weeds	*Lindernia crustacea* (L.) F. Muell.	Malaysian false pimpernel	Scrophulariaceae
	Lindernia procumbens (Krock.) philcox	Prostrate false pimpernel	Scrophulariaceae
	Eclipta alba (L.) Hassak	Phyllanthus	Phyllanthaceae
	Phyllanthus niruri L.	Stonebreaker	Euphorbiaceae
	Spilanthes acmella auct.non L.	Pellitary	Asteraceae
	Paspalum conjugatam	Sour paspalum	Poaceae

Table 4.1(b): Relative composition of weed flora in direct seeded rice at 60 days after sowing in weedy plot

Weed species	Scientific Name	Composition
Grasses		
1.	*Echinochloa* spp. *colonum* (L.) Link + E *crusgalli* (L.) Beauv	14.04%
2.	*Cynodon dactylon* (L.) Pers	13.41%
	Total	27.45%
Sedges		
1.	*Cyperus rotundus* L.	30.13%
2.	*Cyperus irria* L	10.10%
3.	*Cyperus haspan* L.	4.53%
	Total	44.76%
Broad leaved		
1.	*Lindernia crustacea* (L.) F. Muell	5.61%
2.	*Lindernia procumbens* (Krock.) philcox	5.89%
3.	*Eclipta alba* (L.) Hassak	5.07%
4.	*Phyllanthus niruri* L.	4.84%
5.	*Spilanthes acmella* auct.non L.	6.34%
	Total	27.75%
	All total	100%

Table 4.2: Effect of cyhalofop-butyl 10% EC on density (No./m^2) of *Echinochloa* spp. in direct-sown rice crop

Treatments	Dosage (ml a.i./ ha)	Initial weed count (Pre-treatment)		Days after crop sowing							
				30		45		60		75	
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.98	(6.67)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	0.71	(0.00)	0.71	(0.00)	3.11	(13.33)	3.65	(17.33)	0.71	(0.00)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	0.71	(0.00)	0.71	(0.00)	1.44	(2.67)	3.24	(13.33)	2.12	(6.00)
Cyhalofop-butyl 10% EC (Market sample)	75.0	0.71	(0.00)	0.71	(0.00)	2.30	(6.67)	2.70	(14.67)	2.25	(9.33)
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	0.71	(0.00)	0.71	(0.00)	2.12	(5.33)	0.71	(0.00)	0.71	(0.00)
Oxyfluorfen 23.5% EC (Market sample)	152.8	0.71	(0.00)	0.71	(0.00)	3.24	(10.67)	4.38	(18.67)	4.60	(20.67)
Hand weeding at 20 & 40 DAS	-	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	4.21	(17.00)	1.74	(4.67)
Untreated control (Weedy check)	-	0.71	(0.00)	0.71	(0.00)	3.75	(32.00)	5.80	(48.00)	6.31	(47.33)
SEm±		0.00		0.00		1.15		1.48		1.05	
CD (P=0.05)		0.00		0.00		NS		3.29		3.19	

Data transformed to square root values $\sqrt{x} + 0.5$, Original values are given in parentheses
DAS= Days after sowing; NS= Not significant

Table 4.3: Effect of cyhalofop-butyl 10% EC on density (No./m^2) of *Cynodon dactylon* in direct-sown rice crop

Treatments	Dosage (ml a.i./ ha)	Initial weed count (Pre-treatment)		Days after crop sowing							
				30		45		60		75	
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	6.93	(50.67)	14.34	(208.00)	8.82	(78.67)	4.77	(32.00)	8.89	(78.67)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	6.79	(45.67)	12.28	(186.67)	8.63	(74.67)	5.87	(34.67)	8.60	(77.33)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	6.66	(45.33)	13.95	(202.67)	7.32	(53.33)	8.17	(80.00)	8.77	(84.00)
Cyhalofop-butyl 10% EC (Market sample)	75.0	6.65	(46.67)	12.09	(149.33)	7.09	(52.00)	5.91	(34.67)	8.75	(76.00)
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	7.08	(49.67)	9.52	(90.67)	6.89	(48.00)	7.14	(50.67)	5.36	(44.00)
Oxyfluorfen 23.5% EC (Market sample)	152.8	5.03	(3.33)	12.68	(160.33)	9.16	(83.33)	7.50	(90.33)	8.82	(77.33)
Hand weeding at 20 & 40 DAS	-	6.04	(36.00)	11.48	(133.33)	5.83	(40.00)	4.11	(22.67)	4.13	(40.00)
Untreated control (Weedy check)	-	6.12	(37.33)	14.17	(200.33)	7.93	(99.33)	8.27	(101.00)	9.77	(95.00)
SEm±		0.77		2.01		0.69		1.43		1.84	
CD (P=0.05)		NS		NS		NS		NS		NS	

Data transformed to square root values $\sqrt{x} + 0.5$, Original values are given in parentheses
DAS= Days after sowing; NS= Not significant

Table 4.4: Effect of cyhalofop-butyl 10% EC on density (No./m^2) of *Cyperus haspan* in direct-sown rice crop

Treatments	Dosage (ml a.i./ ha)	Initial weed count (Pre-treatment)		Days after crop sowing							
				30		45		60		75	
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.83	(5.33)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.44	(2.67)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.18	(1.33)	0.71	(0.00)
Cyhalofop-butyl 10% EC (Market sample)	75.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.39	(3.00)	0.71	(0.00)
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.44	(6.00)	1.32	(2.00)
Oxyfluorfen 23.5% EC (Market sample)	152.8	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	2.00	(35.00)	0.71	(0.00)
Hand weeding at 20 & 40 DAS	-	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.18	(1.33)	2.89	(17.33)
Untreated control (Weedy check)	-	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.76	(20.00)	5.00	(24.67)
SEm±		0.00		0.00		0.00		0.28		0.96	
CD (P=0.05)		0.00		0.00		0.00		NS		NS	

Data transformed to square root values $\sqrt{x}+0.5$, Original values are given in parentheses
DAS= Days after sowing; NS= Not significant

Table 4.5: Effect of cyhalofop-butyl 10% EC on density (No./m^2) of *Cyperus irria* in direct-sown rice crop

Treatments	Dosage (ml a.i./ ha)	Initial weed count (Pre-treatment)		Days after crop sowing							
				30		45		60		75	
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	4.45	(19.33)	2.45	(8.00)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	3.37	(14.67)	0.71	(0.00)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.18	(1.33)	0.71	(0.00)
Cyhalofop-butyl 10% EC (Market sample)	75.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	3.54	(16.00)	1.55	(3.33)
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.00	(0.67)
Oxyfluorfen 23.5% EC (Market sample)	152.8	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)
Hand weeding at 20 & 40 DAS	-	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.18	(1.33)	0.71	(0.00)
Untreated control (Weedy check)	-	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	5.67	(32.00)	4.04	(16)
SEm±		0.00		0.00		0.00		0.66		0.55	
CD (P=0.05)		0.00		0.00		0.00		2.01		1.67	

Data transformed to square root values $\sqrt{x} + 0.5$, Original values are given in parentheses
DAS= Days after sowing

Table 4.6: Effect of cyhalofop-butyl 10% EC on density (No./m²) of *Cyperus rotundus* in direct-sown rice crop

Treatments	Dosage (ml a.i./ ha)	Initial weed count (Pre-treatment)		Days after crop sowing							
				30		45		60		75	
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	6.67	(46.67)	16.90	(288.00)	17.64	(316.00)	10.08	(160.00)	11.00	(115.33)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	7.05	(49.33)	16.57	(277.33)	19.28	(372.00)	12.94	(168.00)	12.09	(156.67)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	8.05	(69.33)	18.29	(373.33)	20.59	(442.67)	15.07	(226.67)	13.40	(190.00)
Cyhalofop-butyl 10% EC (Market sample)	75.0	8.08	(66.67)	16.05	(272.00)	16.80	(292.00)	16.82	(282.67)	15.62	(247.33)
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	9.58	(96.00)	17.31	(336.00)	19.31	(405.33)	16.06	(278.67)	16.08	(258.67)
Oxyfluorfen 23.5% EC (Market sample)	152.8	7.08	(53.33)	17.55	(313.33)	15.59	(205.33)	16.25	(268.00)	14.28	(209.33)
Hand weeding at 20 & 40 DAS	-	8.71	(77.33)	10.60	(133.33)	15.00	(200.00)	7.33	(56.00)	3.25	(13.33)
Untreated control (Weedy check)	-	8.88	(80.00)	18.45	(340.00)	21.22	(450.00)	16.95	(286.67)	16.46	(270.33)
SEm±		1.23		3.02		2.67		1.63		1.82	
CD (P=0.05)		NS		NS		NS		4.95		NS	

Data transformed to square root values $\sqrt{x} + 0.5$, Original values are given in parentheses
DAS= Days after sowing; NS= Not significant

Table 4.7: Effect of cyhalofop-butyl 10% EC on density (No./m^2) of *Lindernia crustacea* in direct-sown rice crop

Treatments	Dosage (ml a.i./ ha)	Initial weed count (Pre-treatment)		Days after crop sowing							
				30		45		60		75	
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	5.82	(33.33)	5.23	(37.33)	4.07	(38.67)	3.46	(26.67)	3.50	(27.33)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	6.10	(36.67)	4.69	(53.33)	6.91	(66.67)	5.38	(72.00)	5.64	(80.00)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	5.73	(32.33)	6.49	(53.33)	4.59	(50.67)	6.14	(52.00)	7.58	(80.67)
Cyhalofop-butyl 10% EC (Market sample)	75.0	5.52	(30.00)	6.67	(48.00)	4.48	(48.00)	5.33	(70.67)	4.31	(24.67)
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	6.15	(37.33)	1.83	(5.33)	3.44	(11.33)	3.75	(32.00)	4.31	(31.33)
Oxyfluorfen 23.5% EC (Market sample)	152.8	5.67	(31.67)	1.65	(4.00)	1.83	(5.33)	0.71	(0.00)	0.71	(0.00)
Hand weeding at 20 & 40 DAS	-	5.37	(28.33)	3.49	(16.00)	0.71	(0.00)	6.67	(66.67)	6.95	(67.33)
Untreated control (Weedy check)	-	5.31	(27.67)	7.78	(60.00)	7.39	(54.67)	8.90	(78.67)	9.55	(90.67)
SEm±		1.28		1.59		2.07		2.83		1.72	
CD (P=0.05)		NS		NS		NS		NS		NS	

Data transformed to square root values $\sqrt{x} + 0.5$, Original values are given in parentheses
DAS= Days after sowing; NS= Not significant

Table 4.8: Effect of cyhalofop-butyl 10% EC on density (No./m^2) of *Lindernia procumbens* in direct-sown rice

Treatments	Dosage (ml a.i./ ha)	Initial weed count (Pre-treatment)		Days after crop sowing							
				30		45		60		75	
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	7.78	(60.00)	8.54	(115.33)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	0.71	(0.00)	0.71	(0.00)	4.07	(38.67)	6.75	(45.33)	8.47	(104.00)
Cyhalofop-butyl 10% EC (Market sample)	75.0	0.71	(0.00)	0.71	(0.00)	3.23	(22.67)	5.77	(84.00)	6.84	(72.00)
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	0.71	(0.00)	0.71	(0.00)	3.06	(20.00)	6.25	(100.00)	7.71	(94.00)
Oxyfluorfen 23.5% EC (Market sample)	152.8	0.71	(0.00)	0.71	(0.00)	3.31	(24.00)	0.71	(0.00)	3.96	(22.00)
Hand weeding at 20 & 40 DAS	-	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	3.92	(20.00)	4.48	(48.00)
Untreated control (Weedy check)	-	0.71	(0.00)	0.71	(0.00)	3.94	(36.00)	9.53	(90.33)	10.53	(110.33)
SEm±		0.00		0.00		2.04		2.73		3.45	
CD (P=0.05)		0.00		0.00		NS		NS		NS	

Data transformed to square root values $\sqrt{x} + 0.5$, Original values are given in parentheses
DAS= Days after sowing; NS= Not significant

Table 4.9: Effect of cyhalofop-butyl 10% EC on density (No./m^2) of *Eclipta alba* in direct-sown rice crop

Treatments	Dosage (ml a.i./ ha)	Initial weed count (Pre-treatment)		Days after crop sowing							
				30		45		60		75	
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	2.49	(12.00)	2.85	(10.00)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	4.92	(23.67)	1.84	(4.00)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	0.71	(0.00)	0.71	(0.00)	2.98	(18.67)	1.83	(5.33)	2.59	(9.33)
Cyhalofop-butyl 10% EC (Market sample)	75.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	4.07	(22.67)	2.67	(8.67)
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	2.70	(14.67)	3.23	(10.00)
Oxyfluorfen 23.5% EC (Market sample)	152.8	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.44	(2.67)
Hand weeding at 20 & 40 DAS	-	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	2.49	(12.00)	2.75	(9.33)
Untreated control (Weedy check)	-	0.71	(0.00)	0.71	(0.00)	3.19	(9.67)	7.15	(50.67)	3.98	(15.33)
SEm±		0.00		0.00		1.15		1.70		0.95	
CD (P=0.05)		0.00		0.00		NS		NS		NS	

Data transformed to square root values $\sqrt{x} + 0.5$, Original values are given in parentheses
DAS= Days after sowing; NS= Not significant

Table 4.10: Effect of cyhalofop-butyl 10% EC on density (No./m^2) of *Phyllanthus niruri* in direct-sown rice crop

Treatments	Dosage (ml a.i./ ha)	Initial weed count (Pre-treatment)		Days after crop sowing							
				30		45		60		75	
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.83	(5.33)	1.74	(4.67)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.44	(2.67)	2.29	(6.00)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	2.64	(6.67)
Cyhalofop-butyl 10% EC (Market sample)	75.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.61	(2.67)
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.44	(2.67)	2.06	(4.67)
Oxyfluorfen 23.5% EC (Market sample)	152.8	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)
Hand weeding at 20 & 40 DAS	-	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)
Untreated control (Weedy check)	-	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	5.69	(32.00)	2.41	(6.00)
SEm±		0.00		0.00		0.00		0.45		0.59	
CD (P=0.05)		0.00		0.00		0.00		1.36		NS	

Data transformed to square root values $\sqrt{x} + 0.5$, Original values are given in parenthese
DAS= Days after sowing; NS= Not significant

Table 4.11: Effect of cyhalofop-butyl 10% EC on density (No./m^2) of *Spilanthes acmella* in direct-sown rice crop

Treatments	Dosage (ml a.i./ ha)	Initial weed count (Pre-treatment)		Days after crop sowing							
				30		45		60		75	
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	2.79	(16.00)	2.05	(7.33)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	3.14	(9.33)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	2.30	(6.67)
Cyhalofop-butyl 10% EC (Market sample)	75.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	2.12	(8.00)	1.84	(4.00)
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	2.77	(9.33)	2.86	(8.00)
Oxyfluorfen 23.5% EC (Market sample)	152.8	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)
Hand weeding at 20 & 40 DAS	-	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.74	(4.67)
Untreated control (Weedy check)	-	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	5.03	(25.33)	3.21	(10.00)
SEm±		0.00		0.00		0.00		0.94		0.85	
CD (P=0.05)		0.00		0.00		0.00		2.87		NS	

Data transformed to square root values $\sqrt{x} + 0.5$, Original values are given in parentheses
DAS= Days after sowing; NS= Not significant

Table 4.12: Effect of cyhalofop-butyl 10% EC on density (No./m^2) of *Paspalum conjugatam* in direct-sown rice crop

Treatments	Dosage (ml a.i./ ha)	Initial weed count (Pre-treatment)		Days after crop sowing							
				30		45		60		75	
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.65	(4.00)
Cyhalofop-butyl 10% EC (Market sample)	75.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)
Oxyfluorfen 23.5% EC (Market sample)	152.8	0.71	(0.00)	0.71	(0.00)	2.89	(17.33)	7.11	(50.00)	7.43	(54.67)
Hand weeding at 20 & 40 DAS	-	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.55	(3.33)
Untreated control (Weedy check)	-	0.71	(0.00)	0.71	(0.00)	4.01	(37.33)	6.39	(40.33)	7.54	(56.33)
SEm±		0.00		0.00		1.30		0.73		0.89	
CD (P=0.05)		0.00		0.00		NS		2.22		2.70	

Data transformed to square root values $\sqrt{x} + 0.5$, Original values are given in parentheses
DAS= Days after sowing; NS= Not significant

Table 4.13: Effect of cyhalofop-butyl 10% EC on dry matter (g/m^2) of *Echinochloa* spp. in direct-sown rice crop

Treatments	Dosage (ml a.i./ ha)	Initial weed count (Pre-treatment)		Days after crop sowing							
				30		45		60		75	
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.75	(4.71)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	0.71	(0.00)	0.71	(0.00)	2.55	(7.83)	2.55	(8.33)	0.71	(0.00)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	0.71	(0.00)	0.71	(0.00)	1.51	(3.09)	2.56	(7.88)	1.96	(4.20)
Cyhalofop-butyl 10% EC (Market sample)	75.0	0.71	(0.00)	0.71	(0.00)	1.96	(4.16)	2.36	(10.53)	1.69	(4.27)
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	0.71	(0.00)	0.71	(0.00)	1.81	(4.11)	0.71	(0.00)	0.71	(0.00)
Oxyfluorfen 23.5% EC (Market sample)	152.8	0.71	(0.00)	0.71	(0.00)	3.20	(10.30)	3.74	(13.50)	4.16	(16.8)
Hand weeding at 20 & 40 DAS	-	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.80	(5.13)	1.11	(1.04)
Untreated control (Weedy check)	-	0.71	(0.00)	0.71	(0.00)	3.09	(20.48)	5.84	(56.99)	7.07	(69.60)
SEm±		0.00		0.00		0.95		0.94		1.31	
CD (P=0.05)		0.00		0.00		NS		2.84		3.98	

Data transformed to square root values $\sqrt{x}+0.5$, Original values are given in parentheses
DAS= Days after sowing; NS= Not significant

Table 4.14: Effect of cyhalofop-butyl 10% EC on dry matter (g/m^2) of *Cynodon dactylon* in direct-sown rice crop

Treatments	Dosage (ml a.i./ ha)	Initial weed count (Pre-treatment)		Days after crop sowing							
				30		45		60		75	
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	4.27	(17.80)	4.75	(22.29)	2.65	(7.35)	2.03	(4.95)	1.97	(3.59)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	4.39	(18.75)	5.16	(30.67)	2.63	(6.69)	2.43	(5.84)	2.54	(6.15)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	4.10	(17.05)	5.91	(34.39)	3.12	(10.56)	2.84	(8.33)	2.35	(5.07)
Cyhalofop-butyl 10% EC (Market sample)	75.0	4.13	(16.59)	4.36	(25.60)	2.29	(5.49)	2.51	(6.61)	2.73	(6.93)
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	4.23	(18.63)	3.96	(16.96)	3.09	(9.71)	2.56	(8.97)	1.92	(4.76)
Oxyfluorfen 23.5% EC (Market sample)	152.8	4.14	(16.61)	4.36	(18.49)	3.87	(14.48)	2.97	(9.45)	3.62	(11.91)
Hand weeding at 20 & 40 DAS	-	3.65	(12.92)	5.38	(30.35)	0.71	(0.00)	1.59	(2.52)	2.26	(4.61)
Untreated control (Weedy check)	-	4.29	(17.92)	5.90	(35.44)	3.97	(15.28)	3.12	(16.36)	3.45	(12.29)
SEm±		0.59		0.67		0.51		0.32		0.47	
CD (P=0.05)		NS		NS		NS		NS		NS	

Data transformed to square root values $\sqrt{x} + 0.5$, Original values are given in parentheses
DAS= Days after sowing; NS= Not significant

Table 4.15: Effect of cyhalofop-butyl 10% EC on dry matter (g/m^2) of *Cyperus haspan* in direct-sown rice crop

Treatments	Dosage (ml a.i./ ha)	Initial weed count (Pre-treatment)		Days after crop sowing							
				30		45		60		75	
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.20	(1.41)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.08	(0.93)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.83	(0.21)	0.71	(0.00)
Cyhalofop-butyl 10% EC (Market sample)	75.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.97	(0.49)	0.71	(0.00)
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.99	(0.26)	1.26	(1.69)
Oxyfluorfen 23.5% EC (Market sample)	152.8	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.05	(1.05)	0.71	(0.00)
Hand weeding at 20 & 40 DAS	-	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.73	(0.03)	2.07	(1.97)
Untreated control (Weedy check)	-	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.13	(1.50)	1.58	(2.00)
SEm±		0.00		0.00		0.00		0.10		0.41	
CD (P=0.05)		0.00		0.00		0.00		NS		NS	

Data transformed to square root values $\sqrt{x}+0.5$, Original values are given in parentheses
DAS= Days after sowing; NS= Not significant

Table 4.16: Effect of cyhalofop-butyl 10% EC on dry matter (g/m^2) of *Cyperus irria* in direct-sown rice crop

Treatments	Dosage (ml a.i./ ha)	Initial weed count (Pre-treatment)		Days after crop sowing							
				30		45		60		75	
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	3.35	(10.69)	1.62	(2.14)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	2.99	(11.01)	0.71	(0.00)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.49	(2.95)	0.71	(0.00)
Cyhalofop-butyl 10% EC (Market sample)	75.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	3.63	(12.67)	1.64	(3.93)
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.06	(0.86)
Oxyfluorfen 23.5% EC (Market sample)	152.8	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)
Hand weeding at 20 & 40 DAS	-	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.81	(0.17)	0.71	(0.00)
Untreated control (Weedy check)	-	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	3.72	(13.36)	2.11	(3.97)
SEm±		0.00		0.00		0.00		0.96		0.41	
CD (P=0.05)		0.00		0.00		0.00		2.90		1.24	

Data transformed to square root values $\sqrt{x} + 0.5$, Original values are given in parentheses
DAS= Days after sowing

Table 4.17: Effect of cyhalofop-butyl 10% EC on dry matter (g/m^2) of *Cyperus rotundus* in direct-sown rice crop

Treatments	Dosage (ml a.i./ ha)	Initial weed count (Pre-treatment)		Days after crop sowing							
				30		45		60		75	
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	2.99	(8.59)	6.43	(40.99)	11.06	(125.75)	4.01	(22.23)	6.70	(56.69)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	3.26	(10.17)	7.78	(60.37)	10.96	(120.47)	7.49	(55.63)	8.05	(71.09)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	4.23	(18.09)	6.44	(40.97)	11.24	(125.75)	6.77	(45.35)	7.86	(70.34)
Cyhalofop-butyl 10% EC (Market sample)	75.0	3.62	(12.64)	5.47	(34.28)	12.30	(150.67)	7.87	(61.51)	8.17	(71.98)
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	4.61	(20.95)	7.10	(59.87)	12.27	(50.00)	6.65	(61.40)	8.32	(68.70)
Oxyfluorfen 23.5% EC (Market sample)	152.8	3.20	(10.73)	7.20	(60.00)	6.95	(51.67)	7.63	(58.00)	7.86	(70.35)
Hand weeding at 20 & 40 DAS	-	3.42	(11.36)	4.31	(27.84)	0.71	(0.00)	3.33	(11.25)	1.52	(2.20)
Untreated control (Weedy check)	-	4.04	(16.08)	9.00	(80.76)	11.01	(152.28)	9.15	(65.19)	8.55	(74.16)
SEm±		0.42		1.84		1.99		1.56		1.46	
CD (P=0.05)		NS		NS		NS		4.13		4.44	

Data transformed to square root values $\sqrt{x} + 0.5$, Original values are given in parentheses
DAS= Days after sowing, NS: Not significant

Table 4.18: Effect of cyhalofop-butyl 10% EC on dry matter (g/m^2) of *Lindernia crustacea* in direct-sown rice crop

Treatments	Dosage (ml a.i./ ha)	Initial weed count (Pre-treatment)		Days after crop sowing							
				30		45		60		75	
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	1.72	(1.00)	1.16	(1.01)	1.11	(1.05)	1.09	(0.99)	0.85	(0.27)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	1.20	(0.93)	1.35	(1.32)	1.73	(3.00)	1.22	(1.52)	1.50	(1.76)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	1.17	(0.87)	1.19	(1.07)	1.14	(1.16)	1.32	(1.45)	1.58	(2.00)
Cyhalofop-butyl 10% EC (Market sample)	75.0	1.50	(1.75)	1.38	(1.41)	1.41	(2.49)	1.52	(3.16)	1.20	(1.09)
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	1.22	(0.98)	0.74	(0.05)	0.91	(0.40)	0.87	(0.31)	1.25	(1.26)
Oxyfluorfen 23.5% EC (Market sample)	152.8	1.23	(1.02)	1.05	(0.65)	1.08	(0.95)	0.71	(0.00)	0.71	(0.00)
Hand weeding at 20 & 40 DAS	-	1.19	(0.92)	0.91	(0.37)	0.71	(0.00)	1.37	(1.72)	1.23	(1.23)
Untreated control (Weedy check)	-	1.18	(0.89)	1.67	(2.28)	2.47	(5.59)	1.84	(3.20)	1.76	(2.62)
SEm±		0.22		0.36		0.37		0.44		0.37	
CD (P=0.05)		NS		NS		NS		NS		NS	

Data transformed to square root values $\sqrt{x} + 0.5$, Original values are given in parentheses
DAS= Days after sowing; NS: Not significant

Table 4.19: Effect of cyhalofop-butyl 10% EC on dry matter (g/m^2) of *Lindernia procumbens* in direct-sown rice

Treatments	Dosage (ml a.i./ ha)	Initial weed count (Pre-treatment)		Days after crop sowing							
				30		45		60		75	
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.66	(2.24)	2.06	(4.90)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	0.71	(0.00)	0.71	(0.00)	1.11	(0.74)	1.79	(2.71)	1.91	(4.25)
Cyhalofop-butyl 10% EC (Market sample)	75.0	0.71	(0.00)	0.71	(0.00)	1.11	(0.74)	1.30	(1.91)	1.86	(4.05)
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	0.71	(0.00)	0.71	(0.00)	0.97	(0.59)	0.98	(0.61)	1.06	(0.63)
Oxyfluorfen 23.5% EC (Market sample)	152.8	0.71	(0.00)	0.71	(0.00)	1.11	(0.70)	0.71	(0.00)	1.12	(0.91)
Hand weeding at 20 & 40 DAS	-	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.98	(0.52)	1.25	(1.67)
Untreated control (Weedy check)	-	0.71	(0.00)	0.71	(0.00)	1.02	(0.75)	1.53	(3.25)	2.24	(5.94)
SEm±		0.00		0.00		0.25		0.27		0.53	
CD (P=0.05)		0.00		0.00		NS		NS		NS	

Data transformed to square root values $\sqrt{x} + 0.5$, Original values are given in parentheses
DAS= Days after sowing; NS= Not significant

Table 4.20: Effect of cyhalofop-butyl 10% EC on dry matter (g/m^2) of *Eclipta alba* in direct-sown rice crop

Treatments	Dosage (ml a.i./ ha)	Initial weed count (Pre-treatment)		Days after crop sowing							
				30		45		60		75	
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	0.71	(0.00)	0.71	(0.00)	0.71	((0.00)	1.07	(0.92)	1.39	(1.70)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.57	(1.95)	1.15	(0.99)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	0.71	(0.00)	0.71	(0.00)	1.21	(1.47)	1.12	(1.08)	0.96	(0.47)
Cyhalofop-butyl 10% EC (Market sample)	75.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.29	(1.36)	1.46	(1.91)
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.22	(1.51)	1.67	(2.28)
Oxyfluor 23.5% EC (Market sample)	152.8	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.88	(0.34)
Hand weeding at 20 & 40 DAS	-	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.77	(0.11)	0.89	(0.30)
Untreated control (Weedy check)	-	0.71	(0.00)	0.71	(0.00)	1.69	(2.34)	1.82	(2.81)	1.94	(3.27)
SEm±		0.00		0.00		0.92		0.35		0.23	
CD (P=0.05)		0.00		0.00		NS		NS		NS	

Data transformed to square root values $\sqrt{x} + 0.5$, Original values are given in parentheses
DAS= Days after sowing; NS= Not significant

Table 4.21: Effect of cyhalofop-butyl 10% EC on dry matter (g/m^2) of *Phyllanthus niruri* in direct-sown rice crop

Treatments	Dosage (ml a.i./ ha)	Initial weed count (Pre-treatment)		Days after crop sowing							
				30		45		60		75	
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.82	(0.20)	0.91	(0.41)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.32	(1.97)	1.20	(1.07)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.39	(1.55)
Cyhalofop-butyl 10% EC (Market sample)	75.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.27	(1.35)
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.29	(1.84)	1.47	(1.67)
Oxyfluorfen 23.5% EC (Market sample)	152.8	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)
Hand weeding at 20 & 40 DAS	-	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)
Untreated control (Weedy check)	-	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	2.30	(4.83)	1.51	(1.739)
SEm±		0.00		0.00		0.00		0.28		0.27	
CD (P=0.05)		0.00		0.00		0.00		0.85		NS	

Data transformed to square root values $\sqrt{x} + 0.5$, Original values are given in parentheses
DAS= Days after sowing; NS= Not significant

Table 4.22: Effect of cyhalofop-butyl Cyhalofop-butyl 10% EC on dry matter (g/m^2) of *Spilanthes acmella* in direct-sown rice crop

Treatments	Dosage (ml a.i./ ha)	Initial weed count (Pre-treatment)		Days after crop sowing							
				30		45		60		75	
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.15	(1.21)	1.02	(0.75)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.20	(0.95)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.98	(0.51)
Cyhalofop-butyl 10% EC (Market sample)	75.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.87	(0.32)	0.86	(0.25)
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.41	(1.76)	1.20	(0.93)
Oxyfluorfen 23.5% EC (Market sample)	152.8	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)
Hand weeding at 20 & 40 DAS	-	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.87	(0.30)
Untreated control (Weedy check)	-	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	2.12	(4.05)	1.20	(1.01)
SEm±		0.00		0.00		0.00		0.22		0.18	
CD (P=0.05)		0.00		0.00		0.00		0.67		NS	

Data transformed to square root values $\sqrt{x} + 0.5$, Original values are given in parentheses
DAS= Days after sowing; NS= Not significant

Table 4.23: Effect of 10% EC on dry matter (g/m^2) of *Paspalum conjugatam* in direct-sown rice crop

Treatments	Dosage (ml a.i./ ha)	Initial weed count (Pre-treatment)		Days after crop sowing							
				30		45		60		75	
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	1.10	(1.02)
Cyhalofop-butyl 10% EC (Market sample)	75.0	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)
Oxyfluorfen 23.5% EC (Market sample)	152.8	0.71	(0.00)	0.71	(0.00)	2.66	(14.20)	4.30	(18.00)	3.23	(9.95)
Hand weeding at 20 & 40 DAS	-	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.71	(0.00)	0.99	(0.65)
Untreated control (Weedy check)	-	0.71	(0.00)	0.71	(0.00)	4.08	(38.97)	4.13	(16.56)	2.31	(9.98)
SEm±		0.00		0.00		1.29		0.75		0.54	
CD (P=0.05)		0.00		0.00		NS		2.25		NS	

Data transformed to square root values $\sqrt{x} + 0.5$, Original values are given in parentheses
DAS= Days after sowing; NS= Not significant

Table 4.24: Effect of cyhalofop-butyl 10% EC on weed control efficiency (%) of *Echinochloa* spp. in direct-sown rice crop

Treatments	Dosage (ml a.i./ ha)	Weed control efficiency (%) based on weed dry weight in untreated control			
		30 DAS	45 DAS	60 DAS	75 DAS
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	-	100.00	100.00	93.23
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	-	61.77	85.38	100.00
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	-	84.91	86.17	93.97
Cyhalofop-butyl 10% EC (Market sample)	75.0	-	79.69	81.52	93.86
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	-	79.93	100.00	100.00
Oxyfluorfen 23.5% EC (Market sample)	152.8	-	49.71	76.31	75.90
Hand weeding at 20 & 40 DAS		-	100.00	91.00	98.51
Untreated control (Weedy check)		-	-	-	-

DAS= Days after crop sowing

Table 4.25: Effect of cyhalofop-butyl 10% EC on weed control efficiency (%) of *Cynodon dactylon* in direct-sown rice crop

Treatments	**Dosage (ml a.i./ ha)**	**Weed control efficiency (%) based on weed dry weight in untreated control**			
		30 DAS	**45 DAS**	**60 DAS**	**75 DAS**
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	37.10	51.90	69.74	70.79
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	13.46	56.22	64.30	49.96
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	2.96	30.89	55.20	58.75
Cyhalofop-butyl 10% EC (Market sample)	75.0	27.77	64.07	59.60	43.61
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	52.14	36.45	45.17	61.27
Oxyfluorfen 23.5% EC (Market sample)	152.8	47.83	5.24	36.12	3.09
Hand weeding at 20 & 40 DAS		14.36	41.10	84.60	62.49
Untreated control (Weedy check)		-	-	-	-

DAS= Days after crop sowing

Table 4.26: Effect of cyhalofop-butyl 10% EC on weed control efficiency (%) of *Cyperus haspan* in direct-sown rice crop

Treatments	**Dosage (ml a.i./ ha)**	**Weed control efficiency (%) based on weed dry weight in untreated control**			
		30 DAS	**45 DAS**	**60 DAS**	**75 DAS**
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	-	-	100.00	40.00
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	-	-	100.00	46.00
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	-	-	96.42	100.00
Cyhalofop-butyl 10% EC (Market sample)	75.0	-	-	91.65	100.00
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	-	-	95.74	15.50
Oxyfluorfen 23.5% EC (Market sample)	152.8	-	-	82.11	100.00
Hand weeding at 20 & 40 DAS		-	-	99.49	1.50
Untreated control (Weedy check)		-	-	-	-

DAS= Days after crop sowing

Table 4.27: Effect of cyhalofop-butyl 10% EC on weed control efficiency (%) of *Cyperus irria* in direct-sown rice crop

Treatments	Dosage (ml a.i./ ha)	Weed control efficiency (%) based on weed dry weight in untreated control			
		30 DAS	45 DAS	60 DAS	75 DAS
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	-	-	20.0	46.1
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	-	-	17.59	100.00
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	-	-	77.92	100.00
Cyhalofop-butyl 10% EC (Market sample)	75.0	-	-	5.16	1.01
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	-	-	100.0	78.34
Oxyfluorfen 23.5% EC (Market sample)	152.8	-	-	100.0	100
Hand weeding at 20 & 40 DAS		-	-	98.7	100
Untreated control (Weedy check)		-	-	-	-

DAS= Days after crop sowing

Table 4.28: Effect of cyhalofop-butyl 10% EC on weed control efficiency (%) of *Cyperus rotundus* in direct-sown rice crop

Treatments	**Dosage (ml a.i./ ha)**	**Weed control efficiency (%) based on weed dry weight in untreated control**			
		30 DAS	**45 DAS**	**60 DAS**	**75 DAS**
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	49.2	17.42	65.9	23.56
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	25.2	20.89	14.66	4.14
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	86.4	17.42	30.43	5.15
Cyhalofop-butyl 10% EC (Market sample)	75.0	57.6	1.06	5.65	2.94
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	25.9	67.17	5.81	7.36
Oxyfluorfen 23.5% EC (Market sample)	152.8	25.7	66.07	11.00	5.14
Hand weeding at 20 & 40 DAS		65.5	67.82	82.70	97.03
Untreated control (Weedy check)		-	-	-	-

DAS= Days after crop sowing

Table 4.29: Effect of cyhalofop-butyl 10% EC on weed control efficiency (%) of *Lindernia crustacean* in direct-sown rice crop

Treatments	Dosage (ml a.i./ ha)	Weed control efficiency (%) based on weed dry weight in untreated control			
		30 DAS	45 DAS	60 DAS	75 DAS
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	53.1	79.25	54.69	23.70
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	42.1	46.33	52.50	32.80
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	55.7	81.22	69.06	89.69
Cyhalofop-butyl 10% EC (Market sample)	75.0	38.16	55.46	1.25	58.40
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	98.0	92.84	76.3	51.91
Oxyfluorfen 23.5% EC (Market sample)	152.8	71.5	83.01	100.00	100.00
Hand weeding at 20 & 40 DAS		83.8	100.00	46.25	53.05
Untreated control (Weedy check)		-	-	-	-

DAS= Days after crop sowing

Table 4.30: Effect of cyhalofop-butyl 10% EC on weed control efficiency (%) of *Lindernia procumbens* in direct-sown rice crop

Treatments	**Dosage (ml a.i./ ha)**	**Weed control efficiency (%) based on weed dry weight in untreated control**			
		30 DAS	**45 DAS**	**60 DAS**	**75 DAS**
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	-	100.00	100.00	100.00
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	-	100.00	31.1	17.5
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	-	1.33	16.6	28.5
Cyhalofop-butyl 10% EC (Market sample)	75.0	-	1.33	41.2	31.8
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	-	21.33	81.2	89.4
Oxyfluorfen 23.5% EC (Market sample)	152.8	-	6.67	100.00	84.7
Hand weeding at 20 & 40 DAS		-	100.00	84.0	71.9
Untreated control (Weedy check)		-	-	-	-

DAS= Days after crop sowing

Table 4.31: Effect of cyhalofop-butyl 10% EC on weed control efficiency (%) of *Eclipta alba* in direct-sown rice crop

Treatments	Dosage (ml a.i. / ha)	Weed control efficiency (%) based on weed dry weight in untreated control			
		30 DAS	45 DAS	60 DAS	75 DAS
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	-	100	67.3	48.0
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	-	100	30.6	69.7
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	-	37	61.6	85.6
Cyhalofop-butyl 10% EC (Market sample)	75.0	-	100	69	41.6
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	-	100	46.3	30.3
Oxyfluorfen 23.5% EC (Market sample)	152.8	-	100	100	89.6
Hand weeding at 20 & 40 DAS		-	100	96.1	90.8
Untreated control (Weedy check)		-	-	-	-

DAS= Days after crop sowing

Table 4.32: Effect of cyhalofop-butyl 10% EC on weed control efficiency (%) of *Phyllanthus niruri* in direct-sown rice crop

Treatments	Dosage (ml a.i./ ha)	Weed control efficiency (%) based on weed dry weight in untreated control			
		30 DAS	45 DAS	60 DAS	75 DAS
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	-	-	95.86	77.1
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	-	-	59.21	40.2
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	-	-	100.00	13.4
Cyhalofop-butyl 10% EC (Market sample)	75.0	-	-	100.00	24.6
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	-	-	61.90	6.7
Oxyfluorfen 23.5% EC (Market sample)	152.8	-	-	100.00	100.00
Hand weeding at 20 & 40 DAS		-	-	100.00	100.00
Untreated control (Weedy check)		-	-	-	-

DAS= Days after crop sowing

Table 4.33: Effect of cyhalofop-butyl 10% EC on weed control efficiency (%) of *Spilanthes acmella* in direct-sown rice crop

Treatments	Dosage (ml a.i./ ha)	Weed control efficiency (%) based on weed dry weight in untreated control			
		30 DAS	45 DAS	60 DAS	75 DAS
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	-	-	70.12	25.74
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	-	-	100.00	5.94
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	-	-	100.00	49.50
Cyhalofop-butyl 10% EC (Market sample)	75.0	-	-	92.10	75.25
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	-	-	56.54	7.92
Oxyfluorfen 23.5% EC (Market sample)	152.8	-	-	100.00	100.00
Hand weeding at 20 & 40 DAS		-	-	100.00	70.30
Untreated control (Weedy check)		-	-	-	-

DAS= Days after crop sowing

Table 4.34: Effect of cyhalofop-butyl 10% EC on weed control efficiency (%) of *Paspalum conjugatam* in direct-sown rice crop

Treatments	Dosage (ml a.i./ ha)	Weed control efficiency (%) based on weed dry weight in untreated control			
		30 DAS	45 DAS	60 DAS	75 DAS
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	-	100.00	100.00	100.00
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	-	100.00	100.00	100.00
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	-	100.00	100.00	89.78
Cyhalofop-butyl 10% EC (Market sample)	75.0	-	100.00	100.00	100.00
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	-	100.00	100.00	100.00
Oxyfluorfen 23.5% EC (Market sample)	152.8	-	63.56	8.7	30.1
Hand weeding at 20 & 40 DAS		-	100.00	100	93.49
Untreated control (Weedy check)		-	-	-	-

DAS= Days after crop sowing

Table 4.35: Effect of cyhalofop-butyl 10% EC on plant height (cm) of direct-sown rice crop

Treatments	Dosage (ml a.i./ ha)	Plant height (cm)			
		30 DAS	60 DAS	90 DAS	At harvest
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	15.21	55.81	78.30	79
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	15.47	56.56	71.76	75
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	17.53	58.87	76.19	78
Cyhalofop-butyl 10% EC (Market sample)	75.0	15.04	58.17	74.43	79
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	14.60	56.35	71.50	73
Oxyfluorfen 23.5% EC (Market sample)	152.8	14.53	57.20	67.73	72
Hand weeding at 20 & 40 DAS	-	16.21	57.59	72.52	82
Untreated control (Weedy check)	-	16.64	55.39	64.67	76
SEm±		0.96	2.44	2.02	1.28
CD (P=0.05)		NS	NS	6.13	3.82

DAS= Days after crop sowing; NS= Non-significant

Table 4.36: Effect of cyhalofop butyl 10% EC on number of tillers per running meter of direct-sown rice crop

Treatments	Dosage (ml a.i./ ha)	Days after sowing		
		30	60	90
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	15.75	21.42	20.67
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	17.25	20.67	20.83
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	26.08	22.00	23.00
Cyhalofop-butyl 10% EC (Market sample)	75.0	22.92	21.17	22.00
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	19.08	20.33	19.58
Oxyfluorfen 23.5% EC (Market sample)	152.8	16.92	20.00	22.92
Hand weeding at 20 & 40 DAS	-	22.83	22.83	26.42
Untreated control (Weedy check)	-	16.58	17.67	19.33
SEm±		2.05	1.47	1.69
CD (P=0.05)		6.23	NS	NS

DAS= Days after crop sowing; NS= Non-significant

Table 4.37: Effect of cyhalofop butyl 10% EC on dry matter (g) accumulation per running meter of direct-swon rice crop

Treatments	Dosage (ml a.i./ ha)	Date after sowing		
		30	60	90
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	9.02	75.21	120.4
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	8.68	69.77	113.65
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	7.78	73.19	110.2
Cyhalofop-butyl 10% EC (Market sample)	75.0	8.65	67.31	105.89
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	6.12	65.40	87.11
Oxyfluorfen 23.5% EC (Market sample)	152.8	6.86	60.11	84.33
Hand weeding at 20 & 40 DAS	-	10.39	75.19	150.5
Untreated control (Weedy check)	-	5.83	47.48	78.69
SEm±		1.08	1.36	1.75
CD (P=0.05)		NS	4.11	5.31

DAS= Days after crop sowing; NS= Non-significant

Table 4.38: Effect of cyhalofop butyl 10% EC number of leaves per plant of direct-sown rice crop

Treatments	Dosage (ml a.i./ ha)	Days after sowing		
		30	60	90
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	3.58	5.50	4.75
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	3.41	5.42	4.50
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	3.25	5.42	4.67
Cyhalofop-butyl 10% EC (Market sample)	75.0	3.50	5.48	4.08
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	3.25	5.25	4.25
Oxyfluorfen 23.5% EC (Market sample)	152.8	3.75	5.42	4.17
Hand weeding at 20 & 40 DAS	-	3.66	5.50	4.75
Untreated control (Weedy check)	-	3.16	5.33	4.00
SEm±		0.20	0.17	0.23
CD (P=0.05)		NS	NS	0.69

DAS= Days after crop sowing; NS= Non-significant

Table 4.39: Effect of cyhalofop-butyl 10% EC on growth, yield attributes and yield of direct-sown rice crop

Treatments	Dosage (ml a.i./ ha)	Effective panicles/m^2 (No.)	No. of grains / panicle	Panicle length (cm)	Fresh weight of panicle (g)	Test weight (g)	Grain yield (kg/ha)	Straw yield (kg/ha)
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	239	100	20.4	35.4	21.6	3692	4632
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	234	96	20.4	34.6	20.4	3568	4436
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	232	98	20.3	35.9	20.4	3525	4425
Cyhalofop-butyl 10% EC (Market sample)	75.0	218	94	21.2	34.1	20.3	2875	3609
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	213	96	20.7	35.3	19.6	3499	4367
Oxyfluorfen 23.5% EC (Market sample)	152.8	209	90	20.0	31.5	19.9	3379	4237
Hand weeding at 20 & 40 DAS	-	248	103	21.5	35. 5	21.4	4251	5300
Untreated control (Weedy check)	-	218	88	20.7	31.2	20.3	2646	3307
SEm±		2.23	1.24	0.34	0.80	0.60	55.8	71.0
CD (P=0.05)		6.69	3.81	NS	2.40	1.57	169.1	213.3

NS= Non-significant

Table 4.40: Phytotoxicity evaluation of cyhalofop-butyl 10% EC on direct-sown rice crop

Treatment	Dose (ml a.i./ ha)	Phytotoxicity parameters observed based on 0-10 scale*																								
		Leaf injury on tips/ surface (DTA)					Wilting (DTA)					Vein clearing (DTA)					Necrosis (DTA)					Hyponasty/epinasty (DTA)				
		10	20	30	45	60	10	20	30	45	60	10	20	30	45	60	10	20	30	45	60	10	20	30	45	60
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	8	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	3	0	0	0	0	0
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	7	7	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	4	0	0	0	0	0
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	6	5	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	3	0	0	0	0	0
Cyhalofop-butyl 10% EC (Market sample)	75.0	8	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	5	3	0	0	0	0	0
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	5	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	6	4	0	0	0	0	0
Oxyfluorfen 23.5% EC (Market sample)	152.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hand weeding at 20 & 40 DAS	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Untreated control (Weedy check)	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample	1600	6	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	7	5	0	0	0	0	0

DTA: Days of Treatment Application

* Scale 0-10 where: 0=0%, 1=1-10%, 2=11-20%, 3=21-30%, 4=31-40%, 5=41-50%, 6=51-60%, 7=61-70%, 8=71-80%, 9=81-90%, 10=91-100%

Table 4.41: Effect of cyhalofop butyl 10% EC on nutrient content in grain and straw of rice

Treatments	Dosage (ml a.i. ha^{-1})	Nitrogen (%)		Phosphorus (%)		Potassium (%)	
		Grain	Straw	Grain	Straw	Grain	Straw
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	1.44	0.685	0.17	0.076	0.391	1.68
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	1.37	0.692	0.16	0.078	0.376	1.29
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	1.36	0.680	0.15	0.077	0.362	1.32
Cyhalofop-butyl 10% EC (Market sample)	75.0	1.33	0.672	0.13	0.076	0.374	1.29
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	1.50	0.667	0.14	0.075	0.354	1.31
Oxyfluorfen 23.5% EC (Market sample)	152.8	1.59	0.664	0.15	0.077	0.361	1.30
Hand weeding at 20 & 40 DAS	-	1.52	0.682	0.16	0.076	0.341	1.36
Untreated control (Weedy check)	-	1.64	0.671	0.23	0.078	0.312	1.30
SEm±		0.7	0.01	0.12	0.1	0.02	0.09
CD (P=0.05)		NS	NS	NS	NS	NS	NS

NS= Non-significant

Table 4.42: Effect of cyhalofop butyl 10% EC on nutrient uptake by crop

Treatments	Dosage (ml a.i. ha^{-1})	Nitrogen (kg ha^{-1})		Phosphorus (kg ha^{-1})		Potassium (kg ha^{-1})	
		Grain	Straw	Grain	Straw	Grain	Straw
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	53.16	31.72	6.27	3.52	14.43	77.81
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	48.88	30.69	5.7	3.46	13.41	57.22
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	47.94	30.09	5.28	3.40	12.76	58.41
Cyhalofop-butyl 10% EC (Market sample)	75.0	38.23	24.18	3.7	3.36	10.75	46.55
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	52.48	28.82	5.2	3.27	12.38	57.20
Oxyfluorfen 23.5% EC (Market sample)	152.8	53.72	27.96	5.06	3.26	12.19	55.08
Hand weeding at 20 & 40 DAS	-	64.61	36.08	6.8	4.02	13.30	72.08
Untreated control (Weedy check)	-	43.39	22.15	5.29	3.30	8.25	42.99
SEm±		0.76	1.09	0.38	0.37	0.85	9.30
CD (P=0.05)		2.30	3.32	1.16	NS	2.58	NS

NS= Non-significant

Table 4.43: Relative Economics of the treatments.

Treatment	**Dosage (ml a.i. ha^{-1})**	**Total cost of cultivation (ha^{-1})**	**Grain yield (kg ha^{-1})**	**Straw yield (kg ha^{-1})**	**Gross Income (ha^{-1})**	**Net return (ha^{-1})**	**B-C ratio**
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	44115	3692	4632	113313	69198	1.5
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	44318	3568	4436	109144	64826	1.4
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	44522	3525	4425	108210	63688	1.4
Cyhalofop-butyl 10% EC (Market sample)	75.0	44259	2875	3609	88256	43997	0.99
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	45058	3499	4367	107184	62126	1.3
Oxyfluorfen 23.5% EC (Market sample)	152.8	44444	3379	4237	103686	59242	1.3
Hand weeding at 20 & 40 DAS	-	53892	4251	5300	130170	76278	1.4
Untreated control (Weedy check)	-	41052	2446	3307	81096	40044	0.97

Market cost of produce: Grain @ Rs 19.4 kg^{-1}; Straw @ Rs 9 kg^{-1}

Table 4.44: Residual effect of cyhalofop-butyl 10% EC on crop germination, plant population, yield attributes and yield of mustard

Treatments (applied in main paddy crop)	**Dosage (ml a.i. ha^{-1})**	**Per cent crop germination**	**Mean plant population/m^2 (30 DAS)**	**Plant height(cm)**	**Yield attributes**						**Grain Yield (kg ha^{-1})**
					No. of Primary branch	**No. of secondary branch**	**Number of siliquae on main shoot (Per shoot)**	**Siliquae per plant**	**Length of siliqua(cm)**	**1000-Seed weight (g)**	
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	75.0	96.33	15.6	193.13	2.93	4.20	46.53	161.40	26.43	3.83	898
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	80.0	96.00	14.8	182.87	2.93	5.13	54.60	174.07	25.80	4.00	950
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample)	85.0	97.33	13.6	173.47	2.87	3.93	49.07	165	26.91	3.91	953
Cyhalofop-butyl 10% EC (Market sample)	75.0	97.33	14.4	181.07	3.13	5.20	53.47	175	26.36	4.12	917
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample)	54.5	96.67	14.4	174.3	3.40	5.33	44.87	181	26.19	3.90	921
Oxyfluorfen 23.5% EC (Market sample)	152.8	95.00	13.1	177.07	3.00	4.80	49.33	166	26.17	3.40	944
Hand weeding at 20 & 40 DAS	-	98.67	14.0	192.0	3.33	4.27	51.27	179	26.34	3.87	889
Untreated control (Weedy check)	-	97.67	15.4	188.93	3.00	3.07	51.20	157.27	27.01	3.93	931
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample	1600	95.67	13.2	-	-	-	-	-	-	-	-
SEm±		0.77	0.14	3.44	0.22	1.03	3.88	12.4	0.47	0.07	24
CD(P=0.05)		NS	NS	10.42	0.68	3.12	11.77	NS	NS	NS	NS

NS = Non-significant

Chapter V

DISCUSSION

The final yield of a crop is the net result of the extent to which individual plants successfully complete growth and development activities, which would depend on the genetic potential of the cultivar and the environmental conditions to which it is exposed during the course of its life cycle. Several agronomic manipulations are possible to change the micro-environment so that the cultivar's true potential can be realised to the greatest extent possible. As a result, in order to maximise potential under a given set of agroclimatic conditions, it is critical that various plant environment factors remain at optimal levels.

Weeds are considered to be greatest enemy of crop plants and have been found to cause significant economic loss due to their luxuriant growth, which intensification competition for nutrients, moisture, space and light without leaving visible sign of distress. Weed control in rice has been widely recognized and accepted, as weeds, if not controlled, have a number of negative effects on the realization of potential yield of rice crop, even when other inputs are adequate. Because crop and weed have similar growth and development requirements, competition begins when crop and weed grow in close proximity to each other and supply of a single necessary factor falls below the demands of both. When this happens, even if other growth factors are abundant, they can't be used effectively.

In past a number of herbicides have been developed and recommended to control weeds in rice. However, due to varying rice-ecosystem the effectivity of various weed control methods is also affected. As a result, a weed control method that works well in one rice culture may not work well in another. Not only that, but due to frequent changes in weed flora caused by the continued use of similar weed control methods, as well as changes in rice culture, the nature of rice-weed competition has changed over the years. Therefore, integrated weed management practices strategies with various components have emerged. The results of this experiment were previously presented in the preceding chapter.

Keeping all above mention factors and constraints in view, the current research project entitled “**Bio-efficacy of cyhalofop-butyl 10 per cent EC against weeds in direct-sown rice (*Oryza sativa* L.) and their residual effect on mustard (*Brassica juncea* L.)**” was taken up. In this chapter, an attempt has been made to discuss the explanation and experimental evidence for the variations recorded in light of established physiological and biochemical processes whenever possible in order to understand the causes and effect relationship as far as possible in order to draw valid conclusions. Relevant references have been cited to support the findings and possible causes as per need.

5.1 Effect of weather on crop and weeds

Weather conditions have an impact on field investigation results. As a result, any discussion of the results would be inappropriate unless the weather relationship with crop was taken into account in order to arrive at the correct interpretation and conclusion. The details of rainfall, temperature, and relative humidity during the investigation are presented in Table and illustrated in fig. (3.1). The variation in weather parameters has a significant impact on crop growth and development. Every crop has its own cardinal point of air temperature, relative humidity and vapour pressure for maximising yield potential. If the deviation from optimum becomes too large, the plants suffer, resulting in poor growth, development, and yield. This effect is more pronounced in crops which are grown in diverse climatic and environmental conditions. Rice is primarily a crop grown in the warm regions of the tropics and subtropics. The overall performance was good, and the possible reasons appear to be favourable weather conditions during the 2020 wet season.

5.2 Effect of treatments on weeds

5.2.1 Weed flora

The significant weed flora recorded at 30, 45, 60 and 75 DAS suggest that the crop was infested with grasses, sedges and broad-leaved weeds. The important weed species in untreated plot were *Echinochloa colonum, Echinochloa crusgalli*, *cynodon* *dactylon, Cyperus haspan, Cyperus irria, Cyperus rotundus, Eclipta alba, Phyllanthus niruri, Lindernia procumbens, Lindernia crustacea, Spilanthes acmella, Paspalum conjugatam.* The dominance grassy weeds *viz*., *Echinochloa crusgalli,* and *Echinochloa colona* can be attributed to simultaneous germination of these species along with rice seeds under favourable soil moisture and temperature. Further, being C_4 plants, they smothered the germination and growth of the other weed species in the field. These findings are consistent with those of **(Jacab *et al*., 2017), Patel *et al*., 2018** and **Menon, 2019,** who all found that grassy weeds outcompeted other species in direct seeded rice.

5.2.2 Weed density

The data on weed density of different weeds as affected by various treatments sprayed as post emergence envisaged significant reduction in weed density of *Echinochloa* spp., *Eclipta alba*, *Spilanthes acmella* and *Paspalum conjugatum*, at all the dates of observation as compare to the weedy check, but two hand weeding was found to be more effective in reducing weed density as compare to all the herbicidal treatments. The density of various weeds tends to increase with crop age up to 90 days and then decline, regardless of treatment. This is due to the fact that in the early stages of crop, the necessities of weeds plants remain low, resulting in more growth of new weeds plants, so in the early stages of crop, weeds have a higher chance of occurrence, but in the later stages, weed density declines due to crop smothering.

It could be seen from fig. 5.1-5.4 to effect of treatments differed significant for different weeds, two hand weeding at 20 and 40 days after sowing density recorded the maximum reduction of weed density, this results also reported by **Mishra *et al*., 2016 and Singh *et al*. 2017**. Grassy weeds *Echinochloa* spp. was significantly reduced with application of cyhalofop-butyl 10% EC at rates 75.0 ml a.i. ha^{-1} and recorded lower density at all the dates of observation. Any of the treatments was not found significant result against broad leaves but application of oxyfluorfen 23.5% EC (market sample) @ 152.8 ml a.i. ha^{-1} was recorded the minimum weed density of *Eclipta alba and Spilanthes acmella* as compare to other treatments at all the dates of observation. Lower weed density of *Paspalum conjugatum*, was recorded by the application of cyhalofop-butyl 10% EC @ 75.0 ml a.i. ha^{-1} at all the dates observation. This might because of herbicidal effect. Similar finding reported by **(Kumar and Rana, 2013), Permeela *et* al. 2014, and Kailkhura *et al*., 2015.**

5.2.3 Weed dry matter accumulation

It could be seen from fig. 5.5-5.8 that all weed control treatments significantly reduced the dry matter of different weeds as compare to weedy check plot at all the dates of observation. The dry weight of weeds increases with the advancement of crop age up to 90 Days. The lowest weed dry weight recorded under the two hand weeding plots at 20 and 40 days after application of herbicide as compare to all the herbicidal treatments. Among the herbicidal treatments, application of cyhalofop-butyl 10% EC @ 75.0 ml a.i. ha^{-1} was recorded significantly lower weed dry matter accumulation in grassy weeds *Echinochloa* spp. as compare to other treatments at all the dates of observation. This might be because of the minimum weed population of grassy weeds due to the herbicidal effect. Similar results have been also reported by **Mishra *et al*. (2016) and Patel *et al*. (2018).** Among the broad leaves weeds (*Eclipta alba*, *Spilanthes acmella* and *Paspalum conjugatum*) under the application of oxyfluorfen 23.5% EC (market sample) @ 152.8 ml a.i. ha^{-1} was recorded significantly the lowest weed dry matter as compare to the weedy check and all other treatments at all the dates of observation. Lower dry matter accumulation was recorded *Paspalum conjugatum* by the application of cyhalofop-butyl 10% EC @ 75.0 ml a.i. ha^{-1} at all the dates observation. Similar results have been also reported by **Singh *et al*. (2019).**

5.2.4 Weed control efficiency (%)

The relative efficacy of weed control treatments in comparison to untreated control is referred to as weed control efficiency. The weed control efficiency is inversely related to dry matter production of weeds. The manually two-hand weeded plot had the highest weed control efficiency at 20 and 40 days after treatment application. Among the herbicidal treatments, application of cyhalofop-butyl 10% EC (best crop sc LLP sample) @ 75.0 ml a.i. ha^{-1} suppressed *Echinochloa* spp. weed more effectively in comparison to the other treatments, and recorded the maximum WCE 90%. Similar finding also reported by **Kailkhura *et al*. (2015)**

Among the broad-leaved weeds, application of cyhalofop butyl 10% EC @ 75.0 ml a.i. ha^{-1} (market sample) was recorded the highest WCE as compare to the other treatments, *Spilanthes acmella* controlled up to 92.10%, by Oxyfluorfen 23.5% EC (market sample) @ 158.2 ml a.i. ha^{-1} *Eclipta alba* controlled up to 89.6% by cyhalofop butyl 10% EC @ 85.0 ml a.i. ha^{-1} *Paspalum conjugatam* up to 89.78% WCE under these conditions. Similar finding also reported by **Jannu *et al*. (2017), Patel *et al*. (2018) and Joshi *et al*. (2019).**

5.3 Effect of treatment on growth parameters

The results of the experiments revealed that different growth parameters, such as plant height, number of leaves, number of tillers, and dry matter accumulation in rice crop, showed distinct variation as a result of different weed control treatments in direct-sown rice crop fig (5.9-5.12).

Among the herbicidal treatments, application of cyhalofop-butyl 10% EC @ 75.0 ml a.i. ha^{-1} significantly recorded taller plants than the other treatments at all dates of observation. This might be due to lower weed infestation, lower weed density and dry matter and higher weed control efficiency, so the less crop weed for competition for minerals, moisture and light had resulted more availability for better growth and development of crop in this treatment at initial and later stages, similar findings has been also reported by **Jannu *et al.* (2017) and Patel *et al*. (2018).**

In respect of number of tillers and leaves ware higher under the application of cyhalofop-butyl 10% EC @ 85.0 ml a.i. ha^{-1} (market sample) than the other treatments due to higher weed control efficiency and increased availability of nutrients, space, moisture, and light to crop. All treatments produced significantly more tillers than the weedy control. Beneficial effect of weed control treatments on dry matter accumulation of crop might be due to suppression of weeds resulted the minimum crop weed competition for various resources *viz.*, nutrient, moisture, Similar results were reported that **Joshi *et al*. (2019).**

In comparison to weedy check plots Fig. 5.11, plant dry matter accumulation was significantly higher under different weed control treatments. This could be attributed to increased crop availability of growth factors as a result of weed growth elimination, which could have played a significant role in accelerated crop dry matter production. It can be seen as having more leaves per plant and a taller plant. The photo synthetically active surface (leaf) played important role in assimilation of CO_2, to turn out dry matter, application of Cyhalofop-butyl 10% EC @ 75.0 ml a.i. ha^{-1} recorded higher shoot dry weight at all the dates of observation as compare to weedy check and other treatments, superiority of these treatment over other treatments might have been approved to their efficacy in suppressing or reducing the weed growth. Similar results were reported by **Sen *et al*. (2020).**

5.4 Effect of treatment on yield attributes and yield

Grain yield is considered to be a function of yield attributes such as effective number of tillers per m^2, number of grains $panicle^{-1}$, 1000-grain weight, and so on. Crop weed competition can reduce grain yield by influencing these yield-attributing characteristics; different weed management treatments have a significant impact on these attributes and Fig. 5.13 and 5.14.

Number of effective tillers was higher with application of cyhalofop butyl 10% EC @ 75.0 ml ha^{-1} as compare to weedy check and other treatments, this might due to weed less condition almost growing period, poor resurgence and growth of weed, higher weed control efficiency, lower weed index, as evident from weed dry matter studied in these plots. Similar results were also observed by **(Singh *et al*., 2017), Jacob *et al*. (2017) and Joshi *et al.* (2019),**

The number of grains per panicle showed a significant difference among the weed control treatments compared to the weedy check, grains per panicle and test weight were significantly higher in cyhalofop-butyl 10% EC @ 75.0 ml a.i. ha^{-1} as compared to the weedy check, which could be due to weed suppression.

Plant growth must be vigorous in order to produce a higher crop yield. The highest grain and straw yields were obtained after applying cyhalofop-butyl 10% EC @ 75.0 ml a.i. ha^{-1} and hand weeding the plots. It may as a result, lower crop weed competition during the early stages of crop growth, the minimum weed competition allow the crop to make the best use of inputs, which has a positive effect on total dry matter accumulation and yield attributing characters. The weedy check plot produced the lowest grain yield due to increased weed growth, weed population, and poor yield attributing characters. This finding was consistent with **Jannu *et al*. (2017), (Singh *et al*., 2017) and Patel *et al.* (2018).**

5.6 Effect on nutrient content and Uptake

The data presented explain the nutrient uptake by plants under different treatments. Plant nutrient uptake is proportional to the amount of N, P and K in crop grain and straw. It was significantly higher with two-handed weeding, followed by an application of cyhalofop butyl 10% EC @ 75.0 ml a.i. ha^{-1}. Increased availability of N, P and K in soil under this treatment as a result of weed growth inhibition may have been the driving force behind higher dry matter accumulation and nutrient uptake by rice crop. However, the lowest nutrient uptake was recorded in the untreated plot. Similar results have been also given by **Jacob *et al*. (2017).**

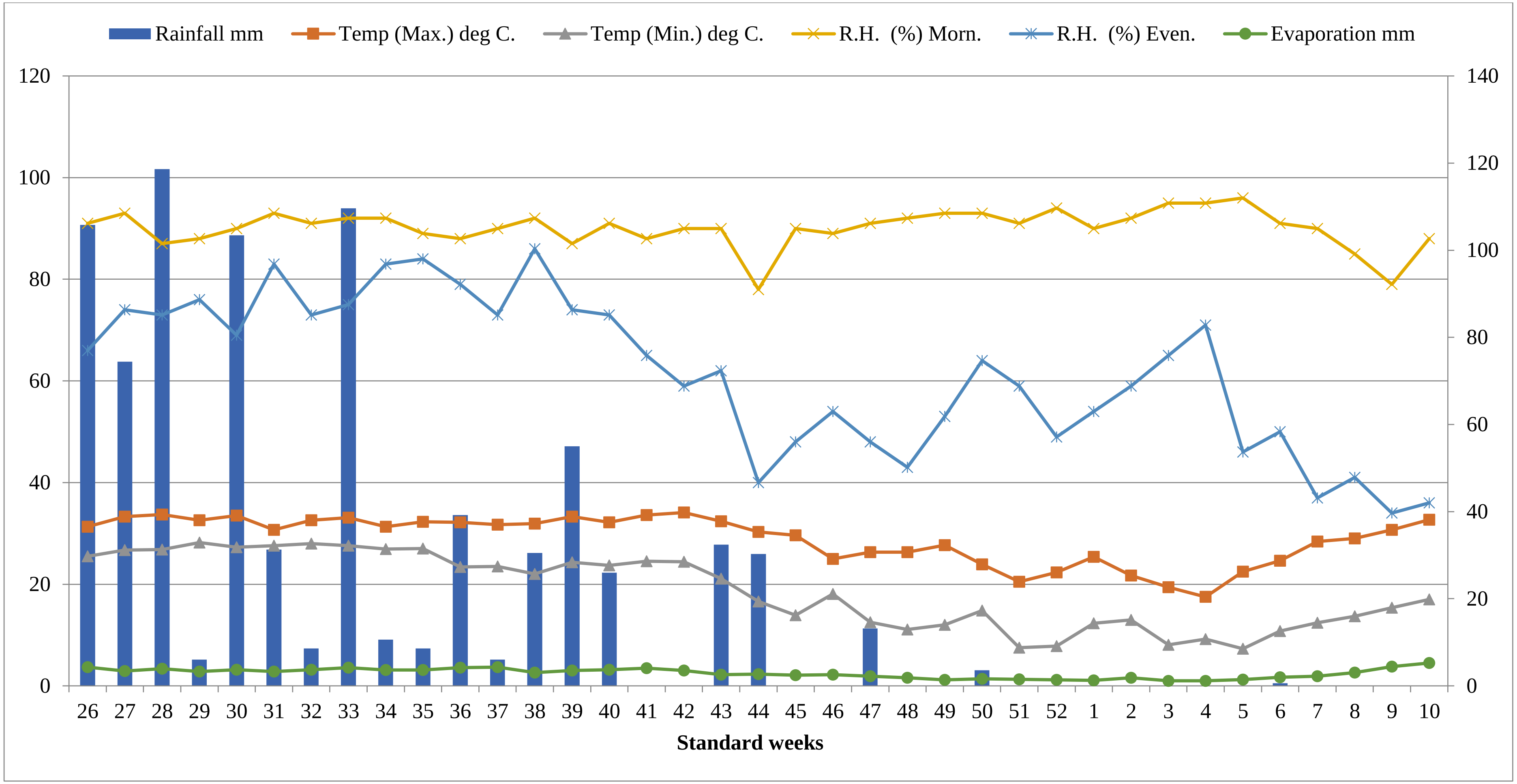


Fig. 3.1: Weekly meteorological data during the period of experiment (*Kharif*, 2020-2021)

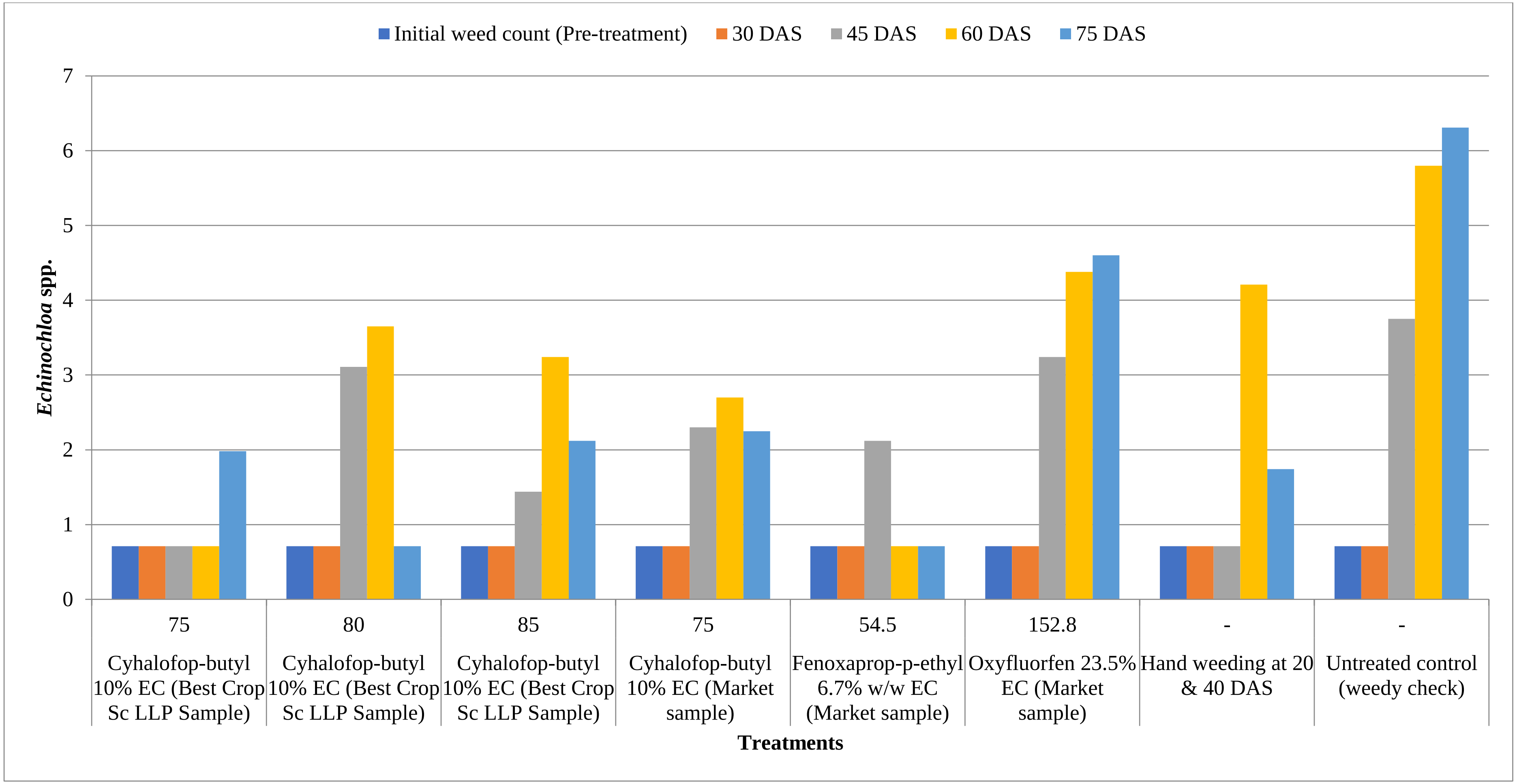


Fig. 5.1: Effect of cyhalofop-butyl 10% EC on density (No./m^2) of *Echinochloa* spp. in direct-sown rice crop

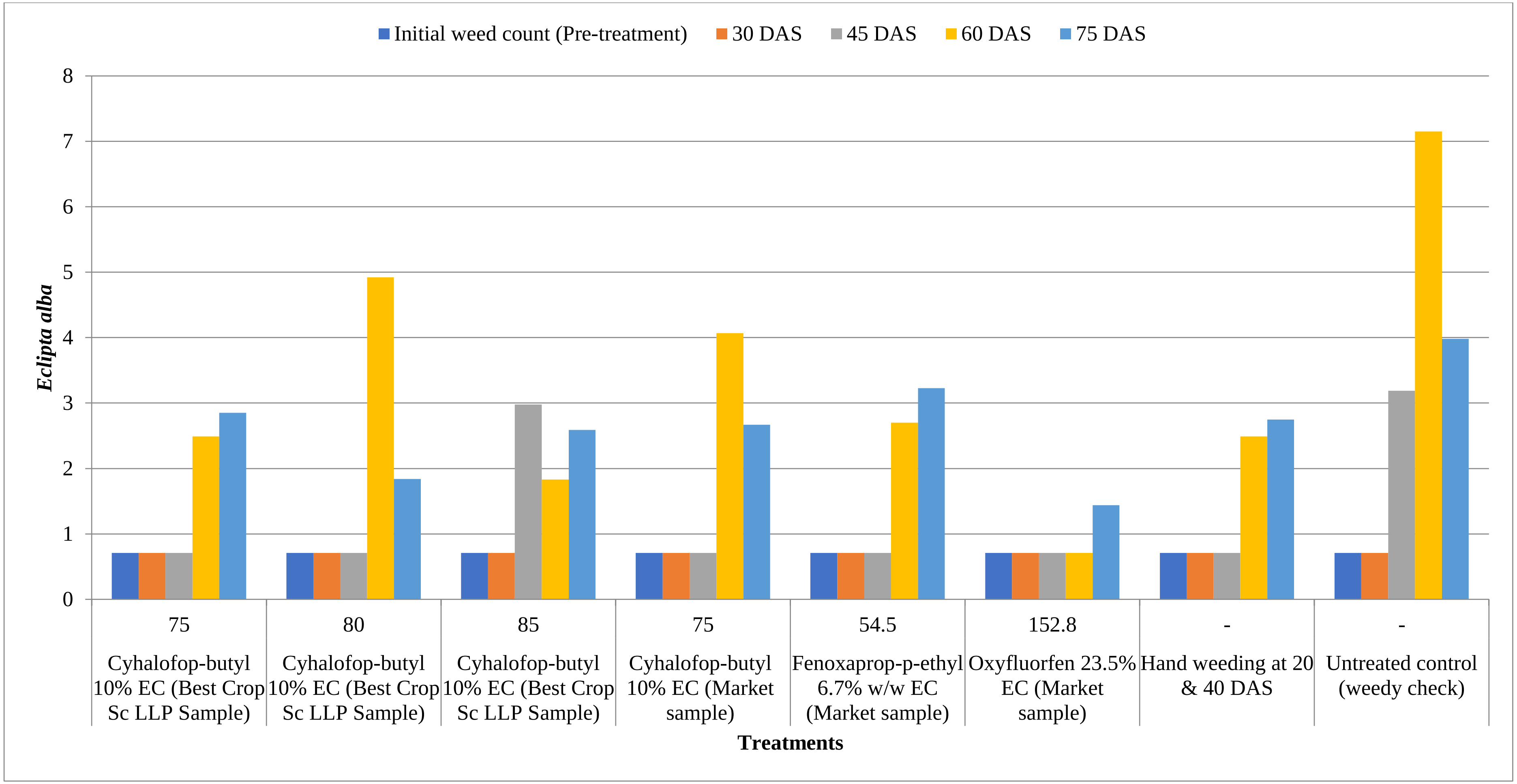


Fig. 5.2: Effect of cyhalofop-butyl 10% EC on density (No./m^2) of *Eclipta alba* in direct-sown rice crop

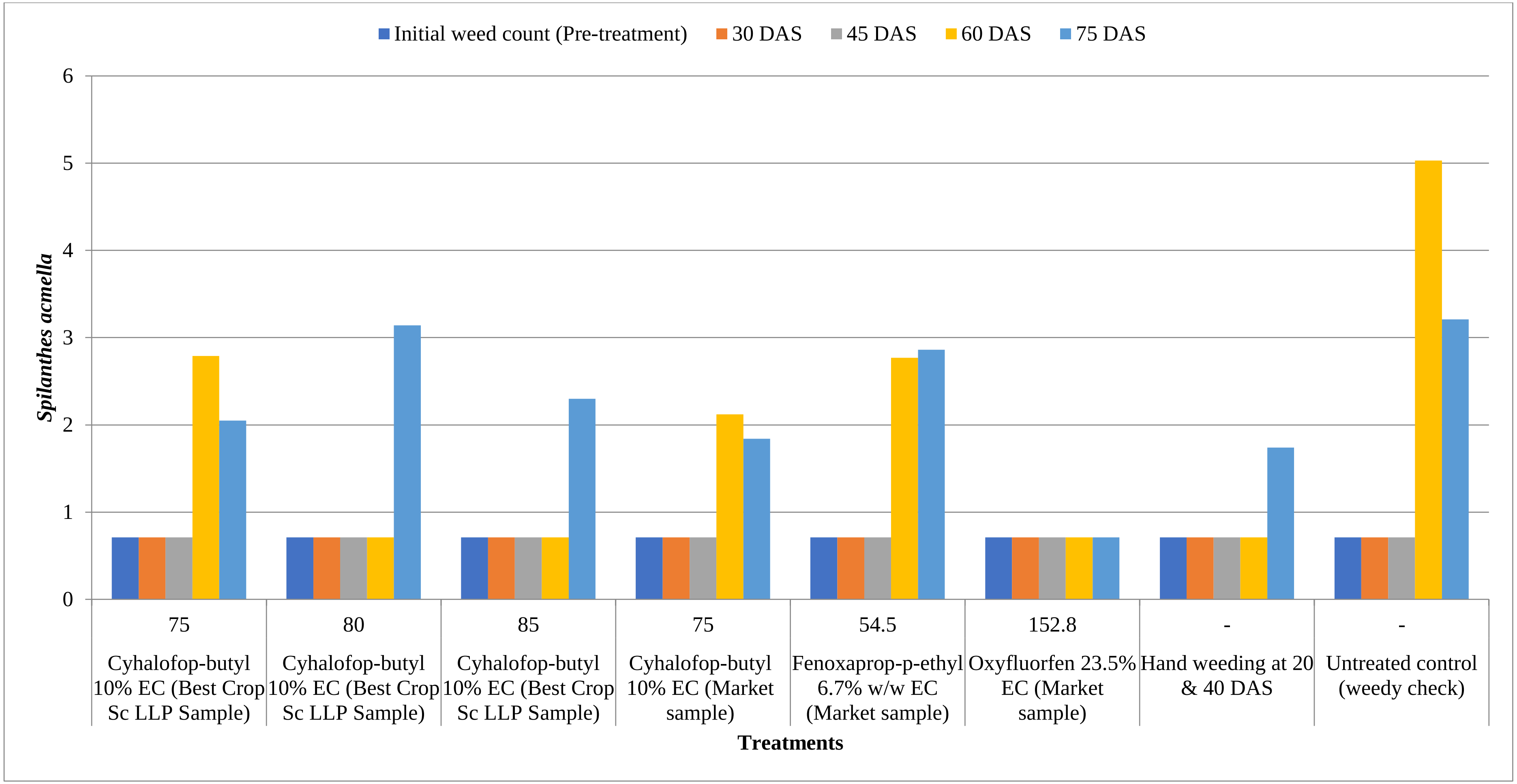


Fig. 5.3: Effect of cyhalofop-butyl 10% EC on density (No./m^2) of *Spilanthes acmella* in direct-sown rice crop

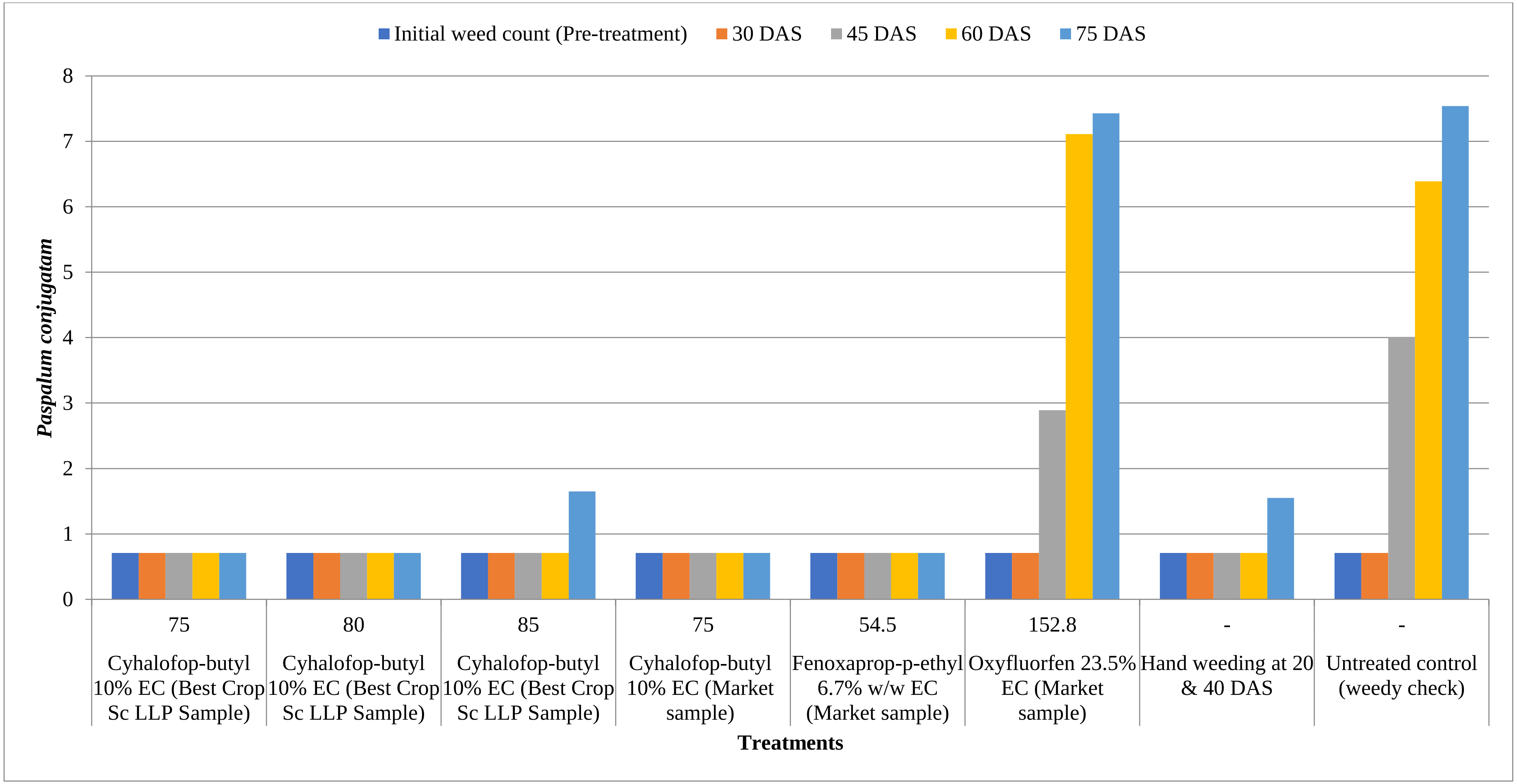


Fig. 5.4: Effect of cyhalofop-butyl 10% EC on density (No./m^2) of *Paspalum conjugatam* in direct-sown rice crop

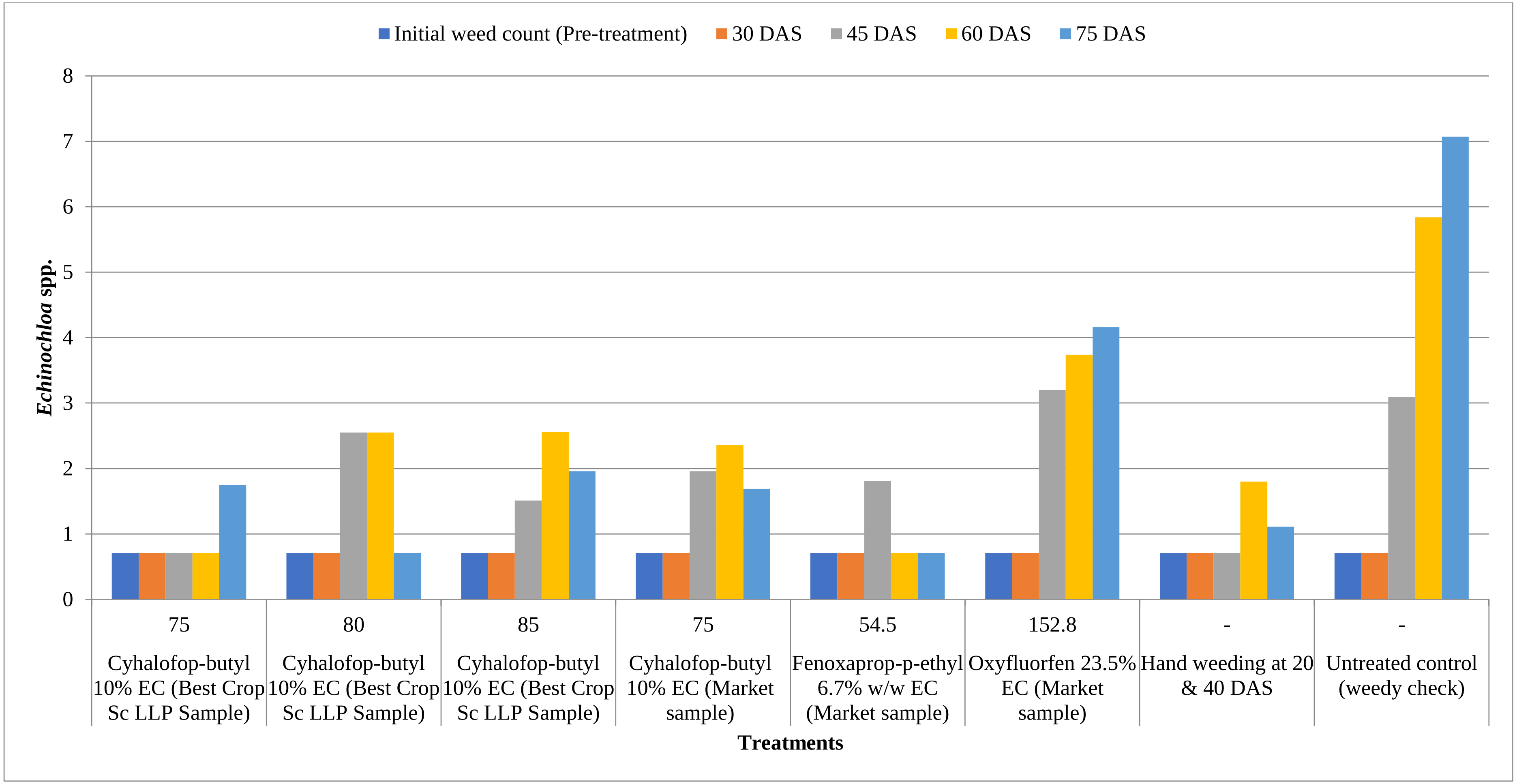


Fig. 5.5: Effect of cyhalofop-butyl 10% EC on dry matter (g/m^2) of *Echinochloa* spp. in direct-sown rice crop

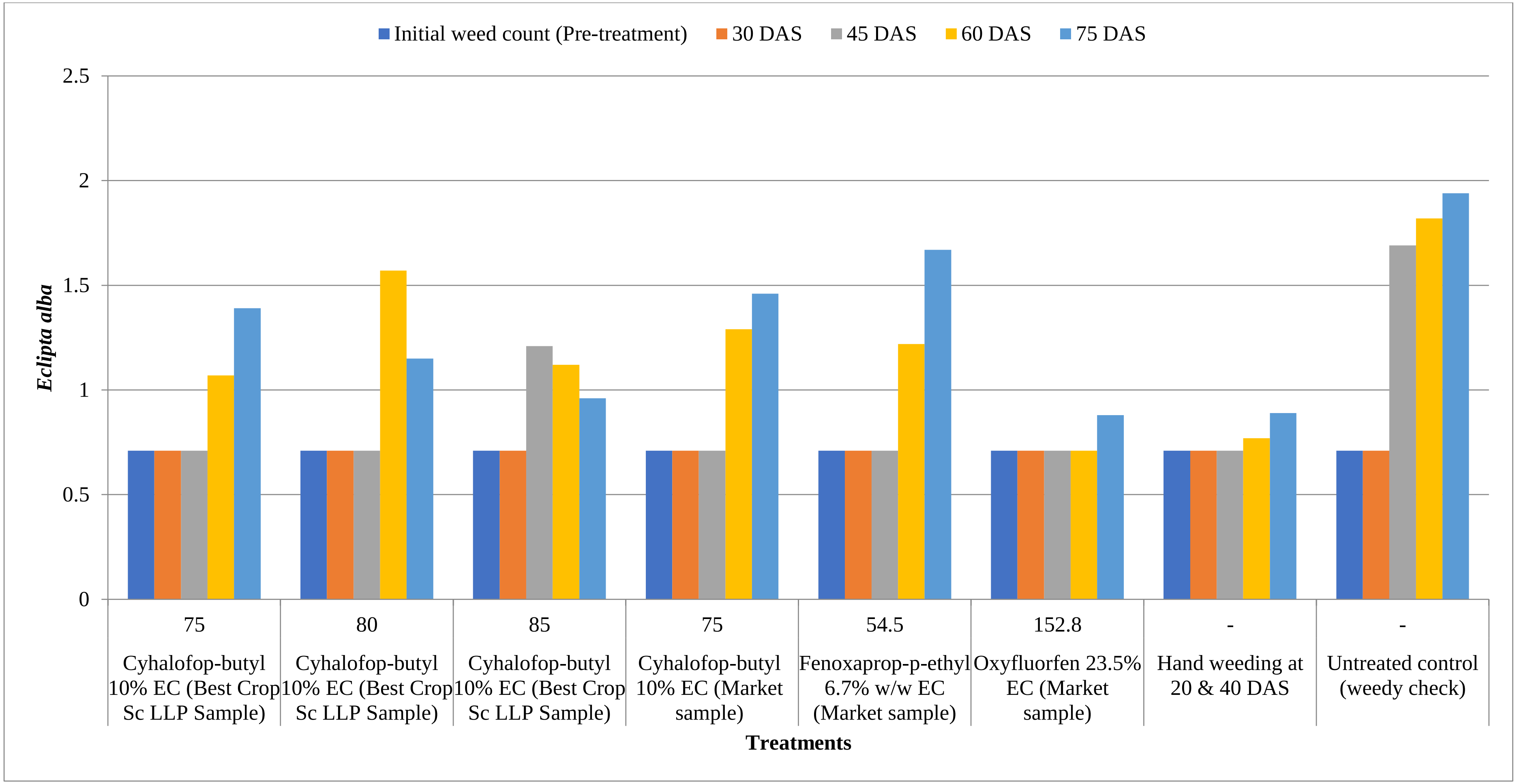


Fig. 5.6: Effect of cyhalofop-butyl 10% EC on dry matter (g/m^2) of *Eclipta alba* in direct-sown rice crop

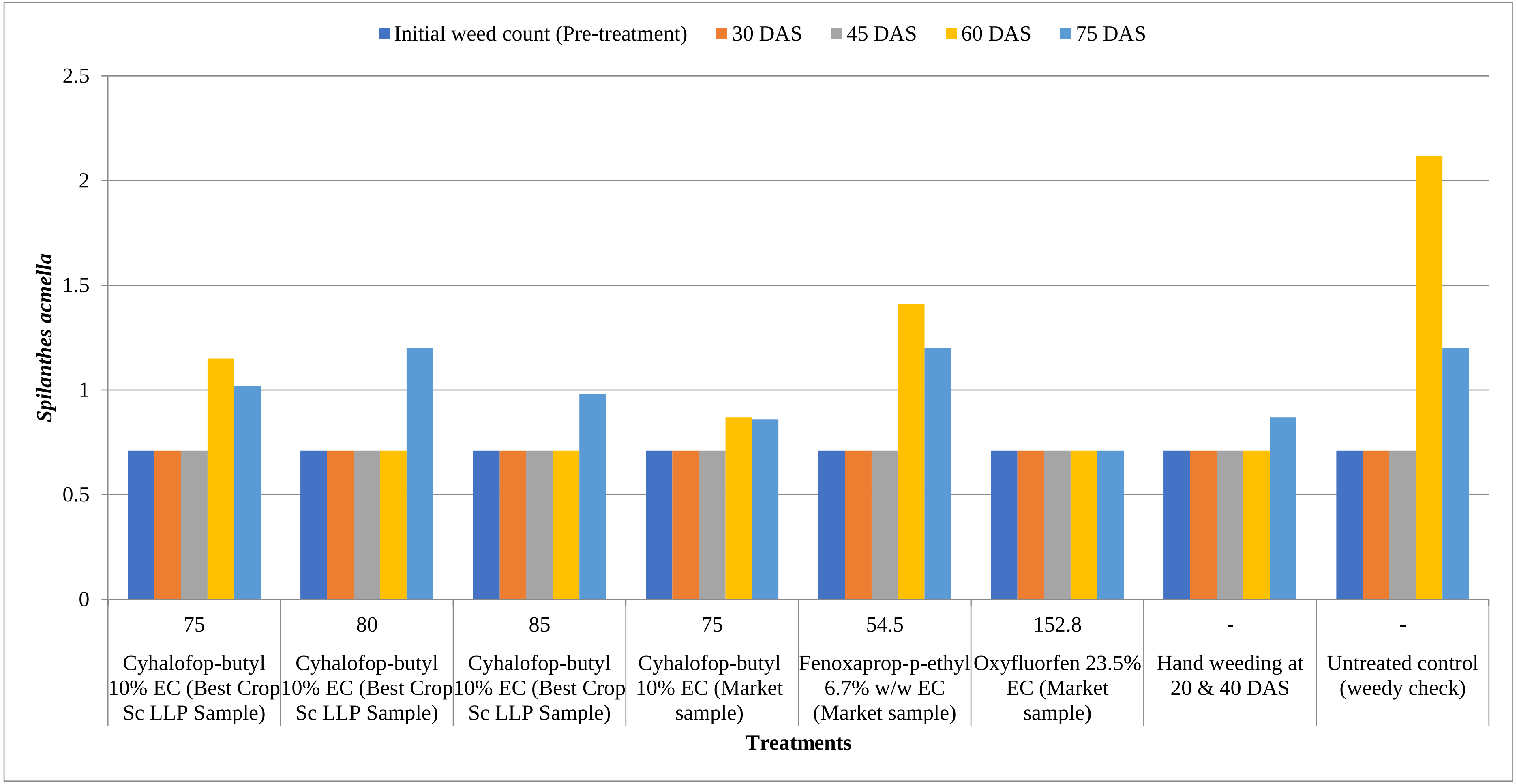


Fig. 5.7: Effect of cyhalofop-butyl Cyhalofop-butyl 10% EC on dry matter (g/m^2) of *Spilanthes acmella* in direct-sown rice crop

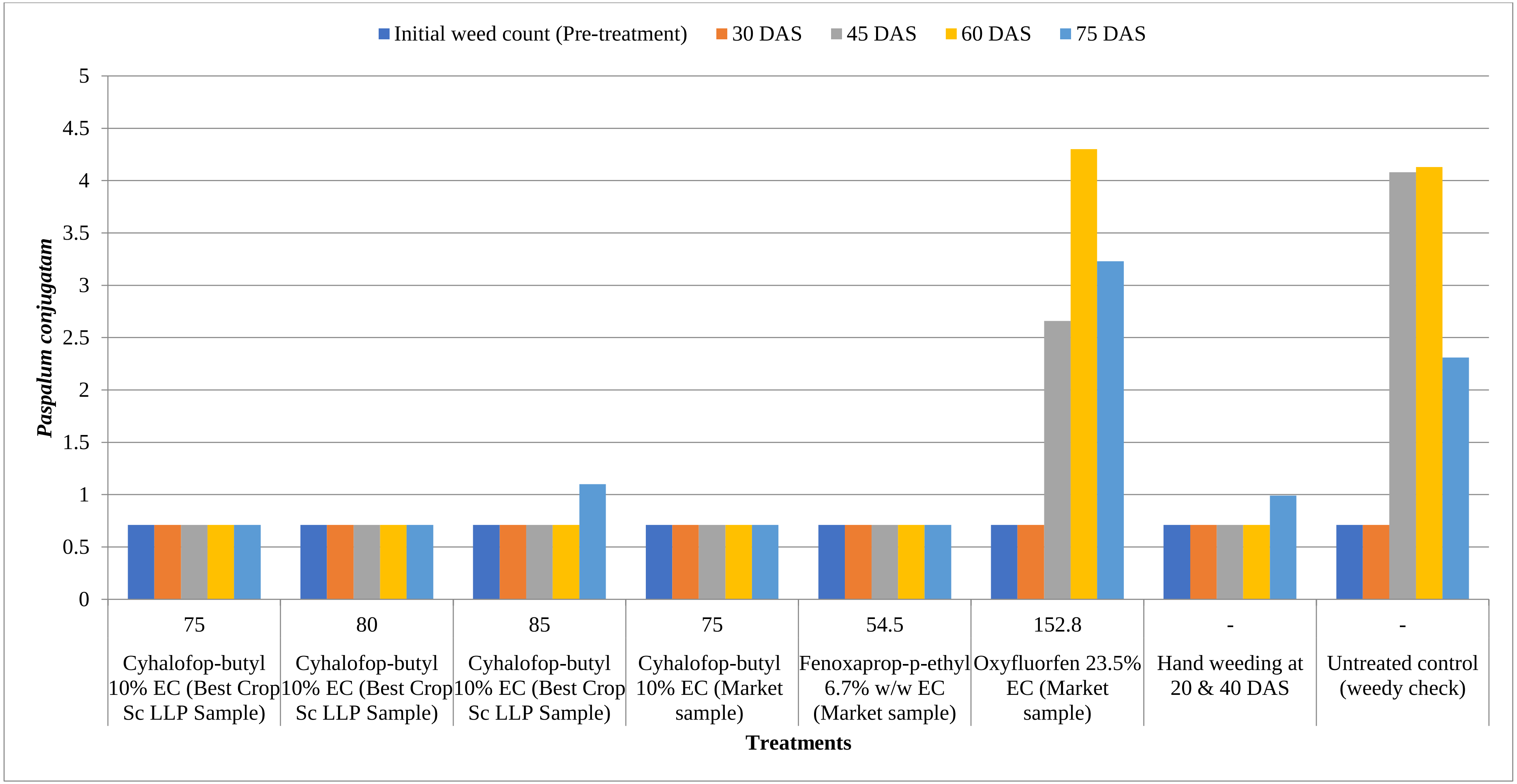


Fig. 5.8: Effect of 10% EC on dry matter (g/m^2) of *Paspalum conjugatam* in direct-sown rice crop

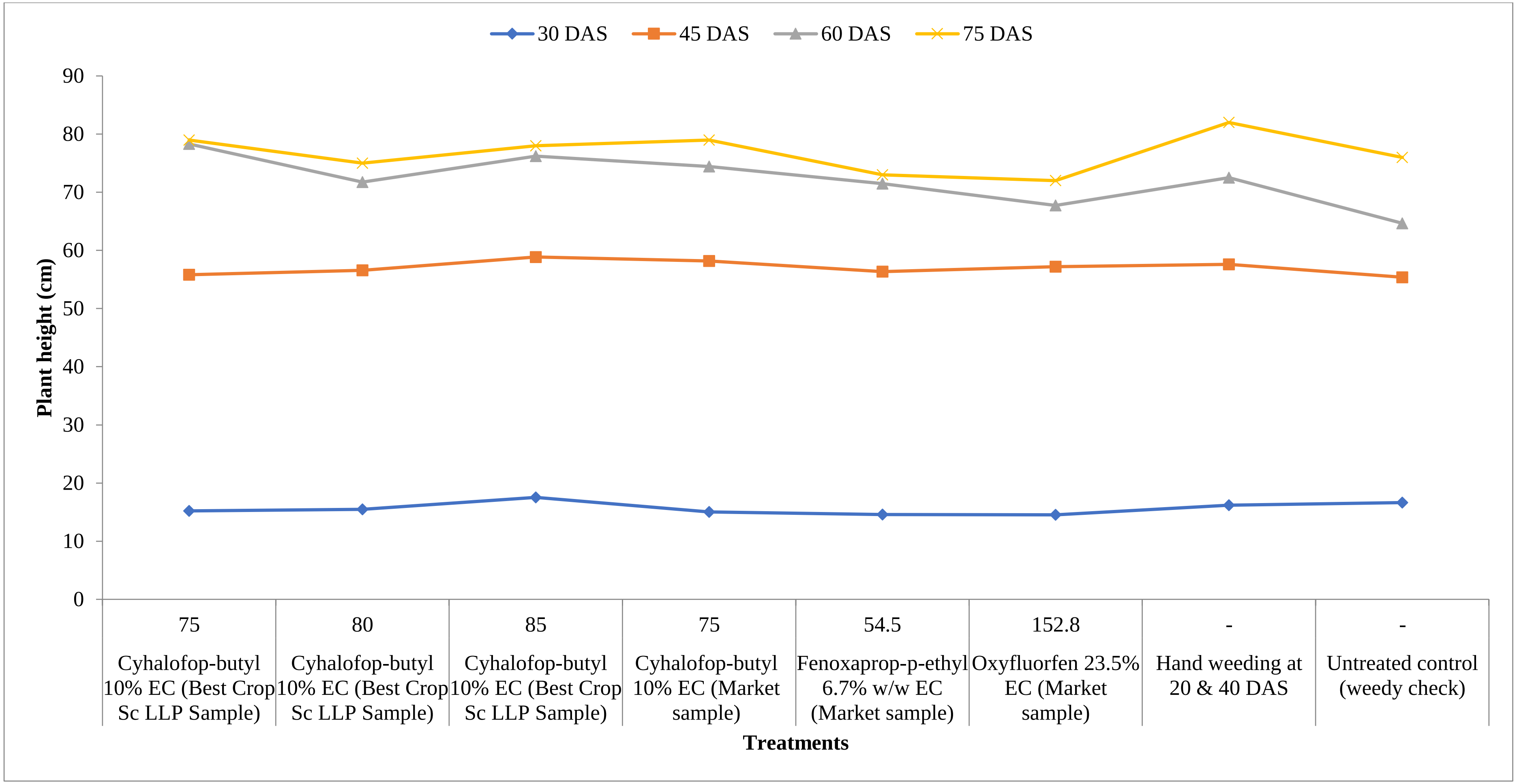


Fig. 5.9: Effect of cyhalofop-butyl 10% EC on plant height (cm) of direct-sown rice crop

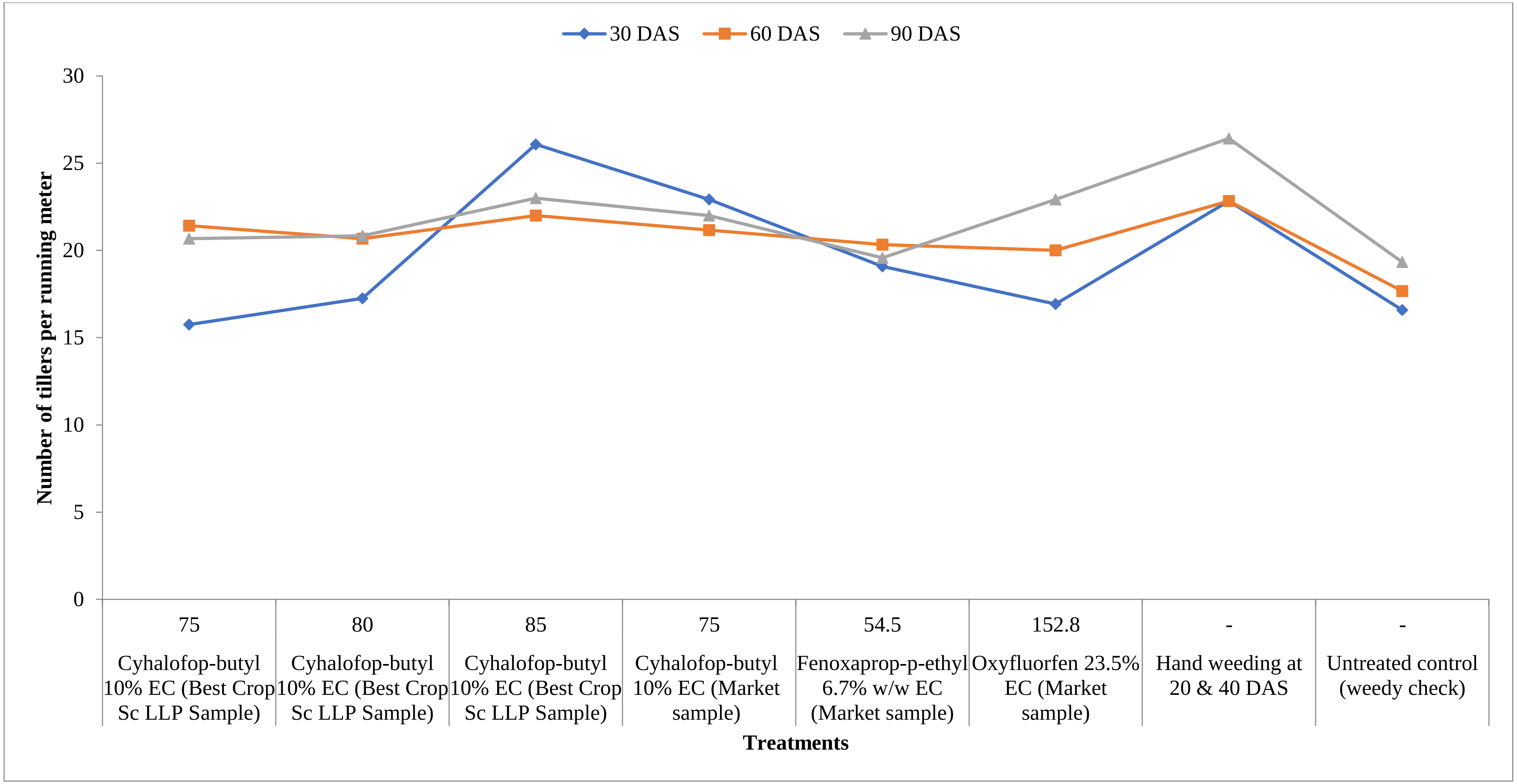


Fig. 5.10: Effect of cyhalofop butyl 10% EC on number of tillers per running meter of direct-sown rice crop

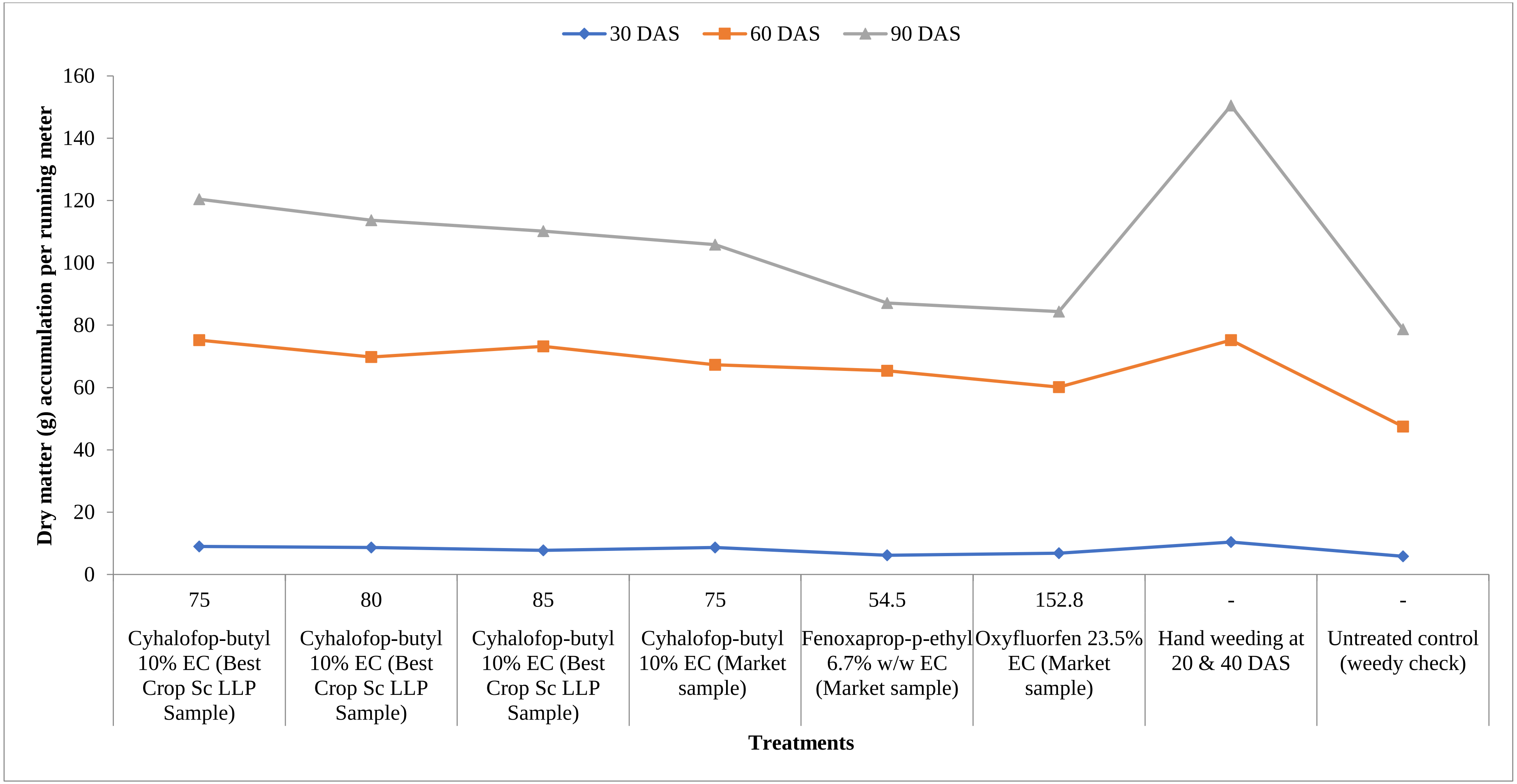


Fig. 5.11: Effect of cyhalofop butyl 10% EC on dry matter (g) accumulation per running meter of direct-swon rice crop

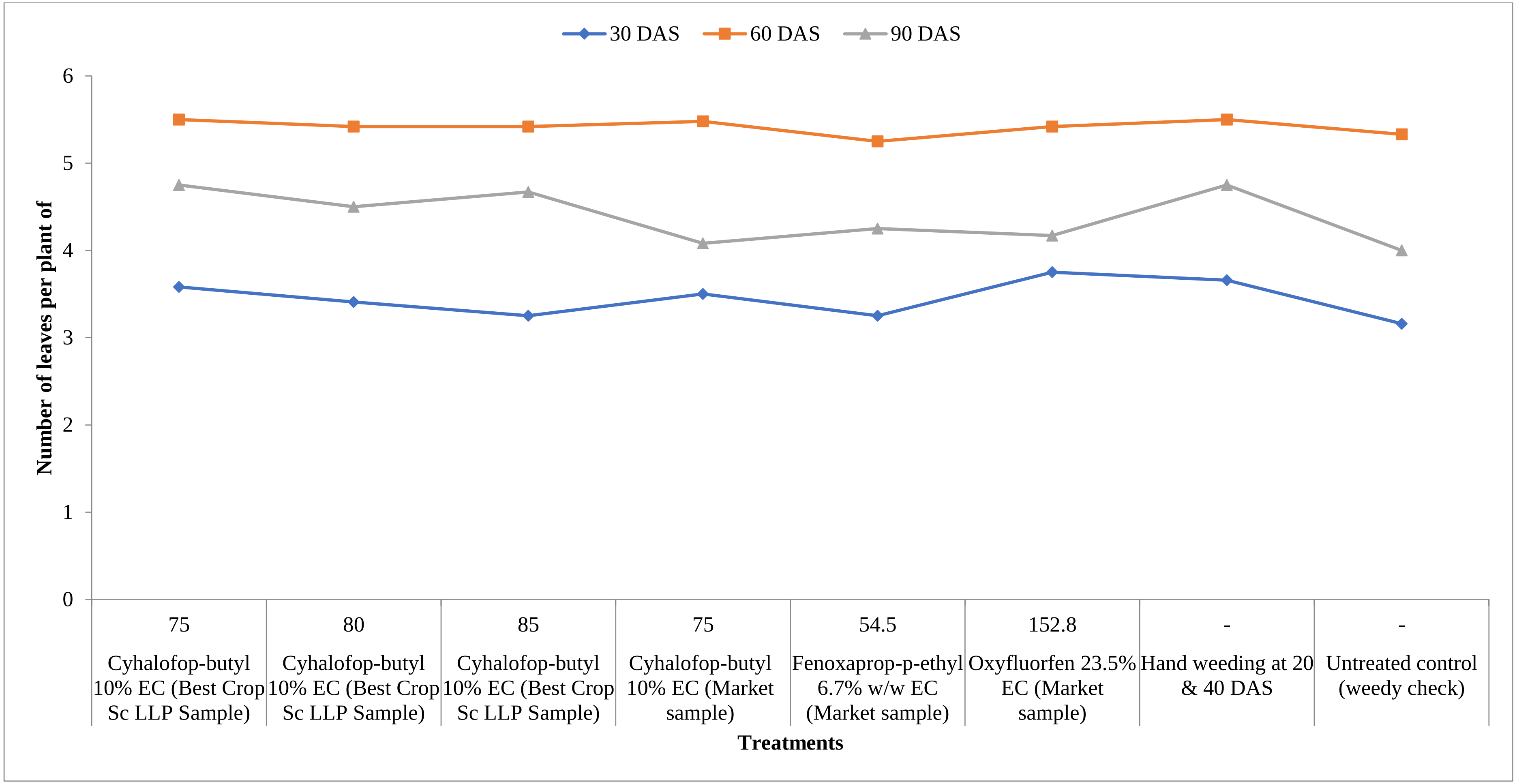


Fig. 5.12: Effect of cyhalofop butyl 10% EC number of leaves per plant of direct-sown rice crop

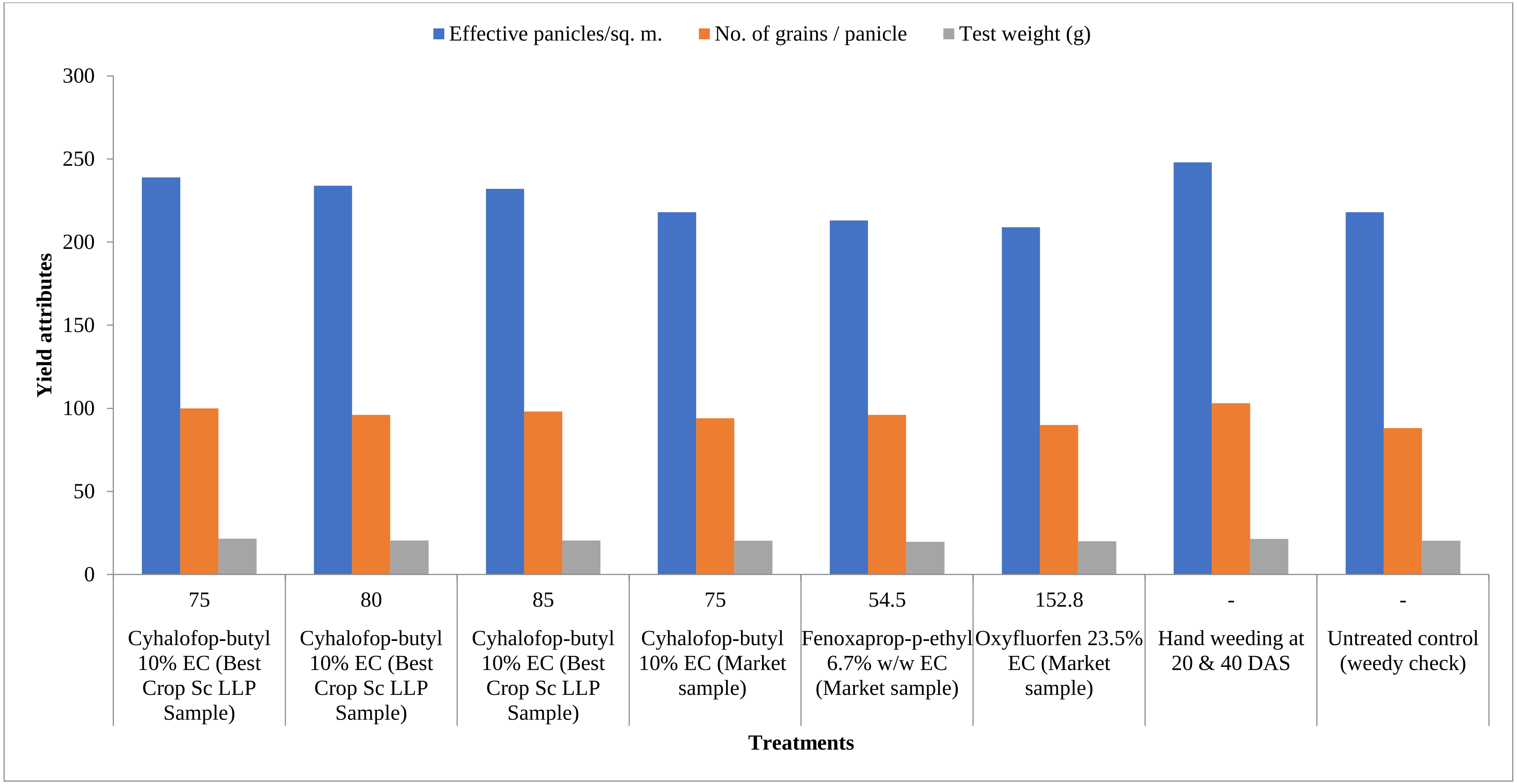


Fig. 5.13: Effect of cyhalofop-butyl 10% EC on yield attributes of direct-sown rice crop

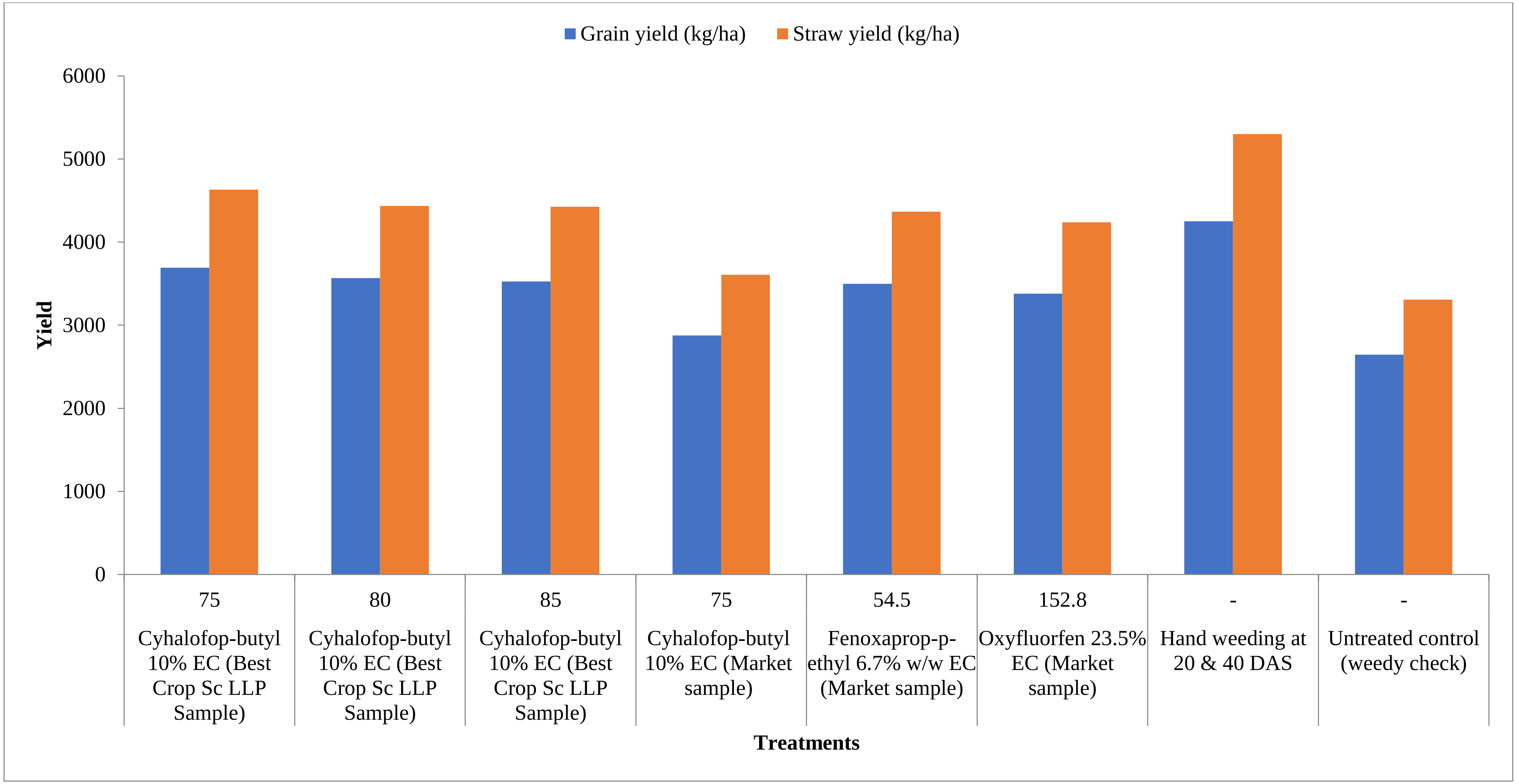


Fig. 5.14: Effect of cyhalofop-butyl 10% EC on yield of direct-sown rice crop

General view of succeeding mustard crop at 35 DAS

General view of experiment


T_1
Cyhalofop-butyl 10%EC
(Best Crop Sci. LLP sample)
@ 750 mL/ ha


T_2
Cyhalofop-butyl 10%EC
(Best Crop Sci. LLP sample)
@ 800 mL/ ha


T3
Cyhalofop-butyl 10%EC
(Best Crop Sci. LLP sample)
@ 850 mL/ ha


T4
Cyhalofop-butyl 10%EC
(Market sample)
@ 750 mL/ ha


T5
Fenoxaprop-p-ethyl 6.7% EC (w/w)
EC (Market sample)
@ 812.5 mL/ ha


T6
Oxyfluorfen 23.5% EC
(Market sample)
@ 650 mL/ ha


T7
Untreated Control
(Weed free check)
(HW at 20 & 40 DAS)


T8
Untreated control
(Weedy check)


T9
Cyhalofop-butyl 10%EC
(Best Crop Sci. LLP Sample)
for phytotoxicity & residue
studies only

Chapter VI

SUMMARY AND CONCLUSION

In this chapter an attempt has been made to summarize the results presented in the chapter experimental findings, and also to draw valid conclusion based on the significant findings of the present investigation entitled "**Bio-efficacy of cyhalofop-butyl 10 per cent EC against weeds in direct-sown rice (*Oryza sativa* L.) and their residual effect on mustard (*Brassica juncea* L.)**" was carried out at the Agriculture Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, during the rainy (*kharif*) season 2020-2021 with the following objectives:

i) To evaluate the bio-efficacy of cyhalofop butyl 10% EC against weeds.

ii) To evaluate the phytotoxicity of cyhalofop-butyl 10% EC in rice.

iii) To find out relative economics of the treatment.

iv) Effect on succeeding crop growing in same field/ plot in the coming season.

The experiment was laid out in Randomized Block Design and was replicated three times. The treatment consists *viz*., T_1 - Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample) 75.0 ml a.i. ha^{-1}, T_2 - Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample) 80.0 ml a.i. ha^{-1}, T_3 - Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample) 85.0 ml a.i. ha^{-1}, T_4 - Cyhalofop-butyl 10% EC (Best Crop Sc market Sample) 75.0 ml a.i. ha^{-1}, T_5 - Fenoxaprop-p-ethyl 6.7% w/w EC (market sample) 54.5 ml a.i. ha^{-1}, T_6 - Oxyfluorfen 23.5% EC (market sample) 152.8 ml a.i. ha^{-1} T_7 - Hand weeding at (20 & 40 DAS), T_8 - Untreated Control (weedy check), T_9 - Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample) 160.0 ml a.i. ha^{-1} (only for phytotoxicity evaluation).

The treatments were allocated randomly to each plot. The herbicides treatments were applied as pre-emergence and post-emergence and rice variety 'HUR-1304' selected for the experiment.

The soil in the experimental field was Gangetic alluvial with a sandy clay loam texture and a pH of 7.32. It had a moderate fertility status with low available nitrogen (176 kg ha^{-1}), medium available phosphorus (23.43 kg ha^{-1}) and potassium (207 kg ha^{-1}) and low organic carbon (0.33%). Irrigation was used during critical stages of crop growth. A recommended dose of nitrogen, phosphorus, potassium, and zinc were applied at rates of 120, 60, 40 and zinc sulphate monohydrate. and using urea, di-ammonium phosphate (DAP), murate of potash (MOP). Half of the nitrogen, along with the full doses of phosphorus and potash, was applied as a basal at sowing time, and the other half was top-dressed in two equal splits.

The treatment's effectiveness in terms of weed density, weed dry matter accumulation, and weed control efficiency. The weed population (pre-treatment), weed dry matter and weed control efficiency was recorded at 30, 45, 60 and 75 days after sowing (DAS), Various crop growth parameters *viz,* plant height (cm), number of leaves (no./plant), number of tillers, plant dry weight (g) at 30, 60, and 90 DAS, and yield attributes characters *viz,* number of effective tillers, length of panicles (cm), number of grains per panicles, fresh weight of panicle**,** test weight (g), grain yield (kg ha^{-1}) and straw yield (kg ha^{-1}). The nutrient content (N, P and K) and their uptake were estimated at harvest. Data from weed component analyzed were appropriate statistical methods to square root transformation ($\sqrt{x+0.5}$) for uniformity. Finally, the economics of the experimental crop rice as influenced by the various treatments were calculated using the current market price. The following are the highlights of the experimental findings:

6.1 Effect of herbicide

6.1.1 Effect on weeds

6.1.1.1 Weed density and dry matter

The major weed species in rice (*Echinochloa colona* (L.) Link., *Echinochloa crusgalli* (L.) Beauv), *Cynodon dactylon* L., crop field were grasses weeds, sedge leaved weeds *Cyperus rotundus, Cyperus irria, Cyperus haspan,* broad leaved weeds;

Lindernia crustacea (L.) F. Muell, *Lindernia procumbens* (Krock.) philcox, *Eclipta alba* L. Hassak, *Phyllanthus niruri* L, *Spilanthes acmella* auct.non L, *Paspalum conjugatam.*

All the weed management treatment caused reduction of weeds growth as compare to the untreated control except *Cynodon dactylon* L., *Cyperus rotundus, Cyperus irria, Cyperus haspan*, *Lindernia crustacea*, *Lindernia procumbens* did not influence much initially by the herbicidal treatments. Further, post-emergence application of cyhalofop- butyl 10% EC (Best Crop Sci LLP sample) @ 75.0 ml a.i. ha^{-1} exhibited lower density of weeds like *Echinochloa* spp., *Eclipta alba*, *Phyllanthus niruri, Spilanthes acmella* and *Paspalum conjugatum* over the treatments except cyhalofop- butyl 10% EC (Best Crop Sci LLP sample) @ 80.0 and 85.0 ml a.i. ha^{-1}. The density of *Cyperus rotundus* was increased at 45 days after sowing (DAS) as compared to 30 DAS.

The species wise weed dry matter recorded at 30, 45, 60 and 75 DAS. The dry matter of *Echinochloa* spp., *Eclipta alba*, *Phyllanthus niruri*, *Spilanthes acmella* and *Paspalum conjugatum* in all the treatments was lower as compared to the untreated control (weedy check) at 30, 45, 60, and 75 DAS. The dry matter in each treatment was found proportionate to weed density. The trend of effectiveness of all the treatments based on dry matter was similar to that observed based on density. The treatments hand weeding control and post-emergence application of cyhalofop- butyl 10% EC (Best Crop Sci LLP sample) @ 75.0 ml a.i. ha^{-1} effectively controlled growth and development of weeds and resulted in to lower weed dry matter than other treatments in respect of most of the weed species.

6.1.1.2 Weed control efficiency

Weed control efficiency of post-emergence application of cyhalofop-butyl 10% EC (Best Crop Sci LLP sample) @ 75.0 ml a.i. ha^{-1} exhibited higher weed control efficiency which was followed by cyhalofop-butyl 10% EC (Best Crop Sci LLP sample) @ 80.0 and 850 ml a.i. ha^{-1} over rest of the herbicidal treatments in respect to the control of weeds in direct-sown rice crop.

6.1.2 Effect on crop

The growth parameters, yield attributes and yield of rice crop showed that improvement in plant height, dry matter accumulation, number of leaves per plant, effective tillers m^{-2}, number of grains panicle^{-1}, fresh weight of panicle, test weight with the application of cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 75.0 ml, followed by its higher dose of 80.0 and 85.0 ml a.i. ha^{-1} and cyhalofop-butyl 10% EC (market sample) @ 75.0 ml a.i. ha^{-1} and fenoxaprop-p-ethyl 6.7% w/w EC (market sample) 54.5 ml a.i. ha^{-1} and oxyfluorfen 23.5% EC (market sample) @ 152.8 ml a.i. ha^{-1} as compared to the untreated control (weedy check). Appliction of cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 75.0 ml a.i. ha^{-1} recorded higher plant height, dry matter accumulation, number of leaves per plant, effective tillers m^{-2}, number of grains panicle^{-1}, fresh weight of panicle, test weight as compared to the untreated control (weedy check). Further, there was no significant difference in panicles length, due to the herbicidal treatments application.

The grain and straw yield of rice were recorded higher under application of cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) 75.0 ml a.i. ha^{-1} followed by cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) 80.0 and 85.0 ml a.i. ha^{-1}. However, the minimum grain and straw yield was recoded the untreated plot (weedy check).

6.2 Phytotoxicity on rice

Visual observations were recorded on phytotoxicity parameters *viz*., leaf injury on tips/surface, wilting, vein clearing, necrosis, epinasty and hyponasty in rice crop due to the application of cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 75.0, 80.0, 85.0 and 160 ml a.i. ha^{-1}. The application of cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) 75.0 ml a.i. ha^{-1} either of the doses and fenoxaprop-p-ethyl 6.7% w/w EC at 54.5 ml a.i. ha^{-1} (market sample) exhibited injury on tips or surface of leaf at 10 and 20 of treatment application DTA and necrosis at 30 and 60 DTA on rice. However, wilting, vein clearing, necrosis, epinasty and hyponasty did not appear on rice by the application of herbicidal treatments during different dates of observation.

6.3 Effect of treatments on the succeeding crop (mustard)

Residual effect of herbicidal treatments in rice did not show marked variation in per cent crop germination, plant population, number of primary branch and number of secondary branch of mustard, number of siliquae on main shoot (per shoot), length of siliqua, siliquae per plant. However, application of the herbicides to rice crop influenced on plant height, grain yield, yield of succeeding mustard crop. Post-emergence application of cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) at either of the doses applied to rice exhibited higher plant height, grain yield, which was followed by application of cyhalofop-butyl 10% EC (market sample) @ 75.0 ml a.i. ha^{-1}. Thus there was no any adverse impact of cyhalofop-butyl 10% EC on mustard crop, when applied in main rice crop. Also no phytotoxicity symptoms were observed on mustard crop.

Conclusion

Based on the present study, it is concluded that the post-emergence application of cyhalofop-butyl 10% EC at 75.0 ml a.i. ha^{-1} is effective for the control of weeds in direct-sown rice crop. Thus, for competent control of weeds and higher yield of direct-sown rice crop, cyhalofop-butyl 10% EC (Best Crop Sc LLP sample) @ 75.0 ml a.i. ha^{-1} as post-emergence application 18 days after sowing is suggested under Agro-climatic condition of Varanasi.

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APPENDICES

Appendix I: Common cost of cultivation (₹ ha^{-1})

S.No.	Operation	Input	Rate (`)	Cost (` ha^{-1})
1.	Field operation			
	a. One disc ploughing	One tractor (35 HP) for 2.5 hrs.	400 hrs^{-1}	1000
		One labour for 2.5 hrs	37.5 hrs^{-1}	93.75
	b. One ploughing and with cultivator and planking	One tractor (35 HP) for 2 hrs.	400 hrs^{-1}	800
2.	Layout	4 farm worker	300 farm worker^{-1}	1200
3.	Seed and sowing			
	a. Seed	100 kg	70 kg ha^{-1}	7000
	b. Sowing with *kudal*	20 farm worker	300 farm worker^{-1}	6000
4.	Fertilizer (120:60:40)			
	a. Urea	275.04 kg	6.6 kg^{-1}	1815.26
	b. DAP	130.44 kg	22 kg^{-1}	2869.68
	c. MOP	100 kg	14 kg^{-1}	1400
	d. $ZnSO_4$	2.5 kg	25 kg^{-1}	62.5
5.	Fertilizer application			
	a Basal application	2 farm worker	300 farm worker^{-1}	600
	b Top dressing	1 farm worker	300 farm worker^{-1}	300
6.	Irrigation			
	a. Tube well charge	Water for 1 irrigation	400 irrigation^{-1}	1600
	b. Irrigation application	2 farm worker	300 farm worker $^{-1}$	600
7.	Harvesting a. Bundle making and transportation	20 farm workers	300 farm worker $^{-1}$	6000
8.	Threshing			
	a. Threshing by tractor	One tractor (35 HP) for 6 hrs.	400 hrs^{-1} 2400	
	b. Labour charge for threshing and winnowing	10 farm workers	300 farm worker $^{-1}$	3000
9.	Land revenue	For 6 months	250 annum^{-1}	125
10.	Rental value of land Interest on capital	For 6 month 14 % annually	3000 annum^{-1}	1500
			Total cost 7% for 6 month	**38366.19** 2685.63
			Grand total	**41052**

Appendix II: Treatment wise cost of cultivation (` ha^{-1})

Treatments	Rate (`)	Cost of herbicide (`)	Farm worker	Rate (`)	Cost of farm worker (`)	Cost (` ha^{-1})	Interest charge 7% for 6 month	Total cost (`ha^{-1})
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample) 75.0 ml a.i. ha^{-1}	750 ml /530 Rs	1590.00	3	300	900	2862	200.34	3063
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample) 80.0 ml a.i. ha^{-1}	800 ml /530 Rs	1696.00	3	300	900	3052	213.64	3266
Cyhalofop-butyl 10% EC (Best Crop Sc LLP Sample) 85.0 ml a.i. ha^{-1}	850 ml /1530 Rs	1802.00	3	300	900	3243	227.01	3470
Cyhalofop-butyl 10% EC (Market sample) 75.0 ml a.i. ha^{-1}	750 ml /550 Rs	1665.00	3	300	900	2997	209.79	3207
Fenoxaprop-p-ethyl 6.7% w/w EC (Market sample) 54.5 ml a.i. ha^{-1}	812.5 ml /1280 Rs	2080.00	3	300	900	3744	262.08	4007
Oxyfluorfen 23.5% EC (Market sample) 152.8 ml a.i. ha^{-1}	650 ml /271 Rs	1761.5	3	300	900	3170	221.9	3392
Farm workers /Hand weeding at 20 & 40 DAS			40	300	12000	12000	840	12840
Untreated control (weedy check)			-	-	-	-	-	-