

**Studies on Bioefficacy of Herbicides to control
Cyperus weed spp. in Direct Seeded Rice (*Oryza sativa* L.)**

RIFAT UN NISA

(MSA-2018-1196)



**Division of Agronomy
Faculty of Agriculture
Sher-e-Kashmir University of Agricultural Sciences
& Technology of Kashmir**

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Cyperus Weed spp. in Direct Seeded Rice (*Oryza sativa* L.)**

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Thesis

Submitted to

**The Faculty of Agriculture
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In partial fulfilment of requirement for the award of the degree of

Master of Science in Agriculture

(Agronomy)

2021

Dedicated

To

My Mother

*A Strong and gentle soul who taught me to trust Allah Believe
in work hard and that so much could be done with little*

My Father

*For earning and honest living for us and for supporting and
encouraging me to believe in myself*

Sher-e-Kashmir
University of Agricultural Sciences and Technology of Kashmir
Division of Agronomy, Faculty of Agriculture Wadura
193201

Certificate – I

This is to certify that the thesis entitled, “**Studies on bioefficacy of herbicides to control cyperus weed spp. in direct seeded rice (*Oryza sativa* L.)**” Submitted in partial fulfillment of the requirements for the award of the degree of **Master of Science in Agriculture (Agronomy), to the Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir** is a record of bonafide research work carried out by **Ms. Rifat un Nisa (Regd. No. MSA-2018-1196)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that information received during the course of investigation has duly been acknowledged.

(Dr. Tahir Ahmad Sheikh)

Chairman
Advisory Committee

Endorsed

Professor & Head
Division of Agronomy

Sher-e-Kashmir
University of Agricultural Sciences and Technology of Kashmir
Faculty of Agriculture Division of Agronomy, Wadura Sopore
193201

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We, the members of the Advisory Committee of Ms. Rifat un Nisa (Regd. No.MSA-2018-1196), a candidate for the degree of Master of Science in Agriculture (Agronomy) have gone through the manuscript of the thesis entitled, “**Studies on bioefficacy of herbicides to control cyperus weed spp. in direct seeded rice (*Oryza sativa* L.)**” and recommend that it may be submitted by the student in partial fulfillment of the requirements for the award of the degree.

Advisory Committe

Chairman

Dr. Tahir Ahmad Sheikh

Assistant professor, Division of agronomy
Faculty of Agriculture Wadura

Members

Dr.Waseem Raja

Assistant professor, Division of agronomy
Faculty of Agriculture Wadura

Dr.Zahoor Ah.Baba

Associate professor Division of Basic Sciences
and Humanities
Faculty of Agriculture Wadura

Dr. Showkat Maqbool

Associate Professor Division of AGB,
FVSC and AH Shuhama, SKUAST-Kashmir

Deans Nominee

Dr. Khalid Rasool

Professor and Head, Division of Horticulture

Sher-e-Kashmir
University of Agricultural Sciences and Technology of Kashmir
Division of Agronomy, Faculty of Agriculture, Wadura
193201

Certificate – III

This is to certify that the thesis entitled, “**Studies on bioefficacy of herbicides to control cyperus weed spp. in direct seeded rice (*Oryza sativa* L.)**” submitted by **Ms. Rifat un Nisa (Regd. No. MSA-2018-1196)** to the **Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir** in partial fulfillment of the requirements for the award of the degree of **Master of Science in Agriculture (Agronomy)** was examined and approved by the Advisory Committee and External Examiner on.....

Chairman
Advisory Committee

External Examiner

Professor & Head,
Division of Agronomy

Dean
Faculty of Agriculture,
SKUAST-Kashmir, Wadura

Sher-e-Kashmir
University of Agricultural Sciences and Technology of Kashmir
Faculty of Agriculture Division of Agronomy, Wadura
193201

Name of the student : **Rifat un Nisa**
Registration No. : **MSA/2018/1196**
Major subjects : **Agronomy**
Minor subjects : **Soil science/ Plant physiology**
Major Advisor : **Dr.Tahir Ahmad Sheikh**
Title of the Thesis : **“Studies on bioefficacy of herbicides to control cyperus weed spp.in direct seeded rice (*Oryza sativa* L.)”**

ABSTRACT

A field experiment was conducted at Faculty of Agriculture, SKUAST Kashmir, Wadura during *Kharif* 2019. The soil of the experimental field was slightly acidic in reaction pH (5.9), medium in available Nitrogen (327kg ha^{-1}), Phosphorus (17.3kg ha^{-1}) and Potassium (248kg ha^{-1}) with high organic carbon content (0.98%). The experiment was laid out in Randomized block design (RBD) comprised of nine treatments including seven herbicidal treatments *viz*, Halosulfuron (75 WG) @ 35 g ha^{-1} , Bensulfuronmethyl (60 DF), @ 60 g ha^{-1} , Cyhalofopbutyl (10 EC) @ 100 g ha^{-1} , Bispyribacsodium (10 SC) @ 30 ha^{-1} , Ethoxysulfuron (15 WDG) @ 45 g ha^{-1} , Pretilachlor @ 700 g ha^{-1} Pendimethalin (30 EC) *fb* 2,4-D (58 SL) ($0.75\text{kg ha}^{-1} + 1.0\text{kg}^{-1}$), along with Weedy check and Weed free within three replications. Among the herbicides application of Bispyribacsodium @ 30 g ha^{-1} provided excellent control of weed species (grasses, cyperus weed spp. and broad leaf weeds) which resulted in significant increase in growth parameters like plant height, LAI, dry matter accumulation. Significant increase in panicles m^{-2} , filled grains panicle $^{-1}$ and thousand grain weight was recorded by the application of herbicides as compared to weedy check. The data revealed that different weed control treatments significantly increased the grain yield of (80.10 q ha^{-1}) compared to weedy check (32.02 q ha^{-1}). Application of bispyribacsodium @ 30 g ha^{-1} recorded lowest population of weeds and weed dry matter, depicting higher weed control efficiency. The highest benefit: cost ratio of 1.49 was recorded with the application of bispyribacsodium

@ 30 g ha⁻¹. Therefore, from the present study it can be concluded that application of bispyribacsodium @ 30 g ha⁻¹ is promising for improving rice yield by controlling weeds especially cyperus weed spp. in direct seeded rice.

Keywords: Growth, Herbicides, Rice, Yield, weed control.

Signature of Student

Signature of Major Advisor

Dated _____

Dated _____

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Chapter-1

INTRODUCTION

Rice is one of the most important global staple foods for more than 3.5 billion people in the world (CGIAR, 2016) and thus holds the lead in global food security (Dass and Chandra, 2013). The quantitative population growth and the subsequent demand for rice production leave the food production to a major break (Rajendran and Ganesa, 2014) Global rice production is 496.1 mt from an area of 167.13 m ha worldwide (Stastica, 2020). The annual production of rice in india was 116.42 mt during 2018 from an area of 43.79 mha (Statistics, 2018). In J&K rice is grown from ancient times and serves as the state's most important staple food cultivation. The state's current rice area was 0.28 million hectares, with 0.55 mt and 2.1tha^{-1} productivity (DES, 2018).

Owing to the conversion of rice land to horticulture, the region under rice crop has been decreasing year by year in recent years. Rice is grown in a wide variety of habitats, from irrigated to shallow lowlands, mid-level lowlands, and level upland waters. Establishment method is one of the cultural practices influencing rice crop by its effect on growth and development. Transplanting is India's most effective method of cultivating rice. Rice is normally cultivated in northern India by transplanting into the puddled field seedlings of 25-30 days old nursery. The transplanting of rice seedlings into flooded fields gives the crop a significant competitive advantage over weeds, as standing water suppresses most of the weeds (Pathak *et al.*, 2011). However, enormous labor and water are required to grow rice through a puddle transplanted system and the conventional puddle rice system is losing its sustainability and economic viability due to declining water resources and scarcity of labour (Akbar *et al.*, 2011). These factors involve a significant shift from the production of puddled transplanted rice to the direct seeded rice (DSR) in irrigated areas.

In Kashmir valley DSR was grown from last many decades with locally known as 'watur' direct seeding of rice, a traditional practice in India prior to the green revolution, is once again becoming widespread due to its ability to save water and labor. Currently, direct seeded rice in Asia occupies 29 mha, approximately 21% of the region's total rice area (Pandey and velasco, 2002). DSR has been practiced effectively across various nations around the world, such as the U.S.A, Sri Lanka, India, China etc (Kumar and Ladha, 2011). Direct seeded rice under reduced tillage is an efficient resource conservation (RCT) technology which holds good promise in the coming days due to the following advantage over rice transplantation.

Usually, Direct rice seeding can be achieved by sowing pre-germinated seed into puddled soil (wet seed) or standing water (water seed) or prepared seedbed. However, the combination of dry seeding (Dry-DSR) with minimum tillage (e.g., conservation agriculture (CA) is growing in popularity as a way to tackle increasing water and labor shortages and to boost sustainability of the system. Recent research has shown that direct seeding has various advantages over puddling transplantation, typically including (1) equal yields; (2) savings in irrigation water, labor and production costs; (3) higher net economic yields; and (4) significant reduction in methane emissions. Direct seeding is a good alternative to transplantation because it is more affordable and saves time. DSR matures seven to ten days earlier than transplanted rice due to absence of transplanting shock (Rana *et al.*, 2014).

The simultaneous emergence of competitive weeds, the lack of water to suppress weeds at the time of the emergence of rice seedlings with the proliferation of difficult to control weeds are the key reasons for heavy weed infestation in DSR. Due to competition for various growth factors, weeds would adversely affect the yield, quality and production costs (Singh, 2008). Weeds dominate the crop environment and reduce the yield capacity due to broad adaptability and faster growth (Rao, 2011).

Weed competition in some cases is so severe that failure to control weeds in DSR can result in yield losses of 65 to 92 per cent Naresh *et al.*, (2011). Furthermore, stress related to agricultural activity in general, and weeding in particular, compels the young generation to resign from farming and opt for other livelihood choices. Weed management during the critical crop-weed competition is important in order to minimize weed competition and to allow effective use of the available resources for improved productivity of economic crop. Azmi *et al.*, (2007). Reported that during mixed weed infestation critical period for weed control in in DSR was from 12 to 60 DAS.

DSR fields are more species-rich with more variety in weed flora than TPR fields (Tomita *et al.*, 2003; Singh *et al.*, 2008; Kamoshita *et al.*, (2010). The fundamental weed species related with rice crop in DSR are *Echinochloa colona*, *Echinochloa crusgalli*, *Cyperus iria*, *Cynodon dactylon* , *Caesulia axillaris*, *Commelina benghalensis* , *Phyllanthus niruri*, *Eclipta alba* and *Physalis minima* (Gupta *et al.*, 2006; Pathak *et al.*, 2011). Changing the species composition of the accompanying weed flora as well as the rapid change in weed flora is a key issue with DSR. Ingestion of annual grasses and perennial sedges presents unique threat to weed management with continuous direct seeding. Previously, numerous weed control measures were introduced to reduce the weed pressure in DSR.

In order to effectively control the weed problem and also to utilise the full benefit of the DSR program, the use of herbicides at the right rate and time of application is very important at this time. There are now many pre-emergence and post-emergence herbicides available and used by farmers in different countries (Ahmed & Chauhan, 2014). Among them, pendimethalin is a pre-emergence herbicide applied in the soil and is absorbed by roots and coleoptiles, inhibiting cell division and elongation (Pathak *et al.*, 2011). Ethoxysulfuron is used as an early post-emergence to control broadleaf weeds and sedges, mostly taken from roots and leaves and translocated in the plant (Pathak *et al.*, 2011). Bispyribacsodium is a contact herbicide for POST control of grasses, broadleaf

and sedge weeds in rice (Valent USA, 2003). It inhibits the enzyme acetolactate synthase (ALS), which prevents biosynthesis of branched-chain amino acids. (Vencill, 2002). Bispyribac sodium can be applied alone or in tank mixes with other herbicides for control of number of weed species in rice (O'Barr *et al.*, 2003). Halosulfuron are relatively recent introductions, which provides protection against *Cyperus* spp., including *Cyperus rotundus*, with activity on broadleaf weeds also the diverse weed flora (terrestrial and aquatic) in dry seeded rice fields usually necessitated this herbicide for wide spectrum weed control (Gianessi *et al.*, 2002) In India, cyhalofopbutyl followed by 2, 4-D was found effective against mixed weed populations (Angiras and Attri, 2002). Keeping in view the above facts a field trial entitled “**Studies on Bioefficacy of herbicides to control cyperus weed spp. in direct seeded rice (*oryza sativa* L.)**” is proposed to be conducted with the following objectives:

- To study the response of growth and yield of direct seeded rice to different herbicides.
- To evaluate the performance of different herbicides to control *Cyperus* weed species in direct seeded rice.
- To work out relative economics.

Chapter-2

REVIEW OF LITERATURE

Crop yields are correlated with different production technologies. Weed management as one of the important practices play a vital role in enhancing crop yields, especially in direct seed rice. In this chapter, attempts have been made to present research work done on weed management in direct seed rice in the country and abroad.

2.1 Direct seeded rice problems and prospects

One of the oldest rice setting techniques is direct-seeding. Direct seeding was the dominant method used in developing countries prior to the late 1950s (Pandey and Velasco, 2005). In India, dry direct seeding of rice is widely practiced in lowland rainfed, uplands and areas prone to flooding, while wet seeding of rice remains a common practice in irrigated areas (Misra *et al.*, 2005). Direct dry seeding offers benefits such as faster and easier planting, reduced labor, 7-10 days earlier crop maturity, more productive water uses and water resistance up to 7 water deficits, lower methane emissions and also higher income in secured water supply areas (Balasubramanian and Hill, 2002; Sidhu *et al.*, 2014).

Infestation of weeds in direct seeded rice is one of the major reasons for poor productivity. Uncontrolled weeds may reduce grain yields in dry direct seeded rice by 96 percent and in wet seeded rice by 61 percent (Maity and Mukerjee, 2008). Mukherjee *et al.*, (2008) suggested that the direct seeded rice is subject to weed competition than the rice transplanted, since under direct seeded rice both weed and crop seeds emerge simultaneously and compete with each other for resources right from the germination stage leading to lower grain yield. To prevent any yield loss, a weed-free period for the first 30-45 days after sowing is necessary because the dry weight of weeds in dry-direct seeded rice increases significantly from 30 DAS onwards.

2.2 Critical period of crop-weed competition

The crucial weed control period is a time in the crop growth cycle during which weeds have to be managed to prevent yield losses (Zimdahl, 1988 and 2004). Studies conducted in India on critical period of crop weed competition reported that the first 30-70 days are critical, depending on the type of rice cultivar and the method of rice establishment. The principles of the crucial time of competition for crop weed, the period of crop growth definitively measured during which yield is reduced (Zimdahl, 1999), hold an attraction in that it finds attention to the critical period of time when weeding should take place.

In a crop weed community, the overall impact of weed competition resulting from competition is reflected in the growth and yield of the crop in various forms such as nutrients, moisture, space, light, oxygen, carbon dioxide. The duration of weed competition as determined by the selective removal of the weed species in rice, along with associated agronomic and cultural management factors. Under direct seed, weed competition would be harsher than those under transplanted (Savary *et al.*, 2005 and Rao and Nagamani, 2007). Rice cultivation requires initial 30 days of weed-free condition without adverse effect on final yield (Bhan *et al.*, 1980). Similarly, 95 percent of weed-free rice yield was obtained in field trials of dry-seeded irrigated rice by controlling weeds until 32 DAS in the season and until 83 DAS in the dry season in the Senegal River delta (Johnson *et al.*, 2004).

The general conclusion that emerges from DSR rice – weed competition studies is that competitive processes occur earlier in crop life and re-emphasize the often-quoted need to control early weeds.

2.3 Effect of weeds on yield of direct-seeded rice

Aerobic soil, dry-tillage and alternative wetting and drying conditions, on the other hand, are leading to the germination and growth of weeds, causing losses of rice grain yield between 50-91 percent, according to Elliot *et al.* (1984).

Ranjit (2007) observed that weeds caused yield loss in direct seeded rice ranging from 14-93 percent. The grain yield decreased by 79.7 percent, due to season long weed crop competition in direct seeded rice (Gopinath and Kundu, 2008).

Raj *et al.* (2013) observed a 72 percent decrease in grain yield, because of the infestation of non-grassy broad-leaved weeds and sedges in direct seeded rice, Uncontrolled weeds reduced direct seeded rice grain and straw yields by 42 and 46 percent respectively (Singh *et al.* 2010).

Maity and Mukerjee (2008) estimated that the uncontrolled weeds in wet direct seeded rice reduced the grain yield by 61 percent. Yield losses of up to 74 percent for wet seeded rice due to weed infestation (Ramzan, 2003).

Ali and Sankaran (1984) computing the yield loss of rice under non puddled and puddled condition reported that unchecked weed growth caused 53 percent reduction in grain yield in puddled conditions, and 91 percent yield reduction in non-puddled conditions.

Mamun (1990) indicated that for direct seeded aus rice, weed growth reduced grain yield by 68-100 percent, for transplant aman rice by 16-48 percent and for modern boro rice by 22-36 percent.

Ramamurthy (1991) revealed that excessive weed growth and severe crop-weed competition drastically reduce the crop yield in the unweeded 9 control and it was 88 percent of the treatments where higher doses of herbicides were applied in the kharif rice.

Amarjit *et al.* (1994) reported that weeds under adverse condition affect plant height, leaf architecture, Tillering habit, shading ability, and growth pattern and life duration of rice cultivars.

Gibson *et al.* (2001) recorded a grain yield reduction of up to 99 percent with a mixed infestation of *Echinochloa oryzoides* and *Echinochloa phyllopogon* in wet-seeded rice.

Daniel *et al.* (2012) reported that the uncontrolled weeds reduce aerobic rice yield by 90.3 percent over weed control treatments.

2.4 Weed flora in direct seeded rice

The predominant weeds infesting direct seeded rice under Palampur conditions consisted of *Echinochloa*, *Cyperus iria*, *Setaria glauca*, *Panicum spp.* and *Commelina benghalensis* (Nandal and Singh, 1995).

Saha (2005) observed significantly higher number of broad leaf weeds (43.2 percent) compared to sedges (32.6 percent) and grasses (24.2 percent) under direct seeded rice.

Prabhakaran and Chinnusamy (2006) from Coimbatore (Tamil Nadu) reported that sedges were dominant (54.3 percent), followed by grassy (27.3 percent) and broad-leaved (17.9 percent) weeds in direct-seeded rice.

Kikon and Gohain. (2016). reported that the dominant weed species observed were *Digitaria setigera* Roth ex Roem. & Schult, *Cynadon dactylon* (L.) Pers., *Eleusine indica* (L.) Gaertn., *Echinochloa colona* (L.), *Cyperus rotundus* L., *Cyperus iria* L., *Borreria articularis* (L. f.) F. N. Will., *Ageratum conizoides* L., *Ipomoea triloba* L., *Mimosa pudica* L. and *Melochia corchorifolia* L.

In a recent survey in Punjab, the dominant weed species reported by the farmer in DSR field ware *Cyperus iria* L., *Echinochloa colona* (L.) Link, *Eragrostis spp.*, *Leptochloa chinensis* (L.) Nees, *Digitaria sanguinalis* (L.) Scop,

Dactyloctenium aegyptium (L.) Willd., *Cyperus rotundus* L., and *Eleusine indica* (L.) Gaertn (Mahajan *et al.*, 2013).

Kaur and Singh (2014) at Ludhiana, Punjab reported that weed flora of the experimental field consisted mainly of grasses, viz. *Echinochloa crusgalli* and *Echinochloa colona* and sedges, viz. *Cyperus iria*, *Cyperus compressus* and *Cyperus rotundus*.

Kumar *et al.* (2012) In Pantnagar, Uttarakhand, recorded that during both years, *Echinochloa colona* among grasses, *Commelina benghalensis* and *Caesulia axillaris* among nongrasses and *Cyperus rotundus* among sedges were the dominant weed species in the experimental site.

2.5 Effects of weed control methods on weed dynamics

Walia *et al.* (2008a) reported that pre-emergence application of pendimethalin provide effective control of non-predominant weed, whereas bispyribacsodium controlled the entire predominant weed including *Echinochloa colona* and *Cyperus rotundus* and other broad-leaved weeds.

Rao *et al.* (2008) reported that the lowest weed growth was observed by the pre-emergence application of pendimethalin @ 1.0 kg ha⁻¹ integrated with one-hand weeding at 30 DAS.

Thura (2010) revealed that weed density, dry weight of weeds and efficiency of weed control were significantly affected by various treatments for weed control. Two hand weedings at 21 and 35 DAT demonstrated good output with minimum weed dry weight and the highest weed control efficiency at harvest in both experiments. The percentage of yield loss due to weed competition was found to range from 59.5 to 74.06 percent in the dry season and from 49.97 to 73.4 percent in the wet season.

While working on trisulfuron, + pretilachlor, and bensulfuron methyl output in transplanted rice, Rampool *et al.* (2007) reported that the combination

of trisulfuron + pretilachlor @ 0.009 + 0.5 kg a.i. ha⁻¹ (6 DAT), resulted in 50 m⁻² weeds with a dry weight of 101 g, statistically equal to butachlor @ 1.5 kg a.i. ha⁻¹ + one weeding hand (3 DAT).

Rekha *et al.* (2002) reported that compared to weedicides and untreated control, twice-hand weeding resulted in lower weed density.

Riaz *et al.* (2007) showed that pendimethalin 700g (30 EC) as pre-emergence herbicide was found better to control early flush of weeds while, 2, 4-D (ester) and ethoxysulfuron 18g (36) were equally effective in reducing post-emergence weeds.

During Kharif 2009 and 2010, Simerjeet and Singh conducted field experiments to study the bio-efficacy of various herbicides in direct-seeded rice. In comparison with other pre-emergence herbicides, significantly lower numbers of grass weeds were observed when pendimethalin was applied. The lowest weed biomass and 100 percent weed control efficiency were recorded by the sequential application of pendimethalin *fb* bispyribacsodium.

A field investigation was conducted by Kumar and Raina at Palampur during *Kharif* 2013, to evaluate the efficacy of bispyribacsodium along with cyhalofopbutyl and butachlor for controlling mixed weed flora in direct seeded upland rice. Bispyribacsodium 30 g ha⁻¹ resulted in highest weed control efficiency (WCE) of 85.7% which was followed by butachlor *fb* metsulfuron methyl with 84.2 percent.

Iqbal *et al.* (2013) found that the highest weed control (94.8 - 98.1%) was achieved with two post-emergence herbicide (bispyribacsodium) sprays (21 & 40 DAS) followed by single application (21 DAS) of the same herbicide that offered 77.5 to 82.3 percent weed control efficacy.

Yogananda *et al.* conducted field experiment to study the impact on weed management practices of wet direct-seeded rice during the rainy seasons

of 2014 and 2015 (*Oryza sativa* L.). Pre-emergence application of bensulfuron-methyl + pretilachlor GR (Londax Power) at 660 g/ha *fb* bispyribacsodium (Nominee Gold) at 25 g/ha at 20 days after sowing (DAS) significantly reduced weed growth.

Hussain *et al.* (2008) conducted field experiment and the results revealed that the highest weed control was given by manual/hand weeding (98.18%).

Khaliq *et al.* (2013) found that the supplementing herbicide application with manual weeding in dry seeded rice fields can help control weeds more effectively. Bispyribacsodium recorded higher weed suppression when it was followed by manual 13 weeding.

Kumar *et al.* (2013) reported that bispyribacsodium 20-30g/ha effectively controlled *E. colona* in direct seeded rice.

Ganie *et al.* (2013) found that the highest weed control efficiency (WCE) was recorded with pendimethalin 1.0 kg ha⁻¹ (PE) *fb* bispyribac-Na 25g ha⁻¹ + ready-mix chlorimuron-ethyl + metsulfuron-methyl 4g ha⁻¹ (PoE) at 30 DAS *fb* one hand weeding (HW) 60 DAS. 1 + one hand weeding at 30 days after seeding was found the most successful reduction in the overall weed population and dry matter of weeds.

In hand weeding, the minimum weed density was recorded twice at 30 and 50 DAT, which was statistically equal to butachlor + 2, 4-D with maximum weed control efficiency, as stated by Rajkhowa and Gogoi (2004).

Mishra and Singh (2012) reported that pre-emergence application of pendimethalin (1.0 kg ha⁻¹) *fb* post-emergence of 2, 4-D (0.50 kg ha⁻¹) significantly reduced the population density of *Echinochloa colona*, *Cyperus iria* and *Axalaris sessilis* than the weedy check.

2.6 Effects of weed control methods on growth parameters of direct seeded rice

Sunil *et al.* (2010) revealed that 3 DAS + hand weeding at 40 DAS applied with Bensulfuron-methyl + Pretilachlor (6.6 GR) @ 0.06 + 0.60 kg ha⁻¹ resulted in higher plant height, higher number of tillers, higher leaf area and higher aerobic rice production of dry matter and remained on par with weed-free 12 control.

Application of pre-emergence Oxyflourofen @ 0.25 kg ha⁻¹ *fb* post emergence application of Bispyribacsodium @ 0.05 kg + Metsulfuron methyl @ 0.01 kg ha⁻¹ produced highest plant height (105.8 cm) and higher number of productive tillers (308) in rice over other treatments, but was found on par to that of two hand weedings treatment (94.6 cm and 254) (Gnanavel and Anbhazhagan, 2010).

Bhowmick and Ghosh (2002) reported that two hand weedings were statistically at par with application of butachlor and 2, 4-D @ 1.5 kg a.i and 1.0 kg a.i. ha⁻¹, respectively recorded significantly higher plant height of transplanted rice than weedy check.

Higher plant height was recorded with sequential application of pendimethalin @ 1 kg ha⁻¹ + 2, 4-D @ 0.5 kg ha⁻¹ or fenoxaprop @ 0.07 kg ha⁻¹ 18 over hand weeding at 20 and 45 DAS in dry seeded irrigated rice at Jabalpur (Mishra and Singh, 2008).

In direct dry seeded rice at Ludhiana, plant height was found to be significantly higher with application of post-emergence bispyribacsodium @ 25 g ha⁻¹ or azimsulfuron @ 20 g ha⁻¹ after pre-emergence application of pendimethalin @ 0.75 kg ha⁻¹ over alone application of pendimethalin at 0.75 kg ha⁻¹ (Walia *et al.* 2009).

Similarly, taller plants were observed in hand weeding at 20, 40 and 60 DAS over different pre-emergence herbicides alone or in combination with postemergence herbicide. It was at par with pretilachlor @ 0.75 kg ha⁻¹ *fb* 2, 4-D @ 0.5 kg ha⁻¹ in direct seeded rice (Singh and Singh, 2010).

Singh and Singh (2010) reported at Varanasi that the LAI recorded at 90 DAS with HW thrice at 20, 40 and 60 DAS was at par with pretilachlor @ 0.75 kg ha⁻¹ fb 2, 4-D @ 0.5 kg ha⁻¹ in direct seeded rice.

Sunil *et al.* (2010) reported that bensulfuron-methyl + pretilachlor (6.6 GR) @ 0.06 + 0.60 kg ha⁻¹ applied at 3 DAS + hand weeding at 40 DAS resulted in higher plant height, a greater number of tillers, higher leaf area and greater dry matter production of aerobic rice and remained, on par with weed free check.

Narolia *et al.* (2014) reported that among weed management practices, preemergence application of pendimethalin @ 1.0 kg ha⁻¹ fb bispyribac-sodium @ 35 g ha⁻¹ showed 16.5 percent higher plant height, 36.9 percent higher tillers m⁻² and 137.2 percent higher dry matter at harvesting than weedy check.

2.7 Effect of weed control methods on yield and yield attributes of direct seeded rice.

Singh and Singh (2014) indicated that with the application of pendimethalin 1000 g ha⁻¹ (preemergence) followed by azimsulfuron 35 g ha⁻¹ at 15-20 DAS + one hand weeding at 40 DAS, the maximum grain yield, straw yield and biological yield of rice was observed, which was considerably superior to the rest of the treatments during both years of experimentation.

Joshi *et al.* (2015) reported that the highest grain yield was recorded by pre-emergence application of pendimethalin (1 kg ha⁻¹) followed by post-emergence application of bispyribacsodium (25 g ha⁻¹) supplemented with one hand weeding 45 days after sowing, which was significantly higher than both pre- and post-emergence application of herbicide together with one hand weeding.

Singh *et al.* (2014) observed that the efficacy of the treatments influenced rice grain yield and yield attributing characters (tillers m⁻² and grains panicle⁻¹). Weed free (4.03 t ha⁻¹) was recorded as the highest grain yield of rice, which was equal to bispyribacsodium 20 and 25 g ha⁻¹.

Sharma *et al.* (2016) found that among herbicidal weed management, postemergence application of bispyribacsodium at 30 g ha⁻¹ recorded higher number of panicles m⁻² grains panicle⁻¹ and 1000-grain weight, higher grain and straw yield in direct seeded rice.

Mahajana and Chauhan (2015) found that highest grain yield (7.2 t ha⁻¹ in 2013 and 7.9 t ha⁻¹ in 2014). Applied with tank mixture of azimsulfuron + bispyribacsodium + fenoxaprop.

Tej pratap *et al.* (2016) confirmed that with twice-hand weedings at 20 and 40 DAS, the higher grain yield (3.50 t ha⁻¹) was recorded at par with fenoxaprop + ethoxysulfuron 60 + 15 g ha⁻¹, followed by bispyribacsodium 25 g ha⁻¹ alone and fenoxaprop + chlorimuron + metsulfuron 60 + 20 g ha⁻¹ ready mix.

Kaur and Singh (2015) recorded highest grain yield in two hand weedings which was at par with consecutive application of pendimethalin, butachlor, thiobencarb and oxadiargyl with bispyribacsodium.

Ali *et al.* (2014) concluded that highest number of filled grains panicle⁻¹ (116.3) and lowest number of filled grains per panicle (43.6) were recorded with application of bispyribacsodium than other herbicidal treatments and weedy check.

Mahajan *et al.* (2014) revealed that sequential application of pendimethalin (PE) and bispyribacsodium provided the maximum grain yield among all the weed control treatments and this treatment produced grain yield of 6.1 t ha⁻¹

Ganie *et al.* (2013) found that the effective tillers (245.9 m⁻²), number of grains/spikelet (68.9 m⁻²), 1000 grain weight (24.9 g), grain and straw yield were the highest in the weed free plot, which was at par with treatment pendimethalin 1.0 kg ha⁻¹ (PE) fb bispyribacsodium 25g ha⁻¹ + ready-mix chlorimuron-ethyl +

metsulfuron-methyl 4g ha^{-1} (PoE) at 30 DAS fb one hand weeding (HW) 60 DAS least value recorded under weedy check.

Bhat *et al.* (2008) from SKUAST-J confirmed that compared to weedy control, all weed control treatments had a significant effect on yield characteristics of direct wet seeded rice and most outstanding yield characteristics were recorded in weed-free plots. Among various herbicides, butachlor @ $1.5\text{ kg a.i ha}^{-1}$ (7 DAS), anilophos @ 312 g a.i ha^{-1} + ethoxysulfuron @ 15 g a.i ha^{-1} (10 DAS) and pretilachlor @ $0.75\text{ kg a.i ha}^{-1}$ (3 DAS) were used provided highest number of effective tillers m^{-2} , number of grains panicle⁻¹ and 1000 grain weight with the complementary increase in the grain yield than other weed control treatment

Banerjee *et al.* (2005) found that bensulfuron-methyl + butachlor @ $0.05 + 0.938\text{ kg a.i. ha}^{-1}$ applied as pre-emergence recorded at par grain yield and 1000 grain weight with that of 2 hand weedings at 20 and 40 DAT and weed free check.

Higher number of panicles was recorded with pre-emergence application of pendimethalin @ 1 kg a.i. ha^{-1} fb 2, 4-D @ $0.5\text{ kg a.i. ha}^{-1}$ at 21 DAS over weedy check in direct seeded rice at Kaul (Ram *et al.*, 2004).

Padhi *et al.* (1991) conducted an experiment in Odisha in well drained sandy loam soils and concluded that the maximum grain yield was recorded from two hand weedings (20 and 40 DAS) which differed significantly from the weedy control.

Nandal and Singh (1995) observed that in direct-seeded rice the weed free treatment recorded the highest grain yield which was followed by two hand weedings (30 and 60 DAS).

Choubey *et al.* (1998) reported that grain yield was enhanced with the applications of butachlor @ 1.5 kg a.i ha⁻¹ as pre-emergence and post-emergence application of cyhalofopbutyl @ 80 g ha⁻¹.

2.8 Effects of weed control treatments on economics of direct seeded rice

The cost effectiveness of bispyribacsodium as a post-emergence herbicide for weed management in aerobic rice has been suggested by Mahajan *et al.* (2009). The application of 20 g ha⁻¹ bispyribacsodium was more affordable (2.63) than that of the remaining treatments, including weed-free treatment (2.06) in drilled rice (Rawat *et al.*, 2012).

Khaliq *et al.* (2012) confirmed that post-emergence application of bispyribacsodium in direct seeded rice with higher economic returns seemed to be an effective method for weed control. The second successful treatment concerning net fits was bispyribacsodium. Marginal and dominance results showed that by applying bispyribacsodium, the highest marginal rate of return (11037-28250 Rs ha⁻¹) was obtained.

Prameela *et al.* (2014) reported that the economics of rice cultivation shows that for high returns (Rs. 67,090) and B:C ratio (1.8), spraying cyhalofopbutyl followed by chlorimuron-ethyl + metsulfuron-methyl is the best. Although the yield was a little lower in bispyribac sodium, as the cost of cultivation was low due to onetime application of herbicide, it could maintain high B:C ratio of 1.8 in direct seeded rice.

Sunil *et al.* (2010) reported that with Bensulfuronmethyl+ Pretilachlor (6.6 GR) @ 0.06+0.60 kg ha⁻¹ applied at 3 DAS + One intercultivation at 40 days followed by Bensulfuron-methyl + Pretilachlor (6.6 GR) @ 0.06+0.60 kg ha⁻¹ applied at 3 DAS with a benefit cost ratio of 2.14, the monetary advantage in terms of net returns (Rs. 26,815 ha⁻¹) and benefit cost ratio (3.9) was maximum.

Netam *et al.* (2016) conducted an experiment in rainy season of 2011-2012 in Pantnagar, found that maximum (41760 ha⁻¹) net return was recorded under weed free condition and minimum (14560 ha⁻¹) under weedy check.

An experiment in Ludhiana (Punjab) 46 performed by Kaur and Singh (2015) reported that maximum grain yield was observed under weed-free treatment that was statistically equivalent to sequential use of pendimethalin 0.75 kg ha⁻¹ with bispyribacsodium 0.025 kg (6.6 t ha⁻¹) or azimsulfuron 0.02 kg ha⁻¹ (6.5 t ha⁻¹). Sequential use of herbicides from pre-emergence and post-emergence resulted in a greater benefit: cost ratio (1.66).

Hussain *et al.* (2008) performed an experiment to manage weeds in direct seeded rice and concluded that weedicides nominee 100 SC (bispyribac sodium) 250 ml ha⁻¹ and sunstar gold 60 WG (ethoxysulfuron) 62.5 g ha⁻¹ were the best weedicides with 90.5 and 87.19 percent weed control efficiency respectively 15 and 25 days after sowing. The paddy yield was also significantly greater than other weedicides in both of the weedicide treatments. The maximum net benefit was obtained by the application of nominee 100 SC followed by treatment with sunstar gold 60 WG, while control (weedy check) provided the lowest net benefits.

Chapter-3

MATERIALS AND METHODS

The present investigation entitled “**Studies on bioefficacy of herbicides to control cyperus weed species in direct seeded rice (*Oryza sativa* L.)**” was conducted on agronomy research form at Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Faculty of Agriculture, Wadura (Sopore), during and kharif 2019. The techniques followed and materials used during the course of investigation are detailed in this chapter as under:

3.1 Location and climate

The experimental site is a temperate region of the union territory between 34° 34/ N latitude and 74° 40/ E longitude at an altitude of 1584m above mean sea level. Climatically the experimental site is in mid altitude temperate zone characterized by hot summers and experience very cold winters with an average annual precipitation of 812 mm (average of past 20 years) most of which is received from December to April in the form of snow and rains. The mean meteorological data during the cropping seasons was recorded at Meteorological Observatory, Kupwara is presented in Fig.1 and Appendix-I. It is evident from the data that average maximum and minimum temperatures were 33.34°C and 5.34°C, respectively and the total average precipitation amounted to 355.2 mm during crop growth period, and the mean average maximum and minimum relative humidity were 87.29 % and 44 %, respectively during the crop growth period.

3.2 Soil characteristics

Composite soil sample was collected from 0-15 cm soil depth before laying experimental trial were subjected chemical analysis. The results affirm that the soil was high in organic carbon (0.98%), medium in available nitrogen (327 kg ha⁻¹

¹), phosphorous (17.3kg ha⁻¹) and potassium (248 kg ha⁻¹) with slight acidic pH (5.9) (Table 3.1).

Table 3.1: Physic-chemical characteristics of the soil of experimental field

Particulars	Status	Rating	Method employed
Chemical analysis			
pH (1:2.5 soil water suspension)	5.9	Slightly acidic	Blackman's glass electrode pH meter (Jackson, 1973)
Electrical conductivity at 25°C	0.14 dSm ⁻¹	Normal	Sloubridge conductivity meter (Piper, 1966)
Organic carbon (%)	0.98	High	Walkely and Black rapid titration method (Jackson, 1973)
Available nitrogen (kg ha ⁻¹)	327	Medium	Medium Potassium Alkaline permanganate method (Subbiah and Asija, 1956)
Available phosphorus (kg ha ⁻¹)	17.3	Medium	Extraction with 0.5 M NaHCO ₃ (Olsen <i>et al.</i> , 1954)
Available potassium (kg ha ⁻¹)	248	Medium	Flame photometer method (Jackson, 1973)

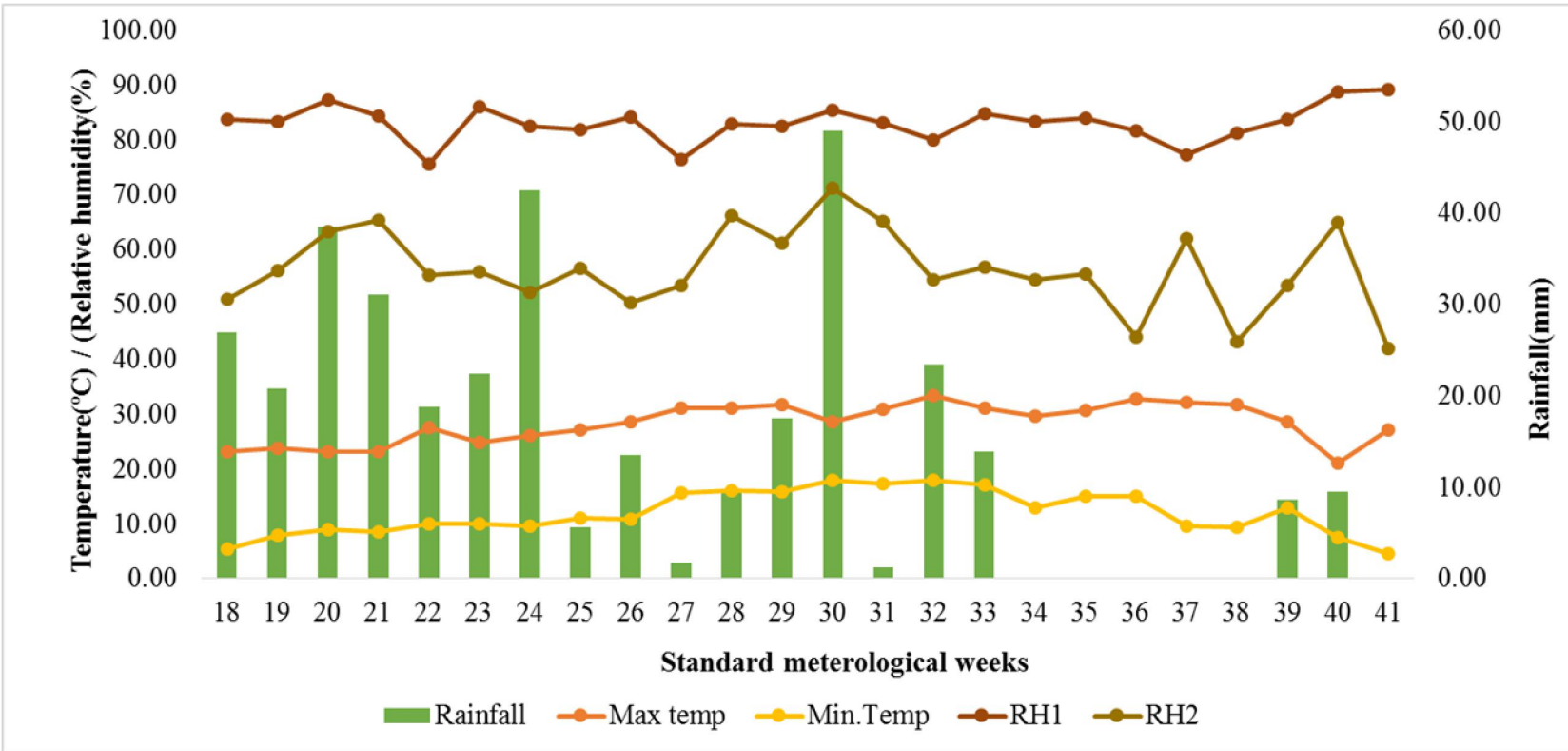


Fig. 1: The temporal change in weather parameters during the growing season (2019) of the experimentation crop.

3.2 Cropping history of experimental field

The detail of cropping history of an experimental field from 2014-2018 (Table 3.2).

Table 3.2: Cropping history of experimental field

Cropping season		
Year	Kharif	Rabi
2014	Rice	Fallow
2015	Rice	Fallow
2016	Rice	Rapeseed
2017	Rice	Brown sarson
2018	Rice	Fallow
2019	Rice(experimental)	

3.4 Experimental details

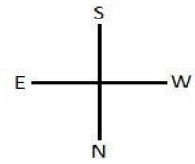
The experiment comprised of nine weed control treatments including two checks (manual weeding and control (weedy check) was laid out in random block Design with three replications as per layout plan shown in Fig. 2. The details are given below:

3.4.1 Details of the treatments:

Treatments:

T ₁ Halosulfuron	35 g a.i ha ⁻¹ (post-emergence)
T ₂ Cyhalofopbutyl	100 g a.i ha ⁻¹ (post-emergence)
T ₃ Bensulfuronmethyl	35 g a.i ha ⁻¹ (post-emergence)
T ₄ Bispyribacsodium	30 g a.i ha ⁻¹ (post-emergence)
T ₅ Ethoxysulfuron	45 g a.i ha ⁻¹ (post-emergence)
T ₆ Pretilachlor	700 g a.i ha ⁻¹ (pre-emergence)
T ₇ Pendimethalin <i>fb</i> 2,4-D	0.75 kg ha ⁻¹ + 1.0 kg ha ⁻¹ (pre-emergence +post-emergence)
T ₈ Weedy check	
T ₉ Weed free	

Application of herbicides either at 3-leaf stage (weed) or 25 DAS whichever is earlier except pre-emergent herbicides (PE)



Main Irrigation Channel			
R1	R2	Sub irrigation channel	R3
T ₅ Ethoxysulfuron (45 g a.i ha ⁻¹)	T ₇ Pendimethalin <i>fb</i> 2,4-D (0.75 kg ha ⁻¹ +1.0kg ha ⁻¹)		T ₁ Halosulfuron (45 g a.i ha ⁻¹)
T ₈ Weedy check	T ₅ Ethoxysulfuron (45 g a.i ha ⁻¹)		T ₉ Weed free
T ₃ Bensulfuronmethyl (60 g a.i ha ⁻¹)	T ₁ Halosulfuron (45 g a.i ha ⁻¹)		T ₆ Pretilachlor (700 g a.i ha ⁻¹)
T ₇ Pendimethalin <i>fb</i> 2,4-D (0.75kg ha ⁻¹ +1.0 kg ha ⁻¹)	T ₆ Pretilachlor (700 g a.i ha ⁻¹)		T ₈ Weedy check
T ₄ Bispyribacsodium (30 g a.i ha ⁻¹)	T ₃ Bensulfuronmethyl (60 g a.i ha ⁻¹)		T ₂ Cyhalofopbutyl (100 g a.i ha ⁻¹)
T ₆ Pretilachlor (700 g a.i ha ⁻¹)	T ₉ Weed free		T ₇ Pendimethalin <i>fb</i> 2,4-D (0.75kg ha ⁻¹ +1.0kg ha ⁻¹)
T ₂ Cyhalofopbutyl (100 g a.i ha ⁻¹)	T ₈ Weedy check		T ₄ Bispyribacsodium (30 g a.i ha ⁻¹)
T ₉ Weed free	T ₄ Bispyribacsodium (30 g a.i ha ⁻¹)		T ₅ Ethoxysulfuron (45 g a.i ha ⁻¹)
T ₁ Halosulfuron (45 g a.i ha ⁻¹)	T ₂ Cyhalofopbutyl (100 g a.i ha ⁻¹)		T ₃ Bensulfuronmethyl (60 g a.i ha ⁻¹)

Fig.2 Layout of the experimental field

3.4.2 Other experimental detail

Location of Experiment : Research Farm,FOA, Wadura,SKUAST-K
Crop : Rice
Variety : Shalimar Rice-4
Replication : 03
Total no. of experimental plots : 27
Design : Randomised block design (RBD)
Gross plot size : 3.0 m x 5.0 m
Spacing : 20 cm (Row to Row)
Date of sowing : 20 May 2019.

Table 3.3: Calendar of field operations

Operation	Dates of different operations	Remarks
Tractorization with tiller	15/05/2019	The field was ploughed with cultivator followed by rotary tiller. Field was properly levelled.
Layout/levelling	17/05/2019	Layout was done as per experimental details. Plot bunds, paths and irrigation channels were made.
Seed soaking/incubation	17/05/2019	Seed soaking and incubation was done 3 days before sowing.
Application of fertilizers	19/06/2019	Basal dose of N, P, K fertilizers through urea, DAP, MOP was applied as per package of practices to each plot
Seed Sowing	20/05/2019	Sowing of seeds was done manually in lines with chisel
Application of herbicide	23/05/2019 (PE) 15/06/2019(PoE)	Pendemethalin and pretilachor were applied at 3 DAS while as, cyhalofopbutyl, bispyribacsodium, ethoxysulfuron, Halosulfuron and 2,4-D were applied at 25 DAS to each plot, respectively.
Irrigation and drainage	12/6/2019	Shallow irrigation was supplied to the entire field.
Harvesting	3/10/2019	Harvesting of crop was done manually treatment wise.
Threshing	7/10/2019	Threshing was done plot wise manually by beating sheaves against wooden logs.



Sprouted seeds



watering of seeds



Sowing of seeds



covering of seeds with soil



Final making of bunds and irrigation channel



Herbicide application



Manual weeding

Plate 1: Field operations carried out during experimentation



Plate 2: overview of field

3.6 Land preparation

Experimental field was ploughed with tractor-drawn cultivator followed by rotary tiller, to carry the dirt to a fine tilth and leveling was done physically with conventional land leveler. Replication bunds, plot-ways, irrigation drainage channels were made manually, sowing of seeds was done under dry condition and afterward entire field was supplied with shallow irrigation. Appropriate. Leveling of plots was done before the sowing of seed with etch. Water was depleted out of the field at the hour of seed planting. Field was separated into plots giving water system and waste channels as indicated by the layout plan.

3.7 Fertilizer application

Full recommended dose of phosphorus and potassium through di-ammonium phosphate and muriate of potash at the level of 60 and 30 kg P_2O_5 and K_2O ha^{-1} , separately was consistently applied to each plot as basal portion before seed sowing. Nitrogen @ 120 kg ha^{-1} was applied through urea with half as basal and staying half in two equivalent parts for example tillering and panicle initiation stages.

3.8 Sowing

Partially sprouted wet seeds of Paddy variety Shalimar Rice-4 (SR-4) free from any weed seeds/inert material was sown @ 80 kg ha^{-1} were absorbed water for 48 hours and afterward incubated for 48 hours for growing. Sprouted seeds were consistently sowing in columns dispersed 20 cm separated. Before seed sowing activity, it was guaranteed that adequate dampness for germination of seed is available in the dirt. Pre-germinated treated seeds with Tricyclazole 75 WP @ 0.6 g kg^{-1} seed, were planted manually in the lines with row spacing of 20 cm towards north-east direction.

3.9 Herbicide application

Weed control in the experimental field was done as per the treatments including weedy check and weed free. The herbicide pendimethalin *fb* 2,4-D ($0.75\text{kg ha}^{-1}+1.0\text{kg ha}^{-1}$) were applied as pre-emergent at 3 DAS, while as cyhalofopbutyl (100g a.i ha^{-1}) bispyribacsodium (30 g a.i ha^{-1}) ethoxysulfuron (45 g a.i ha^{-1}) and halosulfuron (35 g a.i ha^{-1}) as post emergent were applied at 25 DAS. The herbicides were sprayed on moist soil on the plots with a knapsack sprayer equipped with a flat fan nozzle using 500 liters of water per hectare.

3.10 Harvesting and Threshing

Harvesting of paddy was done after attaining physiological maturity at 20 percent moisture content. Leaving fringe and penultimate lines from all the sides of each plot. The crop was dried after harvesting for 72 hours and weight was taken with spring balance in kg per plot and afterward changed over into q ha^{-1} . Sifting was finished by beating the harvest against wooden logs and the grain yield was recorded in kg per plot and afterward communicated in q ha^{-1} .

3.11 Experimental observations

The following observations were recorded during the experiment:

3.11.1 Crop studies

3.11.1.1 Plant height

The height of five randomly selected plants from each plot was measured periodically (20, 40, 60, 80, 100, 120, DAS and at harvest) from ground level to the apex of last fully opened leaf during vegetative period and up to the tip of the panicle after flowering. It was averaged and expressed in centimeters.

3.11.1.2 Dry matter production

Sampling was done Plant samples contained in a quadrant $0.5\text{ m} \times 0.5\text{ m}$ (0.25 m^2) were collected from each plot. The samples were collected periodically (20, 60, 80, 100,120 DAS and at harvest) and after fresh weight taken then, the

samples were oven dried at 60-65°C for 48 hours to a constant weight. The dry weight was recorded in grams and then converted into $q \text{ ha}^{-1}$.

3.11.1.3 Leaf area index

The periodic leaf area (20, 60, 80, 100, 120, DAS and at harvest) was measured with Leaf area meter.

3.11.1.4 Number of panicles m^{-2}

The number of panicles falling in quadrant 0.25m^{-2} were counted from each plot before harvesting and the numbers were converted into m^{-2} .

3.11.1.5 Number of filled grains panicles⁻¹

Total number of filled grains from each panicle was counted from each plot and expressed as filled grains panicle⁻¹.

3.11.1.6 1000-grain

Weight Grain samples from each plot collected separately at threshing were dried properly. 1000 grains from each of these samples were taken and their weights recorded and expressed in grams.

3.11.1.7 Biological yield

The bundle weight of each net plot was recorded three days after harvest and expressed in $q \text{ ha}^{-1}$.

3.11.1.8 Grain yield

The grain yield from the respective net plots (15 m^2) was threshed, weight recorded and expressed as $q \text{ ha}^{-1}$.

3.11.1.9 Straw yield

The straw yield of each plot was computed by deducting the grain yield from biological yield and expressed as $q \text{ ha}^{-1}$.

3.11.1.10 Harvest index

It was determined by the following formula:

$$\text{Harvest index} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.11.2 Weed studies

3.11.2.1 Weed density

Weeds falling in the quadrant of 0.25 m² were uprooted from each plot periodically at 20 40, 60 80 DAS, identified, counted and expressed as weeds m⁻².

3.11.2.2 Weed dry weight/Dry weed biomass

Weeds uprooted from each plot at 30, 45, 60, 80 DAS for weed count were washed and after sun dried followed by oven dried at 60-65°C for 48 hours to a constant weight. The weight was showed in g m⁻²

3.11.2.3 Weed control efficiency (%)

Weed control efficiency for different weed control treatments was worked out on weed dry weight. This was calculated as per the following formula:

$$\text{WCE (\%)} = \frac{\text{Weed count in unweeded plot} - \text{Weed count in treated plot}}{\text{Weed count in unweeded plot}} \times 100$$

Where.

WCE = weed control efficiency

WDC = Weed dry weight in control plot

WDT = Weed dry weight in treated plot

3.11.2.4 Weed index

Weed index for different weed control treatments was worked out. This was calculated as per the following formula:

$$\text{Weed index} = \frac{\text{Yield from weed free plot} - \text{yield from treated plot}}{\text{Yield from weed free plot}} \times 100$$

Where,

YWF is the crop yield in weed free plot

YT is the crop yield in treated plot

3.11.3 Soil studies

Soil samples from each plot up to depth 15 cm were taken before harvest of the crop and were shade dried label wise on plane white papers for few days. The soil samples after drying were ground, sieved through 2 mm mesh and a 5 composite sample was taken from each representative sample for further laboratory analysis

3.11.3.1 Organic carbon (%)

The organic carbon was determined by Walkely and Black rapid titration method, given by Jackson (1973) and calculated in percent.

3.11.3.2 pH

pH was determined by making a suspension of soil water in the ratio of 1:2.5 and was read on Blackman's glass electrode pH meter" given by Jackson (1973).

3.11.3.3 Available nitrogen

The available soil nitrogen was determined by using alkaline potassium permanganate method (Subbiah and Asija, 1956) for each soil sample and was calculated in kg ha⁻¹.

3.11.3.4 Available phosphorus

The available phosphorus in soil samples of each treatment was determined by using the 0.5 N NaHCO₃ at pH 8.5 (Olsen *et al.*, 1954) and recorded in kg ha⁻¹.

3.11.3.5 Available potassium

The potassium content from soil samples was seen by the method of extraction with 1N ammonium acetate at pH 7.0 (Jackson, 1973) and was recorded in kg ha⁻¹.

3.12 Relative economics

Economics of different treatments was worked out on the basis of grain and straw yield per hectare. The cost of input and output was estimated as per prevailing market rates. The benefit cost ratio (returns per rupee invested) was determined as:

$$\text{Benefit cost ratio} = \frac{\text{Net returns}}{\text{Total cost of cultivation}}$$

3.13 Statistical analysis

The data obtained in respect of various observations were statistically analyzed by method described by Cochran and Cox (1963). The significance of 'F' and 't' was tested at 5 percent level of significance. The critical difference value was determined when 'F' test was significant. Analysis of the data was done by using OP Stat software programme (Anonymous, 2012).

Chapter-4

EXPERIMENTAL FINDINGS

The observations recorded and results obtained from field experiment entitled “Studies on bioefficacy of herbicides to control cyperus weed species in direct seeded rice (*Oryza sativa* L.)” have been reported in this chapter. The data has been analyzed statistically and presented through tables and illustrated graphically. The analysis of variance has been included in Appendix section.

4.1 Growth parameters

4.1.1 Plant height

The data pertaining to plant height under different treatments recorded at different growth intervals are presented in Table 4.1 and depicted in Fig. 3, with corresponding analysis of variance depicted in Appendix-II.

Perusal of data indicated that different weed control treatments had significant effect on the plant height at different growth intervals of the crop. However, no significant effect of treatments was recorded on plant height at 20 DAS. Maximum plant height (121.79cm) was under weed free (T_9) treatment at maturity. Among the herbicides used, application of Bispyribacsodium @ 30 g a.i. ha^{-1} recorded significantly height plant height (118.66cm) at maturity as compared to rest of the weed control treatments. The rest of the weed control treatments with respect to plant height showed a decreasing trend of $T_7 > T_2 > T_3 > T_5 > T_6$. Moreover, it was found that weedy check (T_8) treatment recorded significantly lowest plant height at maturity with value of 98.21cm.

4.1.2 Leaf area index

The data recorded on leaf area index (LAI) at different growth intervals is presented in Table 4.2 and depicted in Fig. 4 with corresponding analysis of variance depicted in Appendix-III.

The analysis of data of leaf area index (LAI) showed non-significant results at 20 DAS for various treatments. However, the treatments at different growth intervals (40, 60, 80, 100, and 120 DAS) showing significant effect for leaf area index (LAI). The results obtained suggest that leaf area index (LAI) first increases from 20 DAS upto 80 DAS and then decreases from 80 DAS till the crop was ready for harvest. At 80 DAS the maximum leaf area was recorded in weed free (T₉) treatment which recorded value of (5.22). Among the herbicides applied, bispyribacsodium @ 30 g a.i. ha⁻¹ recorded significantly highest LAI (4.96) at 80 DAS as compared to Pendimethalin fb 2,4-D (0.75kg ha⁻¹+1.0kg ha⁻¹) and Halosulfuron @ 35 g ai ha⁻¹ respectively, the rest of the weed control treatments with respect to leaf area index showed decreasing trend of T₂ > T₃ > T₅ > T₆. Moreover, it was found that weedy check (T₈) treatment recorded significantly lowest leaf area index throughout the crop growth season.

4.1.3 Dry matter accumulation (q ha⁻¹)

The data on dry matter accumulation as per treatments is presented in Table 4.3 and depicted in Fig. 5 with corresponding analysis of variance depicted in Appendix-IV.

The data revealed that, the different weed control treatments influenced dry matter accumulation of crop significantly at different growth intervals except 20 DAS. The data obtained showed that weed free treatment recorded significantly the highest dry matter accumulation at all growth intervals and at maturity (155.16 q ha⁻¹) over weedy check. Among the different herbicides used, bispyribacsodium @ 30 g a.i. ha⁻¹ recorded significantly the highest dry matter accumulation at all growth intervals and at maturity (147.03 q ha⁻¹) as compared to Pendimethalin fb 2,4-D (0.75kg ha⁻¹+1.0kg ha⁻¹) and Halosulfuron @ 35 g a.i ha⁻¹, respectively. The

rest of the weed control treatments with respect to dry matter accumulation showed decreasing trend of $T_2 > T_3 > T_5 > T_6$. Moreover, it was found that weedy check (T_8) treatment recorded significantly lowest dry matter accumulation at maturity with values and 96.34 q ha^{-1} .

Table 4.1: Effects of different weed control treatments on plant height (cm) in direct seeded rice (DSR) at different intervals after sowing.

Treatments	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	120 DAS	At maturity
Halosulfuron (35 g a.i ha ⁻¹)	16.22	22.01	51.95	90.95	108.63	113.50	115.54
Bensulfuronmethyl (60 g a.i ha ⁻¹)	16.20	21.52	51.80	88.25	105.16	111.25	113.96
Cyhalofopbutyl (100 g a.i ha ⁻¹)	16.20	21.00	51.46	87.68	104.88	109.63	111.73
Bispyribacsodium (30 g a.i ha ⁻¹)	16.25	23.76	54.04	95.14	111.69	116.10	118.66
Ethoxysulfuron (45 g a.i ha ⁻¹)	16.10	20.58	50.99	85.32	104.70	108.25	110.82
Pretilachlor (700 g a.i ha ⁻¹)	16.00	20.03	50.54	82.62	102.08	106.30	108.40
Pendimethalin fb 2,4-D (0.75 kg ha ⁻¹ +1.0 kg ha ⁻¹)	16.07	22.51	52.58	92.52	109.80	114.69	116.77
Weedy check	15.67	19.23	39.87	72.34	100.66	95.43	98.21
Weed free	17.27	24.25	56.02	97.87	113.11	118.15	121.70
SE(m)±	0.55	0.97	0.70	1.17	2.05	1.97	1.11
CD(p≤0.05)	N. S	2.93	2.12	3.55	6.22	5.96	3.38

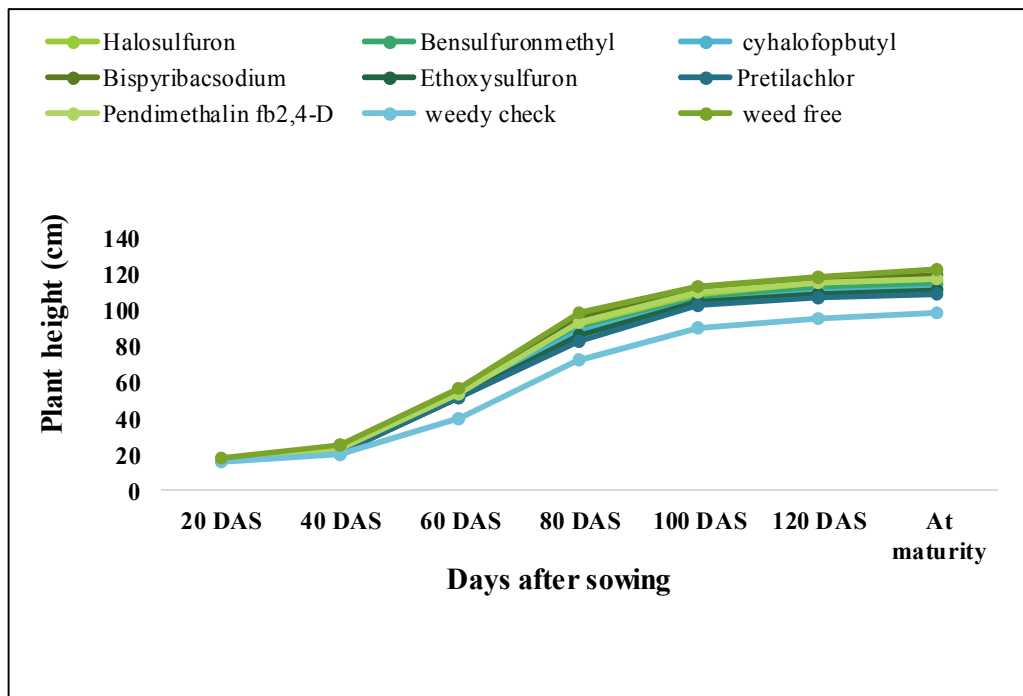


Fig. 3: Plant height (cm) as influenced by different weed control treatments.

Table 4.2: Effects of different weed control treatments on leaf area index in direct seeded rice (DSR) at different intervals after sowing

Treatments	20DAS	40DAS	60DAS	80DAS	100DAS	120DAS
Halosulfuron (35 g a.i ha ⁻¹)	0.24	1.84	2.87	4.66	3.77	3.35
Bensulfuronmethyl (60 g a.i ha ⁻¹)	0.22	1.82	2.37	4.47	3.61	3.21
Cyhalofopbutyl (100 g a.i ha ⁻¹)	0.20	1.80	2.14	4.32	3.46	3.15
Bispyribacsodium (30 g a.i ha ⁻¹)	0.27	2.18	3.24	4.96	4.18	3.49
Ethoxysulfuron (45 g a.i ha ⁻¹)	0.17	1.75	2.03	4.26	3.36	3.04
Pretilachlor (700 g a.i ha ⁻¹)	0.15	1.36	1.98	4.15	3.26	2.72
Pendimethalin fb 2,4-D (0.75 kg ha ⁻¹ +1.0 kg ha ⁻¹)	0.26	1.86	3.00	4.76	3.90	3.44
Weedy check	0.12	1.10	1.86	3.82	3.10	2.45
Weed free	0.28	2.49	3.58	5.22	4.34	3.54
SE(m)±	0.05	0.19	0.32	0.21	0.03	0.04
CD(p≤0.05)	N. S	0.58	0.96	0.63	0.11	0.13

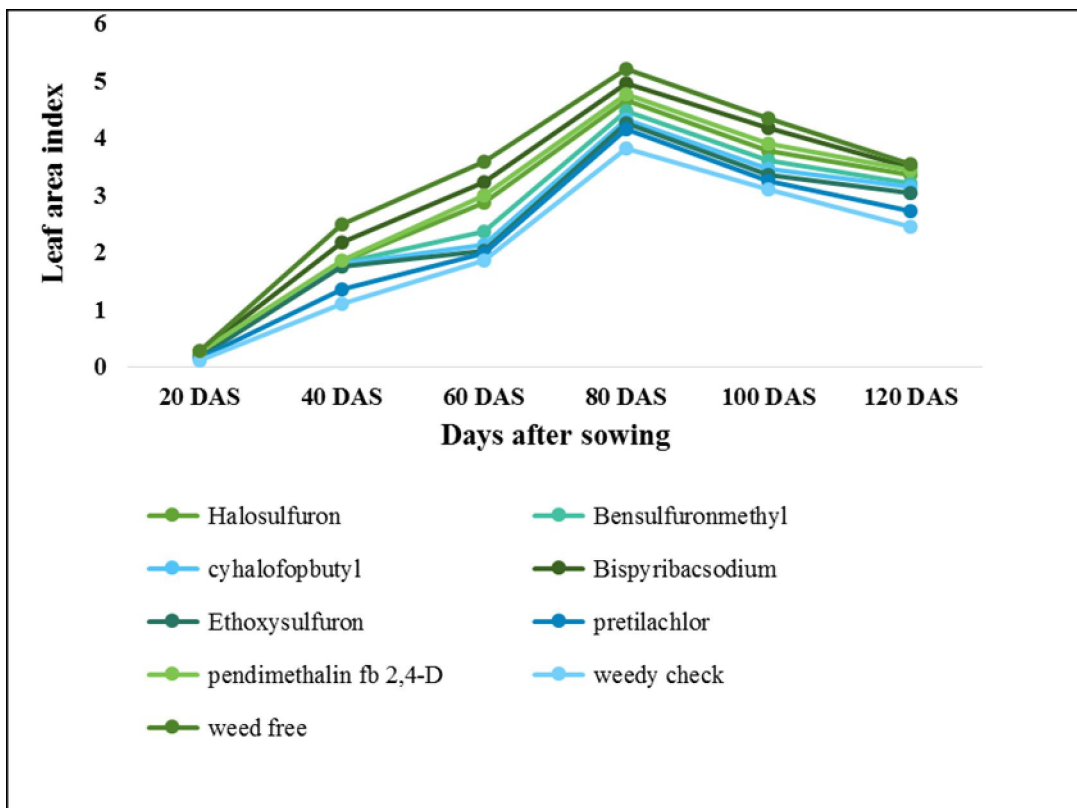


Fig. 4: Leaf area index (%) as influenced by different weed control treatments.

Table 4.3: Effects of weed control treatments on dry matter accumulation ($q\text{ ha}^{-1}$) in direct seeded rice (DSR) at different intervals after sowing.

Treatments	20DAS	40DAS	60DAS	80DAS	100DAS	120DAS	At Maturity
Halosulfuron (35 g a.i ha^{-1})	1.17	5.25	34.37	94.87	115.76	131.84	136.58
Bensulfuronmethyl (60 g a.i ha^{-1})	1.14	4.75	31.26	91.77	110.52	126.13	131.85
Cyhalofopbutyl (100 g a.i ha^{-1})	1.09	4.25	26.40	88.85	107.280	122.61	127.99
Bispyribacsodium (30 g a.i ha^{-1})	1.21	6.42	40.54	100.69	124.83	142.58	147.03
Ethoxysulfuron (45 g a.i ha^{-1})	1.07	4.00	23.32	85.03	105.98	118.95	123.67
Pretilachlor (700 g a.i ha^{-1})	1.00	3.92	21.71	82.03	103.87	114.74	116.95
Pendimethalin fb 2,4-D (0.75 kg ha^{-1} +1.0 kg ha^{-1})	1.21	5.74	37.70	97.81	120.55	136.26	141.97
Weedy check	0.94	3.08	17.52	56.21	76.21	93.13	96.34
Weed free	1.22	6.92	43.15	103.32	131.14	150.10	155.16
SE(m)±	0.07	0.36	1.17	1.81	1.54	1.75	2.15
CD(p≤0.05)	N. S	1.09	3.54	5.48	4.66	5.31	6.52

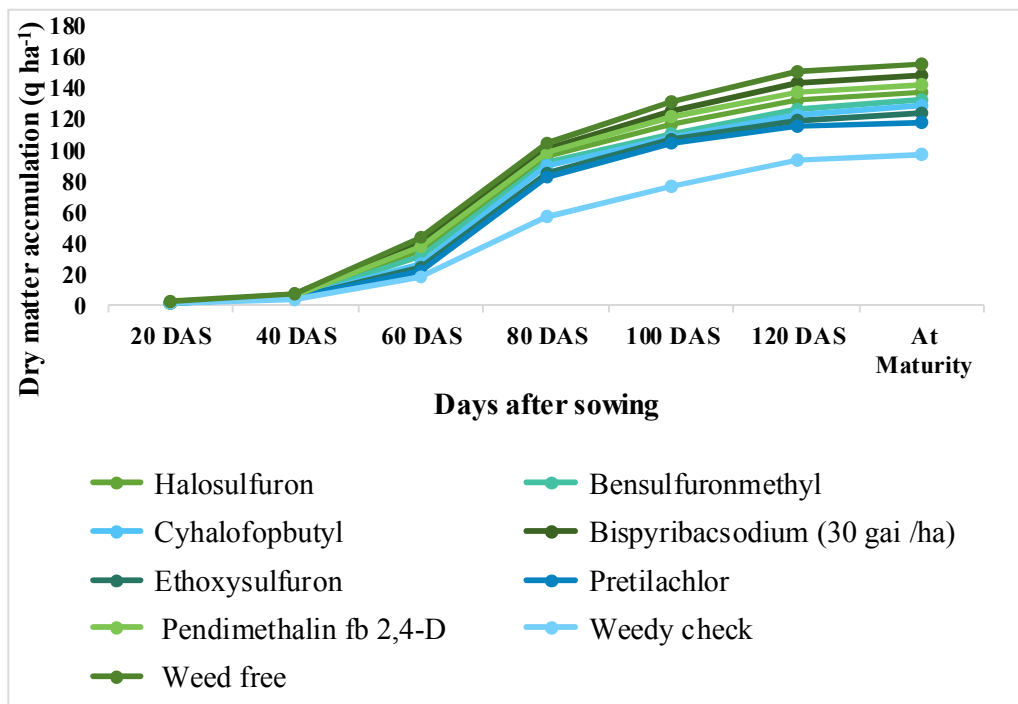


Fig. 5: Dry matter accumulation (q ha⁻¹) as influenced by different weed control treatments.

4.2 Yield attributing characters

4.2.1 Panicle density (m^{-2})

The data pertaining to the panicle density at harvest are presented in Table 4.4 and depicted in Fig. 5 with corresponding analysis of variance depicted in Appendix-VI. Data revealed that different weed control treatments had a significant effect on panicle density. Weed free treatment (T_9) significantly improved the number of panicles (402.00) over weedy check and other weed control treatments. Among different herbicides used, application of bispyribacsodium @ 30 g a.i. ha^{-1} recorded significantly higher number of panicles (360.66) than other weed control treatments and weedy check treatment. The rest of the weed management treatments with respect to number of panicles m^{-2} showed decreasing trend of $T_7 > T_1 > T_2 > T_3 > T_5 > T_6$. However, least number of panicles (320.00) were recorded in weedy check treatment (T_8).

4.2.2 Filled grains panicle $^{-1}$

The data obtained for grains panicle $^{-1}$ presented in Table 4.4 and Fig.6 Appendix-IV. The different weed control treatments showing significant effect on filled grains panicle $^{-1}$, Weed free treatment recorded higher number of filled grains panicle $^{-1}$ (93.00) than other weed control treatments. Application of bispyribacsodium @ 30 g a.i. among the various herbicides used a significantly higher number of filled grains panicle ha^{-1} was recorded by (87.00) over rest of the herbicidal treatments. However, it was found that weedy check (T_8) treatment recorded significantly lowest number of filled grains panicle $^{-1}$ (67.00) The rest of the weed management treatments with respect to number of filled grains panicle $^{-1}$ showed decreasing trend of $T_7 > T_1 > T_2 > T_3 > T_5 > T_6$.

4.2.3 1000-grain weight (g)

The data on 1000-grain weight presented in Table 4.4 with corresponding analysis of variance depicted in Appendix-VI. Perusal of the data on different weed control

treatments indicated that significant increase in 1000-grain weight (25.50) was recorded by weed free (T₉) treatment though at par with application bispyribacsodium @ 30 g a.i. ha⁻¹ and application of Pendimethalin *fb* 2,4-D (0.75kg ha⁻¹+1.0kg ha⁻¹) over unweeded control. However, weedy check treatment recorded lowest (21.00) 1000-grain weight.

Table 4.4: Effect of different weed control treatments on yield attributes of Direct seeded rice (DSR) at different intervals after sowing.

Treatments	Panicle density (No.m⁻²)	Filled grains panicle⁻¹	1000-grain weight (g)
Halosulfuron (35 g a.i ha ⁻¹)	348.00	76.00	23.96
Bensulfuronmethyl (60 g a.i ha ⁻¹)	343.66	74.00	23.26
Cyhalofopbutyl (100 g a.i ha ⁻¹)	340.66	72.00	22.80
Bispyribacsodium (30 g a.i ha ⁻¹)	360.66	87.00	25.06
Ethoxysulfuron (45 g a.i ha ⁻¹)	334.00	70.00	22.20
Pretilachlor (700 g a.i ha ⁻¹)	330.66	69.00	21.63
Pendimethalin fb 2,4-D (0.75 kg ha ⁻¹ +1.0 kg ha ⁻¹)	358.00	80.00	24.03
Weedy check	302.00	67.00	21.00
Weed free	402.00	93.00	25.50
SE(m)±	5.60	1.19	0.53
CD(p≤0.05)	16.94	3.59	1.60

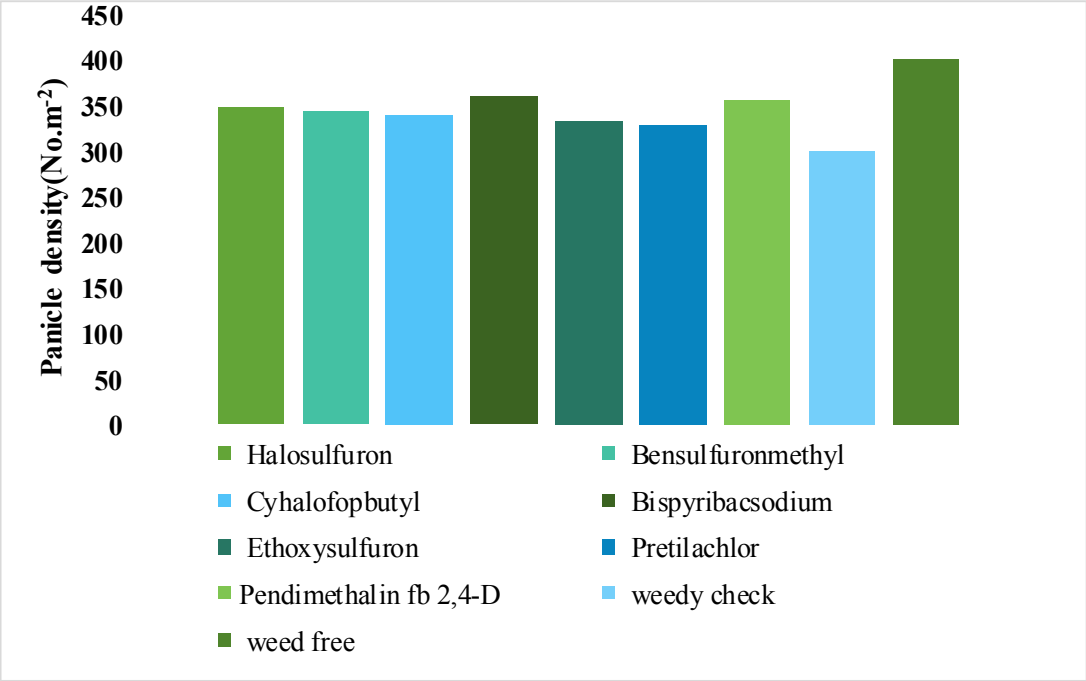


Fig 6: panicle density (No.m⁻²) as influenced by different weed control treatments.
 CD (p≤0.05) = 16.94

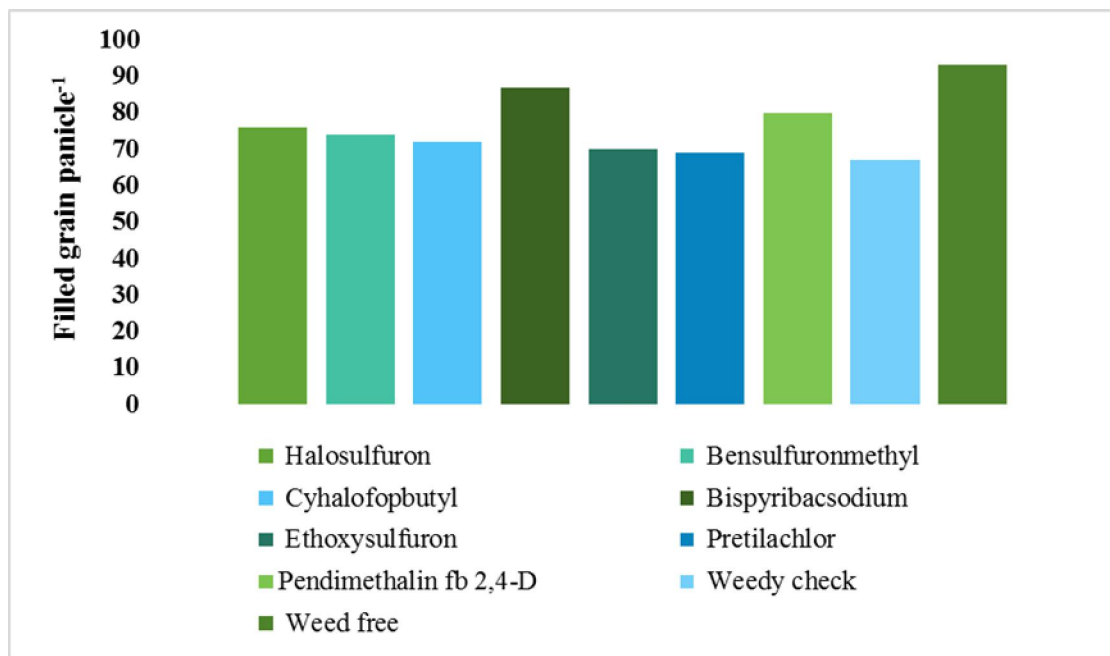


Fig 7: Filled grains⁻¹ as influenced by different weed control treatments.

CD ($p \leq 0.05$) = 3.59.

4.2.4 Grain and straw yield

4.2.4.1 Grain yield

Grain yield being an economic component of the crop, which reflects the consequent impact of all crop growth parameters and yield attributes that are affected by various input treatments. The data with respect to grain yield under different treatments are presented in Table 4.5 and depicted in Fig. 7 with corresponding analysis of variance depicted in Appendix-VII. The data revealed that significant improvement in grain yield was recorded by different weed control treatment. The different weed control treatments weed free (T_9) recorded higher grain yield (80.10 q ha^{-1}) which was significantly superior to weedy check and other weed control treatments. Among the herbicides applied, bispyribacsodium @ $30 \text{ g a.i. ha}^{-1}$ provided significantly higher grain yield (74.14 q ha^{-1}) over rest of the herbicidal treatments and weedy check (T_8). However, it was found that weedy check treatment recorded significantly lowest grain yield (42.02 qha^{-1}). The rest of the weed management treatments with respect to grain yield were in decreasing order of $T_7 > T_1 > T_2 > T_3 > T_5 > T_6$.

4.2.4.2 Straw yield

The data on straw yield of rice under different treatments presented in Table 4.5 and Fig.8 appended in Appendix-VII indicated that, the different weed control treatments had a significant effect on straw yield of the crop. Among the different weed control treatments, weed free (T_9) recorded higher straw yield (96.16 qha^{-1}) which was significantly superior to weedy check and other weed control treatments. Among the herbicides applied bispyribacsodium @ $30 \text{ g a.i. ha}^{-1}$ and Pendimethalin fb 2, 4-D ($0.75 \text{ kg ha}^{-1} + 1.0 \text{ kg ha}^{-1}$) recorded significantly higher straw yield than weedy check treatment. The rest of the weed management treatments with respect to straw yield showed decreasing trend of $T_1 > T_2 > T_3 > T_5 > T_6$. However, it was found that weedy check treatment recorded significantly lowest straw yield (71.56 q ha^{-1}).

4.2.4.3 Biological yield

The data obtained for biological yield is presented in Table 4.5 and Appendix-VII the data revealed that, different weed control treatments had a significant effect on biological yield. Weed free (T₉) recorded the highest biological yield (176.27q ha⁻¹) than other weed management practices and weedy check treatment. Among the herbicides applied bispyribacsodium @ 30 g a.i. ha⁻¹ provided significantly higher biological yield (165.87 q ha⁻¹) than other weed control treatments as well as against weedy check treatment. However weedy check treatment recorded significantly lowest biological yield (100.59q ha⁻¹) among all the weed control treatments. The rest of the weed management treatments with respect to biological yield showed decreasing trend of T₁ > T₂> T₃> T₅> T₆.

4.2.4.4 Harvest index

The data pertaining to harvest index presented in Table 4.5 with corresponding analysis of variance depicted in Appendix-VII revealed that different weed control treatments had a significant effect on harvest index of rice. Among the different weed control treatments weed free (T₉) treatment recorded highest harvest index (45.40%). Among herbicides applied bispyribacsodium @ 30g a.i. ha⁻¹ recorded highest harvest index (44.63%) which was significantly superior to weedy check and other weed control treatments. However, weedy check treatment recorded lowest harvest index (31.80%). The rest of the weed management treatments with respect to harvest index were in decreasing order of T₇ > T₁ > T₂ > T₃ > T₅ > T₆.

Table 4.5: Effect of different weed control treatments on yield of direct seeded rice (DSR) at different intervals after sowing.

Treatments	Grain yield (qha⁻¹)	Straw yield (qha⁻¹)	Biological yield (qha⁻¹)	Harvest index (%)
Halosulfuron (35 g a.i ha ⁻¹)	58.20	84.50	138.70	41.86
Bensulfuronmethyl (60 g a.i ha ⁻¹)	56.15	82.63	138.59	40.46
Cyhalofopbutyl (100 g a.i ha ⁻¹)	50.00	82.43	134.50	37.13
Bispyribacsodium (30 g a.i ha ⁻¹)	74.14	91.73	165.87	44.63
Ethoxysulfuron (45 g a.i ha ⁻¹)	48.50	81.00	132.80	36.90
Pretilachlor (700 g a.i ha ⁻¹)	45.80	80.50	131.13	34.43
Pendimethalin fb 2,4-D (0.75 kg ha ⁻¹ +1.0 kg ha ⁻¹)	65.10	87.00	146.10	44.50
Weedy check	32.02	68.56	100.25	31.90
Weed free	80.10	96.16	176.27	45.40
SE(m)±	1.32	1.34	2.01	0.66
CD(p≤0.05)	4.00	4.07	6.07	2.01

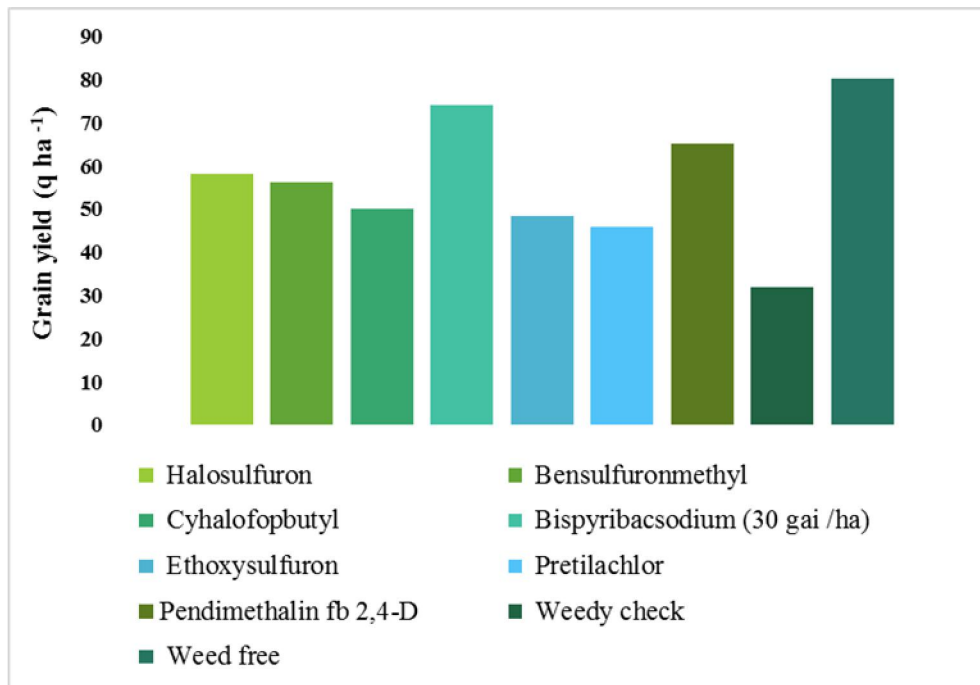


Fig 8: Grain yield (q ha⁻¹) as influenced by different weed control treatments.
 CD ($p \leq 0.05$) = 4.00

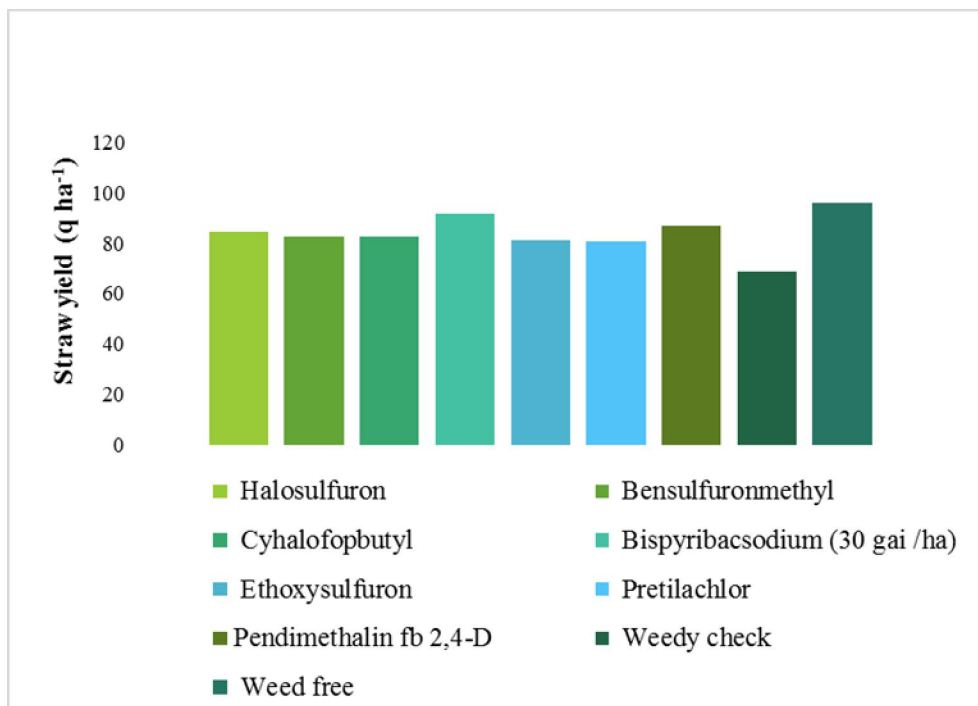


Fig 9: Straw yield (q ha⁻¹) as influenced by different weed control treatments.

CD ($p \leq 0.05$) = 4.07

4.3 Studies on weeds

4.3.1 Weed flora

The predominant weed flora identified during the crop growth are given in Plate-3, Plate-4 and Plate-5. The data showed that the experimental field was infested with grasses, broad leaf weeds and sedges. The prominent grass weeds were *Echinochloa crusgalli*, *Echinochloa colona* and *Cynodon dactylon*, broad leaf weeds were *Ammannia baccifera*, *Alisma plantago-aquatica*, *Xanthium strumarium*, and *Delphinium menziesii* while the prominent Cyperus spp. included *Cyperus iria*, *Cyperus esculentus* and *Cyperus difformis* (Table-4.6).

Table 4.6: Dominant weed flora of DSR identified during experimentation

Weed category	Scientific name	Family	Common name
Grasses	<i>Echinochloa colona</i>	Poaceae	Jungle rice
	<i>Echinochloa crusgalli</i>	Poaceae	Barnyard grass
	<i>Cynodon dactylon</i>	Poaceae	Bermuda grass
Sedges	<i>Cyperus iria</i>	Cyperaceae	Rice flat sedge
	<i>Cyperus difformis</i>	Cyperaceae	Rice sedge
	<i>Cyperus esculentus</i>	Cyperaceae	Yellow nut sedge
Broad leaf weeds	<i>Ammannia baccifera</i>	Lathyraceae	Monarch redstem
	<i>Xanthium strumarium</i>	Asteraceae	Rough cocklebur
	<i>Alisma plantago-aquatica</i>	Alismataceae	European water-plantain



Echinochloa crusgalli



Echinochloa colona



Cynodon dactylon

Plate3:Grassy weeds associated with crop



Ammania baccifera



Alisma plantago-aquatica



Delphinium menziessi



Xanthium strumarium

Plate 4: Broad leaf weeds associated with crop



Cyperus iria



Cyperus esculentus



Cyperus difformis

Plate 5: Sedges associated with crop

4.3 Total weed density

Data regarding total weed density as affected by various treatments are presented in Table 4.7 and depicted in Fig. 9. In general, the population of total weeds was maximum at 80 DAS irrespective of treatment. However, all the weed control methods provided effective control of population of weeds over weedy check at all crop growth stages. All the weed control treatments had a significant effect on total weed density throughout the crop growth season, application of bispyribacsodium @ 30 g a.i. ha⁻¹, recorded significantly lower total weed population. However, at 40, 60 DAS and 80 DAS application of bispyribacsodium @ 30 g a.i. ha⁻¹ significantly reduced the weed population over weedy check and other herbicidal treatments. Weedy check treatment recorded significantly higher total weed density at 20, 40, 60 and 80 DAS and was followed by pretilachlor @ 700 g a.i. ha⁻¹, which in turn recorded significantly higher total weed density than rest of the weed control treatments. However, lowest total weed density was recorded in weed free treatment.

4.3.2.1 Density (No. m⁻²) of grassy weeds

Different weed control treatments significantly influenced number of grassy weeds at different growth stages of rice (Table 4.7 and Fig. 10). Density of grassy weeds varied significantly. Weedy check treatment recorded significantly higher density of grassy weeds at 20, 40, 60 and 80 DAS and was followed by pretilachlor @ 700 g a.i. ha⁻¹ (pre-emergence) which in turn recorded significantly higher density of grassy weeds than rest of the weed management practices. However lowest density of grassy weeds was recorded in weed free treatment at 20, 40, 60 and 80 DAS. Among the herbicides used, application of bispyribacsodium @ 30 g a.i. ha⁻¹ recorded significantly lower density of grassy weeds at 20, 40, 60 and 80 DAS over weedy check (T₈) and other weed control treatments. The rest of the weed management treatments with respect to density of grassy weeds showed decreasing trend of T₇ > T₁ > T₂ > T₃ > T₅ > T₆

4.3.2.2 Density (No. m⁻²) of broad leaf weeds

Different treatments for weed control have greatly affected the number of broad leaf weeds at different growth stages of direct seeded rice, as shown in Table 4.7 and Fig. 11. Density of broad leaf weeds varied significantly with respect to different weed control treatments. Weedy check treatment recorded significantly higher density of broad leaf weeds at 20, 40, 60 DAS and at harvest and was followed by pretilachlor @ 700 g a.i. ha⁻¹ (pre-emergence) which in turn recorded significantly higher density of broad leaf weeds than rest of the weed management practices. However lowest density of broad leaf weeds was recorded in weed free treatment at 20, 40, 60 and 80 DAS. Among the herbicides applied bispyribacsodium @ 30 g a.i. ha⁻¹ recorded significantly lower density of broad leaf weeds at 20, 40, 60 and 80 DAS over weedy check (T₈) and other weed control treatments. The rest of the weed management treatments with respect to density of broad leaf weeds showed decreasing trend of T₇ > T₁ > T₂ > T₃ > T₅.

4.2.2.3 Density (No. m⁻²) of cyperus weed spp.

Different weed control treatments practice significantly influenced number of cyperus weed spp. at different growth stages of direct seeded rice (Table 4.7 and Fig. 12). Density of cyperus weed spp. varied significantly with respect to different weed control treatments. Weedy check treatment recorded significantly higher density of cyperus weed spp. at 20, 40, 60 DAS and at harvest and was followed by pretilachlor @ 700 g a.i. ha⁻¹ (pre-emergence) which in turn recorded significantly higher density of cyperus weed spp. than rest of the weed management practices. However lowest density of cyperus weed spp. was recorded in weed free treatment at 20, 40, 60 and 80 DAS. Among the herbicides used, application of bispyribacsodium @ 30 g a.i. ha⁻¹ recorded significantly lower density of cyperus weed spp. at 20, 40, 60 and 80 DAS over weedy check (T₈) and other weed control treatments. The rest of the weed management treatments with respect to density of cyperus weed spp. showed decreasing trend of T₇ > T₁ > T₂ > T₃ > T₅.

Table 4.7: Effect of different weed control treatments on density (No.m⁻²) of grassy, broad leaf weed and cyperus weed species in direct seeded rice (DSR) at different intervals after sowing.

Treatments	20 DAS				40 DAS				60 DAS				80 DAS			
	Grassy weeds	BLW	Cyperus Spp.	Total weed density	Grassy weeds	BLW	Cyperus Spp.	Total weed density	Grassy weeds	BLW	Cyperus Spp.	Total weed density	Grassy weeds	BLW	Cyperus Spp.	Total weed density
Halosulfuron (35 g a.i ha ⁻¹)	2.74 (6.66)	2.56 (5.66)	2.88 (7.33)	4.53 (19.66)	2.26 (4.33)	2.13 (3.66)	2.50 (5.33)	3.77 (13.33)	2.70 (6.33)	2.50 (5.33)	2.88 (7.33)	4.47 (19.00)	2.87 (7.33)	2.75 (6.66)	2.94 (7.66)	4.75 (21.66)
Bensulfuronmethyl (60 g a.i ha ⁻¹)	2.87 (7.33)	2.68 (6.33)	2.93 (7.66)	4.71 (21.33)	2.56 (5.66)	2.29 (4.33)	2.58 (5.66)	4.08 (15.66)	2.87 (7.33)	2.70 (6.33)	2.93 (7.66)	4.70 (21.33)	3.04 (8.33)	2.92 (7.66)	2.99 (8.00)	4.98 (24.00)
Cyhalofopbutyl (100 g a.i ha ⁻¹)	2.90 (7.66)	2.87 (7.33)	3.04 (8.33)	4.92 (23.33)	2.74 (6.66)	2.50 (5.33)	2.68 (6.33)	4.37 (18.33)	3.04 (8.33)	2.92 (7.66)	3.04 (8.33)	5.02 (24.33)	3.19 (9.33)	3.05 (8.33)	3.16 (9.00)	5.25 (26.66)
Bispyribacsodium (30 g a.i ha ⁻¹)	2.68 (6.33)	2.45 (5.33)	2.68 (6.33)	4.30 (18.00)	1.79 (2.33)	1.88 (2.66)	1.88 (2.66)	2.93 (7.66)	2.33 (4.66)	2.07 (3.33)	1.98 (3.00)	3.45 (11.00)	2.45 (5.33)	2.29 (4.33)	2.06 (3.33)	3.73 (13.00)
Ethoxysulfuron (45 g a.i ha ⁻¹)	3.03 (8.33)	3.04 (8.33)	3.09 (8.66)	5.13 (25.33)	2.87 (7.33)	2.69 (6.33)	2.74 (6.66)	4.59 (20.33)	3.19 (9.33)	3.04 (8.33)	3.09 (8.66)	5.20 (26.33)	3.34 (10.33)	3.26 (9.66)	3.20 (9.33)	5.49 (29.33)
Pretilachlor (700 g a.i ha ⁻¹)	2.54 (5.66)	2.29 (4.33)	2.50 (5.33)	4.02 (15.33)	2.93 (7.66)	2.57 (6.66)	2.79 (7.00)	4.70 (21.33)	3.25 (9.66)	3.09 (8.66)	3.15 (9.00)	5.32 (27.33)	3.49 (11.33)	3.36 (10.33)	3.45 (11.00)	5.79 (32.66)
Pendimethalin fb 2,4-D (0.75 kg ha ⁻¹ +1.0 kg ha ⁻¹)	2.44 (4.33)	2.13 (3.66)	2.43 (5.00)	3.82 (14.00)	2.06 (3.33)	2.06 (3.33)	2.07 (3.33)	3.30 (10.00)	2.45 (5.33)	2.29 (4.33)	2.26 (4.33)	3.85 (14.00)	2.69 (6.33)	2.50 (5.33)	2.43 (5.00)	4.19 (16.66)
Weedy check	3.02 (8.33)	3.04 (8.33)	3.07 (8.66)	5.12 (25.33)	4.23 (17.00)	4.07 (15.66)	4.03 (15.33)	6.99 (48.00)	5.12 (25.66)	4.61 (20.33)	4.93 (23.33)	8.36 (69.00)	5.40 (28.33)	5.03 (24.33)	5.19 (26.00)	8.92 (78.66)
Weed free	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
SE(m)±	0.27	0.22	0.15	0.25	0.19	0.21	0.20	0.22	0.16	0.14	0.17	0.15	0.18	0.13	0.13	0.17
CD(p≤0.05)	0.84	0.68	0.48	0.75	0.60	0.64	0.61	0.68	0.48	0.42	0.52	0.48	0.55	0.41	0.39	0.53

Figures in parenthesis are original values, data subjected to $\sqrt{x+1}$ transformation

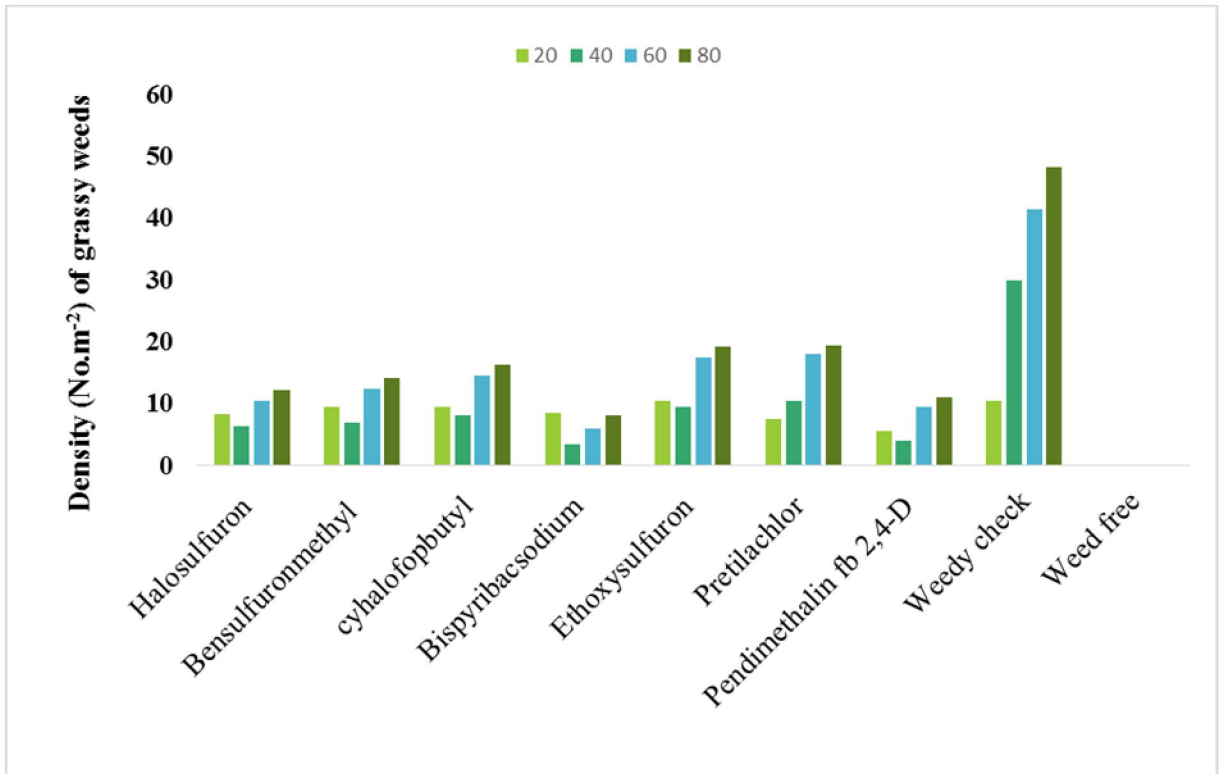


Fig.10: Density (No.m⁻²) of grassy weeds as influenced by different weed control treatments.

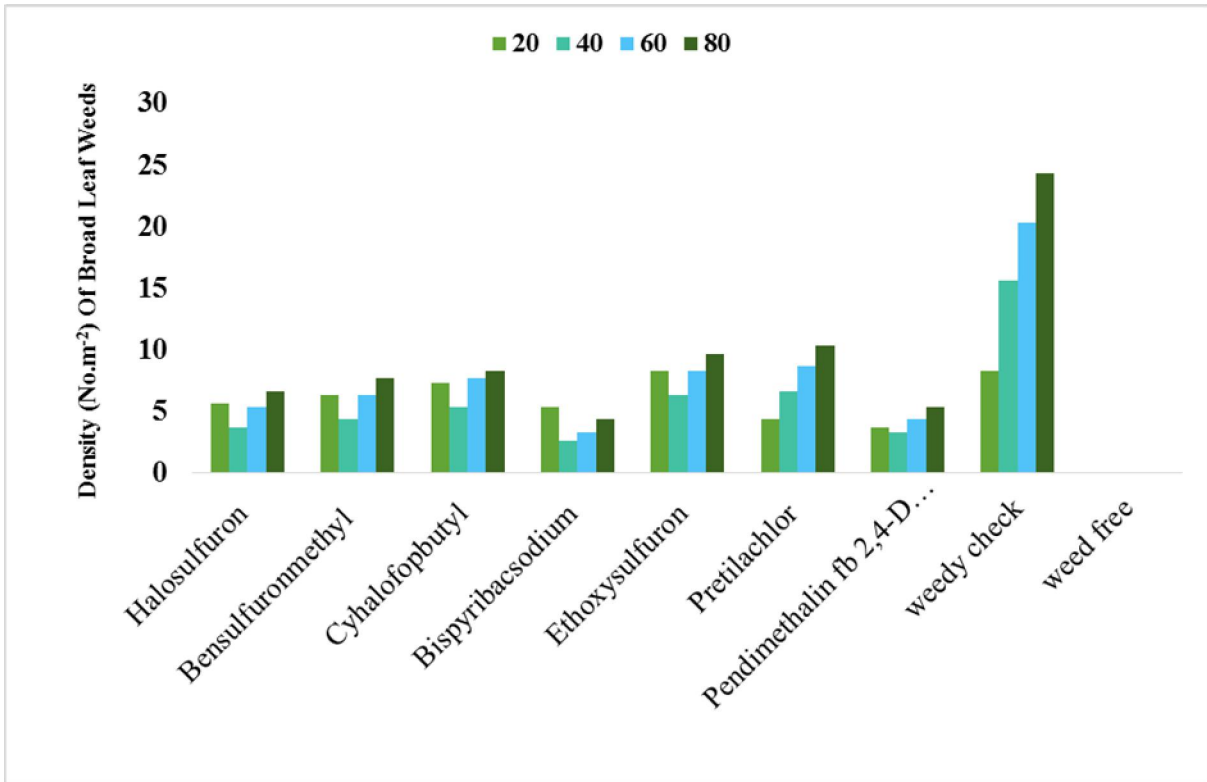


Fig.11: Density (No.m⁻²) of Broad leaf weeds as influenced by different weed control treatments.

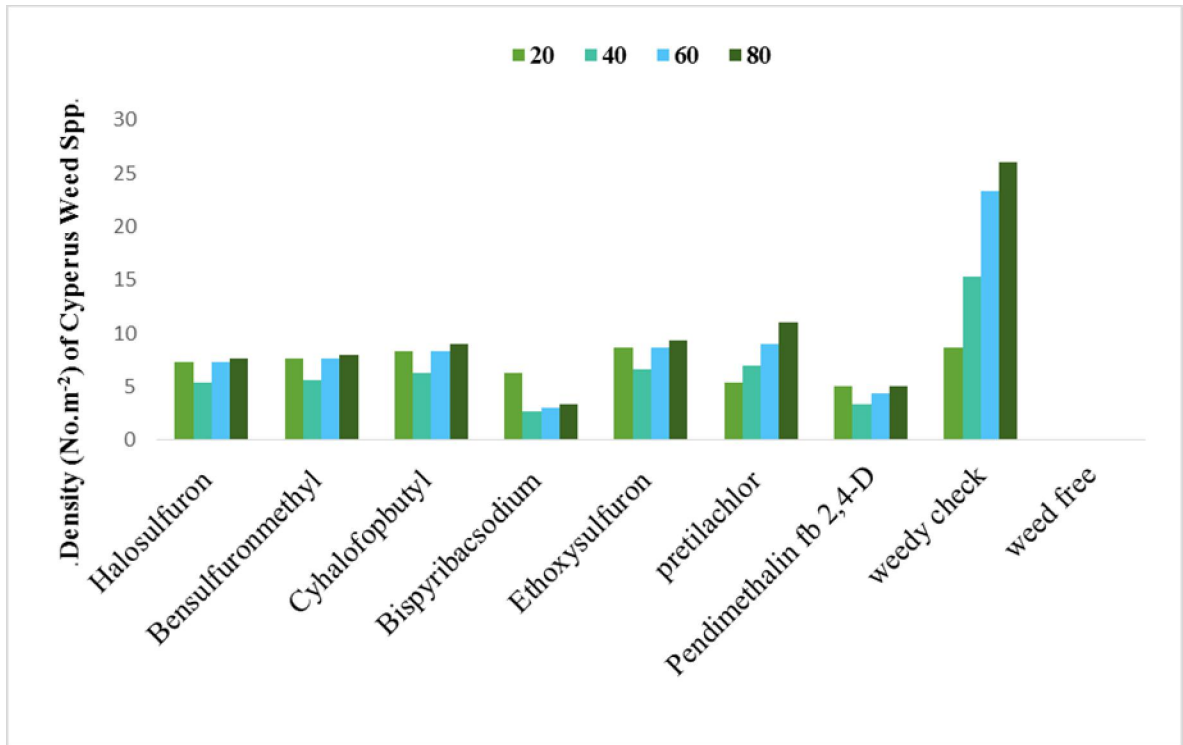


Fig.12: Density of (No.m⁻²) of cyperus weed spp.as influenced by different weed control Treatments.

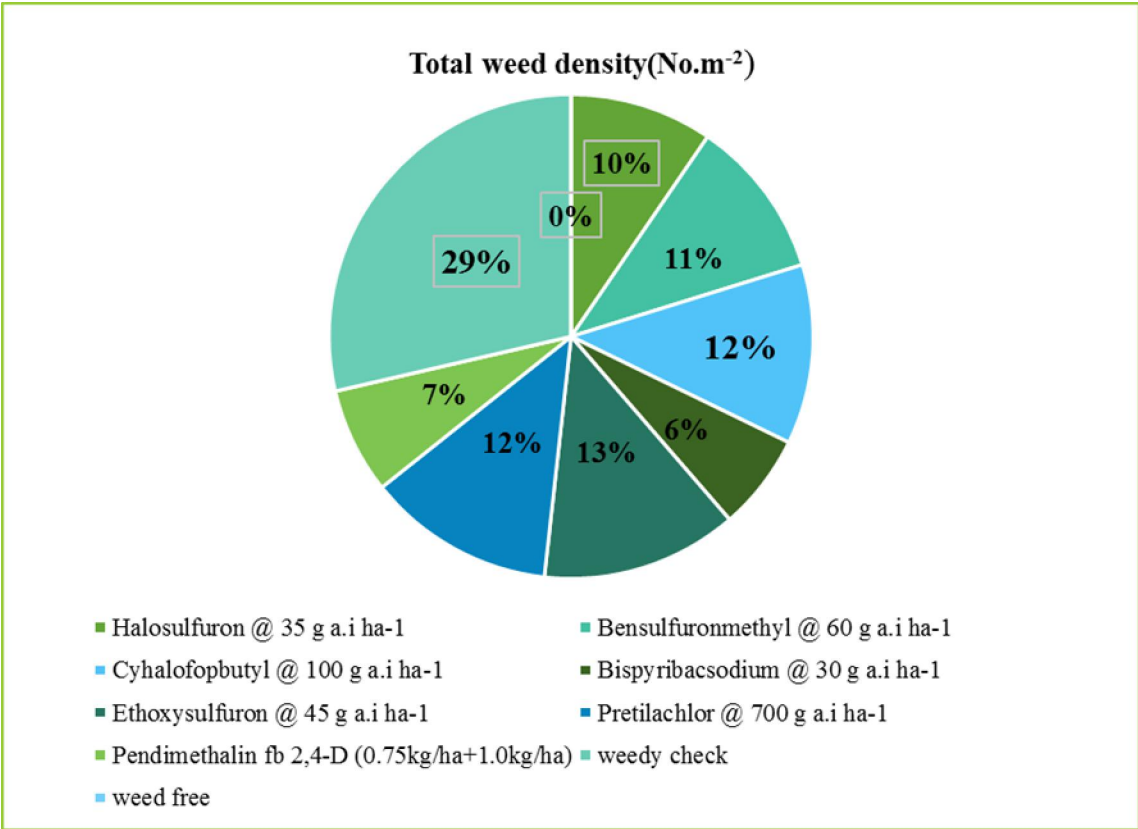


Fig.13: Total weed density (No.m⁻²) as influenced by different weed control treatments.

4.3.3 Total weed dry matter

The data pertaining to weed dry matter presented in Table 4.8 and depicted in Fig. 12 reveal that different weed control treatments had significantly influenced the total weed dry matter throughout the crop growth season. The total weed dry matter was substantially reduced by all the weed control treatments over weed control treatment at 20, 40, 60 and 80 DAS. Application of bispyribacsodium @ 30g a.i. ha⁻¹ among the various weed control treatments the total weed dry matter was substantially reduced over weed control and other weed control treatments at 20, 40, 60 and 80 DAS. However lowest total dry weed biomass was recorded in the weed free (T₉) treatment. Weedy check treatment recorded significantly higher total dry weed biomass than other weed control treatments. The rest of the weed management treatments with respect to total dry weed biomass showed decreasing trend of T₇ > T₁ > T₂ > T₃ > T₅.

4.3.3. 1 Dry weight (g m⁻²) of grassy weeds

Data presented in Table 4.8 and depicted in Fig. 13 showed that dry weight of grassy weeds was significantly affected by different weed control treatments. practices, dry weight of grassy weeds. All the weed management practices significantly reduced the weed dry matter over unweeded control at 20, 40, 60 and 80 DAS. Among the different weed management practices application of bispyribacsodium @ 30g a.i. ha⁻¹ significantly reduced the weed dry matter of grasses over weedy check and other weed control treatments at 20, 40, 60 and 80 DAS. Weedy check treatment recorded significantly higher dry weed biomass than other weed control treatments. However lowest dry weed biomass of grassy weeds was recorded in the weed free (T₉) treatment. The rest of the weed management treatments with respect to dry weight of grassy weeds showed decreasing trend of T₇ > T₁ > T₂ > T₃ > T₅.

4.3.3.2 Dry weight (g m^{-2}) of broad leaf weeds

Data provided in Table 4.8 and illustrated in Fig. 14 showed that the dry weight of broad leaf weeds was greatly impacted by various treatments for weed control. The dry weed biomass of broad leaf weeds was significantly reduced by all weed control treatments over unweeded control at 20, 40, 60 and 80 DAS. The usage of bispyribacsodium @ 30 g a.i ha⁻¹ among the various weed control treatments significantly reduced weed dry matter over weed control and other weed control treatments at 20, 40, 60 and 80 DAS. Weedy check treatment recorded significantly higher dry weed biomass than other weed management practices. However lowest dry weed biomass of broad leaf weeds was recorded in the weed free (T₉) treatment. The rest of the weed management treatments with respect to dry weight of broad leaf weeds showed decreasing trend of T₇ > T₁ > T₂ > T₃ > T₅.

4.3.3.3 Dry weight (g m^{-2}) cyperus weed spp.

Data presented in Table 4.8 and depicted in Fig. 15 showed that dry weight of cyperus weed spp. was significantly affected different weed control treatments. All the weed control treatments remarkably reduced the dry weight of cyperus weed spp. over unweeded control at 20, 40, 60 and 80 DAS. Among the different weed control treatments bispyribacsodium @30 g a.i ha⁻¹ applied, considerably reduced the weed dry matter over weedy check and other weed control treatments at 20, 40, 60 and 80 DAS. Weedy check treatment recorded significantly higher dry weed biomass than other weed management practices. However lowest dry weed biomass of cyperus weed spp. was recorded in the weed free (T₉) treatment. The rest of the weed management treatments with respect to dry weight of cyperus weed spp. were in decreasing order of T₇ > T₁ > T₂ > T₃ > T₅

Table 4.8: Effect of different weed control treatments on dry weight (g m⁻²) of grassy, broad leaf weed and cyperus weed species in direct seeded rice (DSR) at different intervals after sowing.

Treatments	20 DAS				40 DAS				60 DAS				80 DAS			
	Grassy weeds	BLW	Cyperus Spp.	Total dry weight	Grassy weeds	BLW	Cyperus Spp.	Total dry weight	Grassy weeds	BLW	Cyperus Spp.	Total dry weight	Grassy weeds	BLW	Cyperus Spp.	Total dry weight
Halosulfuron (35 g a.i ha ⁻¹)	3.07 (8.47)	3.06 (8.39)	3.09 (8.60)	5.14 (25.47)	2.72 (6.43)	2.70 (6.34)	2.74 (6.54)	4.50 (19.32)	3.41 (10.65)	3.39 (10.57)	3.42 (10.72)	5.73 (31.95)	3.65 (12.35)	3.63 (12.19)	3.64 (12.32)	6.14 (36.75)
Bensulfuronmethyl (60 g a.i ha ⁻¹)	3.24 (9.56)	3.23 (9.48)	3.27 (9.72)	5.45 (28.76)	2.83 (7.13)	2.82 (7.09)	2.85 (7.24)	4.71 (21.47)	3.67 (12.51)	3.65 (12.38)	3.69 (12.650)	6.20 (37.55)	3.92 (14.43)	3.90 (14.28)	3.92 (14.39)	6.63 (43.11)
Cyhalofopbutyl (100 g a.i ha ⁻¹)	3.26 (9.72)	3.24 (9.59)	3.28 (9.80)	5.47 (29.12)	3.05 (8.39)	3.02 (8.20)	3.07 (8.51)	5.10 (25.11)	3.97 (14.79)	3.94 (14.57)	3.97 (14.82)	6.72 (44.19)	4.18 (16.50)	4.17 (16.40)	4.18 (16.500)	7.09 (49.41)
Bispyribacsodium (30 g a.i ha ⁻¹)	3.10 (8.65)	3.08 (8.52)	3.10 (8.63)	5.17 (25.81)	2.11 (3.51)	2.10 (3.45)	2.11 (3.49)	3.37 (10.45)	2.67 (6.21)	2.64 (6.02)	2.63 (5.96)	4.36 (18.20)	3.03 (8.22)	3.01 (8.14)	2.93 (7.60)	4.99 (23.96)
Ethoxysulfuron (45 g a.i ha ⁻¹)	3.41 (10.65)	3.38 (10.47)	3.41 (10.71)	5.72 (31.85)	3.26 (9.68)	3.24 (9.54)	3.28 (9.78)	5.47 (29.01)	4.33 (17.79)	4.31 (17.58)	4.34 (17.84)	7.36 (53.22)	4.53 (19.59)	4.51 (19.35)	4.52 (19.44)	7.70 (58.39)
Pretilachlor (700 g a.i ha ⁻¹)	2.95 (7.75)	2.93 (7.63)	2.96 (7.81)	4.90 (23.19)	3.39 (10.55)	3.38 (10.43)	3.42 (10.71)	5.71 (31.69)	4.37 (18.14)	4.36 (18.06)	4.37 (18.18)	7.43 (54.38)	4.55 (19.79)	4.52 (19.51)	4.54 (19.63)	7.73 (58.94)
Pendimethalin/ <i>fb</i> 2,4-D (0.75 kg ha ⁻¹ +1.0 kg ha ⁻¹)	2.60 (5.84)	2.57 (5.68)	2.62 (5.93)	4.27 (17.45)	2.30 (4.39)	2.24 (4.10)	2.32 (4.45)	3.70 (12.96)	3.26 (9.66)	3.24 (9.57)	3.27 (9.72)	5.47 (28.99)	3.49 (11.21)	3.48 (11.14)	3.49 (11.26)	5.87 (33.62)
Weedy check	3.42 (10.70)	3.40 (10.58)	3.42 (10.72)	5.74 (32.00)	5.58 (30.21)	5.56 (30.03)	5.60 (30.39)	9.56 (90.63)	6.55 (42.05)	6.52 (41.59)	6.56 (42.14)	11.25 (125.78)	7.02 (48.41)	7.02 (48.32)	6.99 (47.91)	12.06 (144.65)
Weed free	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
SE(m)±	0.11	0.10	0.11	0.19	0.13	0.14	0.12	0.22	0.09	0.09	0.08	0.15	0.06	0.07	0.07	0.12
CD(p≤0.05)	0.34	0.32	0.33	0.59	0.40	0.42	0.37	0.69	0.27	0.28	0.26	0.45	0.20	0.23	0.23	0.38

Figures in parenthesis are original values, data subjected to $\sqrt{x+1}$ transformation

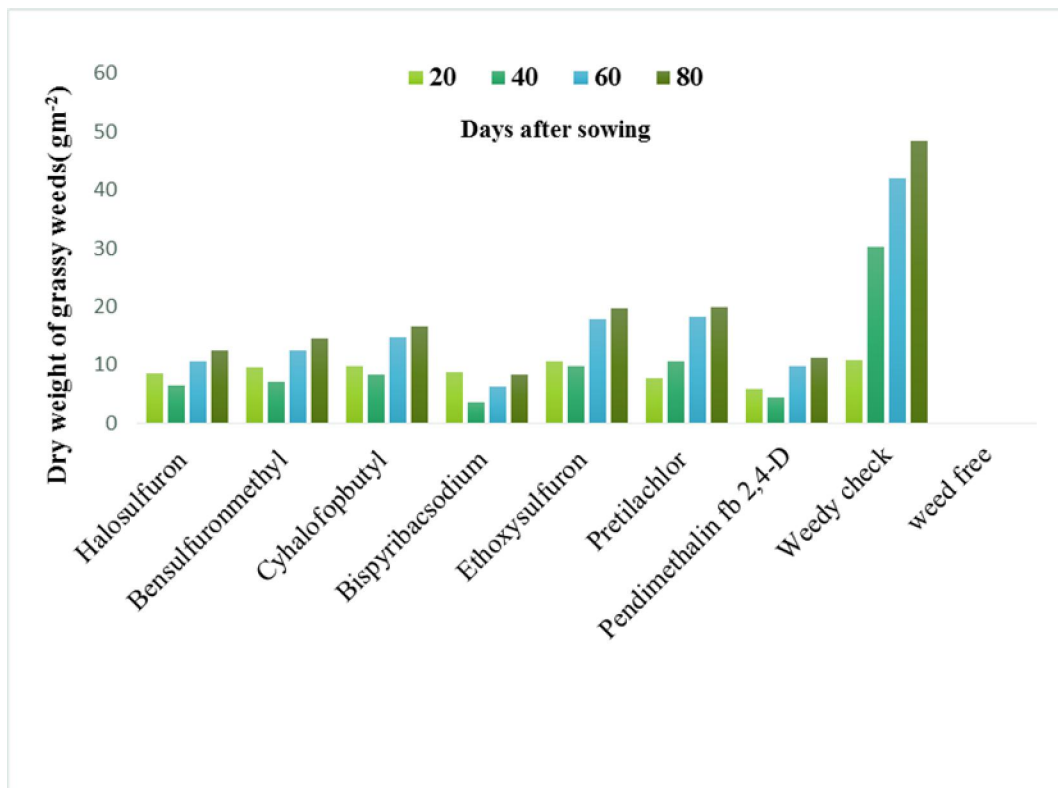


Fig.14: Dry weight (g m^{-2}) of grassy weeds as influenced by different weed control treatments.

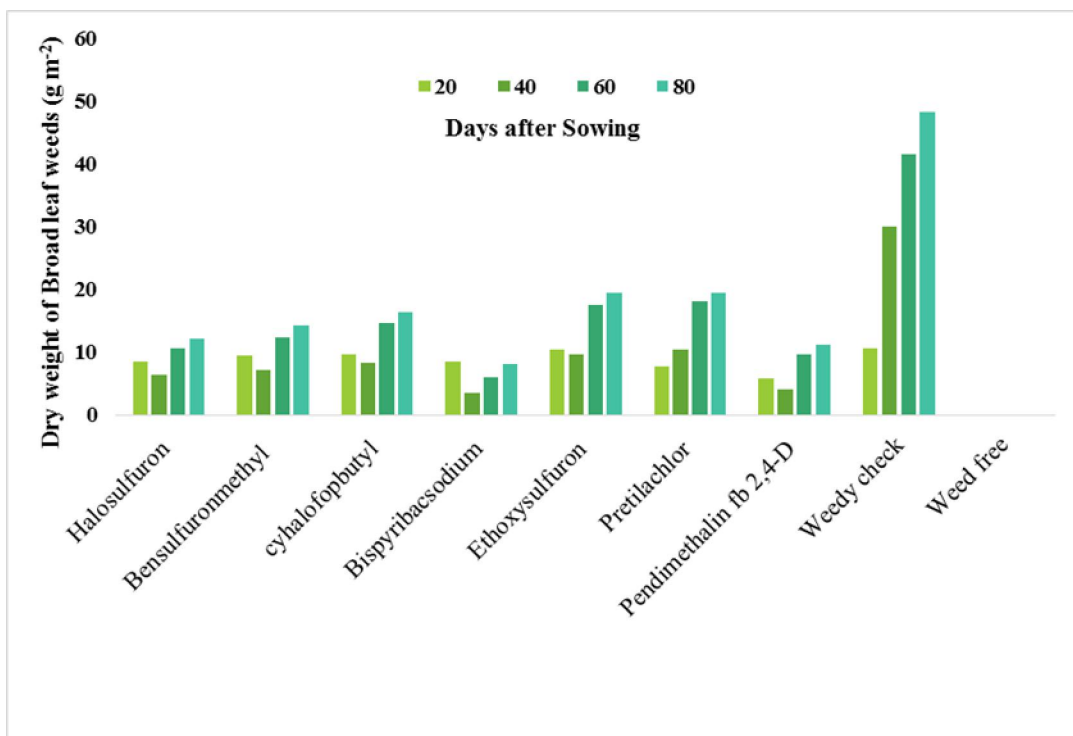


Fig.15: Dry weight (g m⁻²) of broad leaf weeds as influenced by different weed control treatments.

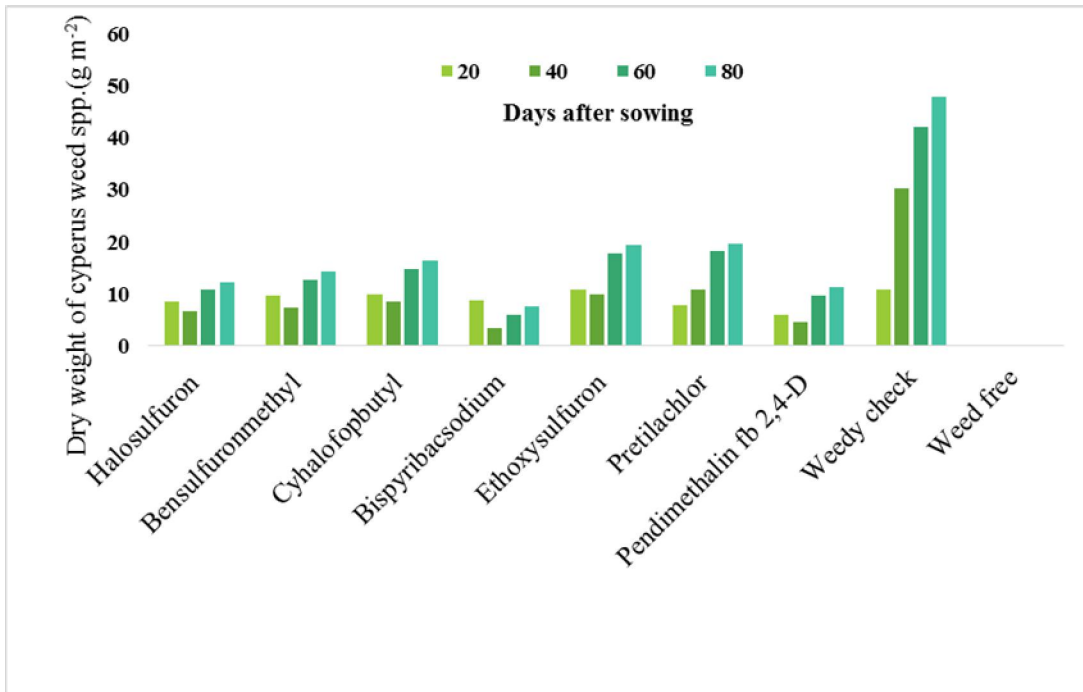


Fig. 16: Dry weight of cyperus weed spp. (g m⁻²) as influenced by different weed control treatments.

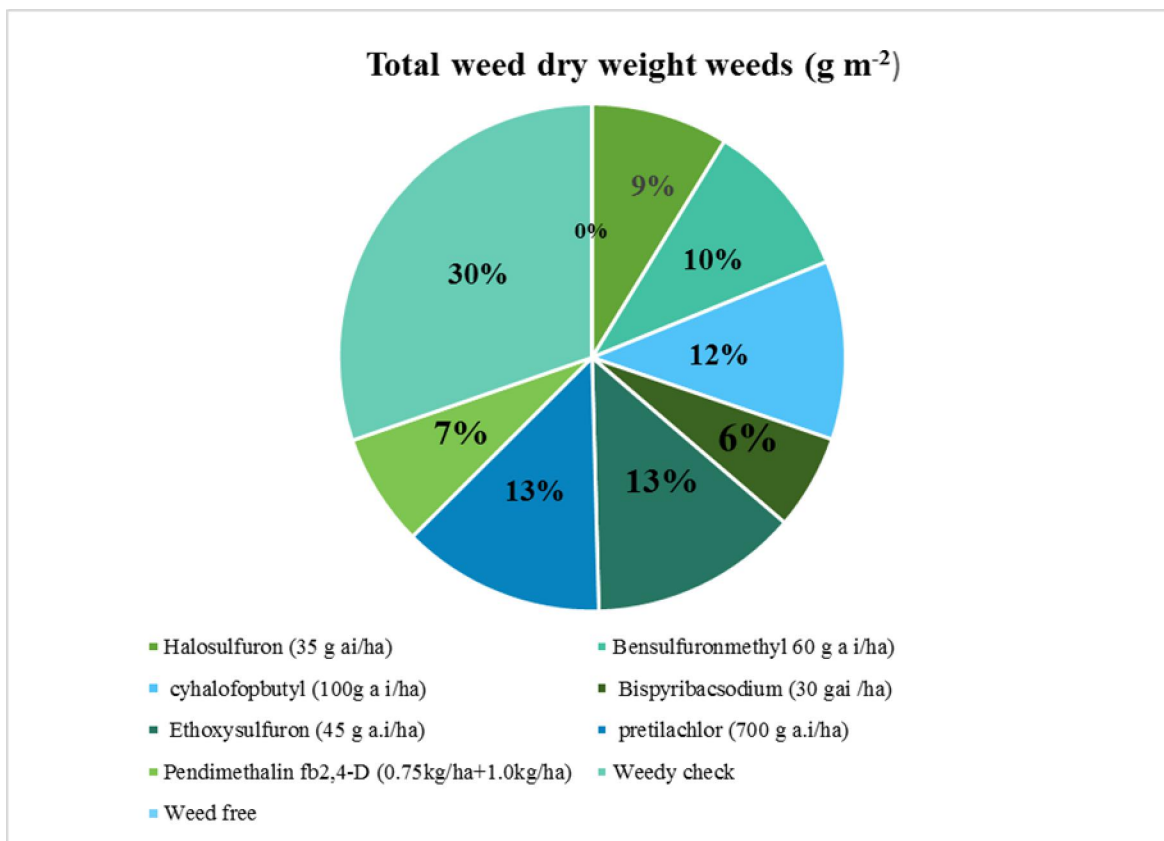


Fig. 17: Total dry weight of weeds (g m⁻²) as influenced by different weed control treatments.

4.3.4 Weed control efficiency (%)

The data regarding weed control efficiency presented in Table 4.9 and depicted in Fig. 15 revealed that weed control efficiency was significantly affected by different weed control treatments. Among the weed control treatments weed free (T₉) recorded significantly highest weed control efficiency at 60 DAS. Among the weed control treatments apart from weed free, application of bispyribacsodium @ 30 g a.i ha⁻¹ recorded highest weed control efficiency than other weed control treatments at 60 DAS. However, the lowest weed control efficiency was recorded in weedy check treatment. The rest of the weed management treatments with respect to weed control efficiency showed decreasing trend of T₇ > T₁ > T₂ > T₃ > T₅.

4.3.5 Weed index

The data pertaining to weed index presented in Table 4.10 and depicted in Fig. 16 Among the different weed control treatments apart from weed free (T₉) treatment application of bispyribacsodium @ 30 g a.i. ha⁻¹ recorded minimum weed index while as weedy check treatment recorded highest weed index than all other weed control treatments.

4.5 Relative economics

The economics was worked out taking into consideration, the cost of production for each treatment, the corresponding marketable yield with prevalent prices per unit output. The data on economics analysis of treatments presented in Table 4.11. The data revealed that across the different measures, weed free treatment recorded the highest gross returns (1329781ha⁻¹) and net monetary return (71913ha⁻¹) but lower B:C ratio of (1.17). Application of bispyribacsodium @ 30 g a.i ha⁻¹ provided the gross returns of (123901ha⁻¹), net monetary return of (74261ha⁻¹) and registered the highest B: C ratio (1.49).

Table 4.9: Effect of different herbicides on weed control efficiency (%) in direct seeded rice (DSR) at 60 DAS.

Treatments	60 DAS
Halosulfuron (35 g a.i ha ⁻¹)	8.68 (74.46)
Bensulfuronmethyl (60 g a.i ha ⁻¹)	8.42 (70.05)
Cyhalofopbutyl (100 g a.i ha ⁻¹)	8.10 (64.72)
Bispyribacsodium (30 g a.i ha ⁻¹)	9.29 (85.35)
Ethoxysulfuron (45 g a.i ha ⁻¹)	7.64 (57.50)
Pretilachlor (700 g a.i ha ⁻¹)	7.60 (56.80)
Pendimethalin <i>fb</i> 2,4-D (0.75 kg ha ⁻¹ +1.0 kg ha ⁻¹)	8.82 (76.85)
Weedy check	1.00 (0.00)
Weed free	10.05 (100.00)
SE(m)±	0.07
CD(p≤0.05)	0.21

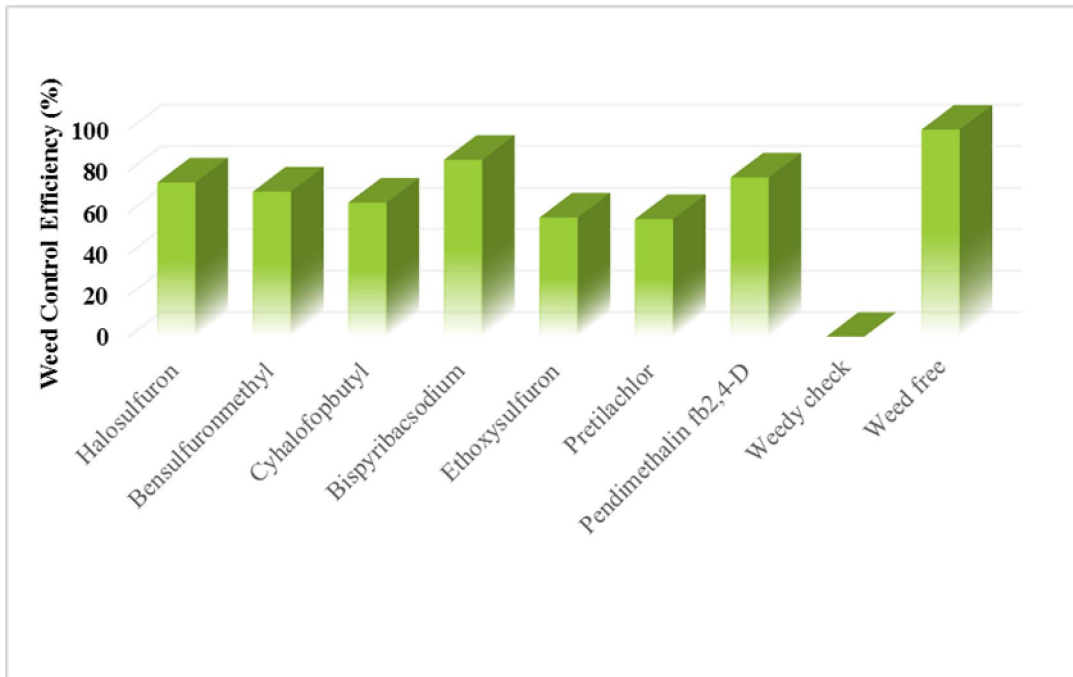


Fig.18: Weed control efficiency (%) as influenced by different weed control treatments. CD ($p \leq 0.05$) = 0.21

Table 4.10: Effect of different treatment control on weed index (%) in direct seeded rice (DSR).

Treatments	Weed index (%)
Halosulfuron (35 g a.i ha ⁻¹)	5.31 (27.30)
Bensulfuronmethyl (60 g a.i ha ⁻¹)	5.55 (29.86)
Cyhalofopbutyl (100 g a.i ha ⁻¹)	6.20 (37.5)
Bispyribacsodium (30 g a.i ha ⁻¹)	2.84 (7.36)
Ethoxysulfuron (45 g a.i ha ⁻¹)	6.34 (39.36)
Pretilachlor (700 g a.i ha ⁻¹)	6.60 (42.73)
Pendimethalin <i>fb</i> 2,4-D (0.75 kg ha ⁻¹ +1.0 kg ha ⁻¹)	4.43 (18.66)
Weedy check	7.81 (60.00)
Weed free	1.00 (0.00)
SE(m)±	0.17
CD(p≤0.05)	0.52

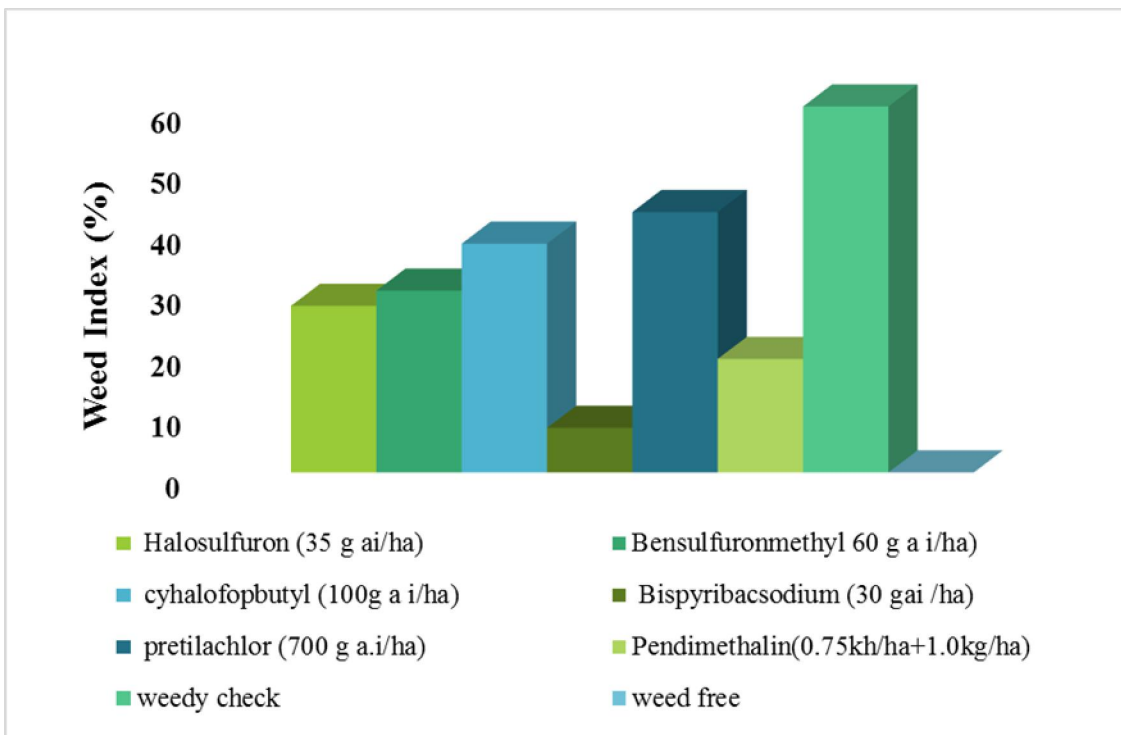


Fig.19: Weed index (%) as influenced by different weed control treatments.

CD ($p \leq 0.05$) = 0.52

Table 4.11: Effect of different Treatment control on Relative economics \square (ha^{-1}) in direct seeded rice (DSR) at different intervals after sowing.

Treatments	Total cost of cultivation (Rs.)	Gross returns from grain yield (Rs.)	Gross returns from straw yield (Rs.)	Total returns (Rs.)	Net returns (Rs.)	B:C ratio
Halosulfuron (35 g a.i ha^{-1})	48608	75660	25350	101010	52402	1.07
Bensulfuronmethyl (60 g a.i ha^{-1})	49475	72995	24789	97784	48309	0.97
Cyhalofopbutyl (100 g a.i ha^{-1})	49395	65000	24729	89729	40334	0.81
Bispyribacsodium (30 g a.i ha^{-1})	49640	96382	27519	123901	74261	1.49
Ethoxysulfuron (45 g a.i ha^{-1})	49365	63050	24300	87350	37985	0.76
Pretilachlor (700 g a.i ha^{-1})	47742	59540	24150	83690	35948	0.75
Pendimethalin fb 2,4-D (0.75 kg ha^{-1} +1.0 kg ha^{-1})	49190	84630	26100	110730	61540	1.25
Weedy check	45065	41626	20568	62194	17129	0.38
Weed free	61065	104130	28848	132978	71913	1.17

Labour @ Rs. 400/day; Seed @ Rs. 25/kg; Urea @ Rs. 5.50/kg; DAP @ Rs. 26.00/kg; MOP @ Rs. 19/kg; ZnSo4 @ Rs. 72/kg; Halosulfuron @ Rs 1943/kg; Bensulfuronmethyl @ Rs.2810/kg; Cyhalofopbutyl @ Rs. 2730/kg; Bispyribacsodium @ Rs 2975 /kg. Ethoxysulfuron @ Rs 2700/kg Pretilachlor @ Rs 1077/L Pendimethalin @ Rs 1620/L;.2,4-D @ Rs 905/L. Cost of Manual weeding (4 times), 1 labour/2 kanal @ Rs. 400/labour. Rice @ 1300/q; Straw @ Rs 27/bundle (9 kg).

Chapter-5

DISCUSSION

The experimental findings of the investigation entitled “studies on bioefficacy of different herbicides to control cyperus weed species in direct seeded rice (*Oryza sativa* L.)” have been described in chapter 4. In this chapter, an attempt has been made to justify the results critically based on the treatment effects. The relevant findings of earlier workers on the subject have also been taken in to consideration as research support the results of the present investigation.

5.1 Crop studies

5.1.1 Growth characteristics

5.1.1.1 Plant height

The results revealed that periodic plant height was significantly influenced by different weed control treatments. Among different chemical weed control treatments applied bispyribacsodium @ 30 g a.i ha⁻¹ increased the plant height during the course of investigation. This could be ascribed to better weed control by bispyribacsodium during the crop growth resulting in better nutrient uptake by the crop. These findings are in accordance with the Kumar and Rana (2013).

5.1.1.2 Leaf area index

Total leaf area per unit ground area known as LAI which increases according to the compound interest law, reaches its maximum value around heading of rice crop and thereafter decreases leading to shading of lower leaves (Murata and Matsushima, 1978). LAI being directly correlated to leaf area (Gomez, 1972) was found to increase up to 80 DAS along with the growth of the leaf and decreased subsequently due to withering and senescence of lower leaves. The data revealed that different weed control treatments apart from weed free treatment,

bispyribacsodium @ 30 g a.i ha⁻¹ significantly increased leaf area index of crop at various growth stages over other weed control treatments. This could be attributed to the fact that weeds cause shading to lower leaves causing their senescence and subsequent death. The reduction in weed growth with the herbicidal application might have allowed the crop to get adequate supply of light, water and nutrients resulting in higher leaf area index. These results are in line with Dangol *et al.* (2020).and Sangra *et al.* (2018).and Bhurer *et al.* (2012).

5.1.1.3 Dry matter accumulation

The amount of dry matter production depends on the photosynthetic efficacy of crop and compensate by other metabolic activities. The total dry matter yield produced minus the photosynthates used for respiration and finally, the manner in which dry matter produced is distributed among different parts of plant, determines magnitude of the economic yield (Arnon, 1972). Among different chemical weed control treatments, bispyribacsodium @ 30 g a.i ha⁻¹ significantly improved dry matter production of rice at different growth stages over other weed control methods. This might be due to better growth of rice plants on account of reduced competition due to weeds at the initial stages of crop growth leading to availability of nutrients and light, resulting in better accumulation of photosynthates. The reduction in weed growth with herbicide application allowed the crop to grow to its highest potential thereby increased dry matter and yield. Sangra *et al.* (2018). and Bhurer *et al.* (2012). reported similar results.

5.1.2 Yield attributing characters

The important yield contributing characters viz; number of panicles m⁻², number of filled grains panicle⁻¹ showed significant variation due to the effect of different weed control treatments. Out of various weed control treatments the application of bispyribacsodium @ 30 g a.i ha⁻¹, was attributed to a sizeable improvement in all of the yield related traits, like the number of panicles m⁻² grains per panicle and the 1000-grain weight. The improvement in the yield-related traits was positively

associated with reduced weed density and biomass because of efficient weed control, the results are in conformity with (Jabran *et al.*2012). As a result of the weed-free environment, the rice plants got a competition-free environment, with a larger availability of water, sufficient essential nutrients and solar radiation while a high level of weed infestation caused an ~75% yield reduction as a consequence of the reduction in the number of productive tillers, grains per panicle, 1000-grain weight and the increase in the number of unproductive tillers, related to severe competition with the weeds (Johnson *et al.* 2004; Razzaq *et al.* 2012).and Sharma *et al.* (2016).

5.1.3 Grain yield, straw yield, biological yield and harvest index

Grain yield being an economic component of the crop is the important crop parameter, which reflects the resultant impact of all crop growth parameters and yield attributes that are affected by various input treatments. The data revealed that different weed control treatments apart from weed free treatment, bispyribacsodium 30 g a.i ha⁻¹ significantly increased grain yield, straw yield and harvest index of rice over other weed control measures. This could be attributed to the fact that reduction in weed growth with the herbicide application allowed the crop to get adequate nutrient supply resulting in higher leaf-area index and thus more photosynthates, which in turn contributed to the sink resulting in higher grain and straw yield. Such findings are confirmed by the results of Dangol *et al.* (2020). Sharma *et al.* (2016). and Yadav *et al* (2009). Hand weeding has also been recorded as an efficient method of weed control to achieve the maximum yield of direct seeded rice.

5.2 Weed studies

5.2.1 Weed density and weed dry weight

All weed control treatments greatly decreased weed densities and weed dry weight relative to weed control. This is obvious due to reduction in weed population by different weed control treatments. Among weed control measures,

apart from weed free the maximum reduction of weed density and weed dry weight was observed as a result of the postemergence application postemergence application of bispyribacsodium @ 30 g a.i ha⁻¹. This may be due to the fact that herbicides not only exhibited significantly lesser toxicity to rice seedling but controlled the weeds very efficiently. This has established that bispyribacsodium @ 30 g a.i ha⁻¹ is an effective post-emergence herbicide against a wider weed flora and selectivity to rice crop as well. (Jabran *et al.*2012). Walia *et al.* (2008).and Ghosh *et al.* (2013). who reported that.bispyribacsodium @ 30 g a.i ha⁻¹ is a member of the Pyrimidiynyl carboxy chemical family with ALS (acetolactate synthase).

5.2.2 Weed control efficiency

Different weed control treatments improved the weed control efficiency greatly. Apart from weed free treatment which recorded 100 per cent weed control efficiency, Bispyribacsodium 30 g a.i ha⁻¹ proved significantly better measure for recording higher weed control efficiency in view of its efficiency in reducing the growth of weeds. This could be attributed due to reduction of weed biomass on account of effective weed control measures adopted and thus resulted in higher weed control efficiency. The results are in conformity with Singh *et al.* (2014). Dahiphale *et al.* (2015) and Ghosh *et al.* (2013).

5.2.3 Weed index

The study on weed index revealed that apart from weed free treatment bispyribacsodium 30 g a.i ha⁻¹ resulted in lower weed index. This may be due to lower weed densities that resulted in increased uptake of nutrients and thus increased grain yield the results are in conformity with kumar *et al.* (2013).

5.4 Relative Economics

The efficiency of different treatments are finally decided in terms of the economics (benefit:cost) of the treatments (Table 4.11). The present investigation

revealed that during the course of investigation across the different measures, weed free treatment recorded the highest gross returns (1329781ha^{-1}) and net monetary return (71913ha^{-1}) but lower B:C ratio of (1.17). This can be due to high cost incurred for repeated four manual weeding required to provide a weed free situation throughout the growing season compared to other weed control measure. application of bispyribacsodium @ 30 g a.i ha^{-1} provided the gross returns of (123901ha^{-1}), net monetary return of (74261ha^{-1}) and registered the highest B: C ratio (1.49) This is because application of bispyribacsodium @ 30 g a.i ha^{-1} sowing provided nearly a weed free situation at the critical growth stages of crop and enhanced the competitive ability of the rice crop. However, weedy check treatment recorded the lowest benefit cost ratio among all the weed management practices. Lower grain and straw yields of rice might have been responsible for the corresponding lower returns and lowest benefit cost ratio of weedy check treatment. These results are in close conformity with the results obtained by Mahajan *et al.* (2009). and Hussain *et al.* (2008). Subramaniam *et al.* (2006) .and Yadav *et al.* (2009).

Chapter-6

SUMMARY AND CONCLUSION

Field experiments were performed at the Crop Research Farm of the Agronomy Division, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences & Technology in Kashmir during Kharif 2019. The experiment was planned in a random block design with three replications and 27 plots. Nine different weed control treatments were assigned in different plots: {T₁- Halosulfuron @ 35g a.i ha⁻¹ (post-emergent), T₂-Bensulfuronmethyl @ 60 g a.i ha⁻¹ (post-emergent), T₃-cyhalophopbutyl @ 100 g a.i ha⁻¹ (post-emergent), T₄- Bispyribacsodium @ 30 g a.i ha⁻¹ (post-emergent), T₅-Ethoxysulfuron 45g a.i ha⁻¹ (post-emergent), T₆-Pretalachlor @ 700 g a.i ha⁻¹ (pre-emergent), T₇-Pendimethalin fb 2,4-D @ 0.75kg ha⁻¹+1.0kg ha⁻¹), T₈-Weedy check, T₉-Weed free.}. The plots were given a uniform prescribed dose of fertilizers. The soil of the experimental field was medium in available nitrogen, phosphorus and potassium and neutral in reaction. The main results of the study are summarized below:

6.1 Effect of different weed control treatments

- ❖ Beside weed free treatment application of bispyribacsodium @ 35g a.i. ha⁻¹ significantly increased plant height, dry matter production and leaf area index at different growth intervals.
- ❖ Apart from weed free treatment, application of bispyribacsodium @ 35g a.i. ha⁻¹ significantly improved yield contributing character viz. number of panicles m⁻², Filled grains panicle⁻¹ and 1000 grain weight.
- ❖ Grain yield, straw yield and biological yield as well as harvest index showed significant improvement with over application of bispyribacsodium @ 35 g a.i. ha⁻¹ other weed control treatments except weed free treatment.

- ❖ Herbi-
cidal treatment viz., application of bispyribacsodium @ 35g a.i. ha⁻¹ apart from weed free treatment, caused significant decrease in total weed dry weight and total weed density at various crop growth stages over other different weed control treatments, weed control efficiency also remained significantly higher with the said treatment.
- ❖ Apart
from weed free treatment application of bispyribacsodium @ 35g a.i. ha⁻¹ significantly reduced the density and dry weight of grasses, and broad leaf weeds and cyperus weed spp.
- ❖ Lower
weed index was recorded by application of bispyribacsodium @ 35g a.i. ha⁻¹.
- ❖ Apart
from weed free treatment application of bispyribacsodium @ 35g a.i. ha⁻¹ significantly reduced the density and dry weight of cyperus weed spp. weed control efficiency also remained significantly higher with the said treatment.

6.2 Relative economics

The study revealed that highest benefit cost ratio was realized with application of bispyribacsodium @ 35 g a.i. ha⁻¹.

Conclusion

From the present investigation it is concluded that among different weed control treatments apart from weed free treatment, bispyribacsodium @ 30g ha⁻¹ was found more efficient in controlling almost all types of weeds including cyperus weed spp. under direct seeded rice. Higher rice grain yield and economic returns were observed with application of bispyribacsodium @ 30 g ha⁻¹ as post emergent at 25 DAS.

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Appendix-I**Standard weekly meteorological data for 2019 of Wadura, SKUAST Kashmir**

Standard week	Temperature (° C)		Rainfall (mm)	Humidity (%)	
	Max.	Min.		Max.	Min.
18	23.17	5.34	27.00	83.86	50.86
19	23.86	7.84	20.80	83.29	56.29
20	23.07	8.87	38.50	87.29	63.29
21	23.10	8.44	31.10	84.43	65.43
22	27.61	9.96	18.80	75.71	55.29
23	24.81	9.90	22.40	86.14	56.00
24	26.06	9.57	42.50	82.57	52.14
25	27.21	10.99	5.60	81.86	56.57
26	28.56	10.89	13.50	84.29	50.43
27	31.20	15.64	1.70	76.43	53.43
28	31.04	16.14	9.60	82.86	66.29
29	31.74	15.86	17.50	82.57	61.29
30	28.66	17.84	49.00	85.43	71.29
31	30.93	17.24	1.30	83.14	65.14
32	33.34	17.90	23.40	80.00	54.43
33	31.17	17.04	13.90	84.71	56.71
34	29.74	12.93	0.00	83.29	54.57
35	30.74	14.96	0.00	84.00	55.57
36	33	15	0.00	82	44
37	32.14	9.54	0.00	77.29	62.00
38	31.64	9.40	0.00	81.29	43.29
39	28.59	12.90	8.60	83.86	53.43
40	21	8	10	89	65
41	27.13	4.51	0.00	89.29	42

Appendix-II

Analysis of variance of plant height as affected by different weed control treatments in DSR

Source of Variation	d.f	Mean Sum of Squares						
		20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	120 DAS	At maturity
Replications	2							
Treatments	8	0.56	8.30	61.03	172.11	139.15	137.78	140.80
Error	16	0.93	2.83	1.47	4.14	12.72	11.67	3.75

Appendix-III

Analysis of variance of leaf area index (LAI) of rice as affected by different weed control Treatments in DSR

Source of Variation	d.f	Mean Sum of Squares						
		20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	120 DAS	
Replications	2							
Treatments	8	0.01	0.49	1.16	0.56	0.52	0.41	
Error	16	0.01	0.11	0.31	0.13	0.00	0.01	

Appendix-IV

Analysis of variance of dry matter accumulation (qha⁻¹) of rice as affected by different weed control Treatments in DSR

Source of Variation	Mean Sum of Squares							
	d.f	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	120 DAS	At maturity
Replications	2							
Treatments	8	0.03	4.79	240.87	600.40	753.84	848.49	920.12
Error	16	0.02	0.39	4.12	9.88	7.15	9.27	13.98

Appendix-V

Analysis of variance of yield attributes of rice as affected by different weed control Treatments in DSR

Source of Variation	Mean Sum of Squares			
	d.f	Panicle density (No.m ⁻²)	Filled grains panicle ⁻¹	Test weight (g)
Replications	2			
Treatments	8	2192.54	228.83	6.92
Error	16	94.22	4.25	0.85

Appendix-VI

Analysis of variance of yield and harvest index of rice as affected by different weed control treatments in DSR

Source of Variation	Mean Sum of Squares				
	d.f	Grain yield (q ha ⁻¹)	Straw yield (q ha ⁻¹)	Biological yield (q ha ⁻¹)	H.I (%)
Replications	2				
Treatments	8	661.84	180.23	1411.55	70.56
Error	16	5.27	5.44	12.12	1.34

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir Division of
Agronomy, Faculty of Agriculture, Wadura
193201

CERTIFICATE

Certified that all the corrections/amendments as suggested by External Examiner Dr. Anchal Dass Principal Scientist, Division of Agronomy, IARI, New Delhi during viva-voce examination held on 22th of February, 2021 have been incorporated in the manuscript entitled “Studies on bioefficacy of herbicides to control Cyperus weed spp. In direct seeded rice (*oryza sativa* L.)” submitted by Ms. Rifat un Nisa (Regd. No. MSA-2018-1196).

(Dr.Tahir Ahmad Sheikh)
Chairman
Advisory Committee