EFFECT OF GREEN MANURING AND HERBICIDES ON WEED DYNAMICS AND YIELD OF DIRECT SEEDED RICE

By

Shubham Jamwal

(J-18-M-543)

Thesis submitted to Faculty of Postgraduate Studies
in partial fulfilment of the requirements
for the degree of

MASTER OF SCIENCE IN AGRICULTURE
AGRONOMY

Division of Agronomy
Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu
Main Campus, Chatha, Jammu 180009

2020

CERTIFICATE – I

This is to certify that the thesis entitled **"Effect of Green Manuring and Herbicides on Weed Dynamics and Yield of Direct Seeded Rice"** submitted in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture (Agronomy)** to the Faculty of Post-Graduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, is a record of bonafide research carried out by **Mr. Shubham Jamwal**, Registration Number **J-18-M-543** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma. It is further certified that such help and assistance received during the course of investigation have been duly acknowledged.

Dr. Ramphool Puniya
(Major Advisor)

Place: Jammu

Date: 15-09-2020

Endorsed:

Head

Division of Agronomy

Date: 15.09.2020

CERTIFICATE – II

We, the members of Advisory Committee of **Mr. Shubham Jamwal**, Registration Number **J-18-M-543,** a candidate for the degree of **Master of Science in Agriculture (Agronomy)** have gone through the manuscript of the thesis entitled **"Effect of Green Manuring and Herbicides on Weed Dynamics and Yield of Direct Seeded Rice"** and recommend that it may be submitted by the student in partial fulfillment of the requirements for the degree.

Dr. Ramphool Puniya
Junior Scientist (Agronomy)
AICRP-Weed Management
Major Advisor & Chairman Advisory Committee

Place: Jammu

Date: 15-09-2020

Advisory Committee Members:

1 **Dr. B.R. Bazaya**
Senior Scientist (Agronomy)
AICRP-Weed Management
(Member from Major Subject)

2 **Dr. Gurdev Chand**
Assistant Professor (Plant Physiology)
Division of Plant Physiology
(Member from Minor Subject)

3 **Dr. Brij Nandan**
Senior Scientist (Agronomy)
PRSS Samba
(Dean's Nominee)

CERTIFICATE - III

This is to certify that the thesis entitled "**Effect of Green Manuring and Herbicides on Weed Dynamics and Yield of Direct Seeded Rice**" submitted by **Mr. Shubham Jamwal**, Registration No. **J-18-M-543** to the Faculty of Post-Graduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture (Agronomy)** was examined and approved by the Advisory Committee and External Examiner(s) on 18.11.2020.

External Examiner 18.11.2020

Dr. Anil Kumar Sharma
Ex. Professor Division of Agronomy
SKUAST Jammu

Dr. Ramphool Puniya
Junior Scientist, (Agronomy)
AICRP-Weed Management
(Major Advisor)

Dr. B.C. Sharma 18.11.2020.
Head, Division of Agronomy

Director Education/ Dean, FOA 4/12/2020
SKUAST- Jammu.

ACKNOWLEDGEMENT

ACKNOWLEDGEMENT

"First of all, I bow my head with great reverence in the pious feet of Almighty God and Adorable my Goddess Mata Neresa Devi Ji for his eternal blessing for me to whom I owe my existence and well being.

With pleasure and sincerity, I take it to be my proud privilege, deep sense of gratitude and indebtedness to my major advisor, mentor, erudite and revered teacher, elite guide and path director, ***Dr. Ramphool Puniya****, Junior Scientist (Agronomy) AICRP-Weed Management, Division of Agronomy, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences & Technology – Jammu for his incessant motivation, valuable suggestions, amicable behavior, genial temperament, precious guidance, constant and constructive criticism, sustained encouragement and parental affection which assisted me to overcome every problem that came in my way during the period of this investigation and preparation of manuscript.*

I also wish to thank ***Dr. B.C. Sharma,*** *Head, Division of Agronomy for his valuable guidance, constant encouragement and facilitating the study and providing necessary facilities.*

I am sincerely obliged, indebted and have immense pleasure in expressing my heartiest gratitude to my co-advisors ***Dr. B.R. Bazaya,*** *Senior Scientist (Agronomy) AICRP-Weed Management,* ***Dr. Gurdev Chand,*** *Assistant Professor, Division of Plant Physiology and* ***Dr. Brij Nandan,*** *Senior Scientist (Agronomy) PRSS Samba, Dean's nominee for their expert technical guidance, sagacious advice, emphatic help, intellectual stimulation, supervision and critical amendments during the course of investigation and bringing out this manuscript and also thankful for providing the necessary field and laboratory facilities for carrying out the experiment.*

I would be remiss if I don't mention the name of the faculty members Dr. Anil Kumar, Dr. Rajeev Sangra, Dr. Anuradha Saha, Dr. Neetu Sharma, *Dr. Meenakshi Gupta, Dr. Rakesh Sharma and Dr. Manpreet Kaur for their support and motivation.*

I shall fail in my duty, if I don't thanks the non-teaching staff members, Mr. Om Prakash (FCLA), Sumit Gupta (FCLA), Dinesh Khajuria (Computer Assistant), Mr. Om Prakash (Mali), Rajesh, Sat Pal, Madan Lal, and Surinder Mohan of Division of Agronomy who were ever ready to help me. I shall always cherish the sweet memories of lovely company and sincere co-operation of loving friends Akhil Bharti, Aaina Sharma, Jyoti Sharma, Asif Ali, Rakshit and Kazem for their whole hearted support and constant inspiration during this investigation.

It is with my personal touch and emotions that I seize this opportunity to express my heartfelt and affectionate gratitude to my parents and family members who were always been in my heart and thought. I am gratefully indebted to my beloved godly parents ***Sh. Dilbag Singh, Smt. Urmila Devi****, who always been an ideal and touch bearer to me. The eternal blessings and love of my younger brother* ***Mr. Abhishek Jamwal*** *and my loving Bua* ***Mrs. Anchali Devi*** *who has always inspired me to achieve very best in life. Without their love, graceful sacrifice and constant inspiration this dream would not have materialized.*

Special thanks to all my lovely Friends; Suresh Kumar, Ranjeet Bochalya, Jitender Sharma, Rahul Sharma, Honey and Tanuj Bhardwaj whose everlasting blessings love and affection and untiring efforts brought me here up to ....

None is forgotten but everyone is not included.

Last but not least, I owe my gratitude to all those persons who helped me directly or indirectly during the course of investigation.

Date : 15-09-2020

Place : SKUAST-Jammu

SHUBHAM JAMWAL

(Shubham Jamwal)

ABSTRACT

Title of the Thesis	**:**	**Effect of Green Manuring and Herbicides on Weed Dynamics and Yield of Direct Seeded Rice**
Name of the student	**:**	**Shubham Jamwal**
Registration No.	**:**	**J-18-M-543**
Major Subject	**:**	**Agronomy**
Name and Designation of Major Advisor	**:**	**Dr. Ramphool Puniya, Junior Scientist (Agronomy) AICRP- Weed Management**
Degree	**:**	**M. Sc. (Ag)**
Name of University	**:**	**Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu**

ABSTRACT

An experiment entitled, **“Effect of Green Manuring and Herbicides on Weed Dynamics and Yield of Direct Seeded Rice”** was conducted at the Research Farm, Chatha of SKUAST-Jammu during the *Kharif* season of 2019. The soil of the experimental site was sandy clay loam in texture, slightly alkaline in reaction, low in organic carbon and available nitrogen but medium in phosphorus and potassium. The experiment was laid out in Factorial Randomized Block Design with two factors and three replications. The first factor consisted of three green manuring crops *viz*. Sunnhemp, Dhaincha and Cowpea and a stale seedbed treatment and another factor consisted of three herbicidal treatments *viz*. pendimethalin 1 kg/ha as PE, bispyribac-sodium 25 g/ha at 25 DAS and pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS and a weedy check treatment. After layout, green manuring crops were sown and incorporated into the soil at the age of 45 days. The rice crop variety Basmati-370 was sown on 16^{th} June, 2019. Full dose of potassium and half dose of nitrogen were applied through inorganic sources of nutrients *viz.* MOP and Urea. The remaining nitrogen was top dressed in two equal splits at mid tillering and at panicle initiation stages. The recommended phosphorus (20 kg P_2O_5/ha) for Basmati-370 was applied to green manuring crops. Irrigation was applied at regular intervals in rice as per need. The pre-emergence herbicide was applied on same day after sowing of the crop and the post-emergence herbicide was applied at 25 DAS of the crop.

The major weed flora observed in the rice field were, *Echinochloa spp. Dactloctenium aegyptium, Cucumis spp., Phyllanthus niruri, Cyperus rotundus, Cyperus iria.* The crop was also found infested with *Eclipta alba, Physalis mimima,* *Digitaria sanguinalis, Solanum nigrum* and *Cyanodon dactylon* but these were less in number and denoted as other weeds. A weed control efficiency ranging from 40-58% was observed in different green manuring treatments. The highest value of growth parameters, grain and straw yield were recorded under sunnhemp green manuring. Significantly higher nutrient uptake by rice crop was recorded with green manuring of sunnhemp which was statistically at par with dhaincha.

Among the herbicidal treatments, application of pendimethalin 1 kg/ha as pre-emergence *fb* bispyribac-sodium 25 g/ha at 25 DAS recorded significantly highest grain, straw yields and nutrient uptake by rice, besides highest weed control and significant reduction in density and dry biomass of weeds .The significantly highest nutrient uptake by weeds was recorded in weedy check followed by pendimethalin 1 kg/ha as pre-emergence. The highest net returns (Rs. 57773/ha) were recorded in green manuring of sunnhemp but highest B: C ratio (1.57) was found with green manuring of dhaincha. In herbicidal treatments, pendimethalin 1 kg/ha as pre-emergence *fb* bispyribac-sodium 25 g/ha at 25 DAS fetched higher net return (Rs. 78710) with highest B: C ratio (2.12) followed by bispyribac-sodium 25 g/ha at 25 DAS (Rs. 71050) with B: C ratio (2.01). On the basis of interaction, highest grain yield of rice was recorded with green manuring of sunnhemp with application of pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS which was statistically at par with green manuring of cowpea, dhaincha and stale seedbed in combination with pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS and green manuring of cowpea, dhaincha in combination with bispyribac-sodium 25 g/ha at 25 DAS. Henceforth, based on the one year of investigation it can be safely concluded that stale seedbed in combination of pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS recorded numerically highest benefit cost ratio followed by green manauring of dhaincha combination of bispyribac-sodium 25 g/ha at 25 DAS and these treatment combinations found suitable for weed management in direct seeded rice.

Key Words: Direct seeded rice, Green Manuring, Herbicide, Grain yield, Weed control

Signature of Major Advisor

SHUBHAM JAMWAL

Signature of the Student

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

CHAPTER-1

INTRODUCTION

CHAPTER-1

INTRODUCTION

Agriculture is the Keystone of Indian economy and about 54.6% of Indian population still depends on agriculture (Anonymous, 2018). Due to various Agro-climatic conditions, the successful cultivation of different types of crops could be possible. Various crops grow in different climatic conditions. Indian soils are mainly famous for production of cereals, pulses, oilseeds, beverages, spices etc. As the demand of food grains is increasing, therefore rice plays a main role as staple food crop. Rice is one of the most important staple food crops of more than half of the world's population. It plays a pivotal role in Indian economy. In India, rice ranks first among all the crops in terms of area and production. The area, production and productivity of rice in India are 43.79 mha, 112.91 mt and 2578 kg/ha, respectively (Anonymous, 2018a). The area, production and productivity of rice in Jammu and Kashmir are 283.44 thousand hectares, 572.54 thousand tonnes and 2020 kg/ha, respectively. The area, production and productivity of rice in Jammu region of the Jammu and Kashmir are 116 thousand hectares, 168.5 thousand tonnes and 1453 kg/ha, respectively (Anonymous, 2017).

Rice is normally grown by transplanting seedlings into puddled soil. Puddling benefits rice by reducing water percolation losses, controlling weeds, facilitating easy seedling establishment but requires more energy inputs in the form of tillage and involves huge quantities of water and labour. Also repeated puddling adversely affects soil physical properties by destroying soil aggregates, reducing permeability in subsurface layers and form hard-pan at shallow depth. All these can negatively affect the following non-rice crops in rotation (Tripathi *et al*., 2005). In general, rice consumes about 34-43% of the world's irrigation water (Bouman *et al*., 2007). Water is also becoming an increasingly scarce resource in India. Excessive pumping of water for puddling in peak summers has lead to extensive depletion of water table in various parts of the country. All these factors demand a shift from puddled-transplanted rice production system to direct seeding of rice (DSR) in irrigated areas. According to Pandey and Velasco (2005), low labour wages and adequate availability of water favour transplanting, whereas high labour wages and low water availability favour direct seeded rice (DSR).

Direct seeding of rice is done by directly sowing of seeds in non-puddled, non-flooded fields and is one of the most promising approach for saving water and labour. The DSR requires less water, labour and capital input. In addition, DSR matures 7-10 days earlier than transplanted rice, allowing timely sowing of the succeeding wheat crop (Singh *et al*., 2006). Other benefits of DSR include faster and easier planting, improvement of soil health, higher tolerance to water deficit, less methane emission and often higher profit in areas with an assured water supply. Despite several advantages, various production obstacles are also encountered in DSR in which heavy weed infestation is the major one (Chauhan, 2012). Direct seeded rice is subjected to more severe weed infestation and competition than transplanted rice, because in this system weeds germinate simultaneously with rice and there is no water layer to suppress weed growth. The weed infestation in DSR leads to 70 to 80% yield loss (Dass *et al*., 2016). Weeds in DSR system are mainly managed by using herbicides and manual weeding. Manual weeding, however, is becoming less popular due to labour scarcity and high labour wages. In the absence of manual weeding, farmers in irrigated areas mainly rely on herbicides to control weeds. In DSR systems, herbicide use is must and their use is likely to increase further with the rising labour scarcity. The pre-emergence herbicides are mainly used to control early flash of weeds in DSR. However, sometimes due to less soil moisture, it leads to poor control of weeds. Also pre-emergence herbicides in direct seeded rice impart only partial control and weeds like *Cyperus rotundus*, become highly competitive. Most of the soil applied rice herbicides require moist or even flooded condition for efficient actions against weeds which is not satisfied under DSR. In such situations post-emergence herbicides are needed for use in combination with pre-emergence herbicides to control weeds in DSR because a single herbicide cannot control all weeds of the community.

The sequential application of pre-emergence followed by (*fb*) post-emergence herbicides in alone or/and tank mixtures of herbicides are in use (Walia *et al*., 2012). This practice is likely to be expensive and creates heavy herbicidal load in crop/soil and thus results in adverse effect on environment and human health. Also only chemical approach of weed control may results shift in weed flora and resistance development. Therefore, adoption of eco-friendly weed management technology is essential to reduce weed population and to minimize adverse herbicidal effects on soil health or environment. Some cultural weed management approaches are the use of a stale seedbed technique, different tillage systems, weed-competitive cultivars, and cultivars capable of emerging under anaerobic conditions, crop residue for mulches, high seeding rates, narrow crop rows, optimum time, soil solarization and green manure crops. The growing of allelo-green manure crops and incorporation of their residue before sowing of main crop may be an eco-friendly weed management technology (Khaliq *et al*., 2011a).

Green manuring (GM) is the practice of enriching the soil by incorporation of their nutrient rich residue and also decreasing weed population by secreting allelo-chemical into soil after decomposition of residue on one side. On another side, weeds germinated with the green manure crops are also incorporated in soil with green manure crops which reduce the weed seed bank in soil (Khaliq *et al*., 2011a). Green manuring of crops like cowpea, sunflower, sunnhemp, dhaincha, sorghum, mungbean, mustard, alfa alfa, clover crops etc, have shown detrimental effect on weeds due to their allelepathic properties and thus reduce the use of herbicides in the rice crop (Khaliq *et al*., 2011a; Odhiambo *et al*., 2010; Ullah *et al*., 2018). The raising of green manure crop of *Sesbania aculeata* and ploughing it in-situ at the age of 45 days, before the cultivation of rice helped in reducing weed population in rice through allelopathic weed interference and reducing weed seed bank in soil (Gnanavel and Kathiresan, 2002). The pre-emergence or post-emergence application of herbicide may be skipped by using pre-rice green manure crops due to their allelopathic effects. Stale seedbed technique is preventive method of weed management. In stale seedbed technique, after pre-sowing irrigation, fields are left as such and weeds are allowed to germinate and there after weeds are destroyed through cultivation or with the use of non-selective herbicide application. This technique reduces the size of the weed seed bank in soil. Singh *et al*. (2009) reported that 53% lower weed density in DSR after stale seedbed than without this practice. In general a reduction of 59% in the density and by 78% in the fresh weight of *Echinochloa colonum* was recorded after using stale bed technique in the Philippines (Moody, 1982).

Pre-rice green manure coupled with herbicide application as pre- and/or post-emergence for weed management in direct seeded rice has not been evaluated in the irrigated sub tropics of Jammu and Kashmir and literature also meager in India. So the present study, entitled "**Effect of Green Manuring and Herbicides on Weed Dynamics and Yield of Direct Seeded Rice**" is proposed with the following objectives:

- To study the effect of green manuring and herbicides on growth and yield of direct seeded rice.
- To determine the effect of green manuring and herbicides on weed dynamics in direct seeded rice.
- To work out relative economics of different treatments

CHAPTER-2

REVIEW OF LITERATURE

CHAPTER-2

REVIEW OF LITERATURE

Rice is one of the leading food crops of the world and occupies significant position among the cultivated cereals. Rice in general, is cultivated by transplanting. However, in direct seeded rice (DSR) seed is sown directly in non-puddled soil which saves the resources of farmers but is also subjected to heavy weed infestation which makes farmers rely on herbicide application rather than manual weeding thereby increase the farmer's cost of cultivation. Further green manuring enrich the soil with nutrients thereby increase the soil fertility and decrease weed population. A very little information regarding green manuring and herbicides application is available. However, here an attempt has been made to collect and review the research work conducted so far in India and abroad and the available information relevant to the research investigation entitled **"Effect of Green Manuring and Herbicide on Weed Dynamics and Yield of Direct Seeded Rice"** has been reviewed and presented in this chapter under the different sub-headings.

2.1 Weed flora in direct seeded rice

2.2 Losses due to weeds in direct seeded rice

2.3 Effect of green manuring

2.3.1 Effects on growth, yield attributes and yields

2.3.2 Effects on weed density and biomass

2.4 Effect of stale seedbed on growth, yield attributes and yields of rice

2.5 Effect of stale seedbed on weed density and weed biomass

2.6 Effect of herbicides on growth, yield attributes and yield

2.6.1 Pendimethalin

2.6.2 Bispyribac-sodium

2.6.3 Pendimethalin *fb* bispyribac-sodium

2.1 WEED FLORA IN DIRECT SEEDED RICE

The degree of damage caused by weeds is related to the type, species and density of weeds growing in a crop community, as weeds vary from place to place and season to season. Direct seeded rice (DSR) is infested with a complex and diverse flora weed species *i.e.* grasses, sedges and broad leaved. Weeds community composition of an area depends largely on the crop establishment techniques, soil and water management, cultural practices, crop rotation, weed control measures, climatic and edaphic conditions of the location and inherent weed flora in the area. The DSR production system observes much higher pressure of weeds than puddled transplanted rice because of dry ploughing and alternate wetting and drying. In DSR grasses are more problematic, constituting of 60% followed by sedges 25% and broad-leaved weeds 15% at Kumargang, Faizabad, Uttar Pradesh (Singh and Tripathi, 2007). In the contrary, broad-leaved weeds and sedges constituted about 82% and grassy weeds account only 18.5% of total weed flora at Jabalpur, Madhya Pradesh (Dixit and Varshney, 2008). Similarly, at the same place Mishra and Singh (2008) reported that broad-leaved weeds account for about 55% followed by 32% grassy weeds and 10% sedges weeds for crop losses. Upasani and Barla (2014) reported that broad-leaved weeds and sedges were equally found in DSR fields but it dominated by grassy weeds in sandy soils at Ranchi.

Cynodon Dactylon, Chloris barbata, Dactyloctenium aegytium, Digiteria sangunalis, Echinochola colona, Elusine indica and *Panicum repens* among the grasses; *Alternanthra pungers, Cleome chelidori, Eclipta alba, Euphorbia hirta, Ludwigia parviflora, Parthenium hysterophorus, Phyllanthus niruri, Portulaca olerace* and *Tridax procumbens* among the broad-leaved weeds and *Cyperus rotundus* and *Cyperus iria* among the sedges were reported to be the major weed flora on direct seeded rice from different parts of the Indian conditions (Musthafa and Potty, 2001, Moorthy and Saha, 2002). At Raipur conditions, weed flora of experimental plots consisted of broad-leaved weeds like *Eclipta alba, Eclipta postrata, Traianthema portulaca oleracea, Commelina communis, Commelina benghalensis, Ludwigia parviflora, Parthenium hysterophorus, Physallis minima, Alternanthera sesillis* and *Ageratum conzoides*; grasses like *Cynodon dactylon, Dactyloctenium aegytium, Digiteria sangunalis, Echinochola colona, Elusine indica, Echinochola crusgali* and *Eragrotis tenella*, and sedges like *Cyperus rotundus, Cyperus iria, Fimbristylis miliacea* and *Fimbristylis dihotoma* were reported by Choudhary and Dixit (2018). Sanodiya and Singh (2018) found *Echinohcloa colona* (13.83%), *Echinochloa crusgali* (13.70%), *Cynadon dactylon* (10.16%) among grasses; *Cyperus iria* (10.59%), *Cyperus difformis* (10.25%) and *Fimbristylis milliacea* (10.90%) among sedges; and *Ammannia baccifera* (10.12%) and *Caesulia axillaris* (10.14%) among broad-leaved weeds beside other weeds (10.27%) in direct seeded rice. Walia *et al*. (2012) reported that the major weed flora of the experiment field were sedges (*Cyperus rotundus, Cyperus iria* and *Cyperus compressus*), grasses (*Digitaria sanguinalis, Echinochloa spp, Eleusine aegyptiacum, Leptochloa chinesis* and *Eragrostis spp*.) and broad-leaved (*Ammania baccifera* and *Caesulia axillaris*) in Punjab. The major weeds associated with dry-seeded rice were *Echinochloa crusgalli, Cyperus iria, C. difformis, Paspalum distichum, Eclipta prostrata* and *Trianthema portulacastrum* (Mann *et al*., 2007). Similarly Khaliq *et al*. (2011a) reported that *Trianthema portulacastrum, Echinochloa colona, Dactyloctenium aegyptium, Elusine indica, Echinochloa crusgalli, Spergula arvensis, Leptochloa chinensis, Cyperus rotundus* and *Cyperus iria* were the important weeds which are associated with direct seeded rice conditions. Further, Khaliq *et al*. (2013) reported that weed flora associated with direct seeded rice were *Trianthema portulacastrum, Alternathera philoxeroides* (broad-leaved), *Echinochloa colona, E.*

crusgalli, Dactyloctenium aegyptium, Leptochloa chinensis, Eleusine indica, Cynadon dactylon (grasses), *Cyperus rotundus* and *C. iria* (sedges). However, Akbar *et al*. (2011) reported that the most common weed flora in DSR were *Cyprus rotundus, Echinochloa colonum*, *Echinochloa crussgalli, Dactyloctenum aegyptium* and *Eclipta alba*. The major weeds infesting the experimental field (RARS, Parwanipur) at Nepal were *Cynodon dactylon*, *Cyperus rotundus*, *Cyperus iria*, *Echinochloa crusgalli*, *Echinochloa colona, Fimbristylis dichotoma*, *Phyllanthus nirui*, etc. (Bhurer *et al.,* 2013). Whereas, most important weeds in aerobic rice in Malaysia were *Eleusine indica, Digitaria ascendense, Echinochloa colonum* and *Cyperus iria* (Rahman *et al*., 2011).

The dominated weed species in direct seeded rice at different farmer's fields of Punjab were *C. iria, E. colon, Eragrostis spp., L. chinensis, D. sanguinallis, D. aegyptium, C. rotundus and E. indica* (Mahajan *et al*., 2013). In loamy soils of Pantnagar, weed flora consisted of *E. colona, E. indica* and *L. chinensis* among grasses; *C. argenita,* a broad leaved weed and *C. rotundus*, and *F. milliacea* among sedges. However, very low density of other weeds *viz. E. crusgalli, C. benghalensis, P. niruri* and *E. alba* were also found in DSR (Singh *et al*., 2014).

2.2 LOSSES DUE TO WEEDS

Weeds compete with crop plants for various resources such as space, light and nutrients. The yield loss by weeds depends on weeds species, relative difference in timing of weed and crop emergence, weed density and its growth and development, competition duration, crop competitiveness and crop management practices followed during cropping season (Yaduraju *et al*., 2005). In India, losses caused by weeds also differ with respect to cropping season (Bhan *et al*., 1999); with more losses in summer and rainy season (36.5%) as compare to winter season (22.7%). Johnson *et al*. (2004) reported that critical period for weed control in dry season was longer (4-83 DAS) as compared to wet season (29-32 DAS). In direct seeded rice, weeds are the major yield limiting factor. Azmi (1992) reported that grasses were main weeds in DSR and caused 41% reduction in grain yield whereas, losses due to broad-leaved weeds and sedges were 28 and 10%, respectively. Gharde *et al.,* (2018) reported that yield losses due to weeds are more in DSR than transplanted rice. In India, on farm research study conducted in 18 States reveals that the highest variation in potential yield losses due to weeds in DSR ranged between 15 to 66% under weedy conditions. Actual yield losses in DSR varied between 6 to 50% compared to 3 to 30% in case of transplanted rice. At similar densities, the losses vary due to different weed species, Smith (1988) found that 19 plants/m^2 of weedy rice caused yield reduction of 50% that was similar by 57 plants/m^2 of *Echinochloa crus-galli* and 148 plants/m^2 of *Leptochloa fascicularis*. In weedy conditions, yield losses in dry direct-seeded was 96% where as in wet DSR it was 61% (Maity and Mukherjee 2008). At 25, 40 and 215 weed density/m^2, yield losses were 48, 58 and 82%, respectively (Diarra *et al*., 1985; Pantone and Baker 1991; Eleftherohorinos *et al*., 2002). Shift from transplanted puddled rice to direct seeded rice results in change in composition of weeds which are related with alteration in crop management practices such as tillage, water and weed management. The shift was more radical in terms of kind of the species and diversity in DSR (Tomita *et al*., 2003). In some cases weeds caused complete crop failure (Dass *et al*., 2012). Weeds not only decrease the rice grain yields but also increase the cost of cultivation, decrease quality of grain, reduce input use efficiency (Singh *et al*., 2009). Furthermore, experimental findings indicated that under DSR weeds caused yield losses to the tune of 65-92% (Naresh *et al*., 2011), even under direct seeded upland rice, weeds sometime drastically reduced yield up to 100% (Choubey *et al*., 2001). Similar, reports of fall in grain yield to the tune of 99% and 98.64% observed by Gibson *et al*. (2003) and Bahar and Rashid (2013), respectively. In direct seeded rice, weeds reduced rice yield by 67-70% (Kumar *et al*., 2012). Whereas, Mishra and Singh (2008) reported that at Jabalpur infestation of weeds reduced the grain yield of dry-seeded rice by 60%. Similarly, Jabran *et al*. (2012) and Khaliq *et al*. (2013) from Pakistan also reported reduction in grain yield of direct seeded rice by 75.2 and 75.0%, respectively.

2.3 EFFECT OF GREEN MANURING

Green manuring of legume plants can be done before sowing or as inter/co-culture/mixed crop in rice (Singh *et al*., 2009). In addition to nitrogen fixation/adding organic matter into soil, some green manure crops also have bio-herbicidal and weed smothering properties (Lazzeri and Manici, 2000). Incorporation of green manure crops into soil results in production of allelo-chemicals that change micro-environment and hinder the germination, growth and development of the weeds (Buhler, 2002). Allelo-chemical is released into the environment through the root exudates, leaching, volatilization and after degradation either from living parts or dead parts (Weir *et al*., 2004). Sunnhemp is a fast-growing, 1 to 3 m tall, leguminous cover crop that generates a large quantity of biomass and a considerable amount of nitrogen (Akanvou *et al*., 2001; Mansoer *et al.*, 1997). Singh *et al*. (2007) suggested that inter/co-culture of green manure preference by farmers over the pre-rice green manure in rainfed areas because of additional cost for establishment and high evaporation demands during summer season in India. Co-culture of green manure in rice helps in suppression of weeds due to quick growing nature and biomass retained as mulch after knockdown. Timely application of herbicide to knock down the green manure is very important in co-culture, sometimes delayed due early onset of monsoon as it may provide competition to the crop also. Singh *et al*. (2007) reported that when green manure *Sesbania* was broadcast at 25 kg seed/ha with rice and burn down with application of 2, 4-D ester at 500 g/ha 30 DAS was equally effective in controlling weeds as wheat residue maintained at 4 t/ha. *Sesbania* intercropping results into reduction in total weed density by half and weed biomass by 37-80% as compared to no intercropping without compromising rice grain yield. In co-culture conditions 2, 4-D application on *Sesbania* was quite effective in controlling broad-leaved weeds and sedges but less effective for grasses. The grass weeds are difficult to control by post-emergence herbicide due to their vigor at 30 DAS therefore, application of pre-emergence herbicide is also suggested in case of co-culture (Kumar and Ladha, 2011). Sunnhemp showed allelopathic effects on *Amaranthus hybridus* under controlled condition (Collins *et al.,* 2007) and could be possible to reduce herbicide load on crop for controlling weeds (Mosjidis and Wehtje, 2011).

2.3.1 Effects on growth, yield attributes and yields

Dhima *et al*. (2009) reported that incorporation of anise, dill and oregano as green manure increased 10-43% maize grain yield compared to non-green manure plots under sandy loam soils at Thessaloniki in Northern Greece. Kumari *et al*. (2010) found that incorporation of field bean before sowing resulted in highest plant height (100.5 cm) and dry matter production (11283 kg/ha) when compared to other leguminous crops on sandy clay loam soil of Tirupathi. Odhiambo *et al*. (2010) found that incorporation of legume as green manure (cowpea, mucuna, lablab, sunnhemp and butterfly pea) in green manure-maize rotation significantly increased the grain yield of maize and significantly reduced total weed dry matter (5.30-21.03 g/m^2) as compared to fallow-maize rotation (49.5 g/m^2 weed dry matter) under clay soil conditions of Venda, Kenya. Among the legumes, highest weed suppression was noticed in cowpea incorporation and least with sunnhemp. Kumar *et al.* (2011) worked on in-situ green manuring in upland rice and revealed that 100% NPK + green manuring with sunnhemp (seed rate @ 40 kg/ha) + uprooting of sunnhemp at 35-40 DAS by manual weeding and kept in inter row space as mulch checked further weed growth and recorded 55.37% higher grain yield of rice as compared to 100% NPK alone under sandy clay loamy soil at Hawalbagh, Almora Uttrakhand. Pooniya and Shivay (2011) stated that *Sesbania aculeata* incorporation before rice sowing recorded more number of effective tillers/hill (12.7), highest panicle length (25.6 cm), more number of grains/panicle (67) and highest grain yield (3.64 t/ha) when compared to other green manure crops incorporation *i.e*. cowpea and mungbean at New Delhi. In contrary, Shah *et al.* (2011) reported that the greatest grain yield of rice was obtained with incorporation of cowpea which was followed by *Sesbania* and mungbean plots at Peshawar. Prathibhasree *et al.* (2016) reported that incorporation of green manure crop (Dhaincha) + $ZnSo_4$ @ 50 kg/ha recorded the highest plant height (103.6 and 103.5 cm) and highest dry matter production (11656 and 11387 kg/ha) of rice during the years of 2010 and 2011 on sandy clay loam soils of Bapatla. Naher and Paul (2017) observed the highest number of panicles/m^2 (245.7), test weight (20.9 g**),** grain yield (5.9 t/ha) and straw yield (7.4 t/ha) of rice with the treatment 70% NPKS + 4 t/ha green manure (Dhaincha) in an experiment conducted in clay loam soil of Dhaka, Bangladesh. Premalatha (2017) noticed the highest number of grains/panicle (120) and grain yield (3.3 t/ha) of rice were recorded with the incorporation of green manure in clayey soil of Dharwad. Cowpea has been shown to suppress weeds when used as a cover crop, intercrop, or organic mulch (Hutchinson and McGiffen, 2000; Ngouajio *et al.*, 2003; Unamma *et al*., 1986). Aqueous cowpea extracts were reported to reduce radical growth in crop and weed seeds (Hill *et al*., 2006). However, no putative allelo-chemicals have as yet been reported for cowpea

2.3.2 Effects on weed density and biomass

Green manure crops reduce weed emergence and reduces soil weed seed bank also (Kumar and Ladha, 2011). The green manuring is more effective on weed species present in top soil layers, light responsive and having low dormancy (Chauhan and Johnson, 2008). The cover crop incorporation in soil suppresses weed germination and establishment through production of allelo-chemicals in the soil (Buhler, 2002). A previously unknown, non protein amino acid isolated from the seeds of sunnhemp and other *Crotalaria* species (Pant and Fales, 1974) can be considered to be a candidate allelo-chemical in sunnhemp. It was identified as delta-hydroxynorleucine (5-hydroxy-2-aminohexanoic acid) (Pilbeam and Bell, 1979) and demonstrated to be phytotoxic to lettuce (Wilson and Bell, 1979). Moonen and Barberi (2004) observed that rye cover crop reduced weed seed bank by 25% and weed biomass by 22% in 7 years in corn crop. Fast growth rate of green manure crops change the micro-environment through release of phyto-toxins which influences weed germination and establishment (Putnam and De-Frank, 1983; Mangan *et al*., 1995). Cover crop of *Vicia villosa* reduced weed population by 70 to 78% and biomass by 52 to70% (Teasdale and Daughtry, 1993). The legumes cover crops produce allelopathic chemicals or cover the ground and reduce need for early-season herbicide use in agricultural crops (Mosjidis and Wehtje, 2011)**.** Onyango *et al*. (2000) reported that green manuring of legumes improve soil fertility and reduced *Striga* weed density as compared to the non-green manuring plots in South Nyanza, Kenya. Khaliq *et al.* (2011a) studied the allelopathic activity of different crop residue incorporations in rice and found that maximum inhibition of germination (34% inhibition) of *Echinocla colonum* was noticed with sorghum+sunflower+*Brassica* spp. residue incorporation @ 12 t/ha (in equal proportion) which was statistically at par with that achieved by incorporating only sunflower @ 12 t/ha (22% inhibition) and *Brassica* spp. @ 12 t/ha (21% inhibition) residues in soil at Faisalabad, Pakistan. Ullah *et al*. (2018) reported that sunflower residue incorporation @ 4 t/ha and 6 t/ha in spring planted mungbean caused 44-57% reduction in weed density (*Trianthema portulacastrum* and *Cyprus rotundus*) and 58-70% reduction in total weed dry weight compared with control under fine-silty soils of Faisalabad, Pakistan. For weed suppression, green manure crop need to produce at least 4.5 t/ha of biomass (Balkcom *et al.,* 2007). In case of sunnhemp the biomass ranges 1 to 9 t/ha (Mansoer *et al*., 1997; Schomberg *et al.*, 2007; Yadvinder *et al.*, 1992). Mosjidis and Wehtje (2011) received effective weed control with moderate to high levels of sunnhemp. Several weed species such as *Cyperus spp*., *Ipomea* spp., and *Cynodon dactyon* are capable of thriving under sunnhemp canopy (Collins *et al.*, 2007). Nahar *et al*. (2018) studied the effect of different crop residues and herbicides on weed control efficiency (WCE) in transplanted rice. The maximum WCE (75%) was found in application of pre-emergence butachlor followed by incorporation of chopped rice residue @ 5 t/ha (72% WCE) and chopped sorghum residue @ 5 t/ha (70% WCE) of 2-3 days before transplanting. They also found that incorporation of chopped soybean residue @ 5 t/ha and chopped mungbean residue @ 5 t/ha at 2-3 day before transplanting recorded 63% and 58% WCE, respectively at Joydebpur, Bangladesh. Yadav *et al*. (2011) reported reductions in weed infestations in no-till direct-seeded and machine-transplanted rice due to green cover crops of cowpea, mungbean and *Sesbania.*

2.4 EFFECT OF STALE SEEDBED ON GROWTH, YIELD ATTRIBUTES AND YIELDS OF RICE

Singh (2013) reported that significantly higher plant height, no. of tillers/m^2, RGR, CGR, LAI at 60 DAS with the treatment of dry seeding of rice after stale seedbed using glyphosate at 1 kg/ha than the dry seeded after stale bed using shallow tillage in sandy clay loam soil at Varanasi. Sindhu *et al*. (2010) found that stale seedbed for 14 days was superior to normal seedbed for 7 days with respect to grain yield and yield attributes at Thrissur, Kerala. The higher no. of panicles/m^2, no. of grain/panicle, 1000-grain weight and grain yield with dry seeded sowing of rice after stale seedbed using glyphosate but statistically at par with dry seeding after stale seedbed using shallow tillage at Jabalpur, Madhya Pradesh. Similarly, Kumar *et al*. (2013) found that stale seedbed with two irrigation + hand weeding recorded significantly higher grain yield than other stale seedbed treatments and no stale seedbed treatments.

2.5 EFFECT OF STALE SEEDBED ON WEED DENSITY AND WEED BIOMASS

Singh *et al*. (2007) found that a stale seedbed reduced the weed density in dry direct seeded rice by 50-53 % compared with the treatments in which this practice was not used. Chauhan (2012) reported that the weed species sensitive to the stale seedbed practice are those that are present in top soil layer, have low initial dormancy and require light to germinate such as *Leptochloa chinensis, Euphorbia prostrata, Digitaria ciliaris* and *Lythrum hyssopifolia*. Singh and Singh (2012) reported that stale seedbed using shallow tillage or glyphosate reduces density and dry matter of *Echinochloa colonum, Echinochloa crus-galli* and broad-leaved weeds and sedges of DSR in sandy loam soils at Varanasi, Uttar Pradesh. The effect of integrated weed management practices in DSR, using stale seedbed *fb* bisparibac-sodium 25 g/ha at 25 DAS recorded lower weed population than pendimethalin 1.0 kg/ha (pre-emergence) *fb* bispyribac-sodium 25 g/ha (post-emergence) at 20 DAS under loamy sand soils of Parwanipur Nepal (Bhurer *et al.*, 2013).

2.6 EFFECT OF HERBICIDES ON GROWTH, YIELD ATTRIBUTES AND YIELD

2.6.1 Pendimethalin

Jabran *et al*. (2012a) observed highest plant height with application of pendimethalin (825 g/ha), whereas, lowest plant height was recorded for the weedy check. Similarly, Walia *et al*. (2012) also observed highest plant height under sequential application of pendimethalin (PE) 750 g/ha *fb* metsulfuron (PoE) 15 g/ha. In another experiment, highest and statistically similar plant height was recorded with the herbicides penoxsulam (15 g/ha) and pendimethalin (825 g/ha), while lowest plant height observed under weedy check (Jabran *et al*. 2012b). Highest number of productive tillers (473/m^2) was recorded where crop was kept weed free for whole season. A combination of pendimethalin (1650 g/ha) PE and penoxsulam (15 g a.i./ha) at 15 DAS recorded second highest number (442/m^2) of productive tillers (Khaliq *et al*. 2011). Jabran *et al*. (2012) also noted higher and statistically similar productive tillers with the herbicides penoxsulam (15 g/ha) and pendimethalin (825 g/ha), while lowest was noted for the weedy check. Kumar *et al*. (2012) observed that in DSR significantly highest number of tillers obtained with application of pendimethalin 1.0 kg/ha (1 DAS) + anilophos 0.4 kg/ha (PE) followed by pendimethalin 1.5 kg/ha (PE) alone. Application of pendimethalin 1.0 kg/ha (PE) increase the grain yield up to 5.4 t/ha over weedy check

(0.09 t/ha) while highest grain yield was recorded from weed free plot (6.28 t/ha) (Bahar and Rashid 2013). Similarly, Rao *et al*. (2007) also reported highest grain yield with application of pendimethalin 1.0 kg/ha (PE) along with one hand weeding (30 DAS) due to lower weed infestation. Ganai *et al*. (2014) reported that application of pendimethalin 1.2 kg/ha at 5 DAS recorded higher growth characters viz. plant height, leaf area index, crop dry matter and higher grain yield of rice under silty clay loam soils of Khudwani, Kashmir.

2.6.2 Bispyribac-sodium

The application of bispyribac-sodium at 25 g/ha at 30 DAS recorded highest plant height which was statistically at par with pendimethalin at 750 g/ha *fb* bispyribac-sodium at 20 g/ha at 30 DAS at Kapurthala, Punjab (Walia *et al*., 2008). Suria *et al*., (2011) found that application of bispyribac-sodium at 30 g/ha at 10 DAS *fb* manual weeding at 30 DAS or bispyribac-sodium at 30 g/ha at 10 DAS *fb* bentazon/MCPA at 600/100 g/ha at 43 DAS resulted in significantly higher grain yield as compared to weedy check. Singh *et al*. (2014) revealed that the highest number of tillers/m^2 and grain yield obtained with weed free conditions, which was at par with the application of bispyribac-sodium 20 g/ha at 1-3 leaf stage of weeds.

2.6.3 Pendimethalin *fb* bispyribac-sodium

Narolia *et al.* (2014) reported that pre-emergence application of pendimethalin 1.0 kg/ha *fb* bispyribac-sodium at 35 g/ha recorded significantly higher plant height, number of tillers/m^2, plant dry matter accumulation and grain yield of rice at harvest over weedy check under vertisols of Rajasthan. Walia *et al*. (2008) reported that pre-emergence application of pendimethalin 750 g/ha *fb* bispyribac-sodium 25 g/ha at 30 DAS recorded significantly higher yield attributes and yield as this treatment provided effective control of associated weed flora and significant reduction in dry matter accumulation of weeds and significantly increased the number of effective tillers/m row length as compared to other treatments. Brar and Bullar (2012) found that application of pendimethalin 0.75 kg/ha (PE) *fb* bispyribac-sodium 30 g/ha at 25 DAS resulted in significantly higher grain yield as compared to hand hoeing at 20, 40 and 60 DAS. Awan *et al*. (2015) reported that application of pendimethalin 1.0 kg/ha at 2 DAS *fb* bispyribac-sodium 30 g/ha at 14 DAS recorded significantly higher yield attributes and yield than the weedy check at IRRI, Phillippines. Kaur and Singh (2015) reported that the yield levels were similar under different sequential application of pre-emergence herbicides pendimethalin or butachlor or thiobencarb or oxadiargyl followed by bispyribac-sodium application and these were also statistically at par with two hand weeding. Singh *et al*., (2016) reported that pre-emergence application of pendimethalin *fb* bispyribac-sodium + azimsulfuron as post-emergence recorded highest grain yield and lower weed biomass whereas, at other location yield levels of this treatment were similar to application of pendimethalin or oxadiargyl *fb* bispyribac-sodium and/or azimsulfuron as post-emergence herbicide. Sequential application of pendimethalin 750 g/ha followed by bispyribac-sodium at 25 g/ha at post-emergence gave effective weed control and higher grain yield which was statistically at par with weed free treatment in dry-seeded rice (Anonymous 2007) and produced significantly higher seed yield than pendimethalin alone (Walia *et al*., 2008).

2.7 EFFECT OF HERBICIDES ON WEED DENSITY AND WEED BIOMASS

2.7.1 Pendimethalin

Pendimethalin is a pre-emergence herbicide which kills germinating weed seeds. Pendimethalin was reported to have the best grassy weed control and economical for DSR (Singh *et al*., 2006). Jabran *et al.* (2012b) observed that pre-emergence application of pendimethalin 825 g/ha reduced 73% and 76% total weeds density and total weeds dry weight in DSR, respectively. Jabran *et al.* (2012b) again confirmed that pendimethalin resulted in 30.8%, 84.9%, 75.0%, 100.0%, 88.9% and 50.5% reductions in the densities of *Cyperus rotundus, Echinochloa crus-galli,Trianthema portulacastrum, Dactyloctenium aegyptium* and the total weeds, respectively over the weedy check in DSR. It lowered the total weed dry weight over the weedy check by 21.4%, 77.8%, 68.9%, 100.0%, 91.7% and 61.6% for *Cyperus rotundus, Echinochloa crusgalli, Trianthema portulacastrum, Dactyloctenium aegyptium* and the total weeds, respectively. The application of pendimethalin reduced the density of the sedges, narrow leaved and broad-leaved weeds by 30.8%, 84.6% and 89.3%, respectively and their dry weight by 21.4%, 73.4% and 88.7%, respectively over the weedy check.

Singh *et al.* (2013) reported that pre-emergence application of pendimethalin 1.0 kg/ha in DSR was more effective against *Echinochloa crusgalli, Ceasulea axillaris, Ammannia baccifera* and not effective against *Cyperus* spp. in sandy clay loamy soil of Varanasi, Uttar Pradesh. Pendimehalin has been found superior to control weeds, particularly against *Dactyloctenium aegyptium, Leptochloa chinensis* and *Eragrostis spp*., but it require extra precaution to avoid possibilities of its phyotoxicity (reduced germination), particularly under high soil moisture conditions when seeds are not properly covered with thin soil layer (Chauhan and Yadav 2013). Pre-emergence application of pendimethlain 1650 g/ha was quite effective in sinking weed count and biomass whether applied as a sole treatment or followed in sequence with post emergence herbicides like bispyribac-sodium 30 g/ha, penoxsulam 15 g a.i./ha (Khaliq *et al*., 2011). Experimental finding reveals that weed biomass was reduced by 75.96 and 78.2% with the pre-emergence application of pendimethalin 825 g/ha (Jabran *et al*., 2012) and 1.65 kg/ha (Akbar *et al*., 2011), respectively. Experiment conducted in Pakistan showed that application of penoxsulam 15 g/ha (early post-emergence) and pendimethalin 825 g/ha (PE) condensed total weed density by 79.88 and 73.1 %, respectively.

2.7.2 Bispyribac-sodium

Mahajan *et al.* (2009) reported that bispyribac-sodium 25 g/ha gave an excellent control of sedges and broad-leaved weeds over weedy check and caused a reduction in dry matter of weeds to the tune of 81.3%, 61.7%, 22.1% and 31.2% over the weedy check, pendimethalin + 1 hand weeding, pretilachlor + metsulfuron and penoxsulam, respectively. It gave highest grain yield and net returns in DSR. Jabran *et al.* (2012b) found that the post-emergence application of bispyribac-sodium 15 g/ha was the best herbicide in reducing the total weed density and dry weight followed by penoxsulam 15 g/ha. In an experiment bispyribac-sodium 25 g/ha was effective on grasses but does not provide effective control of *Leptochloa chinensis* and *Dactyloctenium aegyptium* in DSR (Chauhan and Abugho 2012). Singh *et al*. (2014) reported that the application of bispyribac-sodium 15 to 25 g/ha at 1-6 leaf stage significantly reduces the density of *Echinochloa colona*, *Celosia argenita*, *Cyperus rotundus* and *Fimbristylis miliacea* than weedy check but it was ineffective in reducing the density of *Leptochloa chinensis* in DSR under loamy soils of Pantnagar condition.

Mahajan and Chauhan (2015) reported that among the grassy weeds, bispyribac-sodium 25 g/ha were found to be effective against *Echinochloa spp*. but poor control of *Leptochloa chinensis* and *Dactyloctenium aegyptium, Digitaria sanguinalis* were noticed in DSR under sandy loam soil of Punjab. Khaliq *et al*. (2013) observed sole application of bispyribac-sodium 30 g/ha as post-emergence (PoE) reduced weed density by 68%. However, supplementing bispyribac-sodium with manual weeding recorded 86% reduction in weed density in direct seeded rice. Jabran *et al*. (2012a) reported that of bispyribac-sodium 25 g/ha as PoE was the most effective herbicide in reducing dry weight of weeds. Similarly, Khaliq *et al*. (2012a) reported that under DSR application of bispyribac-sodium 30 g/ha (PoE) and penoxsulam 15 g/ha as early post-emergence (15 DAS) resulted in reduction in weed biomass by 80 and 61%, respectively. Similarly, experiment conducted in DSR indicates that application of bisypribac-sodium 30 g/ha (PoE) reduced weed biomass by 79-80% (Khaliq *et al*., 2012a, Khaliq *et al*., 2013).

2.7.3 Pendimethalin *fb* bispyribac-sodium

Mahajan and Chauhan (2015) reported that application of pendimethalin 750 g/ha at 3 DAS *fb* bispyribac-sodium 25 g/ha at 20 DAS effectively controlled *Cyperus spp., Dactyloctenium aegyptium, Digitaria sanguinalis, Echinochloa colona, Leptochloa chinensis, Eleusine indica, Digera arvensis, Ludwigia octovalvis, Euphorbia spp.* etc. in DSR than their alone application under sandy loam soils of Ludhiana, Punjab. Anonymous (2007) reported that post-emergence application of bispyribac-sodium 25 g/ha at 20 days after sowing (DAS) in combination with pre-emergence pendimethalin 0.75 kg/ha gave effective weed control in DSR and resulted in grain yield at par with hand weeded plots.

Mahajan *et al*. (2009) observed that sequential spray of pre-emergence pendimethalin 1.0 kg/ha *fb* bispyribac-sodium 30 g/ha at 15 DAS was found best for the control of weeds in DSR. Khaliq *et al*. (2011b) revealed that pendimethalin 1.0 kg/ha *fb* post-emergence application of bispyribac-sodium 25 g/ha gave more than 80% reduction in weed density and weed dry weight and concluded that sequential application of herbicides was better than alone herbicide application in dry-DSR. Walia *et al*. (2012) recorded lowest weed dry matter (80 kg/ha) from the pre-emergence application of pendimethalin 0.75 kg/ha followed by post-emergence application of bispyribac-sodium 30 g/ha. Singh *et al*. (2016b) reported that pre-emergence application of pendimethalin *fb* bispyribac-sodium + azimsulfuron post-emergence treatment recorded highest grain yield and lower weed biomass whereas at other location yield levels of this treatment were similar to application of pendimethalin or oxadiargyl as pre *fb* bispyribac-sodium and/or azimsulfuron as post-emergence herbicide. Application of pendimethalin at 750 g followed by bispyribac-sodium at 25 g/ha as post-emergence gave effective weed control and higher grain yield which was statistically at par with weed free treatment in dry-seeded rice (Anonymous 2007) and produced significantly higher seed yield than pendimethalin alone (Walia *et al*., 2008). Ghosh *et al*. (2016) reported that sequential application of pendimethalin or clomazone with bispyribac-sodium and tank mix of clomazone + bispyribac-sodium (500+25 g/ha) as early post-emergence at 10 DAS provided effective control of diverse flora in direct seeded rice.

2.8 EFFECT OF GREEN MANURING AND HERBICIDES ON WEED CONTROL EFFICIENCY

Moonen and Barberi (2004) observed that rye cover crop reduced weed biomass by 22% in 7 years in corn crop. Cover crop of *Vicia villosa* reduced weed population by 70 to 78% and biomass by 52 to70% (Teasdale and Daughtry, 1993). Ullah *et al*. (2018) reported that sunflower residue incorporation @ 4 t/ha and 6 t/ha in spring planted mungbean caused 44-57% reduction in weed density (*Trianthema portulacastrum* and *Cyprus rotundus*) and 58-70% reduction in total weed dry weight compared with control under fine-silty soils of Faisalabad, Pakistan. Nahar *et al*. (2018) studied the effect of different crop residues and herbicides on weed control efficiency (WCE) in transplanted rice. The highest WCE (75%) was found in application of pre-emergence butachlor followed by incorporation of chopped rice residue @ 5 t/ha (72% WCE) and chopped sorghum residue @ 5 t/ha (70% WCE) 2-3 days before transplanting. They also found that incorporation of chopped soybean residue @ 5 t/ha and chopped mungbean residue

@ 5 t/ha at 2-3 day before transplanting recorded 63% and 58% WCE, respectively at Joydebpur, Bangladesh.

In direct seeded rice, sole application of pendimethalin 1.0 kg/ha (PE) recorded WCE of 73.85% (Singh and Singh 2010). Uppermost weed control efficiency 86.2% was recorded with pendimethalin 0.75 kg/ha (PE) *fb* bispyribac-sodium 30 g/ha (PoE) (Walia *et al*. 2012). Similarly, Walia *et al*. (2008) also reported that combination of pendimethalin 0.75 kg/ha (PE) *fb* bispyribac-sodium 25 g/ha or azimsulfuron 20 g/ha or 2, 4-D 500 g/ha (30 DAS) resulted in effective weed control (79.04%). Ganie *et al*. (2013) reported that best weed control efficiency (81.9%) with application of pendimethalin 1.0 kg/ha (PE) *fb* bispyribac-sodiun 25 g/ha + ready-mix chlorimuron + metsulfuron 4 g/ha at 30 DAS *fb* one hand weeding at 60 DAS in direct seeded rice compare to other treatments.

2.9 EFFECT OF GREEN MANURING AND HERBICIDES ON NUTRIENT UPTAKE BY RICE CROP

Weeds also compete with the crop plants for various growth factors *viz.* water, nutrients, sunlight and thereby reduce crop yields and consequently the nutrient use efficiency. Weeds usually grow faster than the crop plants and soak up all nutrients more rapidly and in larger quantities than by the main crops (De-Datta and Baltazar, 1996) and thus divest the supply of all the nutrients in time to the crop plants. Nutrient removal from the soil varies greatly from site to site, depending on the nature and quantum of weed infestation. High amount of nutrients removal by weeds is mainly attributed to increment in its density and dry biomass. Weeds, on an average, remove 30-40 kg N, 10-15 kg P_2O_5 and 20-40 kg K_2O per hectare (Dass *et al*., 2012). Soil nutrients reduction by weed infestation is more under DSR due to more weed density and dry biomass accumulation and may be up to 88.6 kg N, 24.2 kg P and 61.7 kg K per ha under weedy condition (Gopinath *et al*., 2012). Weeds removed nutrients (N, P and K) eight times higher under DSR compared to that of PTR (puddled transplanted rice) (Singh *et al*., 2002). Weed competition hampers nutrient uptake by rice as nutrient depletion by weeds and nutrient uptake by crop are inversely related. Nath *et al*. (2014) showed that weeds under season-long weedy situation removed 41.63 kg N, 5.71 kg P and 19.13 kg K/ha, whereas rice plant was able to uptake only 24.25 kg N, 8.08 kg P and 20.53 kg K per ha. Weed infestation also reduces the response of crop to N application. Thus, direct seeded rice is highly susceptible to weeds compared with other rice ecosystem.

2.10 EFFECT OF GREEN MANURING AND HERBICIDES ON ECONOMICS

Prathibhasree *et al.* (2016) reported that incorporation of green manure crop (Dhaincha) + $ZnSo_4$ 50 kg/ha recorded the highest net return and B: C ratio than the other treatments in rice under sandy clay loam soils of Bapatla. Premalatha (2017) noticed the highest net return of rice with the incorporation of green manure in clayey soil of Dharwad. Bhurer *et al*. (2013) reported that the net returns per investment resulted highest in pendimethalin followed by 2, 4-D followed by one hand weeding. Singh *et al*. (2014) found that different weed control methods involved different amounts of cost which affect the total cost of cultivation, net returns and B: C ratio. Hussain *et al.* (2008) revealed that the highest net benefits of Rs. 78725 was observed in the plots treated with bispyribac-sodium followed by ethoxysulfuron with the corresponding value of Rs. 73900 and hand weeding to the tune of Rs. 73575 respectively, in direct seeded rice. Rawat *et al.* (2012) reported that the highest B: C ratio under bispyribac-sodium 20 g/ha. Bhurer *et al.* (2013) found that stale seedbed *fb* bispyribac-sodium and stale seed bed *fb* pendimethalin *fb* bispyribac-sodium was better than weed free and pendimethalin *fb* bispyribac-sodium in respect to B: C ratio. Narolia *et al*. (2014) reported that pre-emergence application of pendimethalin 1.0 kg/ha *fb* bispyribac-sodium 35 g/ha at 15-20 DAS recorded higher net returns and B: C ratio than the alone application of pendimethalin @ 1.0 kg/ha (PE) or bispyribac-sodium 35 g/ha at 15-20 DAS at Kota, Rajasthan.

.

CHAPTER-3

MATERIALS AND METHODS

CHAPTER-3

MATERIALS AND METHODS

The present investigation entitled "**Effect of Green Manuring and Herbicides on Weed Dynamics and Yield of Direct Seeded Rice**" was conducted at the Research Farm of Division of Agronomy, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu during the *Kharif* 2019. The details of the material used, experimental procedures followed and techniques adopted during the course of investigation have been presented in this chapter.

3.1 EXPERIMENTAL SITE AND LOCATION

The field experiment was conducted during the *Kharif* season of 2019 at the Research Farm of Division of Agronomy, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, main campus, Chatha. Chatha is situated at 32^0-40′ N latitude and 74^0-58′ E longitude with an altitude of 332 m above mean sea level in the Shiwalik Foothills of North-Western Himalayas.

3.2 CLIMATE

The meteorological data with respect to rainfall, temperature and relative humidity acquired from the meteorological observatory located near to the experimental site at Research Farm, Chatha of SKUAST-Jammu, reveals that experimental site, in general is bestowed with hot and dry summers followed by hot and humid monsoon season. The mean annual rainfall of the experimental site is 1154 mm of which 70-75% rainfall is received from June to September, whereas remaining 25-30% of rains are received in few showers during winter as a result of Western disturbances from January to March.

The meteorological data recorded for different weather parameters for the entire crop growing period of the experimental crop taken during *Kharif* 2019 as well as their respective normal's worked out on the basis of their long term data have been presented graphically in Figure 1 and numerically cited in Appendix-I. The crop growing period of rice variety Basmati-370 lied between 24th- 45th standard meteorological weeks (SMW) of experimental year 2019 in the *Kharif* season. A perusal of the rainfall data recorded for the crop growing period showed that a total of 770.3 mm of rainfall was received during the crop growing period and the range of rainfall was between 131.1 mm to 0 mm. The highest weekly rainfall of 131.1 mm was received in the 33rd SMW. The rice crop grown during *Kharif* 2019, recorded a highest maximum mean weekly temperature of 41.7 ^{0}C in the 26th SMW and lowest minimum temperature of 13 ^{0}C in the 45th SMW falling in the month of July and November, respectively. The weekly mean maximum (morning) and minimum (evening) relative humidity's ranged from 93 to 51% and 76 to 21%, respectively. The highest maximum relative humidity of 93% was observed in the 39th SMW and lowest minimum relative humidity of 21 % in the 26th SMW falling in the month of July and September, respectively. The average maximum and minimum relative humidity's recorded during the crop growing season were 81.14% and 56.14%, respectively.

3.3 SOIL CHARACTERISTICS

Before the start of experiment, three soil samples were collected from surface (0-15 cm) layer. The soil samples collected were mixed together to form a composite sample, this composite soil sample so obtained was air dried, ground and passed through 2 mm sieve and was analyzed for different physico-chemical properties of the soil. Likewise, the treatment wise soil sampling was also done after harvesting the crop. The data recorded with respect to initial physico-chemical properties of the experimental site reveals that the soil was sandy clay loam, slightly alkaline, low in organic carbon, low in available nitrogen and medium in phosphorous and potassium (Table 1).

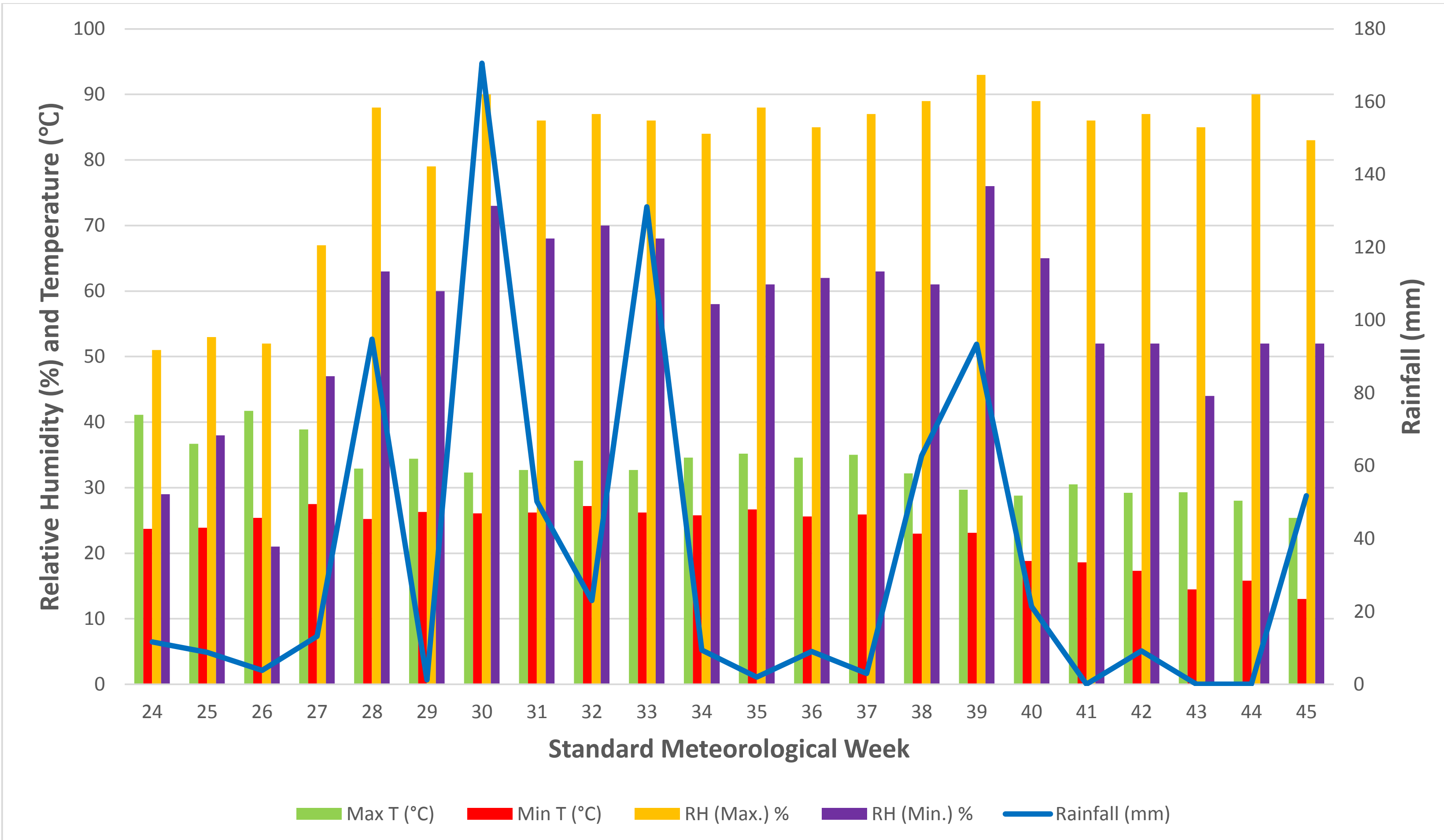


Fig. 1. Weather parameters recorded during crop growing season (*kharif* 2019)

Table 1: Initial soil physico-chemical properties of experimental site (0-15 cm)

S. No.	Parameters	Value	Method employed
A.	**Mechanical properties**		
	Sand (%)	61.46	Bouyoucous Hydrometer method (Piper, 1966)
	Silt (%)	12.10	
	Clay (%)	26.44	
	Textural class	Sandy clay loam	Textural Diagram (Black, 1965)
B.	**Chemical properties**		
	pH	7.89	1:2.5 Soil: water suspension Beckman Glass Electrode pH meter (Jackson, 1973)
	EC (dS/m) at 25° C	0.23	1:2.5 Soil water suspension With glass calomel electrode (Jackson, 1973)
	Organic carbon (g/kg)	4.60	Dichromate oxidation of organic matter (Walkley and Black, 1934)
	Available nitrogen (kg/ha)	236.50	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
	Available phosphorus (kg/ha)	13.63	Sodium bicarbonate method (Olsen *et al*., 1954)
	Available potassium (kg/ha)	143.3	Ammonium acetate extraction method, using flame photometer (Jackson, 1973)

3.4 CROPPING HISTORY OF THE EXPERIMENTAL FIELD

The details of the crops and the cropping systems followed on the experimental field for the last Four years prior to start of the experiment have been given in Table 2.

Table 2: Cropping history of the experimental site

Year	***Kharif***	***Rabi***
2015-16	Rice	Wheat
2016-17	Rice	Wheat
2017-18	Rice	Gobhi- Sarson
2018-19	Rice	Gobhi- Sarson
2019	Experimental Crop (Direct Seeded Rice)	

3.5 EXPERIMENTAL DETAILS

The experiment was laid out in Factorial randomized block design with two factors *i.e*, green manuring and herbicides (Table: 3) with three replications. Recommended doses of fertilizers were applied on green manure crops and rice crop.

(A) TREATMENT DETAILS :-

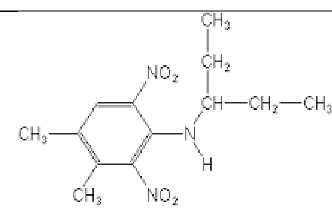
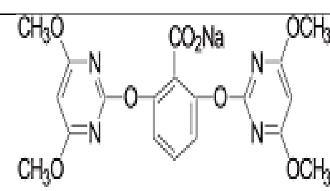
Main Crop	**:**	Rice
Variety	**:**	Basmati-370
Row spacing	**:**	20 cm
Plot size	**:**	Gross plot size 5.0 m x 4.0 m = 20.00 m^2
		Net plot size 4.2 m x 2.8 m = 11.76 m^2

Table 3: Treatment details of the experiment

A.	**In- situ green manure crops ***
1.	Cowpea
2.	Dhaincha
3.	Sunnhemp
4.	Stale seedbed
B.	**Herbicides**
1.	Pendimethalin 1 kg/ha as pre emergence
2.	Bispyribac-sodium 25 g/ha at 25 days after sowing
3.	Pendimethalin 1 kg/ha as pre emergence *fb* bispyribac-sodium 25 g/ha at 25 days after sowing
4.	Weedy check

***In-situ green manuring at 45 DAS**

Table 4: Particulars of herbicides used in the experiment

Common name & group of herbicides and chemical formula	Dose (g ai/ha)	Trade name	Mode of action	Chemical structure
Pendimethalin (Dinitroanilines) $C_{13}H_{19}N_3O_4C_{13}$	1000	Stomp	Microtubule assembly inhibitor	
Bisyribac-sodium, (Pyrimidinylbenzoate) $C_{19}H_{17}N_4NaO_8$	25	Nomi nee Gold	ALS inhibitor	

3.6 DETAILS OF FIELD CULTURAL OPERATIONS

The details of various cultural operations carried out during the crop growing period have been given in Table: 5

Table 5: Calendar of different cultural operation carried out during experimentation

Operation	**Date of Operation**	**Remarks**
Field preparation	26-04-2019	Primary tillage was done with disc harrow while the secondary tillage were done with the help of rotavator
Layout	27-04-2019	Demarcation of plots, channels and bunds were done manually with the help of rope and liner
Sowing of green manure crops	27-04-2019	Sowing of green manure crops i.e, cowpea dhaincha and sunnhemp in line sowing was done manually
Irrigation (in green manure crops and stale seedbed	28-04-2019 03-05-2019	Applied two irrigations to the different plot by the help of sprinkler
Fertilizer application	27-04-2019	Application of full dose of phosphorus was done manually
Incorporation of green manuring crops and stale seedbed	10-06-2019	Incorporation of different green manure crops and stale seedbed was done manually
Pre-sowing irrigation	11-06-2019	Applied irrigation by flooding the entire field to facilitate field preparation

Field preparation and reshaping of layout	15-06-2019	Field preparation and reshaping of layout was done manually
Sowing of rice	16-06-2019	Line sowing was done manually
Fertilizer application	16-06-2019	Application of full dose of potassium and half dose of nitrogen manually
Herbicide application	17-06-2019	Application of pre-emergence herbicide pendimethalin
	11-07-2019	Application of post-emergence herbicide bispyribac-sodium
Irrigation	21-06-2019 28-06-2019 12-07-2019 25-07-2019 10-08-2019 22-08-2019 15-09-2019 27-09-2019 09-10-2019	Irrigation was given to maintain moist condition in soil
First top dressing	26-07-2019	First top dressing of urea was done manually
Second top dressing	28-08-2019	Second top dressing of urea was also done manually
Harvesting of crop	04-11-2019	Harvesting was done manually
Threshing of crop	10-11-2019	Threshing was also done manually

3.6.1 Field Preparation

Initially the field was prepared by giving two runs with tractor drawn disc harrow. Thereafter, final ploughing was done with the help of rotavator to break the clods and bring the soil to the desired tilth. The layout Fig.2 was done as per the requirement of the experimental design and finally the plots were prepared manually**.**

3.6.2 Sowing of green manure crops

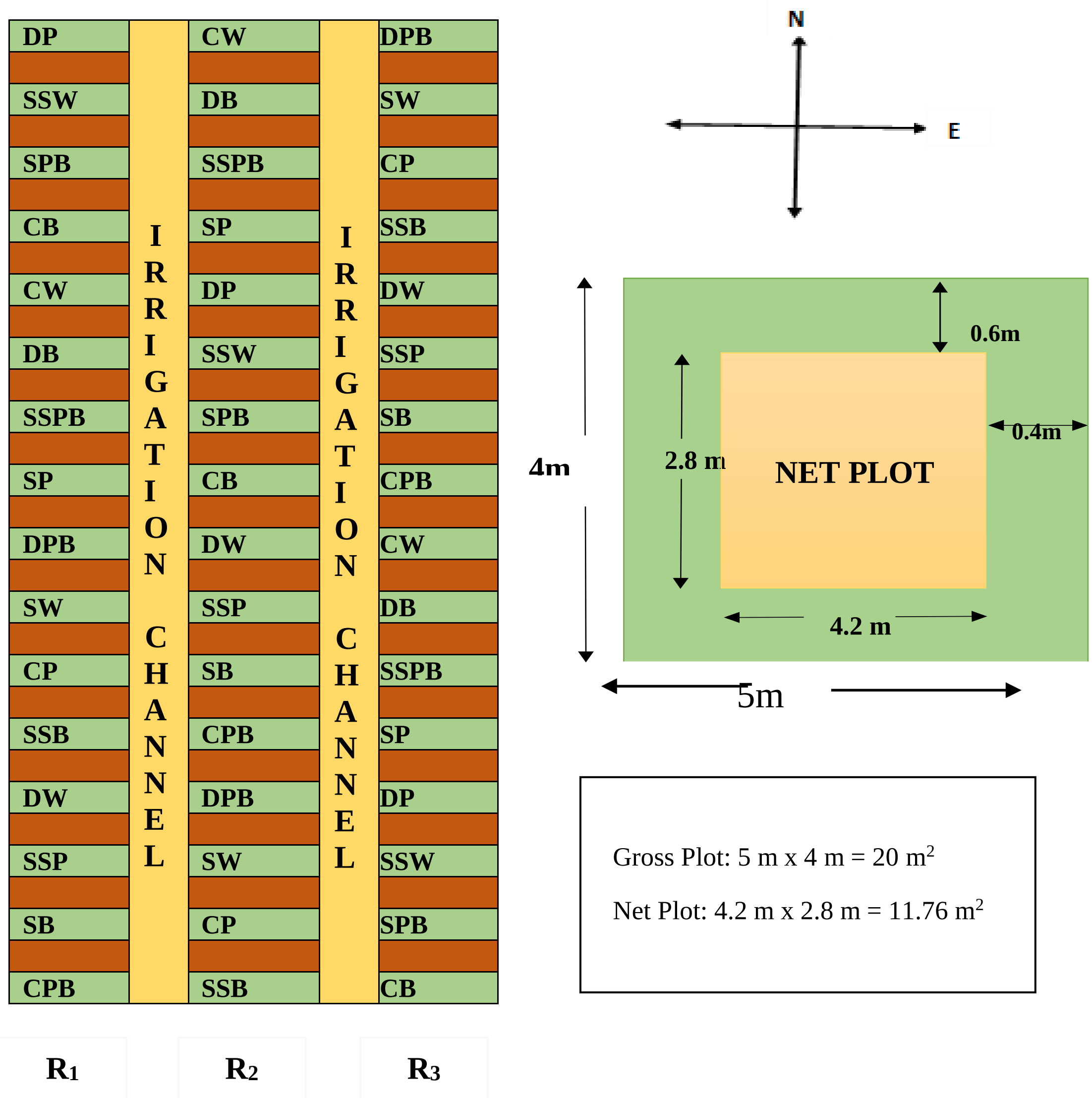
Sowing of green manure crops viz, cowpea @ 40 kg/ha, dhaincha @ 60 kg/ha and sunnhemp @ 50 kg/ha was one in lines uniformly in moist soil as per green manure treatment plots. Green manure crop was incorporated into soil by manually twice with the help of spade on 10 June, 2019 at an age of 45 days. After incorporation, pre-sowing irrigation was applied to the field. The experimental plots were prepared for sowing with help of spade under sufficient moisture conditions.

3.6.3 Stale seedbed

After layout and randomization the stale seedbed plots were irrigated and left for emergence of weeds. The flush of weeds was destroyed by shallow tillage with the help of spade on 10 June, 2019. After weeds incorporation by shallow tillage, pre-sowing irrigation was applied to these plots also. The experimental plots were prepared for sowing with help of spade under sufficient moisture conditions.

3.6.4 Fertilizer Application

The recommended dose of phosphorus (20 kg P_2O_5) for Basmati-370 was applied to the green manuring crops in the form of Diammonium Phosphate (50 kg/ha) as basal. The recommended dose of N and K for Basmati-370 is 30 kg N/ha and 10 kg K_2O/ha and full dose of K_2O was applied in the form of Murate of Potash as basal dose. The nitrogen in the form of urea was applied in three splits with half as basal at the time of sowing, one forth at mid tillering stage and remaining one forth at just before the panicle initiation.



Green Manuring
Sunnhemp (S)
Dhainvha (D)
Cowpea (C)
Stale seedbed (SS)

Herbicides
Pendimethalin 1 kg/ha as pre-emergence (P)
Bispyribac-sodium 25 g/ha at 25 DAS (B)
Pendimethalin 1 kg/ha as pre-emergence *fb* bispyribac-sodium 25 g/ha at 25 DAS (PB)
Weedy check (W)

Fig 2: Layout of the field experiment

3.6.5 Sowing

Furrows were opened manually with the help of liner at a specified row to row distance of 20 cm. The seeds were sown in furrows by *Kera* method and then the seeds were covered with soil. A seed rate of 40 kg/ha was used for rice crop.

3.6.6 Water Management

A pre-sowing irrigation was given on 11th of June prior to sowing of crops. Beside the rainfall, field was kept under moist conditions by applying irrigation as and when hair line cracks developed throughout the crop growth period. However, total nine irrigations were applied on the basis of hair line cracks.

3.7 HARVESTING AND THRESHING

3.7.1 Harvesting of crop

The crop was harvested manually with serrated edge sickles at physiological maturity; three rows from either side of the plots (two border row + 1 sample row) and 40 cm from the proximal and distal ends of the rows of individual plots were harvested separately to eliminate the border effects. The crop plants after cutting from the ground level were allowed for sun drying for 5-6 days. After drying, the harvested produce of net plot was tied separately into bundles, labeled and the bundle weight was recorded with the help of spring balance. The representative sample of straw was taken for moisture determination.

3.7.2 Threshing of crop

The sun dried produce of the each plot was threshed manually by beating the bundles on stone tiles. The grains of rice were separated and cleaned with the help of hand fan “Supa”. The weight of grain was recorded on pan balance and the grain yield per plot was noted at 14% moisture.

3.8 OBSERVATIONS RECORDED

3.8.1 Growth studies

For all the growth and development studies under taken during the crop growth period, five plants were selected randomly and tagged in each plot except for the parameters like dry matter accumulation. The one meter row length was selected randomly from sample rows for dry matter. The growth parameters were recorded at 30, 60, 90 days interval after sowing and at harvest.

3.8.1.1 Plant height (cm)

Five rice plants selected from each plot were tagged. The height of rice plant was measured with the help of meter scale from the base of the plant to the tip of the last fully opened leaf at 30, 60 and 90 days after sowing. Plant height at harvest was measured from the ground level to the uppermost portion of the panicle and mean values were presented in centimeters (cm). Average of all the five plants was taken for statistical analysis.

3.8.1.2 Dry matter accumulation

Plant samples for dry matter accumulation were taken from the 1 m row length from third row of each side at different growth stages *i.e.* at 30, 60, 90 DAS and at harvest. The plants were clipped close to soil surface from each plot. The samples were sundried and thereafter shifted in the oven to dry at a temperature of 65±5°C till a constant weight was achieved and dry weight was recorded on pan balance in laboratory. The final dry matter accumulation was recorded and expressed as dry weight in g/m^2.

3.8.1.3 Number of tillers

Tillers of one meter row length from sampling row were counted and converted into per square meter at 30, 60, 90 days after sowing and at harvest. The mean values were then worked out for each treatment and are presented as number of tillers/m^2.

3.8.1.4 Crop growth rate (g/m²/day)

The increase in plant material per unit time or crop growth rate (CGR) was calculated as per the formula given by Radford (1967) and was expressed as gram per day:

$$\text{CGR (g/m}^2\text{/day)} = \frac{(W_2 - W_1)}{(t_2 - t_1)}$$

Where, W_1= total dry matter of crop plant at the time interval t_1

W_2= total dry matter of crop plant at the time interval t_2

3.9 YIELD AND YIELD ATTRIBUTES

3.9.1 Number of tillers/m²

At harvest, panicle bearing tillers of one square meter area of net plot were counted and expressed as effective tillers/m^2.

3.9.2 Number of grains/ per panicle

From sample rows of each plot ten panicle were selected at random and their grains were counted and averaged to arrive at the number of grains per panicle.

3.9.3 1000-grain weight (g)

From the bulk produce of each net plot, a sizeable sample of grains was taken randomly and from it 1000 grains were counted and weighed. The 1000 grain weight was recorded in gram.

3.9.4 Grain yield (kg/ha)

From the individual plot, net plot was harvested; sun dried for 5-6 days and was subsequently threshed and cleaned. The grain thus obtained, were weighed and expressed in kilogram/hectare (kg/ha).

3.9.5 Straw yield (kg/ha)

The straw yield per net plot was recorded by subtracting the total grain weight from the total biomass from the respective treatment and the straw yield obtained was expressed in kg/ha.

3.9.6 Biological yield (kg/ha)

The total biological yield (grain + straw) from the net plot was recorded and expressed in kg/ha.

3.9.7 Harvest index (%)

Harvest index was calculated by dividing the economic yield to the biological yield as per the formula given by Nichiporovich (1967):

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

3.10 OBSERVATIONS ON WEEDS

3.10.1 Weed density (No./m^2)

The determination of weed density in rice was done by the standard quadrant method given by Mishra and Mishra (1997). Weed population was recorded from quadrant (1 × 1 m) selected at random in each plot at two places at 30, 60, 90 DAS and at harvest and were expressed on per square meter basis (no./m^2). The data thus obtained were subject to square root transformation ($\sqrt{x+1.0}$) as wide variations existed among the treatments before statistical analysis.

3.10.2 Weed biomass (g/m^2)

Weeds collected from 1 m^2 area in rice were first sun dried for 2-3 days and then were oven dried at 65±5°C temperature till the constant weight was recorded at 30, 60, 90, DAS and at harvest. The weed dry biomass was expressed in gram per square meter (g/m^2). The data thus obtained were subject to square root transformation ($\sqrt{x+1.0}$) as wide variations existed among the treatments before statistical analysis.

3.10.3 Weed control efficiency (%)

The weed control efficiency (WCE) was calculated by using the following formula given by Mishra and Mishra (1997) and expressed in per cent as:

$$WCE = \frac{Wd_c - Wd_t}{Wd_c} \times 100$$

Where, Wd_c = Weed dry weight in control plot (weedy check)

Wd_t = Weed dry weight in treated plot (treatment)

3.11 CHEMICAL ANALYSIS OF PLANT AND WEED SAMPLES

The plant samples (grain straw and weeds) taken at the time of harvesting were used for estimation of N, P and K content. The samples were oven dried at 65±1°C till constant weight, then finely ground with electric grinder and mixed well before being proceeded for chemical analysis for nitrogen, phosphorus and potassium concentration. N, P, K uptake by grain straw and weed samples were calculated by multiplying per cent nutrient content with their respective dry matter accumulation as per the formula given below:

$$\text{Nutrient uptake (kg/ha)} = \frac{\text{Nutrient content (\%)} \times \text{dry matter accumulation (kg/ha)}}{100}$$

Table 6: Details of method employed for chemical analysis of plant samples

S. No.	Nutrient assessed	Method employed
1.	Nitrogen	Modified Kjeldhal's method (Jackson, 1973)
2.	Phosphorus	Vanadomolybdo phosphoric acid yellow colour (Jackson, 1973)
3.	Potassium	Ammonium acetate method (Jackson, 1973)

3.12 SOIL STUDIES

3.12.1 Nutrient status of soil

After harvesting of rice crop, individual soil samples from all the plots were taken from the surface for determination of pH, EC, OC, available nitrogen, phosphorus and potassium. The samples were dried under shade, grounded and passed through 2 mm sieve and were analyzed.

3.12.1.1 Available nitrogen

Available nitrogen was determined by modified alkaline permanganate method as described by Subbiah and Asija (1956) and was expressed in N kg/ha.

3.12.1.2 Available phosphorus

Available phosphorus was determined using method described by Olsen *et al*. (1954). The intensity of colour developed by stannous chloride was measured at 660 nm on spectrophotometer and was expressed as P_2O_5 kg/ha.

3.12.1.3 Available potassium

Available K was extracted with neutral normal ammonium acetate solution as described by Jackson (1973) and potassium was determined by flame photometer and expressed as K_2O kg/ha.

3.13 ECONOMIC STUDIES

3.13.1 Gross returns

Gross returns (Rs./ha) were worked out by multiplying the saleable products (wheat grain and straw) by their prevailing respective sale rates and then presented on per hectare basis as per treatments.

3.13.2 Net returns

Net returns (Rs./ha) were computed by deducting the total cost of cultivation from the gross returns as per treatments.

Net returns = Gross returns – Cost of cultivation

3.13.3 Benefit Cost Ratio

Benefit Cost (B: C) ratio was calculated by dividing net returns with the cost of cultivation for each treatment using formula.

$$\text{Benefit: Cost Ratio} = \frac{\text{Net Returns (Rs./ha)}}{\text{Cost of cultivation (Rs./ha)}}$$

3.14 STATISTICAL ANALYSIS

The data presented in the thesis are the mean values. All the observations are statistically analyzed by using the analysis of variance. The results were tested for the treatments mean by applying F- test of significance on the basis of null hypothesis (Cochran and Cox, 1957). Wherever necessary, standard errors along with critical difference at 5% of significance were computed for discriminating the treatment effects for chance effects (Panse and Sukhamate, 1967). The key for degrees of freedom used in analysis of variance (ANOVA) is given in below:

Table 7: Analysis of variance (ANOVA)

Sources of variation	**Degree of freedom**
Replications	(r-1), 3-1 = 2
Factor A	(a-1), 4-1 = 3
Factor B	(b-1), 4-1 = 3
A × B	(a-1) (b-1), (4-1) (4-1) =9
Error	(r-1) (ab-1), (3-1) (4×4-1) = 30
Total	**(rab-1), (3×4×4-1) = 47**

CHAPTER-4

EXPERIMENTAL RESULTS

CHAPTER-4

EXPERIMENTAL RESULTS

The results of the investigation entitled "**Effect of Green Manuring and Herbicides on Weed Dynamics and Yield of Direct Seeded Rice**" conducted during *Kharif* 2019 have been described in this chapter through appropriate data, tables, bar diagrams and graphical illustrations, wherever necessary. The observations pertaining to different parameters of the study were analyzed statistically wherever possible and for other parameters of the study mean values have been given. The mean weekly values of weather parameters and input-output costs have been appended in the appendices. The results of the study have been presented under the following headings:

4.1 GROWTH STUDIES IN RICE

4.1.1 Plant height

Plant height is an important parameter reflecting the vertical growth of a crop plant. In general, the plant height continued to increase with the advancement of age till harvest under various treatments. The data presented in Table 8 reveals that, at 30 DAS, different green manuring treatments failed to show any significant impact on plant height. However, sunnhemp green manuring recorded numerically higher plant height to the tune of 24.21 cm. Similarly, different herbicidal treatments also failed to show any significant impact on plant height at 30 DAS. However, application of pendimethalin 1 kg/ha recorded numerically higher plant height (24.22 cm).

At 60 DAS, amongst different green manuring treatments, highest plant height of rice to the tune of 71.73 cm was recorded in sunnhemp green manuring which was statistically at par with dhaincha and cowpea green manuring and significantly higher than stale seedbed. On contrary, stale seedbed recorded lowest plant height (65.34 cm) which was however, found statistically at par with cowpea green manuring. Among the herbicidal treatments, application of pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS recorded highest plant height to the tune of 72.56 cm which was statistically at par with alone application of bispyribac-sodium 25 g/ha at 25 DAS. While significantly lowest plant height was recorded in weedy check with corresponding value of 64.09 cm. Similar results with respect to plant height of rice were observed at 90 DAS and at harvest.

The interaction effects of green manuring and herbicidal practices on plant height of rice were found statistically non-significant.

4.1.2 Dry matter accumulation (g/m^2)

Dry matter accumulation is an important index indicating the photosynthetic efficiency of the crop which ultimately influences the crop yield. It is a direct index of plant proliferation. Dry matter accumulation (g/m^2) presented in Table 9. All the green manuring treatments recorded significantly higher dry matter accumulation than stale seedbed at 60, 90 and at harvest. Also all the herbicidal treatments recorded significantly higher dry matter accumulation than weedy check at 60, 90 and at harvest.

At 30 DAS, different green manuring treatments failed to show any significant impact on dry matter accumulation (g/m^2). However, sunnhemp green manuring recorded numerically higher dry matter accumulation to the tune of 63.45 g/m^2. Similarly, different herbicidal treatments also failed to show any significant impact on dry matter accumulation (g/m^2) at 30 DAS. However, application of pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS recorded numerically higher dry matter accumulation 63.51 g/m^2.

Amongst different green manuring treatments at 60 DAS, highest dry matter accumulation of rice to the tune of 226.78 g/m^2 was recorded in sunnhemp green manuring which was statistically at par with dhaincha green manuring and significantly higher than stale seedbed. On contrary, stale seedbed recorded lowest dry matter accumulation (188.36) which was however, found statistically at par with cowpea green manuring. Among the herbicidal treatments, application of pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS recorded significantly highest dry matter accumulation to the tune of 265.98 g/m^2 as compared to other treatments. While lowest dry matter accumulation was recorded in weedy check treatment with corresponding value of 131.75 g/m^2.

Table 8: Effect of green manuring and herbicides on plant height of direct seeded rice

Treatment	Plant height (cm)			
	30 DAS	**60 DAS**	**90 DAS**	**At harvest**
Green manure				
Cowpea	23.68	67.77	96.93	127.65
Dhaincha	22.79	69.94	98.46	131.23
Sunnhemp	24.21	71.73	101.77	134.23
Stale Seedbed	22.71	65.34	90.36	119.58
SEm±	0.62	1.53	2.29	3.08
CD (5 %)	NS	4.42	6.61	8.89
Herbicides				
Pendimethalin 1 kg/ha as PE	24.17	66.85	97.67	127.96
Bispyribac-sodium 25 g/ha at 25 DAS	22.45	71.28	104.38	137.90
Pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS	24.22	72.56	106.91	141.81
Weedy check	22.54	64.09	78.55	105.03
SEm±	0.62	1.53	2.29	3.08
CD (5 %)	NS	4.42	6.61	8.89
Interaction	NS	NS	NS	NS

Table 9: Effect of green manuring and herbicides on dry matter accumulation of direct seeded rice

Treatment	Dry matter accumulation (g/m^2)			
	30 DAS	**60 DAS**	**90 DAS**	**At harvest**
Green manure				
Cowpea	60.65	204.87	365.70	531.73
Dhaincha	62.99	216.62	379.73	559.29
Sunnhemp	63.45	226.78	391.28	565.03
Stale Seedbed	57.87	188.36	320.94	454.73
SEm±	1.61	4.76	9.11	10.70
CD (5 %)	NS	13.75	26.32	30.90
Herbicides				
Pendimethalin 1 kg/ha as PE	63.57	192.69	376.44	527.23
Bispyribac-sodium 25 g/ha at 25 DAS	60.11	246.20	429.87	625.24
Pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS	63.51	265.98	467.39	671.27
Weedy check	57.77	131.75	183.94	287.03
SEm±	1.61	4.76	9.11	10.70
CD (5 %)	4.64	13.75	26.32	30.90
Interaction	NS	NS	S	S

Table 9.1: Interaction effect of green manuring and herbicides on dry matter accumulation at 90 DAS of direct seeded rice

Treatment	Pendimethalin 1 kg/ha as PE	Bispyribac-sodium 25 g/ha at 25 DAS	Pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS	Weedy check	Mean
Cowpea	386.41	442.10	450.77	183.51	365.70
Dhaincha	399.78	458.78	474.49	185.86	379.73
Sunnhemp	414.83	473.20	485.87	191.21	391.28
Stale Seedbed	304.72	345.41	458.43	175.18	320.94
Mean	376.44	429.87	467.39	183.94	364.41

SEm± for interaction = 18.23

CD (5%) for interaction = 52.65

Table 9.2: Interaction effect of green manuring and herbicides on dry matter accumulation at harvest of direct seeded rice

Treatment	Pendimethalin 1 kg/ha as PE	Bispyribac-sodium 25 g/ha at 25 DAS	Pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS	Weedy check	Mean
Cowpea	544.05	646.41	658.33	278.12	531.73
Dhaincha	557.00	679.98	693.38	306.80	559.29
Sunnhemp	573.85	681.22	696.57	308.48	565.03
Stale Seedbed	434.03	493.38	636.81	254.71	454.73
Mean	527.23	625.24	671.27	287.03	527.69

SEm± for interaction = 21.39

CD (5%) for interaction = 61.79

Amongest green manuring treatments at 90 DAS, highest dry matter accumulation of rice to the tune of 391.28 g/m^2 was recorded in sunnhemp green manuring which was statistically at par with dhaincha and cowpea green manuring and significantly higher than stale seedbed. On contrary, stale seedbed recorded lowest dry matter accumulation (320.94) which was however, statistically at par with cowpea green manuring. Among the herbicidal treatments, application of pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS recorded significantly highest dry matter accumulation to the tune of 467.39 g/m^2 as compared to other treatments. While lowest dry matter accumulation was recorded in weedy check treatment with corresponding value of 183.94 g/m^2. Similar results at 60 DAS with respect to dry matter accumulation of direct seeded rice were at harvest.

The interaction effect of green manuring and herbicidal practices on dry matter accumulation of direct seeded rice was found statistically non-significant at 30 DAS and 60 DAS while it was significant at 90 DAS and at harvest (Table 9.1 & 9.2). The data presented on interaction effect reveals that the green manuring of sunnhemp in combination with pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS recorded highest dry matter accumulation which was statistically at par with green manuring of dhaincha and cowpea as well as stale seedbed in combination with pendimethalin 1kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS and green manuring of dhaincha and cowpea in combination with bispyribac-sodium 25 g/ha at 25 DAS and significantly higher than other treatment combinations. The lowest dry matter accumulation of direct seeded rice was recorded in stale seedbed in combination with weedy check. At harvest the interaction effect was similar to that of 90 DAS.

4.1.3 Crop growth rate (g/m^2/day)

The data presented in the Table 10 reveals that the crop growth rate increased with the advancement of crop age up to 90 DAS and then showed a declining trend. Among the green manuring, non-significant results were observed with respect to crop growth rate at different growth stages of rice except at 30-60 DAS. At 30-60 DAS, highest crop growth rate of rice to the tune of 5.44 g/m^2/day was recorded in sunnhemp green manuring which was statistically at par with dhaincha green manuring. On contrary, stale seedbed recorded lowest crop growth rate of rice (4.35 g/m^2/day) which was however, found statistically at par with cowpea green manuring.

Among weed control treatments at 30-60 DAS, application of pendimethalin 1 kg/ha as pre-emergence *fb* bispyribac sodium 25 g/ha at 25 DAS recorded significantly highest crop growth rate (6.75 g/m^2/day) than the other herbicidal treatments. At 60-90 DAS and at 90 to harvest, application of pendimethalin 1 kg/ha as pre-emergence *fb* bispyribac sodium 25 g/ha at 25 DAS recorded significantly highest crop growth rate (6.71 g/m^2/day) which was statistically at with bispyribac sodium 25 g/ha at 25 DAS than significantly higher than other herbicidal treatments. The significantly lowest crop growth rate was recorded in weedy check. The interaction effect of green manuring and herbicidal treatments on crop growth rate was found statistically non-significant.

4.1.4 Number of tillers/m^2

The tillers count per unit area is an important parameter for determining the effect of any treatment on growth and yield of rice which is presented at Table 11. Data on number of tillers/m^2 clearly indicated that the number of tillers/m^2 significantly differed in different green manuring and herbicide practices at all the periodic stages of the crop except 30 DAS where, it was non-significant. All the green manuring treatments recorded significantly higher number of tillers/m^2 than stale seedbed at 60, 90 DAS and at harvest. Also all the herbicidal treatments recorded significantly higher number of tillers/m^2 than weedy check at 60, 90 DAS and at harvest.

At 30 DAS, the sunnhemp green manuring recorded numerically higher number of tillers/m^2 to the tune of 124. The application of pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS produced numerically higher number of tillers/m^2 (124).

At 60 DAS, highest number of tillers/m^2 of rice to the tune of 266 was recorded in sunnhemp green manuring which was statistically at par with dhaincha and cowpea green manuring. On contrary, stale seed bed recorded lowest number of tillers/m^2 (224) in the green manuring treatments. Among the herbicidal treatments, application of pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS recorded

Table 10: Effect of green manuring and herbicides on crop growth rate of direct seeded rice

Treatment	Crop growth rate (g/m^2/day))		
	30-60 DAS	60-90 DAS	90 DAS-At harvest
Green manure			
Cowpea	4.81	5.36	3.32
Dhaincha	5.12	5.44	3.61
Sunnhemp	5.44	5.48	3.46
Stale Seedbed	4.35	4.42	2.68
SEm±	0.16	0.36	0.27
CD (5 %)	0.46	NS	NS
Herbicides			
Pendimethalin 1 kg/ha as PE	4.30	6.13	3.02
Bispyribac-sodium 25 g/ha at 25 DAS	6.20	6.12	3.91
Pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS	6.75	6.71	4.08
Weedy check	2.47	1.74	2.06
SEm±	0.16	0.36	0.27
CD (5 %)	0.46	1.03	0.78
Interaction	NS	NS	NS

Table 11: Effect of green manuring and herbicides on number of tillers/m^2 of direct seeded rice

Treatment	Number of tillers/m^2			
	30 DAS	**60 DAS**	**90 DAS**	**At harvest**
Green manure				
Cowpea	122	252	247	240
Dhaincha	123	259	255	247
Sunnhemp	124	266	260	253
Stale Seedbed	120	224	216	210
SEm±	3	5	5	5
CD (5 %)	NS	14	15	14
Herbicides				
Pendimethalin 1 kg/ha as PE	123	237	231	224
Bispyribac-sodium 25 g/ha at 25 DAS	120	283	278	274
Pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS	124	304	301	297
Weedy check	121	175	169	155
SEm±	3	5	5	5
CD (5 %)	NS	14	15	14
Interaction	NS	S	S	S

Table 11.1: Interaction effect of green manuring and herbicides on number of tillers/m^2 at 60 DAS of direct seeded rice

Treatment	Pendimethalin 1 kg/ha as PE	Bispyribac-sodium 25 g/ha at 25 DAS	Pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS	Weedy check	Mean
Cowpea	237	296	302	172	252
Dhaincha	245	303	308	178	259
Sunnhemp	260	308	313	183	266
Stale Seedbed	207	226	293	168	224
Mean	237	283	304	175	250
SEm± for interaction = 10					
CD (5%) for interaction = 29					

Table 11.2: Interaction effect of green manuring and herbicides on number of tillers/m^2 at 90 DAS of direct seeded rice

Treatment	Pendimethalin 1 kg/ha as PE	Bispyribac-sodium 25 g/ha at 25 DAS	Pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS	Weedy check	Mean
Cowpea	228	292	298	168	247
Dhaincha	243	298	305	173	255
Sunnhemp	255	300	308	178	260
Stale Seedbed	197	220	292	155	216
Mean	231	278	301	169	245
SEm± for interaction = 10					
CD (5%) for interaction = 29					

Table 11.3: Interaction effect of green manuring and herbicides on number of tillers/m^2 at harvest of direct seeded rice

Treatment	Pendimethalin 1 kg/ha as PE	Bispyribac-sodium 25 g/ha at 25 DAS	Pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS	Weedy check	Mean
Cowpea	223	287	295	155	240
Dhaincha	235	293	300	158	247
Sunnhemp	245	297	305	163	253
Stale Seedbed	193	218	288	142	210
Mean	224	274	297	155	237
SEm± for interaction = 10					
CD (5%) for interaction = 27					

significantly highest number of tillers/m^2 to the tune of 304 than other herbicidal treatments at 60 DAS. The significantly lowest number of tillers/m^2 was recorded in weedy check treatment with corresponding value of 175. Similar results with respect to number of tillers/m^2 of direct seeded rice were observed at 90 DAS and at harvest also.

The interaction effect of green manuring and herbicides on number of tillers/m^2 of direct seeded rice was found statistically non-significant at 30 DAS and significant at 60 DAS, 90 DAS and at harvest (Tabe 11.1, 11.2 & 11.3). At 60 DAS, data on interaction effect reveals that the green manuring of sunnhemp in combination with pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS recorded highest number of tillers/m^2 which was statistically at par with green manuring of dhaincha and cowpea as well as stale seedbed in combination with pendimethalin 1kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS and green manuring of dhaincha and cowpea in combination with bispyribac-sodium 25 g/ha at 25 DAS and significantly higher than other treatment combinations. The lowest number of tillers/m^2 of direct seeded rice was recorded in stale seedbed in combination with weedy check. At 90 DAS and at harvest the interaction effects were similar to that of 60 DAS.

4.2 YIELD ATTRIBUTES AND YIELD

4.2.1 Effective tillers/m^2

The effective tillers/m^2 is the most important component amongst the yield attributing characters. The effective tillers/m^2 significantly affected by different green manuring and herbicidal treatments and depicted in Table 12. All the green manuring treatments recorded significantly higher number of effective tillers/m^2 than stale seedbed. Also all the herbicidal treatments recorded significantly higher number of effective tillers/m^2 than weedy check.

The highest number of effective tillers/m^2 of rice to the tune of 244 was recorded in sunnhemp green manuring which was statistically at par with dhaincha and cowpea green manuring. On contrary, stale seed bed recorded lowest number of effective tillers/m^2 (199). Different herbicidal practices also showed significant influence with respect to effective tillers/m^2. The highest number of effective tillers/m^2 was observed with application of pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS to the tune of 290 and it was significantly superior to all the other herbicidal treatments. The significantly lowest number of effective tillers/m^2 was recorded in weedy check treatment with corresponding value of 135.

Interaction effect of green manuring and herbicidal practices had significant influence on number of effective tillers/m^2. The data on interaction effect (Table 12.1) reveals that the green manuring of sunnhemp in combination with pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS recorded highest number of effective tillers/m^2 which was statistically at par with green manuring of dhaincha and cowpea as well as stale seedbed in combination with pendimethalin 1kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS and green manuring of dhaincha and cowpea in combination with bispyribac-sodium 25 g/ha at 25 DAS and significantly higher than other treatment combinations. The lowest number of effective tillers/m^2 of direct seeded rice was recorded in stale seedbed in combination with weedy check.

4. 2.2 Number of grains/panicle

Effect of both the factors *i.e.* green manuring and herbicides was found to be significant on number of grains/panicle (Table 12). Like other parameters, number of grains/panicle was also influenced in a similar manner by different green manuring practices. Sunnhemp green manuring recorded highest number of grains/panicle to the tune of 62 which was statistically at par with dhaincha green manuring. The stale seedbed recorded significantly lowest number of grains/panicle to the tune of 52. Among different herbicide practices, pendimethalin 1 kg/ha as pre-emergence *fb* bispyribac-sodium 25 g/ha at 25 DAS recorded highest number of grains/panicle to the tune of 67 which was statistically at par with bispyribac-sodium 25 g/ha at 25 DAS to the tune of 63. While significantly lowest number of grains/panicle was recorded in weedy check treatment with corresponding value of 41. Interaction of the two factors for number of grains/panicle was found non-significant.

Table 12: Effect of green manuring and herbicides on yield attributes of direct seeded rice

Treatment	Effective tillers /m^2	Grains/panicle	1000-grain weight (g)
Green manure			
Cowpea	230	57	20.01
Dhaincha	238	60	20.35
Sunnhemp	244	62	20.46
Stale Seedbed	199	52	19.68
SEm±	5	1	0.38
CD (5%)	14	4	NS
Herbicides			
Pendimethalin 1 kg/ha as PE	216	58	20.52
Bispyribac-sodium 25 g/ha at 25 DAS	269	63	20.63
Pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS	290	67	20.78
Weedy check	135	41	18.57
SEm±	5	1	0.38
CD (5 %)	14	4	1.09
Interaction	S	NS	NS

Table 12.1: Interaction effect of green manuring and herbicides on number of effective tillers/m^2 of direct seeded rice

Treatment	Pendimethalin 1 kg/ha as PE	Bispyribac-sodium 25 g/ha at 25 DAS	Pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS	Weedy check	Mean
Cowpea	215	282	288	133	230
Dhaincha	228	288	297	138	238
Sunnhemp	238	293	300	143	244
Stale Seedbed	182	212	277	125	199
Mean	216	269	290	135	228

SEm± for interaction = 10

CD (5%) for interaction = 29

4.2.3 1000- grain weight (g)

Analysis of the data regarding the 1000-grain weight of basmati rice in direct seeding under different green manuring and herbicidal practices is presented in Table 12. It is clear from data that 1000-grain weight of rice did not influence significantly due to different green manuring treatments. However, sunnhemp green manuring recorded numerically highest 1000-grain weight with the corresponding value of 20.46 g.

Influence of herbicidal treatments on 1000-grain weight was significant. Pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS recorded highest 1000-grain weight (20.78 g) which was statistically at par with bispyribac-sodium 25 g/ha at 25 DAS and pendimethalin 1 kg/ha as PE. Weedy check remained the one with lowest 1000-grain weight (18.57). Interaction of the two factors had non-significant influence on 1000-grain weight.

4.2.4 Grain yield (kg/ha)

Grain yield is the most important parameter to compare effectiveness of different treatments. Influence of different green manuring and herbicidal practices on grain yield are embodied in Table 13 and depicted in Fig. 3. All the green manuring treatments recorded significantly higher grain yield than stale seedbed. The highest grain yield (2234 kg/ha) of rice was recorded in sunnhemp green manuring which was statistically at par with dhaincha green manuring crop (2186 kg/ha). Stale seedbed produced significantly lowest value of grain yield (1758 kg/ha) as compared to green manuring crops.

The highest grain yield was obtained in pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS to the tune of 2750 kg/ha which was significantly superior over all the other herbicidal treatments. This herbicidal treatment showed its superiority over the other two herbicidal treatments *viz*. bispyribac-sodium 25 g/ha at 25 DAS and pendimethalin 1 kg/ha as PE. The treatment weedy check recorded significantly lowest value for grain yield (1070 kg/ha).

The interaction effect of green manuring and herbicides on grain yield of rice was found significant and exhibited in Table 13.1. The data on interaction reveals that the green manuring of sunnhemp in combination with pendimethalin 1kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS recorded highest number grain yield which was statistically at par with green manuring of dhaincha and cowpea as well as stale seedbed in combination with pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS and green manuring of dhaincha and cowpea in combination with bispyribac-sodium 25 g/ha at 25 DAS and significantly higher than other treatment combinations. The lowest grain yield of direct seeded rice was recorded in stale seedbed in combination with weedy check.

4.2.5 Straw yield (kg/ha)

The data with regard to straw yield presented in Table 13 and Fig. 3 clarifies that the trend observed for straw yield under different green manuring and herbicidal treatments was similar to that observed for grain yield. All the green manuring treatments recorded significantly higher straw yield than stale seedbed. The trend of straw yield among green manuring practices was sunnhemp > dhaincha > cowpea > stale seedbed. The significantly highest straw yield was observed in sunnhemp green manuring (3924 kg/ha) which was statistically at par with dhaincha green manuring (3899 kg/ha). The significantly lowest straw yield (3131 kg/ha) was obtained in stale seedbed.

Similar trend like that of grain yield was observed for straw yield. All the herbicidal treatments recorded significantly higher straw yield than weedy check. The highest straw yield (4468 kg/ha) was observed in pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS followed by bispyribac-sodium 25 g/ha at 25 DAS (4204 kg/ha) and pendimethalin 1 kg/ha as PE (3739 kg/ha) treatments. Likewise grain yield, straw yield observed in weedy check was significantly lowest. The interaction effect of green manuring and herbicide was found to be significant.

The interaction effect of green manuring and herbicidal on straw yield of rice was exhibited in Table 13.2. The data on interaction reveals that the green manuring of sunnhemp in combination with pendimethalin 1kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS recorded highest straw yield which was statistically at par with green manuring of dhaincha and cowpea as well as stale seedbed in combination with

Table 13: Effect of green manuring and herbicides on grain yield, straw yield and harvest index of direct seeded rice

Treatment	Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)
Green manure			
Cowpea	2092	3697	35.54
Dhaincha	2186	3899	35.39
Sunnhemp	2234	3924	35.74
Stale Seedbed	1758	3131	35.21
SEm±	42	65	0.45
CD (5 %)	122	188	NS
Herbicides			
Pendimethalin 1 kg/ha as PE	1939	3739	34.18
Bispyribac-sodium 25 g/ha at 25 DAS	2510	4204	37.30
Pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS	2750	4468	38.13
Weedy check	1070	2240	32.27
SEm±	42	65	0.45
CD (5 %)	122	188	1.31
Interaction	S	S	NS

Table 13.1: Interaction effect of green manuring and herbicides on grain yield (kg/ha) of direct seeded rice

Treatment	Pendimethalin1 kg/ha as PE	Bispyribac-sodium25 g/ha at 25 DAS	Pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS	Weedy check	Mean
Cowpea	1916	2632	2740	1079	2092
Dhaincha	2049	2740	2808	1145	2186
Sunnhemp	2151	2744	2842	1197	2234
Stale Seedbed	1640	1923	2610	859	1758
Mean	1939	2510	2750	1070	2067

SEm± for interaction = 85

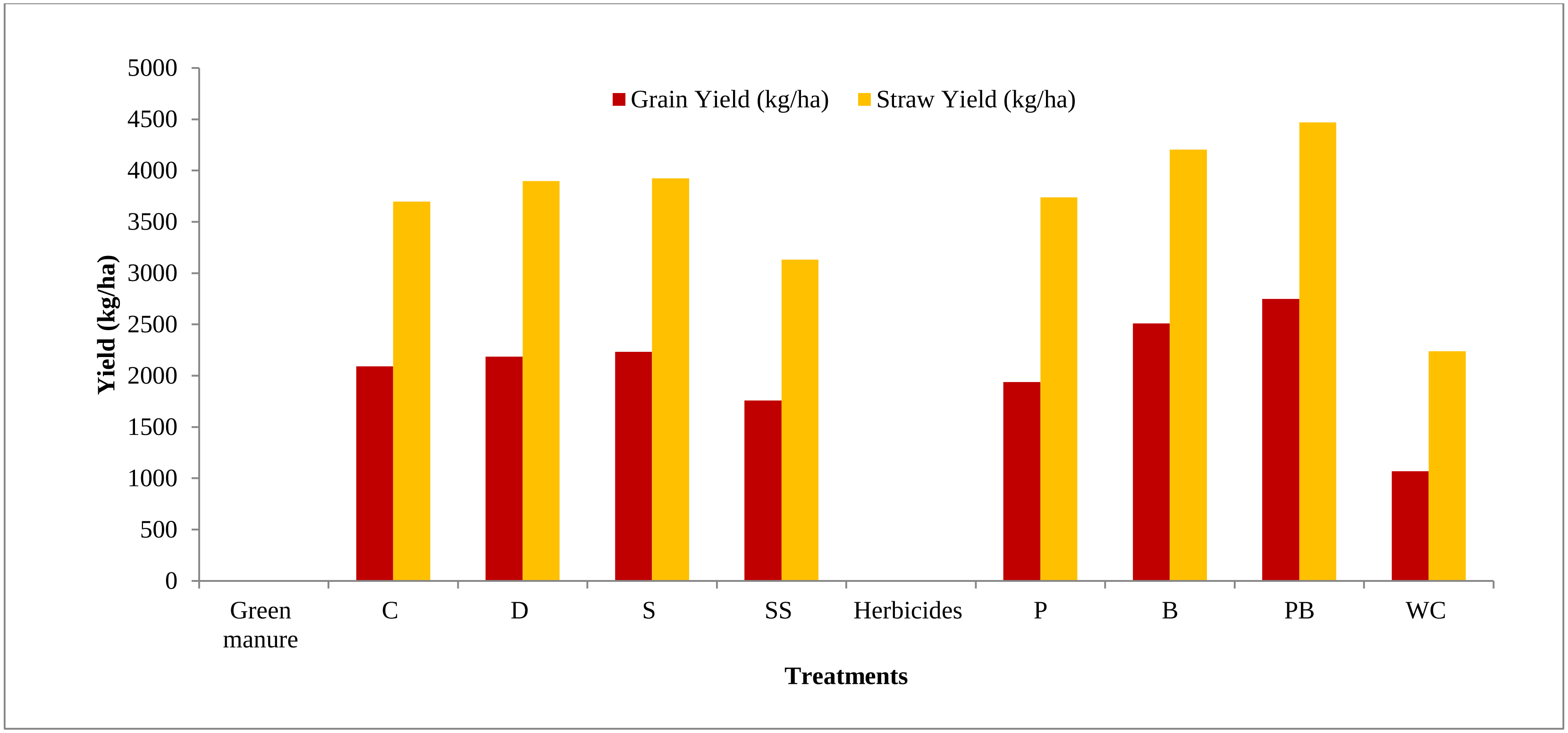
CD (5%) for interaction =245

Table 13.2: Interaction effect of green manuring and herbicides on straw yield (kg/ha) of direct seeded rice

Treatment	Pendimethalin 1 kg/ha as PE	Bispyribac-sodium 25 g/ha at 25 DAS	Pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS	Weedy check	Mean
Cowpea	3934	4282	4339	2234	3697
Dhaincha	3976	4572	4680	2369	3899
Sunnhemp	4019	4581	4616	2478	3924
Stale Seedbed	3027	3382	4237	1879	3131
Mean	3739	4204	4468	2240	3663

SEm± for interaction = 130

CD (5%) for interaction = 377



Green Manuring
Sunnhemp (S)
Dhainvha (D)
Cowpea (C)
Stale seedbed (SS)

Herbicides
Pendimethalin 1 kg/ha as pre-emergence (P)
Bispyribac-sodium 25 g/ha at 25 DAS (B)
Pendimethalin 1 kg/ha as pre-emergence *fb* bispyribac-sodium 25 g/ha at 25 DAS (PB)
Weedy check (W)

Fig 3: Effect of green manuring and herbicides on grain yield and straw yield of direct seeded rice

pendimethalin 1kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS and green manuring of dhaincha and cowpea in combination with bispyribac-sodium 25 g/ha at 25 DAS and significantly higher than other treatment combinations. The significantly lowest straw yield of direct seeded rice was recorded in stale seedbed in combination with weedy check.

4.3 Harvest index (%)

Harvest index is an important criterion which determines the proportion of economic yield expressed as percent of biological yield. The data regarding harvest index is embodied in Table 13. In green manuring treatments, sunnhemp green manuring recorded the highest value (35.74 %) of harvest index whereas stale seedbed treatment recorded the lowest (35.21 %) value of harvest index. However, the treatment means failed to show any significant difference amongst them.

In case of herbicide practices, harvest index of direct seeded rice was found to be significant. The highest harvest index of direct seeded rice was obtained with pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS (38.13 %) which was significantly at par with bispyribac-sodium 25 g/ha at 25 DAS (37.30 %). The significantly lowest value of harvest index was found in weedy check (32.27 %). The interaction effect of green manuring and herbicide practices on harvest index was found non-significant.

4.4 NUTRIENT UPTAKE

4.4.1 Nitrogen uptake (kg/ha)

The uptake of nutrient is a function of soil properties, plant density, amount of dry matter accumulated by crop and amount of fertilizer applied. Nitrogen uptake is a product of biomass and nitrogen content. The scrutiny of data on nitrogen uptake by grain, straw and total is presented in Table 14. The highest nitrogen uptake by grain, straw and total was recorded with sunnhemp green manuring (50.52, 30.72 and 81.84 kg/ha) which was statistically at par with dhaincha green manuring (50.43, 30.55 and 80.98 kg/ha). The stale seedbed recorded significantly lowest nitrogen uptake by grain, straw and total nitrogen uptake (33.11, 24.43 and 58.29 kg/ha).

Among the herbicidal treatments, pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS recorded significantly highest nitrogen uptake by grain, straw and total nitrogen uptake (57.04, 33.89 and 90.93 kg/ha) over all the other herbicidal treatments. The weedy check recorded significantly lowest nitrogen uptake by grain, straw and total nitrogen uptake (25.13, 18.84 and 43.46 kg/ha). The interaction effect of green manuring and herbicide practices was found significant in grain and non significant in straw and total nitrogen uptake**.**

4.4.2 Phosphorus uptake (kg/ha)

The analysis of the data on phosphorus uptake by grain as well as straw and total depicted in Table 14. The data reveals that phosphorus uptake was significantly influenced by different green manuring and herbicidal treatments. The highest phosphorus uptake (grain, straw and total) was recorded by sunnhemp green manuring (9.67, 9.25 and 18.82 kg/ha) which was statistically at par with dhaincha green manuring (9.44, 9.35 and 18.79 kg/ha). The significantly lowest phosphorus uptake by grain, straw and total phosphorus uptake was obtained in stale seedbed (7.36, 7.10 and 14.46).

Among herbicidal treatments, pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS recorded significantly highest phosphorus uptake for grain, straw and total to the magnitude of (11.30, 10.18 and 21.44 kg/ha), respectively over all the other herbicides. The significantly lowest phosphorus uptake by grain, straw and total phosphorus uptake was obtained in weedy check (4.88, 5.42 and 10.27). The interaction effect of green manuring and herbicide practices was found non- significant for phosphorus uptake.

4.4.3 Potassium uptake (kg/ha)

The data of potassium uptake by grain, straw and total depicted in Table 14. The data indicates that green manuring and herbicide practices have significant variation with respect to potassium uptake by grain, straw and total. Sunnhemp green manuring

Table 14: Effect of green manuring and herbicides practices on nitrogen, phosphorus & potassium uptake by crop at harvest of direct seeded rice

Treatment	Nitrogen (kg/ha)			Phosphorus (kg/ha)			Potassium (kg/ha)		
Green manure	**Grain**	**Straw**	**Total**	**Grain**	**Straw**	**Total**	**Grain**	**Straw**	**Total**
Cowpea	44.32	26.08	70.40	8.79	8.50	17.29	13.63	62.37	76.00
Dhaincha	50.43	30.55	80.98	9.44	9.35	18.79	15.45	64.90	80.35
Sunnhemp	50.52	30.72	81.84	9.67	9.25	18.82	15.96	65.61	81.57
Stale Seedbed	33.11	24.43	58.29	7.36	7.10	14.46	11.39	51.03	62.42
SEm±	0.88	0.52	1.37	0.18	0.15	0.28	0.29	1.12	1.25
CD (5 %)	2.53	1.49	3.37	0.53	0.44	0.80	0.85	3.23	3.62
Herbicides									
Pendimethalin 1 kg/ha as PE	42.33	28.65	71.73	8.43	8.85	17.23	13.81	64.33	77.89
Bispyribac-sodium 25 g/ha at 25 DAS	52.98	31.31	84.29	10.61	9.75	20.32	17.14	69.14	86.05
Pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS	57.04	33.89	90.93	11.30	10.18	21.44	18.31	72.69	90.76
Weedy check	25.13	18.84	43.46	4.88	5.42	10.27	7.85	39.74	47.35
SEm±	0.88	0.52	1.17	0.18	0.15	0.28	0.29	1.12	1.25
CD (5 %)	2.53	1.49	3.37	0.53	0.44	0.80	0.85	3.23	3.62
Interaction	S	NS	NS	NS	NS	NS	S	NS	S

recorded the highest uptake values for grain, straw and total (15.96, 65.61 and 81.57 kg/ha) which was statistically at par with dhaincha green manuring (15.45, 64.90 and 80.35 kg/ha). The significantly lowest potassium uptake by grain, straw and total was obtained in stale seedbed (11.39, 51.03 and 62.42).

In case of herbicidal treatments, pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS was statistically superior over all the other treatments for potassium uptake by grain, straw and total (18.31, 72.69 and 90.76 kg/ha). The treatment weedy check recorded significantly lowest potassium uptake values (7.85, 39.74 and 47.35). The interaction effect of green manuring and herbicide practices was found significant grain and total potassium and non-significant in straw.

4.5 WEED STUDIES

4.5.1 Weed density/m^2

The most dominating weed species found in weedy check throughout the crop growth period were mainly *Echinochloa spp.* and *Dactloctenium aegyptium* amongst grassy weeds, *Cucumis spp*. and *Phyllanthus niruri* amongst broad leaved weeds, *Cyperus spp.* amongst sedges and *Eclipta alba, Physalis mimima, Digitaria sanguinalis, Solanum nigrum* and *Cyanodon dactylon* amongst other weeds found in experimental field during crop season.

4.5.2 Grassy weed density

Different green manuring and herbicidal treatments showed significant effect on grassy weed density (*Echinochloa spp.* and *Dactloctenium aegyptium*) at all the crop growth stages except *Echinochloa spp*. at 30 DAS in green manuring treatments where, it was non-significant. All the green manuring treatments recorded lower density of grassy than stale seedbed. Also all the herbicidal treatments recorded lower grassy weed than weedy check.

4.5.2.1 *Echinochloa spp.*

Different green manuring treatments showed non-significant effect on density of *Echinochloa spp* at 30 DAS in Table 16 but sunnhemp green manuring recorded lowest number of *Echinochloa spp.*/m^2 (7.58) than other green manuring treatments. The herbicidal treatments had significant effect of density of *Echinochloa spp*. at 30 DAS. Application of pendimethalin 1 kg/ha as PE recorded significantly lowest density of *Echinochloa spp.* (4.67) than other herbicidal treatments.

At 60 DAS, green manuring of sunnhemp recorded lowest density of *Echinochloa spp.* (9.33) which was statistically at par with dhaincha green manuring (10.17). In herbicidal treatment, significantly lowest numbers of grassy weed *Echinochloa spp.* was found in the pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS. The same statistical result of grassy weed density of *Echinochloa spp.* was recorded at 90 DAS and at harvest. The interaction effect of green manuring and herbicidal treatments combinations on density of *Echinochloa spp* of direct seeded rice was found statistically non-significant at 30 DAS and 90 DAS while it was significant at 60 DAS and at harvest (Table 16.1 & 16.2). At 60 DAS, data on interaction effect reveals that the green manuring of sunnhemp in combination with pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS recorded lowest density of *Echinochloa spp* which was statistically at par with green manuring of dhaincha and cowpea as well as stale seedbed in combination with pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS and green manuring of dhaincha and cowpea in combination with bispyribac-sodium 25 g/ha at 25 DAS and significantly lower than other treatment combinations. The highest density of *Echinochloa spp* of direct seeded rice was recorded in stale seedbed in combination with weedy check. At harvest the interaction effect was similar to that of 60 DAS.

4.5.2.2 *Dactloctenium aegyptium*

All the green manuring treatments and herbicidal treatment showed significant effect on density of *Dactloctenium aegyptium* at all the growth stages (Table 16). At 30 DAS, sunnhemp green manuring recorded lowest number of *Dactloctenium*

Table 15: Weed species identified in the experimental field and their information

Botanical Name	Family	Common name/ English name	Habit & characteristics
Grassy weeds			
Echinochloa spp.	Gramineae	Barnyard grass	--
Dactyloctenium aegyptium	Poaceae	Crowfoot grass	Short annual herb with creeping or erect branches
Broad leaved weeds			
Phyllanthus nirui	Phyllanthaceae	Phyllanthus, niruri, Hazardana Paddy melon	Fleshy branched annual broad-leaved grass herb
Cucumis spp.	Cucurbitaceae		---
Sedges			
Cyperus spp.	Cyperaceae	-	-
Other weeds			
Ecliptam alba/ prostrate	Compositae/Asteraceae	False daisy, Yerba-de-taga	Annual broad-leaved herb with smell in leaves
Eleusine indica	Poaceae	Goosegrass, wiregrass	Erect tufted annual grass
Digitaria sanguinalis	Gramineae	Large crabgrass	Semi-spreading annual grass herb
Solanum nigrum	Solanaceae	Black nightshade	Erect branched annual or biennial broad-leaved herb
Sphenoclea zeylanica	Sphenocleaceae	Gooseweed	Annual broad leaved herb
Physalis minima	Solanaceae	Wild gooseberry, ground cherry	Glabrous annual broad-leaved herb
Cynodon dactylon	Gramineae	Bermundagrass, devilsgrass, stargrass	Annual herb with forking branches Perennial hardy branched usually prostrate herb

Table 16: Effect of green manuring and herbicides on grassy weed density/m^2 in direct seeded rice

Treatment	*Echinochloa spp.*				*Dactloctenium aegyptium*			
	30 DAS	**60 DAS**	**90 DAS**	**At harvest**	**30 DAS**	**60 DAS**	**90 DAS**	**At harvest**
Green manure								
Cowpea	2.93 (8.00)	3.26(11.42)	3.30 (11.92)	3.01 (9.75)	2.22 (4.00)	2.25(4.17)	2.33 (4.58)	2.36 (4.83)
Dhaincha	2.91 (7.83)	3.10(10.17)	3.09 (10.33)	2.86 (8.75)	2.13 (3.58)	2.23(4.08)	2.31 (4.58)	2.35 (4.83)
Sunnhemp	2.88 (7.58)	2.98(9.33)	3.04 (10.00)	2.82 (8.42)	2.13 (3.58)	2.21(4.00)	2.27 (4.33)	2.28 (4.50)
Stale Seedbed	3.06 (8.83)	3.58(13.58)	3.60 (13.92)	3.38 (12.17)	2.32 (4.42)	2.41(4.92)	2.50 (5.42)	2.52 (5.58)
Sem±	0.06	0.05	0.05	0.04	0.04	0.03	0.03	0.04
CD (5%)	NS	0.13	0.14	0.12	0.12	0.09	0.09	0.11
Herbicides								
Pendimethalin 1 kg/ha as PE	2.37 (4.67)	3.81(13.58)	3.86 (14.00)	3.59 (12.00)	1.99 (3.00)	2.29(4.25)	2.29 (4.25)	2.28 (4.25)
Bispyribac-sodium 25 g/ha at 25 Days after sowing	3.46 (11.00)	2.51(5.42)	2.42 (5.00)	2.28 (4.33)	2.38 (4.67)	2.12(3.50)	2.12 (3.50)	2.12 (3.50)
Pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 Days after sowing	2.38 (4.67)	1.63(1.67)	1.60 (1.58)	1.44 (1.08)	2.02 (3.08)	1.93(2.75)	1.93(2.75)	1.91 (2.67)
Weedy check	3.59 (11.92)	4.97(23.83)	5.15 (25.58)	4.75 (21.67)	2.41 (4.83)	2.77(6.67)	3.07 (8.42)	3.21 (9.33)
Sem±	0.06	0.05	0.05	0.04	0.04	0.03	0.03	0.04
CD (5%)	0.18	0.13	0.14	0.12	0.12	0.09	0.09	0.11
Interaction	NS	S	NS	S	NS	NS	NS	NS

The data were subjected to $\sqrt{x+1}$ transformation: Original values are given in parenthesis

Table 16.1: Interaction effect of green manuring and herbicides on density of *Echinochloa spp*. at 60 DAS of direct seeded rice

Treatment	Pendimethalin 1 kg/ha as PE	Bispyribac-sodium 25 g/ha at 25 DAS	Pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS	Weedy check	Mean
Cowpea	3.91 (14.33)	2.44 (5.00)	1.63 (1.67)	5.06 (24.67)	3.26 (11.42)
Dhaincha	3.65 (12.33)	2.31 (4.33)	1.63 (1.67)	4.83 (22.33)	3.10 (10.17)
Sunnhemp	3.46 (11.00)	2.24 (4.00)	1.52 (1.33)	4.69 (21.00)	2.98 (9.33)
Stale Seedbed	4.20 (16.67)	3.05 (8.33)	1.73 (2.00)	5.31 (27.33)	3.58 (13.58)
Mean	3.81 (13.58)	2.51 (5.42)	1.63 (1.67)	4.97 (23.83)	3.23 (11.13)

SEm± for interaction = 0.09

CD (5%) for interaction = 0.27

Table 16.2: Interaction effect of green manuring and herbicides on *Echinochloa spp*. at harvest of direct seeded rice

Treatment	Pendimethalin 1 kg/ha as PE	Bispyribac-sodium 25 g/ha at 25 DAS	Pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS	Weedy check	Mean
Cowpea	3.6 (12.00)	2.24 (4.00)	1.41 (1.00)	4.79 (22.00)	3.01 (9.75)
Dhaincha	3.46 (11.00)	2.00 (3.00)	1.41 (1.00)	4.58 (20.00)	2.86 (8.75)
Sunnhemp	3.31 (10.00)	2.00 (3.00)	1.41 (1.00)	4.54 (19.67)	2.82 (8.42)
Stale Seedbed	4.00 (15.00)	2.89 (7.33)	1.52 (1.33)	5.10 (25.00)	3.38 (12.17)
Mean	3.59 (12.00)	2.28 (4.33)	1.44 (1.08)	4.75 (21.67)	3.02 (9.77)

SEm± for interaction = 0.08

CD (5%) for interaction = 0.24

aegyptium/m^2 (3.58) which was at par with dhaincha (3.58) and cowpea green manuring (4.00). In herbicidal treatments, pendimethalin 1 kg/ha as PE recorded significantly lower density of *Dactloctenium aegyptium* (3.08).

At 60 DAS, sunnhemp green manuring recorded lowest density of *Dactloctenium aegyptium* (4.00) which was at par with dhaincha (4.08) and cowpea green manuring (4.17) treatments. Among the herbicidal treatments, significantly lowest numbers of grassy weed *Dactloctenium aegyptium* was found in the pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS (2.75). The same statistically result or trend of grassy weed density of *Dactloctenium aegyptium* was recorded at 90 DAS and at harvest. The interaction effect of green manuring and herbicidal treatments on density of *Dactloctenium aegyptium* of direct seeded rice was found non-significant at different stages of observations.

4.5.3 Broad-leaved weed density

It is apparent from Table 17 that density of broad-leaved weeds/m^2 (*Cucumis spp.* and *Phyllanthus niruri*) was significantly affected by green manuring and herbicidal treatments at all the growth stages. All the green manuring treatments recorded lower density of broad-leaved weeds than stale seedbed. Also all the herbicidal treatments recorded lower broad-leaved weeds than weedy check.

4.5.3.1 *Cucumis spp.*

At 30 DAS, green manuring of sunnhemp recorded lowest number of *Cucumis spp.*/m^2 (2.58) which was statistically at par with dhaincha (2.75) and cowpea green manuring (2.92). Among herbicidal treatment, pendimethalin 1 kg/ha as PE recorded significantly lowest density of *Cucumis spp.* (1.08) over other herbicidal treatments.

At 60 DAS, sunnhemp green manuring recorded lowest density of *Cucumis spp.* (2.00) which was statistically at par with dhaincha (2.33) green manuring treatment. The highest density of *Cucumis spp.* was recorded in stale seeded bed (3.08). Among the herbicidal treatment the significantly lowest numbers of *Cucumis spp.* was found in pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS (0.00). The highest density of *Cucumis spp.* was recorded in weedy check. The similar result or trend of density of *Cucumis spp.* was recorded at 90 DAS and at harvest. The interaction effect of green manuring and herbicidal practices on density of *Cucumis spp.* in direct seeded rice was found statistically non-significant at different stages of observations.

4.5.3.2 *Phyllanthus niruri*

All the different green manuring treatments and herbicidal treatment showed significant effect on density of *Phyllanthus niruri* at all the stages of crop growth. (Table 17). At 30 DAS, green manuring of sunnhemp recorded lowest density of *Phyllanthus niruri*/m^2 (4.00) which was statistically at par with dhaincha (4.08) and cowpea green manuring (4.75). Among the herbicidal treatments, pendimethalin 1 kg/ha as PE recorded significantly lowest density of *Phyllanthus niruri* (1.92) than all other treatments. The highest density of *Phyllanthus niruri* was recorded in weedy check (8.08).

At 60 DAS, sunnhemp green manuring recorded lowest density of *Phyllanthus niruri* (8.17) which was statistically at par with dhaincha green manuring (8.33). Among the herbicidal treatments, significantly lowest numbers of broad-leaved weed *Phyllanthus niruri* was found in pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS (3.42). The highest density of *Phyllanthus niruri* was found in weedy check (17.25). The same statistically result or trend of broad-leaved weed density of *Phyllanthus niruri* was recorded at 90 DAS. At harvest, green manuring of sunnhemp recorded lowest density of *Phyllanthus niruri* which was statistically at par with dhaincha and cowpea green manuring and significantly lower than stale seeded bed. Among the herbicidal treatments, significantly lowest numbers of *Phyllanthus niruri* was found in pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS. The interaction effect of green manuring and herbicidal practices on density of *Phyllanthus niruri* of direct seeded rice was found statistically non-significant at 30 DAS, 60 DAS and 90 DAS while it was significant at harvest (Table 17.1). The data on interaction effect reveals that green manuring of sunnhemp in combination with pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS recorded lowest density of *Phyllanthus niruri* which was statistically at par with green manuring of dhaincha and cowpea as well as stale seedbed in combination with pendimethalin 1kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS and green

Table 17: Effect of green manuring and herbicides on broad leaved weed density/m^2 in direct seeded rice

Treatment	*Cucumis spp.*				*Phyllanthus niruri*			
	30 DAS	**60 DAS**	**90 DAS**	**At harvest**	**30 DAS**	**60 DAS**	**90 DAS**	**At harvest**
Green manure								
Cowpea	1.92(2.92)	1.80 (2.58)	1.81 (2.58)	1.73 (2.25)	2.32(4.75)	3.13 (9.58)	2.68 (7.00)	1.61 (2.08)
Dhaincha	1.88(2.75)	1.75 (2.33)	1.68 (2.08)	1.66 (2.00)	2.19(4.08)	2.91 (8.33)	2.52 (6.00)	1.57 (1.92)
Sunnhemp	1.84(2.58)	1.66 (2.00)	1.66 (2.00)	1.60 (1.75)	2.16(4.00)	2.88 (8.17)	2.50 (5.92)	1.55 (1.83)
Stale Seedbed	2.01(3.25)	1.92 (3.08)	1.94 (3.17)	1.85 (2.75)	2.49(5.58)	3.36 (11.17)	2.98 (8.67)	1.85 (2.92)
Sem±	0.04	0.04	0.04	0.03	0.06	0.08	0.06	0.03
CD (5%)	0.11	0.11	0.11	0.10	0.17	0.23	0.17	0.09
Herbicides								
Pendimethalin 1 kg/ha as PE	1.49 (1.25)	2.05 (3.25)	2.01 (3.08)	1.91 (2.67)	1.79(2.25)	3.60 (12.00)	3.00 (8.08)	1.79 (2.25)
Bispyribac-sodium 25 g/ha at 25 Days after sowing	2.18 (3.75)	1.60 (1.58)	1.62 (1.67)	1.57 (1.50)	2.67(6.17)	2.34 (4.58)	2.05 (3.25)	1.10 (0.25)
Pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 Days after sowing	1.44 (1.08)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.70(1.92)	2.08 (3.42)	1.78 (2.25)	1.00 (0.00)
Weedy check	2.53 (5.42)	2.48 (5.17)	2.46 (5.08)	2.36 (4.58)	3.01(8.08)	4.26 (17.25)	3.86 (14.00)	2.69 (6.25)
Sem±	0.04	0.04	0.04	0.03	0.06	0.08	0.06	0.03
CD (5%)	0.11	0.11	0.11	0.10	0.17	0.23`	0.17	0.09
Interaction	NS	NS	NS	NS	NS	NS	NS	S

The data were subjected to √x+1 transformation: Original values are given in parenthesis

Table 17.1: Interaction effect of green manuring and herbicides on *Phyllanthus niruri* at harvest of direct seeded rice

Treatment	Pendimethalin 1 kg/ha as PE	Bispyribac-sodium 25 g/ha at 25 DAS	Pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS	Weedy check	Mean
Cowpea	1.73 (2.00)	1.00 (0.00)	1.00 (0.00)	2.71 (6.33)	1.61 (2.08)
Dhaincha	1.63 (1.67)	1.00 (0.00)	1.00 (0.00)	2.64 (6.00)	1.57 (1.92)
Sunnhemp	1.63 (1.67)	1.00 (0.00)	1.00 (0.00)	2.58 (5.67)	1.55 (1.83)
Stale Seedbed	2.16 (3.67)	1.41 (1.00)	1.00 (0.00)	2.82 (7.00)	1.85 (2.92)
Mean	1.79 (2.25)	1.10 (0.25)	1.00 (0.00)	2.69 (6.25)	1.64 (2.19)

SEm± for interaction = 0.06

CD (5%) for interaction = 0.18

manuring of dhaincha and cowpea in combination with bispyribac-sodium 25 g/ha at 25 DAS and significantly lower than other treatment combinations. The highest density of *Phyllanthus niruri* of direct seeded rice was recorded in stale seedbed in combination with weedy check.

4.5.4 Sedges density

A perusal of the data presented in Table 18 reveals that the different green manuring and herbicidal treatments significantly affect the sedges density at all the crop growth stages. All the green manuring treatments recorded lower density of sedges than stale seedbed. Also all the herbicidal treatments recorded lower sedges than weedy check.

At 30 DAS, green manuring of sunnhemp showed lowest sedges density (22.25) which was statistically at par with dhaincha green manuring (22.50). In herbicidal treatments, pendimethalin 1 kg/ha as PE showed significantly lowest density of sedges (18.43) as compared to other treatments.

At 60 DAS, green manuring sunnhemp showed lowest density of sedges (24.08) which was statistically at par with dhaincha green manuring (24.08). In herbicidal treatments, pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS showed significantly lowest density of sedges (4.67). The same statistical result or trend of sedges density was recorded at 90 DAS and at harvest. The interaction effect of green manuring and herbicidal treatments on density of sedges in direct seeded rice was found statistically non-significant at 30 DAS and 60 DAS while significant at 90 DAS and at harvest (Table 18.1 & 18.2). In 90 DAS, the data on interaction effect reveals that the green manuring of sunnhemp in combination with pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS recorded lowest density of sedges which was statistically at par with green manuring of dhaincha and cowpea as well as stale seedbed in combination with pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS and green manuring of dhaincha and cowpea in combination with bispyribac-sodium 25 g/ha at 25 DAS and significantly lower than other treatment combinations. The highest density of sedges in direct seeded rice was recorded in stale seedbed in combination with weedy check.

4.5.5 Other weeds (No./m^2)

It is apparent from the Table 18 that the other weeds/m^2 increased upto 60 DAS and there after showed declining trend till harvest in green manuring treatments as well as stale seedbed. However, in herbicidal treatments the density of other weeds increased upto 60 DAS and there after showed declining trend till harvest except weedy check treatment.

At 30 DAS, green manuring as well as herbicidal treatments showed significant effect on density of other weeds. Green manuring of sunnhemp showed significantly lowest other weed density (4.00) than other green manuring treatments. In herbicidal treatments, pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS showed significantly lowest weed density of other weeds (2.33). At 60 DAS, green manuring of sunnhemp showed lowest density of other weeds (6.83) which were statistically at par with dhaincha green manuring (7.50). Among the herbicidal treatments, pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS showed significantly lowest weed density of other weeds (2.67) than other herbicidal treatments. The same statistically trend of other weed density was recorded at 90 DAS and at harvest. The interaction effect of green manuring and herbicidal treatments on density of other weeds in direct seeded rice was found statistically non-significant at different stages of observations.

4.5.6 Total weed density (No./m^2)

It is apparent from the Table 19 and Fig. 4 that density of total weeds/m^2 increased upto 60 DAS and there after showed declining trend till harvest in green manuring treatments as well as stale seedbed. However in herbicidal treatment increased upto 60 DAS and there after showed declining trend till harvest except weedy check treatment. The green manuring as well as herbicidal treatment showed significant effect on total weed density.

At 30 DAS, green manuring of sunnhemp showed lowest total weed density (44.00) which was statistically at par with dhaincha green manuring (45.50). In herbicidal treatments, pendimethalin 1 kg/ha as PE showed significantly lowest density of total weeds (31.92) than other herbicidal treatments. At 60 DAS, green manuring of sunnhemp

Table 18: Effect of green manuring and herbicides on sedges and other density/m^2 in direct seeded rice

Treatment	Sedges				Other weeds			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
Green manure								
Cowpea	4.99 (24.17)	4.79 (27.00)	4.92 (28.42)	4.83 (27.33)	2.40 (5.00)	2.95(8.33)	2.78(7.33)	2.73(7.00)
Dhaincha	4.83 (22.50)	4.54 (24.08)	4.78 (26.67)	4.66 (25.25)	2.31 (4.58)	2.81(7.50)	2.70(6.92)	2.58(6.25)
Sunnhemp	4.80 (22.25)	4.54 (24.08)	4.68 (25.67)	4.58 (24.50)	2.17 (4.00)	2.69(6.83)	2.62(6.42)	2.56(6.08)
Stale Seedbed	5.23 (26.58)	5.17 (30.75)	5.33 (32.58)	5.14 (30.33)	2.59 (5.92)	3.07(9.17)	2.93(8.33)	2.85(7.75)
Sem±	0.05	0.07	0.06	0.06	0.04	0.07	0.05	0.04
CD (5%)	0.14	0.21	0.16	0.17	0.13	0.19	0.14	0.12
Herbicides								
Pendimethalin 1 kg/ha as PE	4.62 (20.42)	5.99 (34.92)	6.34 (39.33)	6.12 (36.58)	2.07(3.33)	3.13(8.83)	2.98(7.92)	2.82(7.00)
Bispyribac-sodium 25 g/ha at 25 Days after sowing	5.20 (26.17)	3.01 (8.25)	3.14 (9.08)	3.09 (8.75)	2.56(5.58)	2.46(5.08)	2.30(4.33)	2.27(4.17)
Pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 Days after sowing	4.45 (18.83)	2.38 (4.67)	2.41 (4.83)	2.36 (4.58)	1.81(2.33)	1.90(2.67)	1.84(2.42)	1.82(2.33)
Weedy check	5.57 (30.08)	7.67 (58.08)	7.81 (60.08)	7.64 (57.50)	3.04(8.25)	4.02(15.25)	3.91(14.33)	3.81(13.58)
Sem±	0.05	0.07	0.06	0.06	0.04	0.07	0.05	0.04
CD (5%)	0.14	0.21	0.16	0.17	0.13	0.19	0.14	0.12
Interaction	NS	NS	S	S	NS	NS	NS	NS

The data were subjected to $\sqrt{x+1}$ transformation: Original values are given in parenthesis

Table 18.1: Interaction effect of green manuring and herbicides on sedges at 90 DAS of direct seeded rice

Treatment	Pendimethalin 1 kg/ha as PE	Bispyribac-sodium 25 g/ha at 25 DAS	Pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS	Weedy check	Mean
Cowpea	6.32 (39.00)	3.00 (8.00)	2.45 (5.00)	7.92 (61.67)	4.92 (28.42)
Dhaincha	6.30 (38.67)	2.88 (7.33)	2.38 (4.67)	7.55 (56.00)	4.78 (26.67)
Sunnhemp	6.08 (36.00)	2.82 (7.00)	2.31 (4.33)	7.50 (55.33)	4.68 (25.67)
Stale Seedbed	6.68 (43.67)	3.87 (14.00)	2.51 (5.33)	8.26 (67.33)	5.33 (32.58)
Mean	6.34 (39.33)	3.14 (9.08)	2.41 (4.83)	7.81 (60.08)	4.93 (28.33)

SEm± for interaction = 0.11

CD (5%) for interaction = 0.33

Table 18.2: Interaction effect of green manuring and herbicides on sedges at harvest of direct seeded rice

Treatment	Pendimethalin 1 kg/ha as PE	Bispyribac-sodium 25 g/ha at 25 DAS	Pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS	Weedy check	Mean
Cowpea	6.19 (37.33)	3.00 (8.00)	2.38 (4.67)	7.77 (59.33)	4.83 (27.33)
Dhaincha	6.07 (36.00)	2.82 (7.00)	2.38 (4.67)	7.37 (53.33)	4.66 (25.25)
Sunnhemp	5.88 (33.67)	2.77 (6.67)	2.31 (4.33)	7.37 (53.33)	4.58 (24.50)
Stale Seedbed	6.35 (39.33)	3.78 (13.33)	2.38 (4.67)	8.06 (64.00)	5.14 (30.33)
Mean	6.12 (36.58)	3.09 (8.75)	2.36 (4.58)	7.64 (57.50)	4.80 (26.85)

SEm± for interaction = 0.12

CD (5%) for interaction = 0.35

Table 19: Effect of green manuring and herbicides on total weed density/m^2 in direct seeded rice

Treatment	Total weed Density			
	30 DAS	60 DAS	90 DAS	At harvest
Green manure				
Cowpea	6.97 (48.83)	7.46 (63.08)	7.33(61.83)	6.78(53.25)
Dhaincha	6.73 (45.50)	7.05 (56.50)	7.01(56.58)	6.49(49.00)
Sunnhemp	6.62 (44.00)	6.90 (54.42)	6.86(54.33)	6.36(47.08)
Stale Seedbed	7.36 (54.58)	8.06 (72.67)	8.00(72.08)	7.35(61.50)
Sem±	0.09	0.10	0.08	0.07
CD (5%)	0.26	0.28	0.22	0.21
Herbicides				
Pendimethalin 1 kg/ha as PE	5.98 (34.92)	8.81 (76.83)	8.80(76.67)	8.10(64.75)
Bispyribac-sodium 25 g/ha at 25 Days after sowing	7.62 (57.33)	5.38 (28.42)	5.24(26.83)	4.81(22.50)
Pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 Days after sowing	5.73 (31.92)	4.01 (15.17)	3.84(13.83)	3.41(10.67)
Weedy check	8.34 (68.75)	11.26 (126.25)	11.32(127.50)	10.66(112.92)
Sem±	0.09	0.10	0.08	0.07
CD (5%)	0.26	0.28	0.22	0.21
Interaction	NS	NS	NS	S

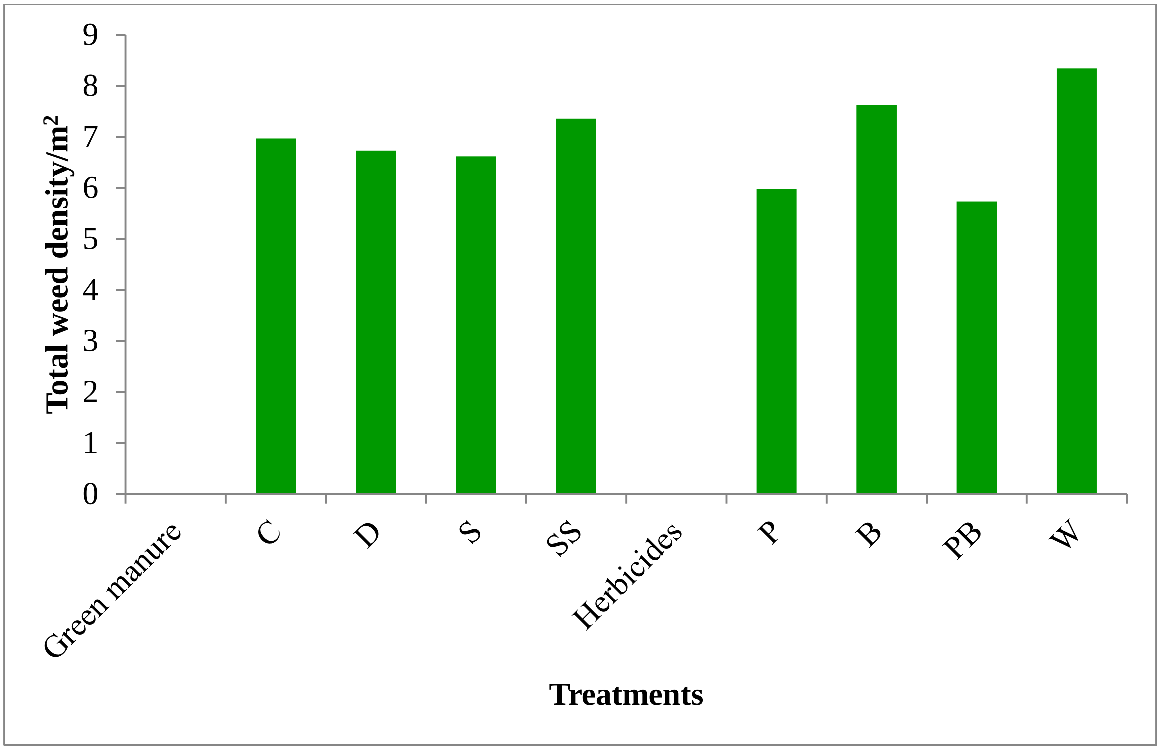
The data were subjected to $\sqrt{x+1}$ transformation: Original values are given in parenthesis

Table 19.1: Interaction effect of green manuring and herbicides on total weed density/m^2 at harvest of direct seeded rice

Treatment	Pendimethalin 1 kg/ha as PE	Bispyribac-sodium 25 g/ha at 25 DAS	Pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS	Weedy check	Mean
Cowpea	8.12 (65.00)	4.76 (21.67)	3.46 (11.00)	10.78 (115.33)	6.78 (53.25)
Dhaincha	7.89 (61.33)	4.35 (18.00)	3.36 (10.33)	10.36 (106.33)	6.49 (49.00)
Sunnhemp	7.66 (57.67)	4.28 (17.33)	3.26 (9.67)	10.23 (103.67)	6.36 (47.08)
Stale Seedbed	8.72 (75.00)	5.83 (33.00)	3.55 (11.67)	11.28 (126.33)	7.35 (61.50)
Mean	8.10 (64.75)	4.81 (22.50)	3.41 (10.67)	10.66 (112.92)	6.74 (52.71)

SEm± for interaction = 0.15

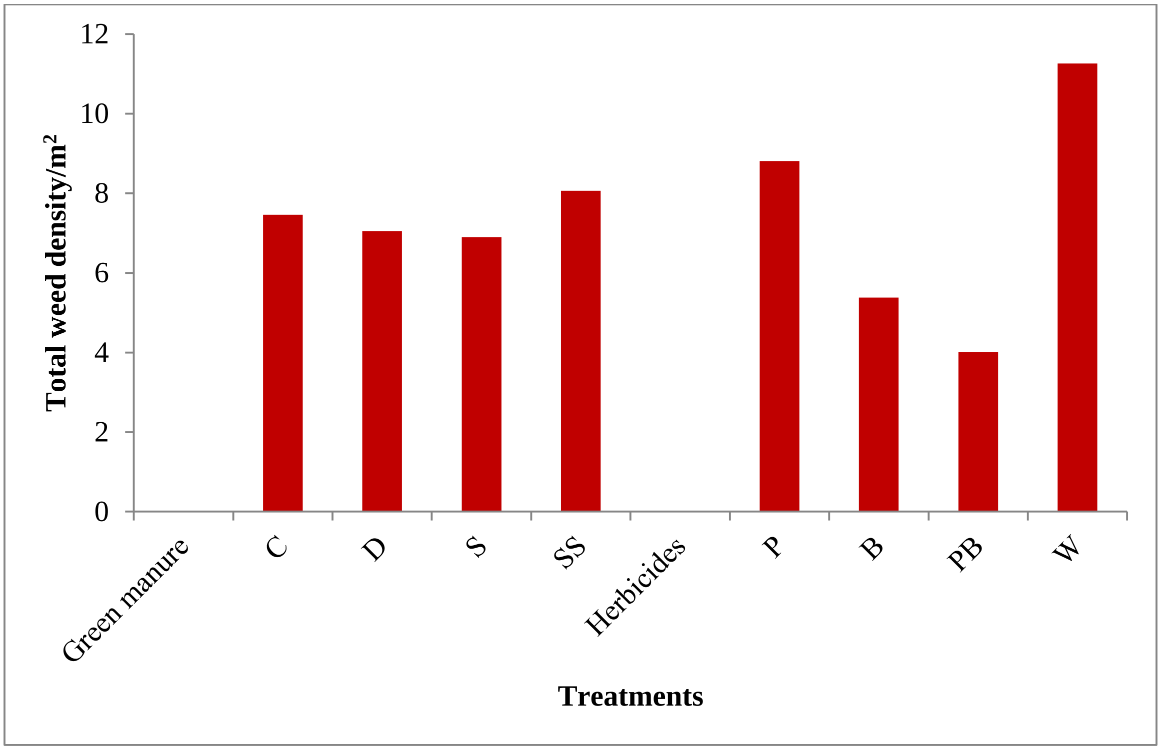
CD (5%) for interaction = 0.42



Green Manuring
Sunnhemp (S)
Dhainvha (D)
Cowpea (C)
Stale seedbed (SS)

Herbicides
Pendimethalin 1 kg/ha as pre-emergence (P)
Bispyribac-sodium 25 g/ha at 25 DAS (B)
Pendimethalin 1 kg/ha as pre-emergence *fb* bispyribac-sodium 25 g/ha at 25 DAS (PB)
Weedy check (W)

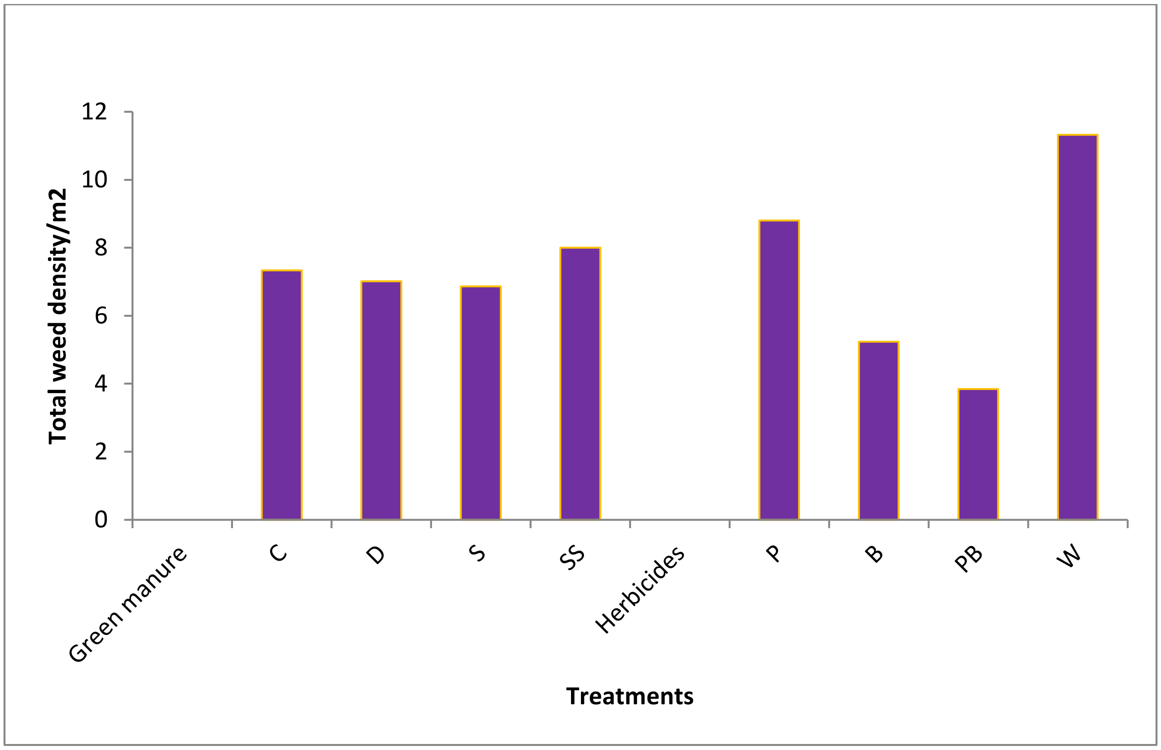
Fig 4: Effect of green manuring and herbicides on total weed density/m^2 in direct seeded rice at 30 DAS



Green Manuring
Sunnhemp (S)
Dhainvha (D)
Cowpea (C)
Stale seedbed (SS)

Herbicides
Pendimethalin 1 kg/ha as pre-emergence (P)
Bispyribac-sodium 25 g/ha at 25 DAS (B)
Pendimethalin 1 kg/ha as pre-emergence *fb* bispyribac-sodium 25 g/ha at 25 DAS (PB)
Weedy check (W)

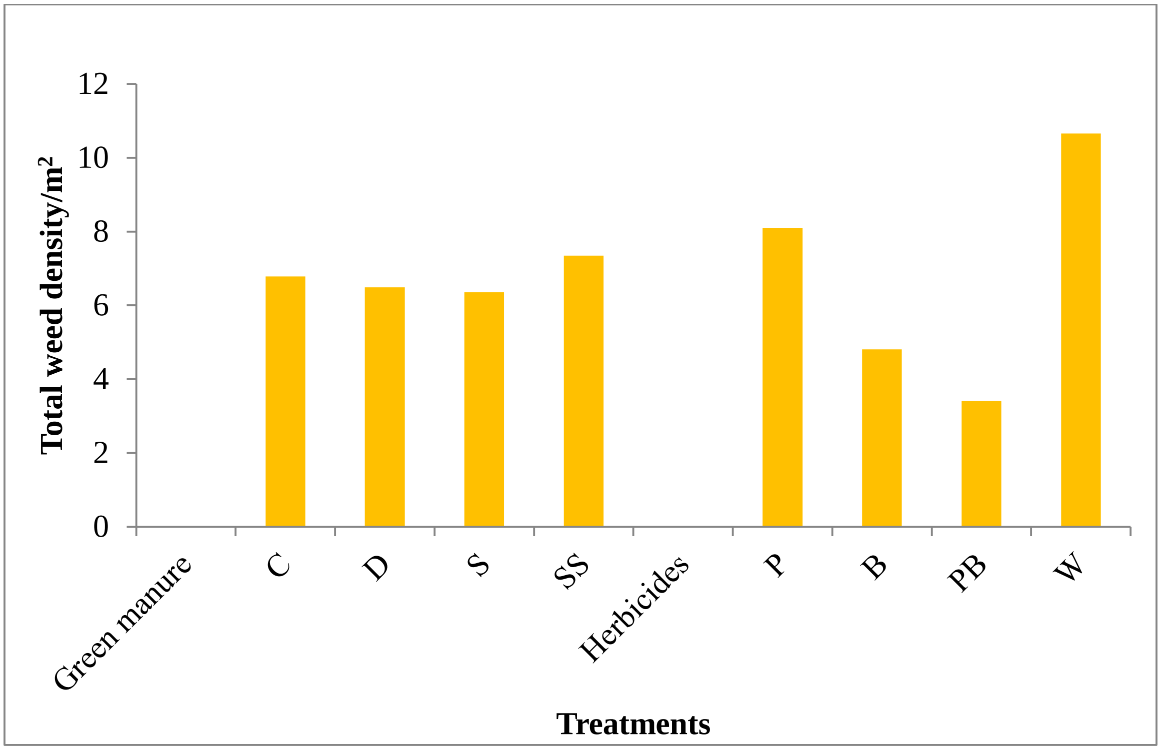
Fig 5: Effect of green manuring and herbicides on total weed density/m^2 in direct seeded rice at 60 DAS



Green Manuring
Sunnhemp (S)
Dhainvha (D)
Cowpea (C)
Stale seedbed (SS)

Herbicides
Pendimethalin 1 kg/ha as pre-emergence (P)
Bispyribac-sodium 25 g/ha at 25 DAS (B)
Pendimethalin 1 kg/ha as pre-emergence *fb* bispyribac-sodium 25 g/ha at 25 DAS (PB)
Weedy check (W)

Fig 6: Effect of green manuring and herbicides on total weed density/m^2 in direct seeded rice at 90 DAS



Green Manuring
Sunnhemp (S)
Dhainvha (D)
Cowpea (C)
Stale seedbed (SS)

Herbicides
Pendimethalin 1 kg/ha as pre-emergence (P)
Bispyribac-sodium 25 g/ha at 25 DAS (B)
Pendimethalin 1 kg/ha as pre-emergence *fb* bispyribac-sodium 25 g/ha at 25 DAS (PB)
Weedy check (W)

Fig 7: Effect of green manuring and herbicides on total weed density/m^2 in direct seeded rice at harvest

showed lowest density of total weeds (54.42) which was statistically at par with dhaincha green manuring (56.50). In herbicidal treatments, pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS showed significantly lowest total weed density (15.17) than other herbicidal treatments. The same statistically trend of total weed density recorded at 90 DAS and at harvest as that of 60 DAS. The interaction effect of green manuring and herbicidal treatments on total weed density in direct seeded rice was found statistically non-significant at 30 DAS, 60 DAS and 90 DAS while it was significant at harvest (Table 19.1). The data presented on interaction effect reveals that the green manuring of sunnhemp in combination with pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS recorded lowest density of total weed which was statistically at par with green manuring of dhaincha and cowpea as well as stale seedbed in combination with pendimethalin 1kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS and green manuring of dhaincha and cowpea in combination with bispyribac-sodium 25 g/ha at 25 DAS and significantly lower than other treatment combinations. The highest density of total weed population of direct seeded rice was recorded in stale seedbed in combination with weedy check.

4.5.7 Total weeds dry biomass (g/m^2)

It is apparent from the Table 20, 21, 22 and 23, that in general, total dry biomass of weeds increased upto till harvest. The green manuring and herbicidal treatments had significant influenced on total weed dry biomass at all crop growth stages. All the green manuring treatments recorded lower dry biomass of weeds than stale seedbed. Also all the herbicidal treatments recorded lower dry biomass of weeds than weedy check.

At 30 DAS, green manuring of sunnhemp showed lowest weed dry biomass (15.90) which was statistically at par with dhaincha green manuring (16.73) and significantly lower than cowpea green manuring (17.84) and stale seedbed (19.78). In herbicidal treatments, pendimethalin 1 kg/ha as PE *fb* showed significantly lowest weed dry biomass (5.85) than other herbicidal treatments.

At 60 DAS, green manuring of sunnhemp showed lowest total weed dry biomass (67.34) which was statistically at par with dhaincha (70.32) green manuring and significantly lower than cowpea green manuring (75.74) and stale seedbed (86.52). In herbicidal treatments, pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS showed significantly lowest weed dry biomass (16.61) as compare to other treatments. The same statistically trend of total dry biomass of weeds was recorded at 90 DAS and at harvest. The interaction effect of green manuring and herbicidal treatments on total dry biomass was found statistically non-significant at all the crop growth stages.

4.5.8 Dry biomass of grassy weeds (g/m^2)

The green manuring and herbicidal treatments had significant influence on dry biomass of grassy weeds at all crop growth stages. At 30 DAS, among the different green mauring treatments, dry biomass of grassy weeds was recorded lowest in sunnhemp green manuring (6.41) which was statistically at par with dhaincha green manuring (6.73). In herbicidal treatments, dry biomass of grassy weeds was recorded lowest in pendimethalin 1 kg/ha as PE (1.47) as compare to other treatments. At 60 DAS, green manuring of sunnhemp showed lowest dry biomass of grassy weeds (23.05) which was statistically at par with dhaincha green manuring (23.70) and significantly lower than cowpea green manuring (26.15) and stale seedbed (29.39). In herbicidal treatments, pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS showed significantly lowest weed dry biomass of grassy weeds (7.23)as compare to other treatments. The same statistically trend of dry biomass of grassy weeds was recorded at 90 DAS and at harvest. The interaction effect of green manuring and herbicidal treatments on weed dry biomass of grassy weeds was found statistically non-significant at all the crop growth stages.

4.5.9 Dry biomass of broad-leaved weeds (g/m^2)

The green manuring and herbicidal treatments had significant influence on dry biomass of broad-leaved weeds at all crop growth stages. At 30 DAS, among the different green mauring treatments the dry biomass of broad-leaved weeds was recorded lowest in sunnhemp green manuring (3.15) which was statistically at par with dhaincha green manuring (3.33) and significantly lower than cowpea green manuring (3.58) and stale seedbed (3.79). In herbicidal treatments, dry biomass of broad-leaved weeds was

Table 20: Effect of green manuring and herbicides on weed dry biomass and weed control efficiency at 30 DAS of direct seeded rice

Treatment	Weed dry biomass (g/m^2)				WCE (%)
	Grassy	Broad-leaved	Sedges	Total	
Green manure					
Cowpea	2.66 (7.25)	2.08 (3.58)	2.74 (7.01)	4.10 (17.84)	46.09
Dhaincha	2.58 (6.73)	2.02 (3.33)	2.68 (6.66)	3.97 (16.73)	49.50
Sunnhemp	2.50 (6.41)	1.97 (3.15)	2.62 (6.34)	3.86 (15.90)	52.00
Stale Seedbed	2.81 (8.13)	2.13 (3.79)	2.88 (7.87)	4.32 (19.78)	40.29
SEm±	0.05	0.03	0.05	0.05	
CD (5 %)	0.13	0.08	0.14	0.15	
Herbicides					
Pendimethalin 1 kg/ha as PE	1.60 (1.58)	1.59 (1.53)	2.08 (3.35)	2.72 (6.45)	80.53
Bispyribac-sodium 25 g/ha at 25 DAS	3.45 (10.98)	2.34 (4.52)	3.21 (9.32)	5.07 (24.82)	25.08
Pendimethalin 1 kg/ha as Pre emergence *fb* bispyribac-sodium 25 g/ha at 25 DAS	1.56 (1.47)	1.54 (1.37)	2.00 (3.02)	2.61 (5.85)	82.34
Weedy check	3.93 (14.49)	2.73 (6.44)	3.63 (12.20)	5.84 (33.13)	0.00
SEm±	0.05	0.03	0.05	0.05	
CD (5 %)	0.13	0.08	0.14	0.15	
Interaction	NS	NS	NS	NS	

The data were subjected to $\sqrt{x+1}$ transformation: Original values are given in parenthesis

Table 21: Effect of green manuring and herbicides on weed dry biomass and weed control efficiency at 60 DAS of direct seeded rice

Treatment	Weed dry biomass (g/m^2)				WCE (%)
	Grassy	Broad-leaved	Sedges	Total	
Green manure					
Cowpea	4.82 (26.15)	3.81 (15.83)	5.38 (33.76)	8.03 (75.74)	53.53
Dhaincha	4.65 (23.70)	3.58 (14.18)	5.27 (32.43)	7.74 (70.32)	56.86
Sunnhemp	4.57 (23.05)	3.44 (12.90)	5.20 (31.39)	7.58 (67.34)	58.68
Stale Seedbed	5.21 (29.39)	4.18 (18.56)	5.83 (38.58)	8.75 (86.52)	46.92
SEm±	0.06	0.05	0.09	0.07	
CD (5 %)	0.17	0.15	0.25	0.21	
Herbicides					
Pendimethalin 1 kg/ha as PE	5.33 (27.47)	4.57 (19.93)	6.49 (41.28)	9.46 (88.67)	45.60
Bispyribac-sodium 25 g/ha at 25 Days after sowing	3.51 (11.48)	2.96 (7.96)	3.61 (12.19)	5.68 (31.63)	80.59
Pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS	2.86 (7.23)	1.82 (2.38)	2.82 (7.01)	4.18 (16.61)	89.81
Weedy check	7.55 (56.12)	5.66 (31.21)	8.75 (75.68)	12.79 (163.01)	0.00
SEm±	0.06	0.05	0.09	0.07	
CD (5 %)	0.17	0.15	0.25	0.21	
Interaction	NS	S	NS	NS	

The data were subjected to $\sqrt{x+1}$ transformation: Original values are given in parenthesis

Table 21.1: Interaction effect of green manuring and herbicides on dry biomass of broad leaf weeds at 60 DAS in direct seeded rice

Treatment	Pendimethalin 1 kg/ha as PE	Bispyribac-sodium 25 g/ha at 25 DAS	Pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS	Weedy check	Mean
Cowpea	4.60 (20.21)	3.14 (8.87)	1.75 (2.07)	5.76 (32.17)	3.81 (15.83)
Dhaincha	4.44 (18.74)	2.56 (5.57)	1.70 (1.91)	5.61 (30.51)	3.58 (14.18)
Sunnhemp	4.39 (18.27)	2.51 (5.34)	1.64 (1.69)	5.22 (26.31)	3.44 (12.90)
Stale Seedbed	4.84 (22.51)	3.61 (12.04)	2.20 (3.84)	6.07 (35.84)	4.18 (18.56)
Mean	4.57 (19.93)	2.96 (7.96)	1.82 (2.38)	5.66 (31.21)	3.75 (15.37)

SEm± for interaction = 0.11

CD (5%) for interaction = 0.31

Table 22: Effect of green manuring and herbicides on weed dry biomass and weed control efficiency at 90 DAS in direct seeded rice

Treatment	Weed dry biomass (g/m^2)				WCE (%)
	Grassy	Broad-leaved	Sedges	Total	
Green manure					
Cowpea	5.89 (40.08)	4.32 (21.45)	6.02 (42.06)	9.34 (103.59)	54.83
Dhaincha	5.70 (37.34)	4.16 (20.04)	5.83 (39.83)	9.03 (97.21)	57.61
Sunnhemp	5.57 (35.91)	4.16 (19.93)	5.74 (38.90)	8.89 (94.73)	58.69
Stale Seedbed	6.32 (45.17)	4.95 (26.64)	6.34 (46.18)	10.11 (117.99)	48.55
SEm±	0.07	0.05	0.06	0.09	
CD (5 %)	0.19	0.15	0.17	0.25	
Herbicides					
Pendimethalin 1 kg/ha as PE	6.71 (44.19)	5.20 (26.10)	7.19 (50.71)	11.03 (121.00)	47.24
Bispyribac-sodium 25 g/ha at 25 DAS	4.28 (17.58)	3.36 (10.53)	4.00 (15.19)	6.61 (43.30)	81.12
Pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS	3.03 (8.21)	2.02 (3.25)	3.06 (8.41)	4.56 (19.87)	91.33
Weedy check	9.46 (88.53)	7.01 (48.18)	9.67 (92.66)	15.17 (229.36)	0.00
SEm±	0.07	0.05	0.06	0.09	
CD (5 %)	0.19	0.15	0.17	0.25	
Interaction	NS	S	NS	NS	

The data were subjected to $\sqrt{x+1}$ transformation: Original values are given in parenthesis

Table 22.1: Interaction effect of green manuring and herbicides on dry biomass of broad leaf weeds at 90 DAS in direct seeded rice

Treatment	Pendimethalin 1 kg/ha as PE	Bispyribac-sodium 25 g/ha at 25 DAS	Pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS	Weedy check	Mean
Cowpea	5.26 (26.67)	3.33 (10.10)	1.78 (2.17)	6.92 (46.87)	4.32 (21.45)
Dhaincha	5.04 (24.40)	2.92 (7.57)	1.85 (2.43)	6.84 (45.77)	4.16 (20.04)
Sunnhemp	4.98 (23.80)	3.04 (8.30)	1.82 (2.37)	6.80 (45.23)	4.16 (19.93)
Stale Seedbed	5.53 (29.53)	4.14 (16.17)	2.65 (6.03)	7.47 (54.83)	4.95 (26.64)
Mean	5.20 (26.10)	3.36 (10.53)	2.02 (3.25)	7.01 (48.18)	4.40 (22.01)

SEm± for interaction = 0.10

CD (5)% for interaction = 0.30

Table 23: Effect of green manuring and herbicides on weed dry biomass and weed control efficiency at harvest of direct seeded rice

Treatment	Weed dry biomass (g/m^2)				WCE (%)
	Grassy	Broad-leaved	Sedges	Total	
Green manure					
Cowpea	7.21 (60.09)	3.90 (20.03)	6.48 (48.83)	10.37 (128.95)	54.70
Dhaincha	6.93 (56.91)	3.69 (17.91)	6.32 (46.34)	9.98 (121.16)	57.44
Sunnhemp	6.91 (56.33)	3.49 (16.70)	6.29 (45.77)	9.88 (118.80)	58.26
Stale Seedbed	7.56 (65.70)	4.22 (23.31)	6.72 (51.88)	10.89 (140.89)	50.51
SEm±	0.05	0.06	0.09	0.08	
CD (5 %)	0.16	0.17	0.25	0.22	
Herbicides					
Pendimethalin 1 kg/ha as PE	8.85 (77.50)	4.79 (22.13)	7.59 (56.71)	12.53 (156.33)	45.09
Bispyribac-sodium 25 g/ha at 25 DAS	4.89 (22.94)	2.28 (4.41)	4.45 (18.95)	6.86 (46.30)	83.73
Pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS	3.57 (11.87)	1.00 (0.00)	3.40 (10.59)	4.83 (22.45)	92.11
Weedy check	11.30 (126.72)	7.23 (51.41)	10.37 (106.58)	16.90 (284.71)	0.00
SEm±	0.05	0.06	0.09	0.08	
CD (5 %)	0.16	0.17	0.25	0.22	
Interaction	NS	S	NS	NS	

The data were subjected to $\sqrt{x+1}$ transformation: Original values are given in parenthesis

Table 23.1: Interaction effect of green manuring and herbicides on dry biomass of broad leaf weeds at harvest of direct seeded rice

Treatment	Pendimethalin 1 kg/ha as PE	Bispyribac-sodium 25 g/ha at 25 DAS	Pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS	Weedy check	Mean
Cowpea	5.00 (23.97)	2.37 (4.67)	1.00 (0.00)	7.24 (51.47)	3.90 (20.03)
Dhaincha	4.54 (19.67)	2.21 (3.93)	1.00 (0.00)	7.00 (48.03)	3.69 (17.91)
Sunnhemp	4.35 (17.93)	1.67 (1.83)	1.00 (0.00)	6.93 (47.03)	3.49 (16.70)
Stale Seedbed	5.28 (26.93)	2.86 (7.20)	1.00 (0.00)	7.75 (59.10)	4.22 (23.31)
Mean	4.79 (22.13)	2.28 (4.41)	1.00 (0.00)	7.23 (51.41)	3.82 (19.49)

SEm± for interaction = 0.12

CD (5%) for interaction = 0.34

recorded significantly lowest in pendimethalin 1 kg/ha as PE (1.37) as compared to other treatments. At 60 DAS, green manuring of sunnhemp showed lowest dry biomass of broad-leaved weeds (12.90) which was statistically at par with dhaincha green manuring (14.18) and significantly lower than cowpea green manuring (15.83) and stale seedbed (18.56). In herbicidal treatments, pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS showed significantly lowest dry biomass of broad-leaved (2.38) as compare to other treatments. The same statistically trend of dry biomass of broad-leaved weeds was recorded at 90 DAS and at harvest. The interaction effect of green manuring and herbicidal treatments on dry biomass of broad-leaved weeds in direct seeded rice was found statistically non-significant at 30 DAS while it was significant at 60 DAS, 90 DAS and at harvest (Table 21.1, 22.1 & 23.1). At 60 DAS, the data presented on interaction effect reveals that green manuring of sunnhemp in combination with pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS recorded lowest dry biomass of broad-leaved weeds which was statistically at par with green manuring of dhaincha and cowpea as well as stale seedbed in combination with pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS and green manuring of dhaincha and cowpea in combination with bispyribac-sodium 25 g/ha at 25 DAS and significantly lower than other treatment combinations. The highest dry biomass of broad-leaved weeds of direct seeded rice was recorded in stale seedbed in combination with weedy check. The same statistically trend was also being observed in the interaction effect on dry biomass of broad-leaved weeds at 90 DAS and at harvest.

4.5.10 Dry biomass of sedges (g/m^2)

The green manuring and herbicidal treatments had significant influenced on dry biomass of sedges at all crop growth stages. At 30 DAS, among the different green mauring treatments the dry biomass of sedges was recorded lowest in sunnhemp green manuring (6.34) which was statistically at par with dhaincha (6.66) and cowpea green manuring (7.01). In herbicidal treatments, dry biomass of sedges was recorded lowest in pendimethalin 1 kg/ha (3.02) as compared to other treatments. At 60 DAS, green manuring of sunnhemp showed lowest dry biomass of sedges (31.39) which was statistically at par with dhaincha (32.43) and cowpea green manuring (33.76) and significantly lower than stale seedbed (38.58). In herbicidal treatments, pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS showed significantly lowest dry biomass of sedges as compare to other treatments. At 90 DAS, green manuring of sunnhemp showed lowest dry biomass of sedges (38.90) which was statistically at par with dhaincha green manuring (39.83) and significantly lower than cowpea green manuring (42.06) and stale seedbed (46.18). In herbicidal treatments, pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS showed significantly lowest dry biomass of sedges (8.41) as compare to other treatments. At harvest the green manuring of sunnhemp showed lower dry biomass of sedges (45.77) which was statistically at par with dhaincha (46.34) and cowpea green manuring (48.83) and significantly lower than stale seedbed (51.88). In herbicidal treatments, pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS showed significantly dry biomass of sedges weeds (10.59) as compare to other treatments. The interaction effect of green manuring and herbicidal treatments on total dry biomass of sedges was found statistically non-significant at all the crop growth stages.

4.5.11 Weed control efficiency (%)

Weed control efficiency (WCE) usually compares different methods/treatments of weed control on the basis of their effect on weeds (Table 20, 21, 22 & 23). Among the green manuring treatments, highest WCE (58.26%) was recorded in sunnhemp treatment while lowest weed control efficiency was observed in stale seedbed treatment (40.29%) at different intervals of crop growth stages. Likewise, in herbicidal treatments, highest WCE value of (92.11%) was recorded with pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS and lowest WCE in weedy check treatment (0 %) at different intervals of crop growth stages.

4.5.12 Nutrient uptake by weeds (kg/ha)

Analysis of the nutrient uptake by weeds at harvest reveals (Table 24) that uptake of three major macro nutrients varied significantly under different green manuring and herbicidal treatments.

Table 24: Effect of green manuring and herbicides practices on nitrogen, phosphorus & potassium uptake by weeds at harvest of direct seeded rice

Treatment	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)
Green manure			
Cowpea	15.55	6.58	24.68
Dhaincha	13.76	6.41	23.15
Sunnhemp	13.29	6.05	22.13
Stale Seedbed	17.30	7.38	28.07
SEm±	0.23	0.10	0.38
CD (5 %)	0.67	0.30	1.10
Herbicides			
Pendimethalin 1 kg/ha as PE	19.39	7.88	30.94
Bispyribac-sodium 25 g/ha at 25 DAS	6.93	3.28	9.96
Pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS	3.46	1.55	4.99
Weedy check	30.12	13.71	52.16
SEm±	0.23	0.10	0.38
CD (5 %)	0.67	0.30	1.10
Interaction	S	S	S

The trend of nutrient uptake *viz.* nitrogen, phosphorus and potassium by weeds in three different green manuring treatments and stale seedbed was that the sunnhemp < dhaincha (< cowpea) < stale seedbed where stale seedbed (17.30, 7.38 and 28.07 kg/ha) recorded highest uptake of these nutrients by weeds. All the herbicidal treatment recorded lower nutrient uptake by the weeds than weed check (30.12, 13.71 and 52.16 kg/ha). Among herbicidal treatments, pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS was recorded (3.46, 1.55 and 4.99 kg/ha) lowest uptake of nitrogen, phosphorus and potash by weeds.

4.6 SOIL STUDIES

4.6.1. Physico-chemical properties

Soil data presented in Table 25 indicates that non-significant influence of the treatments (green manuring and herbicidal treatments) and their interaction on physico-chemical properties of soil like EC, pH, organic carbon. In green manuring the highest value of EC, pH and organic carbon were recorded in the treatment of sunnhemp green manuring while the lowest EC and organic carbon in stale seedbed treatment and pH in dhaincha green manuring. In herbicidal treatments, the highest value of EC was recorded in pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS and pH and organic carbon in weedy check. The lowest value of EC was recorded in weedy check, pH in pendimethalin 1 kg/ha as PE and organic carbon in pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS.

4.6.2 Available N, P and K (kg/ha)

Available N, P and K data presented in Table 25 revealed non-significant difference among the treatments of both the factors. Among the green manuring treatments numerically higher available N (244.12 kg/ha), P (15.01 kg/ha) and K (148.30 kg/ha) were recorded in sunnhemp treatments over the other treatments. Among the herbicidal treatments, highest available N, P and K were observed under weedy check treatment (245.22, 15.00 and 148.44 kg/ha) which was superior over all the herbicide treatments. The lowest available N, P and K in soil were observed in stale seedbed (234.77, 13.70 and 143.55 kg/ha) however, in herbicidal treatments lowest available N, P and K in soil were in pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS (238.15, 13.77 and 143.97 kg/ha) in soil.

4.7 ECONOMICS

Economics in terms of cost of cultivation, gross returns, net returns and B: C ratio were evaluated to work out the most efficient and advantageous treatment**.**

4.7.1 Cost of cultivation

The cost of cultivation **(**Rs./ha) of different treatment presented in Table 26 reveals that the trend as sunnhemp > dhaincha > cowpea > stale seedbed with the corresponding values for cost of cultivation as 37134, 35734, 35334 and 311595 Rs./ha.

Data of cost of cultivation under different herbicide practices reveals that highest cost of cultivation was recorded under pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS to the tune of 37240 Rs./ha followed by bispyribac-sodium 25 g/ha at 25 DAS and pendimethalin 1 kg/ha as PE which recorded the amount of cost of cultivation *i.e*. Rs. 35091 and 34589 per hectare, respectively.

4.7.2 Gross returns

Gross returns showed in Table 26 almost the similar trend with that of grain yield and highest gross returns of 94907 Rs./ha was observed in sunnhemp followed by dhaincha 93017 Rs./ha, cowpea 88949 Rs./ha and stale seedbed 74818 Rs./ha.

Among herbicide treatments, highest gross returns was observed in pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS (115950 Rs./ha) followed by bispyribac-sodium 25 g/ha at 25 DAS (106141 Rs./ha) ,83228 Rs./ha was observed in pendimethalin 1 kg/ha as PE and less gross return of weedy check treatment 46371 Rs./ha.

4.7.3 Net returns

The data showed in Table 26 on net returns reveals that out of all the green manuring treatments, sunnhemp resulted in highest net return of about of 57773 Rs./ha

Table 25: Effect of green manuring and herbicides practices on fertility status of soil after harvest of direct seeded rice

Treatment	EC (ds/m)	pH	OC (g/kg)	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)
Green manure						
Cowpea	0.21	7.77	4.66	241.50	14.13	145.90
Dhaincha	0.22	7.76	4.66	243.54	14.56	147.81
Sunnhemp	0.23	7.78	4.68	244.12	15.01	148.30
Stale Seedbed	0.20	7.84	4.61	234.77	13.70	143.55
SEm±	0.01	0.10	0.07	3.05	0.35	2.05
CD (5 %)	NS	NS	NS	NS	NS	NS
Herbicides						
Pendimethalin 1 kg/ha as Pre emergence	0.21	7.76	4.65	241.67	14.65	147.83
Bispyribac-sodium 25 g/ha at 25 DAS	0.22	7.80	4.66	238.89	13.97	145.33
Pendimethalin 1 kg/ha as Pre emergence *fb* bispyribac-sodium 25 g/ha at 25 DAS	0.23	7.77	4.63	238.15	13.77	143.97
Weedy check	0.20	7.83	4.68	245.22	15.00	148.44
SEm±	0.01	0.10	0.07	3.05	0.35	2.05
CD (5 %)	NS	NS	NS	NS	NS	NS
Interaction	NS	NS	NS	NS	NS	NS
Initial values	**0.23**	**7.89**	**4.61**	**236.50**	**13.63**	**143.32**

followed by dhaincha (57282 Rs./ha), cowpea (53614 Rs./ha) and stale seedbed (43658 Rs./ha).

Among the herbicidal treatments, highest net return of 78710 Rs./ha was achieved from pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS followed by *fb* bispyribac-sodium 25 g/ha at 25 DAS with a net return of 71050 Rs./ha.

4.7.4 B: C ratio

The data on B: C ratio depicted in Table 26 revels that the all the green manuring treatments recorded higher B: C ratio of 1.53 to 1.57 than stale seedbed 1.36. The highest B: C ratio was witnessed in dhaincha followed by sunnhemp green manuring.

Among herbicidal treatment, highest B: C ratio was obtained in pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS (2.12) followed by bispyribac-sodium 25 g/ha and pendimethalin 1 kg/ha as PE with 2.01 and 1.40 values of B: C ratios, respectively. Least value of B: C ratio *i.e.* 0.42 was observed for weedy check.

The interaction table 26.1 showed that the highest B: C ratio (2.28) among the different green manuring and herbicidal treatment combinations (Table 26.1) was observed in stale seedbed with pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS followed by dhaincha green manuring with herbicidal treatment combination of bispyribac-sodium 25 g/ha at 25 DAS.

Table 26: Effect of green manuring and herbicidal practices on relative economics of direct seeded rice

Treatment	Cost of Cultivation (Rs/ha)	Gross Return (Rs/ha)	Net Return (Rs/ha)	B:C ratio
Green manure				
Cowpea	35334	88949	53614	1.49
Dhaincha	35734	93017	57282	1.57
Sunnhemp	37134	94907	57773	1.53
Stale Seedbed	31159	74817	43658	1.36
Herbicides				
Pendimethalin 1 kg/ha as PE	34589	83228	48638	1.40
Bispyribac-sodium 25 g/ha at 25 DAS	35091	106141	71050	2.01
Pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS	37239	115950	78710	2.12
Weedy check	32441	46371	13929	0.42

Table 26.1: Effect of green manuring and herbicides on benefit cost ratio of direct seeded rice

Treatment	Pendimethalin 1 kg/ha as PE	Bispyribac-sodium 25 g/ha at 25 DAS	Pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS	Weedy check	Mean
Cowpea	1.36	2.12	2.05	0.42	1.49
Dhaincha	1.48	2.22	2.11	0.49	1.57
Sunnhemp	1.49	2.10	2.03	0.49	1.53
Stale Seedbed	1.27	1.60	2.28	0.30	1.36
Mean	1.40	2.01	2.12	0.42	1.49

Plate 1 : Green manuring with cowpea

Plate 2 : Green manuring with sunnhemp

Plate 3 : Green manuring with dhaincha

Plate 4 : Stale seedbed

Plate 5 : Cowpea green manuring and pendimethalin 1 kg/ha as PE fb bispyribac-sodium 25 g/ha at 25 DAS

Plate 6 : Sunnhemp green manuring and pendimethalin 1 kg/ha as PE fb bispyribac-sodium 25 g/ha at 25 DAS

Plate 7 : Dhaincha green manuring and pendimethalin 1 kg/ha as PE fb bispyribac-sodium 25 g/ha at 25 DAS

Plate 8 : Stale seedbed and pendimethalin 1 kg/ha as PE fb bispyribac-sodium 25 g/ha at 25 DAS

Plate 9 : Cowpea green manuring and bispyribac-sodium 25 g/ha at 25 DAS

Plate 10 : Sunnhemp green manuring and bispyribac-sodium 25 g/ha at 25 DAS

Plate 11 : Dhaincha green manuring and bispyribac-sodium 25 g/ha at 25 DAS

Plate 12 : Stale seedbed and bispyribac-sodium 25 g/ha at 25 DAS

CHAPTER-5

DISCUSSION

CHAPTER-5

DISCUSSION

The experimental results presented in the previous chapter gave a detailed account of the "**Effect of Green Manuring and Herbicides on Weed Dynamics and Yield of Direct Seeded Rice.**" The complex phenomenon of plant growth and development is governed by the environmental processes which ultimately affect the grain yield and quality of the crop. Green manuring and herbicidal practices alter the environmental conditions which markedly influence the various growth parameters at different developmental stages of the crop and ultimately modified the grain yield of the crop.

The significant experimental findings obtained during the course of experimentation are discussed below with possible explanations and evidences wherever necessary in order to find out the cause and effect relationship among different treatments with respect to various attributes studied and sort out information of practical value.

5.1 WEATHER IN RELATION TO CROP PERFORMANCE

In addition to crop management practices, the growth, development and yield of a crop is also influenced by a number of biotic and abiotic factors. Amongst the abiotic factors rainfall, temperature and relative humidity play an important role in governing the growth, development and ultimately the yield of the crop. A thorough glance of the meteorological data recorded during crop growing period of rice crop (*Kharif* 2019) depicted in Figure 1 and embodied in Appendix-I indicated that amongst the different weather parameters, temperature and humidity by and large did not showed much seasonal variations to impact the growth and development of the experimental crop during the growing period. A considerable variation in the distribution of rainfall had been noticed during the experimental period which was supplemented by irrigations in crop and experimental crop did not suffer from water deficit at any of the crop growth stage.

5.2 CROP STUDIES

5.2.1 Growth parameters of rice crop

The growth performance of the direct seeded basmati rice measured in terms of plant height, dry matter accumulation, crop growth rate, number of tillers/m^2 presented in Table 8, 9, 10 & 11. All the growth parameters were significantly influenced by green manuring treatments at most of the crop growth stages except at 30 DAS and in the order as sunnhemp>dhaincha>cowpea>stale seedbed. The higher growth parameters in sunnhemp, dhaincha and cowpea green manuring than stale seedbed. This could be attributed to the higher supply of N and other micronutrient through the incorporation of legumes or green manuring crops into soil. Similar finding were reported by Raju and Reddy, 1999 and Bisht *et al.*, 2006. In addition to N contribution, the biomnass of these green manures also recycled considerable quantities of P. K and other nutrients, and thus might have improved fertility buildup, physical and biological properties of the soil. These results are in close conformity with the findings by Sharma and Prasad. 1999, Jensen and Hauggaard-Nielsen, 2003; Kirkegaard *et al.,* 2008 and Kumar *et al.,* 2011. Also due to lower weed density resulted in lower weed competition in the green manuring plots and gave higher plant height, dry matter accumulation, crop growth rate and number of tillers/m^2. The similar findings were reported by Kumar and Ladha 2011. Among the green manure crop, sunnhemp green manuring recorded higher growth parameters *viz.* plant height, dry matter and number of tillers/m^2 as compared dhaincha and cowpea green manuring. This might be due to higher biomass production of sunnhemp crop (7920kg/ha) which release the more nutrient availability under sunnhemp green manuring plots. Similar observations were recorded by Mangan *et al*., 1995.

As for herbicidal treatments, our result suggest that poor growth observed in season long weedy plots might be due to lack of adequate supply of resources under prolonged weed competition.. Among the herbicidal treatments, of pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS recorded significantly higher value for each parameter examined for growth parameters over bispyribac-sodium 25 g/ha at 25 DAS and pendimethalin 1 kg/ha as PE. This trend might be because of pre-emergence application of pendimethalin which reduced the initial flushes of mixed weed flora and later flushes were controlled by post-emergence application of bispyribac-sodium. These results are in close conformity with the findings of Narolia *et al*., 2014 and Yadav *et al*., 2014.

Significant interaction was observed between different green manuring and herbicidal treatments for all the growth parameters except plant height and crop growth rate at all the stages, dry matter accumulation on 30 and 60 DAS and number of tillers/m^2 on 30 DAS. The sunnhemp green manuring in combination with pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS recorded highest dry matter accumulation and number of tillers/m^2 which were statistically at par with green manuring of dhaincha and cowpea as well as stale seedbed in combination with pendimethalin 1kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS and green manuring of dhaincha and cowpea in combination with bispyribac-sodium 25 g/ha at 25 DAS and significantly higher than other treatment combinations. This might be due to the pronounced effect of green manuring and herbicidal practices in controlling weeds at respective stages which reduces the competition between crop and weeds, which stimulated plant growth and accelerating maristamatic growth and hence contributed toward plant height, number of tillers and dry matter accumulation. The lowest dry matter accumulation and number of tillers/m^2 of direct seeded rice was recorded in stale seedbed in combination with weedy check.

5.2.2 Yield attributes and yield

The result of the analysis of variance for effect of green manuring treatments on yield attributes and yields of rice have shown that 1000-grain weight did not influence significantly however, significant influence on effective tillers/m^2, number of grains/panicle of rice, grain and straw yield of rice were observed (Table 12 and 13). All the green manuring treatments had higher yield attributes and yields of direct seeded rice than stale seedbed this was due to the higher nitrogen content in green manuring crops that is incorporated in soil than the stale seedbed. Green manuring of legume crops before sowing provides nitrogen through fixation, adding organic matter into soil, release nutrients in soil after their decomposition, some green manure crops also have bio-herbicidal and weed smothering properties (Lazzeri and Manici, 2000). Incorporation of green manure crops into soil results in production of allelo-chemicals that change micro-environment and hinder the germination, growth and development of the weeds (Buhler, 2002). Allelo-chemical is released into the environment through the root exudates, leaching, volatilization and after degradation either from living parts or dead parts (Weir *et al*., 2004). These results are in close conformity with the findings of Chanda and Sarwar 2017. In stale seedbed could not find lower number of weeds and increased availability of nutrients resultant lower value for yield attributes and yield of direct seeded rice were obtained. These results were similar to the findings of Sindhu *et al*. (2010).

In green manuring treatments, the highest yield attributes and yields were obtained under sunnhemp green manuring due to enhanced crop nutrition, less weed competition and better subsequent plant growth leading to more effective tillers/m^2, grains/panicle and yields than dhaincha and cowpea green manuring. Also, the higher yield attributes and yields of direct seeded rice in sunnhemp were due to the sunnhemp producing high residue levels (7920 kg/ha) which results into higher availability of nutrients and release more allele-chemical for weed suppression for the longer than dhaincha (6100 kg/ha) and cowpea (3250 kg/ha). Sunnhemp is a fast-growing, 1 to 3 m tall, leguminous cover crop that generates a large quantity of biomass and a considerable amount of nitrogen (Akanvou *et al*., 2001; Mansoer *et al.*, 1997). The results were similar to the findings of Cherr *et al*., 2006.

The herbicidal practices improved the yield attributes *viz.* effective tillers per/m^2, grains/panicle, 1000-grain weight and yields of direct seeded rice over weedy check. The reduction in crop weed competition provided favorable environment to crop and thus had higher values for yield attributes and yields of direct seeded rice. These results are in close conformity with the findings Longkumar and Singh; 2013, Singh *et al*., 2014; Mandal *et al*., 2011. The highest yield attributes and yields of direct seeded rice were recorded in pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS treated plots while lowest value for yield attributing characters were recorded in weedy check plots. Higher yield attributes *viz.* no of effective tillers/m^2, number of grains/panicle, 1000-grain weight and yields of direct seeded rice were due to effective control of mixed weed flora by sequential application of pre and post emergence herbicides. The yield attributes were statistically comparable due to control of initial flushes of weeds by pendimethalin and later weed flushes were controlled with bispyribac-sodium. Walia *et al*. (2008) reported that application of pendimethalin *fb* bispyribac-sodium reduced the emergence of weeds and gave significantly higher yield attributes and yield in these herbicidal treatments as these provide effective control of complex weed flora and significantly increased the number of effective tillers/m row length. The similar findings were also reported by Narolia *et al*. 2014. Also, Sharif and Chauhan 2014 reported that yield was higher in the plots treated with pre-emergence followed by post-emergence herbicides.

Significant interaction was observed between different green manuring and herbicidal treatments for effective tillers/m^2 and grain and straw yield of direct seeded rice. Interactive effects showed increased value for these parameters with sunnhemp in combination with pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS and these were statistically at par with green manuring of dhaincha and cowpea as well as stale seedbed in combination with pendimethalin 1kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS and green manuring of dhaincha and cowpea in combination with bispyribac-sodium 25 g/ha at 25 DAS and significantly higher than other treatment combinations. This might be due to the pronounced effect of green manuring and herbicidal practices on weed control and increased availability of nutrients at respective stages which stimulated plant growth that leads to higher yield attributes and yields of direct seeded rice. The lowest effective tillers/m^2 and grain and straw yield of direct seeded rice was recorded in stale seedbed in combination with weedy check.

5.2.3 Nutrient uptake of crop

Nutrients (N, P and K) uptake is a function of dry matter production and partly due to increase in nutrient concentration. However, there is a close relationship between the total uptake of nutrients with the grain yield and straw yield of rice crop. Definite proportion of nutrients is always associated with attainable yield of any crop. It is apparent from the Table 14 that nutrient uptake was highest under sunnhemp green manuring followed by dhaincha and cowpea and least was under stale seedbed. This might be because of more available form of respective nutrients in the soil for the uptake under sunnhemp green manuring treatment than under stale seedbed treatment. Moreover, this was because of the higher dry matter accumulation of crop in sunnhemp that led to higher nutrient uptake values. Similar observations were recorded by Singh 2014. Among herbicidal treatment, higher uptake of N, P and K was recorded under the herbicidal application of pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS plots. This might be due to higher efficacy of pendimethalin pre-emergence and bispyribac-sodium as post-emergence herbicides which effectively controlled the weeds and provides less crop weed competition thereby resulting in higher grain yield and crop biomass that leads to higher uptake of nutrients. This result confirms the finding of Mishra and Singh (2008) and Singh and Singh (2010).

Significant interaction was observed between different green manuring and herbicidal treatments for the nutrient uptake by the crop with respect to nitrogen uptake by grain and potassium by grain and total potassium by crop. Interactive effects showed increased value for uptake with sunnhemp and pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha. The better control of weeds in this treatment combination provided favourable conditions and resulted in increased uptakes (N, P and K).

5.3 WEED STUDIES

5.3.1 Weed density and biomass

Lower weed density and hence less dry biomass of weeds were recorded under green manuring treatment at all the stages of growth (Table 16, 17, 18, 19, 20, 21, 22 & 23) than stale seedbed. This might be due to that green manuring gave more effective control of weeds present in top soil layer, light responsive and having low dormancy by producing allelo-chemical or cover the ground. The leguminous cover crops produce allelopathic chemicals or cover the ground and reduce need for early-season herbicide use in agricultural crops. Similar finding of results by Chauhan and Johnson 2008, Cherr *et al*., 2006., Mosjidis and Wehtje, 2011 were also reported under green manure crops, owing to their fast growth, change the micro environment through release of phyto-toxin or allele-chemicals which influence of weed germination or suppress the weed growth. Odhiambo *et al*. (2010) found that incorporation of legume as green manure (cowpea, mucuna, lablab, sunnhemp and butterfly pea) in green manure-maize rotation significantly increased the grain yield of maize and significantly reduced total weed dry matter as compared to fallow-maize rotation.

Among the green manure crops, sunnhemp green manuring provided more control of weeds than dhaincha and cowpea green manuring. It was due to more biomass incorporation in sunnhemp and release of non protein amino acid (Pant and Fales, 1974) which can be considered to be a candidate allele-chemical in sunnhemp. It was identified as delta-hydroxynorleucine (5-hydroxy-2-aminohexanoic acid) (Pilbeam and Bell, 1979) and demonstrated to be phytotoxic to lettuce (Wilson and Bell, 1979). In *Sesbania* revealed that the inhibitory and stimulatory effect may be due to the presence of the allelochemicals like sterols, saponins, phenols and tannins etc., in the aqueous leaf extracts of *Sesbania* which helps to reduce the weed germination and weed growth (Alagesaboopathi and Deivanai 2011).

Among herbicidal treatment, lower weed density and dry biomass were recorded under the herbicidal application of pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS plots. This might be due to higher efficacy of pendimethalin pre-emergence and bispyribac-sodium as post-emergence herbicides which effectively controlled the weeds and provides less crop weed competition thereby favour crop growth. Pre-emergence application of herbicides pendimethalin has lowered down the initial flushes of weeds significantly. Sharif and Chauhan (2014) also reported the same result. Bispyribac has been reported very effective against mixed flora of weeds and same was reported by Yadav *et al*., 2007 which could be witnessed at 60 DAS and thereafter. Throughout the crop growth, at all the stages of examination persistence of weeds such as *Dactyloctenium aegyptium* and *Echinochloa spp.* was observed even after sequential application of above said herbicides. Studies carried out by Khaliq *et al.* 2011a, b, 2012; Rahman *et al.,* 2011 established the same fact that some weed persists in DSR fields even after the use of bispyribac-sodium. Pendimethalin *fb* bispyribac-sodium as application of sequential herbicide reported that very effective on different weeds flora that can control the initial flushes of weeds as well as late flushes of weeds flora. The same finding of results by Mahajan and Chauhan (2015). Lowest weed dry matter from the pre-emergence application of pendimethalin 0.75 kg/ha followed by post-emergence application of bispyribac-sodium 30 g/ha due to the less density of weeds in these treatment plots. The same finding of result by Walia *et al*. (2012).

The data on interaction effect revealed that green manuring of sunnhemp in combination with pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS recorded lowest weed density and dry biomass of weeds which was statistically at par with green manuring of dhaincha and cowpea as well as stale seedbed in combination with pendimethalin 1kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS and green manuring of dhaincha and cowpea in combination with bispyribac-sodium 25 g/ha at 25 DAS and significantly lower than other treatment combinations. The highest weed density and dry biomass of weeds of direct seeded rice was recorded in stale seedbed in combination with weedy check.

5.3.2 Nutrient uptake by weeds

Highest uptake of all the three nutrients *i.e*. N, P and K was recorded by weeds under stale seedbed plots. The probable reason was more weed population in stale seedbed than green manuring plot which grows vigorously taking up the nutrients available for the crop. The lower nutrient uptake in green manuring was observed in sunnhemp green manuring followed by dhaincha green manuring because of the low density of weeds in these plots. The same findings of results also given by (Chauhan and Johnson, 2008).

Among herbicide practices, it has been found that the efficiency of weed control treatment and nutrient uptake by weeds was inversely related to each other. Significantly highest uptake of these nutrients was recorded under weedy check treatment. Among herbicidal treatments, highest uptake of N, P and K was recorded under pendimethalin 1 kg/ha as PE and it was lowest in weed control efficiency among the herbicidal treatments. Rana and Angiras (1999) confirmed that N, P and K removal by weeds was limited in herbicide applied plots compared to unweeded control. Due to uncontrolled weed growth, the removal of N, P and K by weeds was highest in the weedy check which resulted in increased dry matter production of weeds.

5.3.3 Soil physico- chemical properties

The data in Table 25 reveals that there was no significant effect on physico-chemical properties of soil like pH, EC and OC in green manuring and herbicide practices. In green manuring the highest value of EC, pH and organic carbon in the treatment of sunnhemp green manuring while the lowest EC and organic carbon in stale seedbed treatment and pH in dhaincha green manuring. In herbicidal treatments, the highest value of EC in pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS and pH and organic carbon in weedy check and lowest value of EC in weedy check pH in pendimethalin 1 kg/ha as PE and organic carbon in pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS.

5.3.4 Soil available N, P and K

The data presented in Table 25 reveals that green manuring and herbicidal treatments have non-significant effect of soil available nutrients. Among green manuring treatment higher available N, P, K was noticed in sunnhemp treatments over other treatments. This might be due to lesser uptake of these nutrients by the weeds and more nutrients mineralized from biomass incorporated. The green manuring provides more available nutrients in soil after harvest than the stale seedbed due to their leguminous nature. The same findings of results are also given by Cherr *et al*., 2006. The similarly, stale seedbed showed least available N, P and K due to more uptake of these nutrients by the weeds during the experimentation.

Among herbicidal practices, higher available N, P, K was observed under weedy check treatment which was significantly higher over all the herbicidal treatments. The probable reason for higher available nutrients under weedy check plots might be because of addition of more weeds and weeds root biomass that remained in the soil which was utilized by microorganisms leading to increase in mineralization process. Higher nutrient availability under weedy check might also be because of lower crop dry matter accumulation by the crop while in other weed management treatments it was quite high. This resulted in lesser uptake and rendered that portion available in the soil. The in order application of pre and post emergence herbicides effectively control the weeds and provide less crop weed competition produces higher grain yield and crop biomass that leads to take higher uptake of nutrients. These results conform to the findings of Mishra and Singh (2008) and Singh and Singh (2010).

5.4 RELATIVE ECONOMICS

The economic feasibility and usefulness of the treatments can be evaluated in terms of net returns and B: C ratio. Among green manuring practices, sunnhemp green manuring generated highest net returns of 57283 Rs./ha. But the highest B: C ratio was generated from dhaincha green manuring of 1.57 which is more than the sunnhemp green manuring due to the high seed cost of sunnhemp seed. Least net returns and B: C ratio was generated under stale seedbed treatment. Among the herbicidal treatments, the one which generated highest net returns and B: C ratio was pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS with net returns of 78710 Rs./ha and B: C ratio of 2.12. Comparatively higher grain yield might be the reason for better net returns and B: C ratio among these treatments as compared to weedy check and among themselves. Another reason established by the findings of Mishra and Singh, 2008; Singh *et al*. 2012; Bhurer *et al*. 2013a and Mahajan and Chauhan, 2015 was that all the treatments associated with weed management measures were more remunerative than weedy check with respect to monetary returns.

The highest B: C ratio among the different green manuring and herbicidal treatment combinations, stale seedbed with pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS followed by dhaincha green manuring with herbicidal treatment combination of bispyribac-sodium 25 g/ha at 25 DAS.

CHAPTER-6

SUMMARY AND CONCLUSION

CHAPTER-6

SUMMARY AND CONCLUSION

An experiment entitled, **"Effect of Green Manuring and Herbicides on Weed Dynamics and Yield of Direct Seeded Rice"** was conducted at the Research Farm, Chatha of SKUAST-Jammu during the *Kharif* season of 2019. The soil of the experimental field was sandy clay loam in texture, slightly alkaline in reaction, low in organic carbon and available nitrogen, but medium in available phosphorus and potassium. The experiment was laid out in factorial randomized block design with two factors and three replications. The first factor consisted of three green manuring crops (sunnhemp, dhaincha and cowpea) and a stale seedbed treatment and another factor consisted of three herbicidal treatments (pendimethalin 1 kg/ha as PE, bispyribac-sodium 25 g/ha at 25 DAS and pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS) and a weedy check treatment. Rice variety Basmati-370 was sown on 16th June 2019. All treatments were imposed as per the technical programme. The salient findings of the present investigation have been summarized in this chapter.

6.1 CROP STUDIES

6.1.1 Growth parameters

Growth parameters *viz.* plant height, dry matter accumulation, crop growth rate and number of tillers/m^2 were higher in green manuring treatments than stale seedbed and sunnhemp green manuring recorded highest growth parameters. Among the herbicidal treatments, pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS recorded higher values for growth parameters examined over all other herbicidal treatments. In interaction, plant height and crop growth rate have non-significant effect at all the stages of crop growth, in dry matter accumulation non- significant effect at 30 DAS & 60 DAS while significant effect at 90 DAS and at harvest. The interaction effect on number of tillers/m^2 were non-significant at 30 to 90 DAS however, significant at harvest. Where the interaction were significant on growth parameters showed that sunnhemp green manuring in combination with pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS recorded highest growth parameters.

6.1.2 Yield and yield attributes

Different green manuring treatments which are applied in rice showed marked effect on yield attributes except for 1000-grains weight which showed non-significant effect. The yields and yield attributes were recorded higher in green manuring treatments than stale seedbed and sunnhemp green manuring recorded highest yields and yield attributes among green manuring treatments. In herbicidal treatments, the higher yields and yield attributes were obtained in pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS. The effective tillers/m^2, grain and straw yield had significant interaction while grains/panicle, 1000-grain weight and harvest index had non-significant interaction effect. The interaction effect was significant for yield and yield attributes and showed that higher yield and yield attributes were recorded with the green manuring of sunnhemp in combination with herbicidal treatment pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS.

6.1.3 Nutrient uptake

Nutrient uptake *viz.* N, P, K were significantly affected by green manuring and herbicidal treatments. Among green manuring treatments, sunnhemp recorded higher N, P and K uptake than other treatments. In herbicidal treatments, pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS recorded significantly higher values of N, P and K uptake.

6.1.4 Soil physico- chemical properties

The soil parameters with respect to pH, EC, organic carbon, available N P K did not change significantly under different green manuring and herbicidal treatments.

However, in green manuring higher pH, EC, organic carbon and available NPK in sunnhemp green manuring and in herbicidal treatment the higher pH in bispyribac-sodium 25 g/ha at 25 DAS and EC, organic carbon and available NPK in pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS were recorded.

6.2 WEED STUDIES

6.2.1 Weed density and biomass

Among, green manuring the lowest weed density and weed biomass of different weeds were recorded in sunnhemp green manuring. In herbicidal treatment, application of pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS was recorded lowest weed density and weed dry biomass at all the stages of crop than other treatments. In interaction of weed density at 30 DAS, none of the weed spp. showed significant effect. At 60 DAS, in *Echinochloa spp.* interaction effect was significant. At 90 DAS, the interaction effect found significant on sedges density. At harvest, interaction effect was significant on *Echinochloa spp, Phyllanthus niruri*, sedges and total weed density. The interaction effect was significant on broad-leaved weeds biomass at 60 DAS, 90 DAS and at harvest. Where the interaction effect was significant pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS in combination with green manuring of sunnhemp recorded lowest weed density and dry biomass.

6.2.2 N, P, K uptake by weeds

In green manuring treatments, the highest uptake of N, P and K by weeds were recorded by stale seedbed however, among herbicidal treatments, the highest uptake by weedy check treatment. Among green manuring treatments, the lowest uptake by weeds was observed in sunnhemp green manuring and in herbicidal treatments the lowest uptake by weeds was recorded with pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS.

6.3 RELATIVE ECONOMICS

Among the green manuring treatments, the highest net return was obtained by sunnhemp green manuring and highest B: C ratio was obtained by dhaincha green manuring. In herbicidal treatments, the highest net returns and B: C ratio was obtained in pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS. In combination of green manuring and herbicidal treatment the highest B: C ratio is obtained from stale seedbed with herbicidal application of pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium

25 g/ha at 25 DAS followed by green manauring of dhaincha combination of bispyribac-sodium 25 g/ha at 25 DAS.

CONCLUSION

On the basis of one year study, it is concluded that

- In direct seeded rice highest grain yield was obtained with green manauring of Sunnhemp which was statistically at par with Dhaincha as green manure, however highest benefit cost ratio was obtained with green manuring of Dhaincha.
- Among herbicides, pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS performed better in controlling weeds in direct seeded rice.
- Stale seedbed with application of pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS recorded numerically highest benefit cost ratio followed by green manauring of dhaincha with application of bispyribac-sodium 25 g/ha at 25 DAS. In order to arrive at final recommendation, the experiment needs to be conducted in second year also.

REFERENCES

REFERENCES

Akanvou, R. L., Bastiaans, M. J., Kroprr, J., Goudriaan, and Becker, M. 2001. Characterization of growth, nitrogen accumulation and competitive ability of six tropical legumes for potential use in intercropping systems. *Journal of Agronomy and Crop Science*, **187**: 111–120.

Akbar, N., Ehsanullah, Jabran, K. and Ali, M. A. 2011.Weed management improves yield and quality of direct seeded rice. *Australian Journal of Crop Science*, **5**(6): 688-694.

Alagesaboopathi, C. and Deivanai, M. 2011. Allelopathic potential of *Sesbania grandiflora* Pers. on germination of *Cajanus cajan* Millsp. (Redgram) varieties. *International Journal of Biosciences*, **1**(5): 51-55.

Anonymous, 2007. 2nd Annual technical Report 2007-2008 "Zero tillage rice establishment and crop weed dynamics in rice and wheat cropping systems in India and Australia, Department of Agronomy, PAU, Ludhiana, pp, 25-32.

Anonymous. 2017. *DIGEST OF STATISTICS*, 2016-2017. Directorate of Economics and Statistics, Jammu and Kashmir.

Anonymous 2018. *Annual Report.* Department of Agriculture, Cooperation & Farmers Welfare Ministry of Agriculture & Farmers Welfare Government of India.

Anonymous. 2018a. *AGRICULTURAL STATISTICS AT A GLANCE 2018*. Ministry of Agriculture Government of India.

Awan, T. H., Cruz, P. C. S. and Chauhan, B. S. 2015. Agronomic indices, growth, yield contributing traits and yield of dry-Seeded rice under varying herbicides. *Field Crops Research*, **177**: 15-25.

Azmi, M. 1992. Competitive ability of barnyard grass in direct-seeded rice. *Teknol Padi.* **8**: 19-25.

Bahar, F. A. and Rashid, Z. 2013. Effect of different doses of herbicides on yield attributes and grain yield of dry seeded rice (*Oryza sativa* L.). *Journal of Cereals and Oilseeds,* **4**(9): 109-111.

Balkcom, J. K. S., Wood, C. W. J., Adams, F. and Meso, B. 2007. Suitability of peanut residue as a nitrogen source for a *rye cover* crop. *Scientia Agricola,* **64**(2): 181–186.

Bhan, V. M., Sushilkumar and Raghuwanshi, M. S. 1999. Weed management in India. *Indian Journal of Plant Protection,* **17**: 171-202.

Bhurer, K. P., Yadav, D. N., Ladha, J. K., Thapa, R. B. and Pandey, K. 2013. Effect of integrated weed management practices on performance of dry direct seeded rice (*Oryza sativa* L.). *Agronomy Journal of Nepal*, **3**: 53-63.

Bhurer, K. P., Yadav, D. N., Ladha, J. K., Thapa, R. B. and Pandey, K. R. 2013a. Efficacy of various herbicides to control weeds in dry direct seeded rice (*Oryza sativa* L.). *Global Journal of Biology, Agriculture & Health Sciences*, **2**(4): 205-212.

Bisht, P. S., Pandey, P. C. and Singh, D. K. 2006 .Effect of different sources of nutrients on rice (*Oryza sativa)* yield and soil nutrient status in rice-wheat cropping. In. National Symposium on Conservation Agriculture and Environment, October 26-28. Banaras Hindu University, Varanasi. India.

Black, C. A. 1965. *Soil Plant relationship*. First edition Wiley Eastern, Private Limited, New Delhi.

Bouman, B. A. M., Lampayan, R. M. and Tuong, T. P. 2007. Water management in irrigated rice: cropping with water scarcity. *International Rice Research Institute*, Los Banos, Phillippines, 54 p.

Brar, H. S. and Bhullar, M. S. 2012. Dry-seeded rice productivity in relation to Sowing-time, variety and weed control. *Indian Journal of Weed Science,* **44**(3): 193-195.

Buhler, D. D. 2002. Challenges and opportunities for integrated weed management. *Weed Science,* **50**(3): 273-280.

Chauhan, B. S. and Johnson, D. E. 2008. Germination ecology of Chinese sprangletop *(Leptochloa chinensis)* in the Philippines. *Weed Science*, **56**(6): 820-825.

Chauhan, B. S. 2012. Weed management in direct seeded rice system. *International Rice Research Institute, Los Banos, Philippines*. 20 p.

Chauhan, B. S. and Abugho, S. B. 2012. Effect of growth stage on the efficacy of post-emergence herbicides on four weed species of direct-seeded rice. *The Scientific World Journal* ID 123071, 7 p.

Chauhan, B. S. and Yadav, A. 2013. Weed management approaches for dry-seeded rice in India: a review. *Indian Journal of Weed Sciences*, **45**(1): 1-6.

Choubey, N. K., Kolhe, S. S. and Tripathi R. S. 2001. Relative performance of cyhalofopbutyl for weed control in direct seeded rice. *Indian Journal of Weed Science,* **33** (3&4), 132-135.

Choudhary, V. K. and Dixit, A. 2018. Herbicide weed management effect on weed dynamics, crop growth and yield in direct-seeded rice. *Indian Journal of Weed Science*, **50**(1): 6-12.

Cherr, C. M., Scholberg, J. M. S. and McSorley, R. 2006. Green manure *as* nitrogen source for sweet corn in a warm-temperate environment. *Agronomy Journal* **98**(5): 1173-1180.

Chanda, S. C. and Sarwar, A. K. M. G. 2017. Status of dhaincha incorporated soil after rice harvest in (Boro) rice-dhaincha-rice *(T aman)* cropping pattern. *Cercetãri Agronomice in Moldova,* **4**(172): 75-84.

Cochran,W. G. and Cox, G. M. 1957. *Experimental Designs*. Asia Publishing House, Bombay, India.

Collins, A. S., Chase, C. A., StalI, W. M. and Hutchinson, C. M. 2007. Competitiveness of three leguminous cover crops with yellow nutsedge *(Cyperus esculentus)* and smooth pigweed *(Amaranthus hybridus). Weed Science,* **55**(6): 613-618.

Dass, A., Shekhawat, K., Choudhary A. K., Sepat, S., Rathore, S. S., Mahajan, G., Chauhan, B. S. 2016. Weed management in rice using crop competition-a review. *Crop Protection,* **95**: 45-52.

Dass, T. K., Tuti, M. D, Sharma, R., Paul, T. and Mirjhha, P. R. 2012. Weed management research An overview *Indian Journal of Agronomy*, **57**(3rd IAc Special issue) 141-156.

De Datta, S. K. and Baltazar, A. 1996 Weed control technology as a component of rice production system. In: *Weed Management in Rice.* (Auld. B and Kim, KU. Eds). pp 25.52. FAo Plant Production and Protection pp. 139.

Dhima, K. V., Vasilakoglou, I. B., Gatsis, Th.D., Panou-Philotheou, E., and Eleftherohorinos, I. G. 2009. Effects of aromatic plants incorporated as green manure on weed and maize development. *Field Crops Research*, **110**: 235–241.

Diarra, A., Smith, R. J. Jr. and Talbert, R. E. 1985. Interference of red rice (*Oryza sativa*) with rice (*Oryza sativa*). *Weed Science*, **33**: 644-649.

Dixit, A., and Varshney, J. G. 2008. Assessment of post-emergence herbicides in direct seeded rice. *Indian Journal of Weed Science*, **40**(3&4): 144-147.

Eleftherohorinos, I. G., Dhima, K. V. and Vasilakoglou, I. B. 2002. Interference of red rice in rice grown in Greece. *Weed Science*, **50**:167-172.

Ganai, M. A., Hussain, A. and Bhat, M. A. 2014. Bio-efficacy of different herbicides in direct seeded rice (*Oryza sativa*) under temperate Kashmir valley conditions. *Indian Journal of Agronomy,* **59**(1): 86-90.

Ganie, Z. A., Singh, S. and Singh, S. 2013. Effect of seed rate and weed control methods on yield of direct seeded rice (*Oryza sativa*). *Indian Journal of Agronomy,* **58**(1): 125-126.

Gharde, Y., Singh, P. K., Dubey, R. P. and Gupta, P. K. 2018. Assessment of yield and economic losses in agriculture due to weeds in India. *Crop Protection*, **107**: 12-18

Ghosh, D., Singh, U. P., Ray, K. and Das, A. 2016. Weed management through herbicide application in direct seeded rice and yield modeling by artificial neural network. *Spanish Journal of Agricultural Research* **14**(2) p 10

Gibson, K. D., Fischer, A. J., Foin, T. C and Hill, J. E. 2003. Crop traits related to weed suppression in water seeded rice (*Oryza sativa* L.). *Weed Science*, **51**: 87-93.

Gnanavel, I. and Kathiresan, R. M. 2002. Sustainable weed management in rice-rice cropping system. *Indian Journal of Weed Science*, **34**: 192-196.

Gopinath, K. A., Mina, B. L. Singh, K. P. and Nataraja, K. C. 2012. Integrated weed management in direct -seeded rainfed rice (*Oryza sativa). Indian Journal of Agronomy,* **57**(3): 245.249.

Hill, E. C., M. Ngouajio, and M. G. Nair. 2006. Differential response of weeds and vegetable crops to aqueous extracts of hairy vetch and cowpea. *Horticulture Science,* **41**: 695–700.

Hutchinson, C. M. and M. E. McGiffen, Jr. 2000. Cowpea cover crop mulch for weed control in desert pepper production. *Horticulture Science,* **35**: 196–198.

Hussain, S., Ramzan, M., Akhter, M. and Aslam, M. 2008. Weed management in direct seeded rice. *Journal of Animal and Plant Science*, **18**: 2-3.

Jabran, K., Ehsanullah, H., Mubshar, F., Muhammad, B., Muhammad, D., Mehmet N. and Lee, Dong-Jin. 2012a. Application of bispyribac-sodium provides effective weed control in direct-planted rice on a sandy loam soil, *Weed Biology and Management*, **12**: 136–145.

Jabran, K., Farooq, M. and Hussain, M. 2012b. Efficient weeds control with penoxsulam application ensures higher productivity and economic return of direct seeded rice. *International Journal of Agriculture and Biology*, **14**: 901-907.

Johnson, D. E., Wopereis, M. C. S., Mbodj, D., Diallo, S., Powers, S. and Haefele, S. M. 2004. Timing of weed management and yield losses due to weeds in irrigated rice in the Sahel. *Field Crops Research*, **85**(1): 31–42.

Jackson, M. L. 1973. Soil chemical analysis, Prentice Hall Inc., Englewood cliffs, New York, U.S.A.

Jackson, M. L. 1973. *Soil chemical analysis*. pp. 165-167. Asia Publication House, Bombay.

Jackson, M. L. 1973. Soil chemical analysis. Prentice Hall of India Private Limited, New Delhi.

Jensen, E. S. and Hauggaard-Nielsen, H. 2003. How can increased use or biological N_2 fixation in agriculture benefit the environment?, *Plant and Soil*, **252**: 177-186.

Kaur, S. and Singh, S. 2015. Bioefficacy of different herbicides for weed control in direct-seeded rice. *Indian Journal of Weed Science,* **47**:106-109.

Khaliq, A., Matloob, A., Ahmad, N., Rasuland, F. and Awan, I. U. 2012. Post emergence chemical weed control in direct seeded fine rice. *The Journal of Animal and Plant Science,* **22** (4): 1101-1106

Khaliq, A., Matloob, A., Ihsan, M. Z., Abbas, R. N., Aslam, Z. and Rasul, F. 2013. Supplementing herbicides with manual weeding improves weed control efficiency, growth and yield of direct seeded rice. *International Journal of Agriculture & Biology,* **15** (2): 191–199.

Khaliq, A., Matloob, A., Cheema, Z. A., and Farooq, M. 2011a. Allelopathic activity of crop residue incorporation alone or mixed against rice and its associated grass weed jungle rice (*Echinochloa colona). Chilean Journal of Agricultural Research*, **71** (3): 418-423.

Khaliq, A., Matloob, A., Shafiq, H., Muhammad. C., Zahid, A. and Wahid, A. 2011b. Evaluating sequential application of pre and post emergence herbicides in dry seeded fine rice, *Pakistan Journal of Weed Science Research*, **17** (2): 111-123.

Kirkegaard, J., Christen, O., Krupinsky, J. and Layzell, D. 2008. Break crop benefits in temperate wheat production. *Field Crops Research*. **107**: 185-195.

Kumar, J., Singh, D. and Singh, B. 2011. Effect of sowing time and weed management practices on direct seeded unpuddled rice *(Oryza sativa* L.*). Journal of Hill Agriculture*, **2** (1): 107-111.

Kumar, J., Singh, D., Singh, B., Singh, R., Panwar, S. and Gupta, A. K. 2012. Sowing time and weed management practices to enhance yield of direct-seeded rice. *Indian Journal of Weed Science,* **44** (4): 207-209

Kumar, V. and Ladha, J. K. 2011. Direct-seeded rice: recent developments and future research needs. *Advances in Agronomy*, **111**: 297- 413

Kumar, V. Kumar. T., Gupta. P. K., Singh, S. B. and Singh, R. A. 2011. Effect of green manuring and nitrogen on the productivity of rice-wheat cropping svwtem and soil fertility. *Annals or Plant and Soil Research*, **13**(1): 41-46.

Kumar, N., Mina, B. L., Chandra S., Srivastva A. K., 2011. In-situ green manuring for enhancing productivity, profitability and sustainability of upland rice. *Nutrient Cycling in Agroecosystem*, **90**: 369–377.

Kumar. V., Singh, S. S., Chokkar, R. S., Malik. R. K., Daniel. C. B. and Ladha. J. K. 2013. Weed management strategies to reduce herbicide Use in zero-till rice-wheat cropping systems or the Indo-Gangetic Plains. *Weed Technology,* **27**: 241-254.

Kumar, S., Rana,S. S., Ramesh and Chander, N. 2013a. Herbicide combinations for broad-spectrum weed control in wheat. *Indian Journal of weed Science*, **45**(1): 29-33.

Kumari, R. C., Srinivasulu Reddv, D. and Vineetha 2010. Effect of crop residue incorporation and nitrogen management practices on growth and yield of rice *(Oryza sativa* L.). *The Andhra Agricultural Journal,* **57**(1): 14-20.

Lazzeri, L., and Manici, L. M. 2000. The glucosinolate-myrosinase system: a natural and practical tool for biolfumigation. *Acta Horticulturae*, **532**: 89-95.

Longkumar, L.T. and Singh, P.L 2013. Response of rice *(Oryza sativa* L.*)* to sowing dates, nutrient and weed management. *International Journal of Bio-Resource and Stress Management*, **4**(4): 523-528.

Mahajan, G., and Chauhan B. S. 2015. Weed control in dry direct-seeded rice using tank mixtures of herbicides in South Asia. *Crop Protection*, **72**: 90-96.

Mahajan, G., Chauhan, B. S. and Gill, M.S. 2013. Dry-seeded rice culture in Punjab State of India; lession learned from farmers. *Field Crops Research*, **144**: 89-99.

Mahajan, G., Chauhan, B. S., and Johnson, D. E. 2009. Weed management in aerobic rice innorth western Indo-Gangetic Plains. *Journal of Crop Improvement*, **23**(4): 366-382.

Maity, S. K. and Mukherjee, P. K. 2008. Integrated weed management in dry direct-seeded rice (*Oryza sativa*). *Indian Journal of Agronomy*, **53**: 116-120.

Mangan, F., DeGregorio, R., Schonbeck, M., Herbert, S., Guillard, K., Hazzard, R., Sideman, E., and Litchfield, G., 1995. Cover cropping systems for Brassicas in the Northeastern United States: 2. Weed, insect, and slug incidence. *Journal of Sustainable Agriculture*, **5**: 15–37

Mann, R. A., Ahmed, S., Hassan, G. and Baloch, M. S. 2007. Weed management in direct seeded rice crop. *Pakistan Journal of Weed Sciences*, **13**(3-4): 219-226.

Mandal, D., Singh, D., Kumar, R., Kumar, A. and Kumar, V. 2011. Effect on production potential and economics of direct seeded rice, sowing dates and weed management techniques. *Indian Journal of Weed Science*, **43** (3&4): 139-144.

Mansoer, Z., D. W. Reeves, and C. W. Wood. 1997. Suitability of sunn hemp as an alternative late summer legume cover crop. *Soil Science Society of America Journal*, **61**: 246–253.

Mishra, J. S., and Singh, V. P. 2008. Integrated weed management in dry-seeded irrigated rice (*Oryza sativa*). *Indian Journal of Agronomy,* **53**(4): 299-305.

Mishra, M., and Mishra, A. 1997. Estimation of integrated pest management index in Jute-A new approach. *Indian Journal of Weed Science*, **29**(1&2): 39-42.

Moody K. 1982. *Weed control in dry seeded rice. In: Report of a workshop on cropping system research in Asia*. International rice Research Institute; Philippines.

Moonen, A. C. and Barberi, P. 2004. Size and composition of the weed seed bank after 7 years or different cover crop-maize management systems. *Weed Research,* **44**(3): 163-177.

Moorthy. B. T. S. and Saha, S. 2002. Evaluation of pre and post- emergence herbicides for their effects on weeds and Upland direct Seeded rice. *Indian Journal of Weed Science,* **34**(3&4): 197-200.

Mosjidis, J. A. and Wehtje, G. 2011. Weed control in sunnhemp and its ability to suppress weed growth. *Crop Protection,* **30**(l): 70-73

Musthafa, K. and Potty, N. N. 2001. Effect of *in situ* green manuring on weeds in rice seeds dibbled semi dry rice. *Journal of tropical Agriculture,* **39**: 172-174.

Nahar, L., Shultana, R., Bhuiyan, K. A., Baki, Md. Z. I., and Akter, R., 2018. Assessment of different crop residues and herbicide on weedcontrol efficiency in Transplanted Aman rice. *International Journal of Applied Research,* **3**(3): 7-13.

Naher, M. S. and Paul, A. K. 2017. Effect of integrated nutrient management on nutrient uptake and sustainable grain yield in transplanted aman rice. *SAARC Journal of Agriculture,* **15**(1): 43-55.

Naresh, R. K., Gupta, R.K., Singh, R. V., Singh, D., Singh, B., Prakesh, S., Misra, A. K., Rathi, R. C. and Shan, S. 2011. Promotion of integrated weed management for direct- seeded rice in north west India. *Progressive Agriculture*, **11**(2): 215 -232.

Narolia, R. S., Singh, P., Prakash, C. and Meena, H. 2014. Effect of irrigation schedule and weed-management practices on productivity and profitability of direct-seeded rice (*Oryza sativa*) in South-eastern Rajasthan. *Indian Journal of Agronomy,* **59**(3): 398-403.

Nath, C. P., Saha, M., Pandey, P. C., Das, T. K., Meena, R. K. and Paul, T. 2014. Bioefficacy evaluation of different herbicides on weed population, *grain* yield and nutrient uptake *in* direct seeded puddled rice *(Oryza sativa* L.). *Annals of Agricultural Reasearch*, **35**(2): 217-223.

Ngouajio, M., M. E., McGiffen, Jr., and C. M., Hutchinson. 2003. Effect of cover crop and management system on weed populations in lettuce. *Crop Protection*, **22**: 57–64.

Nichiporovich, A. A. 1967. Aims of research on photosynthesis of plants as a factor of soil productivity. In: Nichiporovich A. A. (Ed.) Photosynthesis of productive system, *Israel Programme Science Trans Jerusalem* pp 3-36.

Odhiambo, J. J. O., Ogola, J. B. O., and Madzivhandila, T. 2010. Effect of green manure legume – maize rotation on maize grain yield and weed infestation levels. *African Journal of Agriculture Research*, **5**(8): 618-625.

Olsen, S. R., Sole, C.V., Wantnabe, F.S. and Dean, L. A. 1954. Estimation of available phosphorous in soils by extraction with sodium bicarbonate. *USDA Circulation*, 1939: pp 1-19.

Onyango, C., Oduwo, A., Okoko N., Kidula, N., Mureithi, J. G. 2000. Green manuring to improve soil fertility and reduce weed infestation in smallholder farms in South Nyanza, Kenya. In Mureithi JG, Gachene CKK, Muyekho FN, Onyango M, Mose K, Magenya O (eds) Participatory technology Development for Soil Management by Smallholder in Kenya. Proceeding of the 2nd Scientific Conference of the Soil Management and Legume Research network projects. Mombasa, Kenya, pp. 97-102.

Pandey, S., and Velasco, L. 2005. Trends in crop establishment methods in Asia and research in "Rice Is Life: Scientific Perspective for the 21st Century" (K. Toriyama, K. L. Heong, and B. Hardy, Eds), pp. 178-181. International Rice Research Institute, Los Banos, Phillippines and Japan International Research Centre for Agricultural Sciences Tsukuba, Japan.

Pantone, D. J.and Baker, J. B. 1991.Weedcrop competition models and response surface analysis of red rice competition in cultivated rice: A review. *Crop Science*, **31**:1105-1110.

Panse, V. G. and Sukhamate, P. V. 1967. Statistical method for agricultural workers, 3rd ed., ICAR, New Delhi

Pant, R. and H. M., Fales. 1974. Occurrence of a new amino acid in *Crotalaria* seeds. *Phytochemistry*, **13**: 1626–1627

Pilbeam, D. J. and A. E. Bell. 1979. A reappraisal of the free amino acids in seeds of *Crotalaria juncea* (Leguminosae). *Phytochemistry*, **18**: 320–321.

Piper, C. S. 1966. *Soil and Plant Analysis* (Asian edition), pp 120. Hans Publishers, Bombay.

Pooniya, V. and Shivay, Y. 2011. Effect of green manuring and zinc fertilization on productivity and nutrient uptake in Basmathi rice *(Oryza sativa)-wheat (Triticum aestivum)* cropping system. *Indian Journal of Agronomy*, **56**(1): 28-34.

Prathibhasree, S., Veera Radhavaiah, R., Subbaiah, G.. Ashoka Rani, Y and Sreenivasa Rao, V. 2016. Growth, yield attributes, yield and nutrient uptake of rice as influenced by organic manures and zinc supplementation at different nitrogen levels. *The Andhra Agricultural Journal,* **63**(1): 34-39.

Premalatha, B. R. 2017. Use of leaf colour chart for nitrogen management as a tool in bridging the yield gap in rainfed rice *(Oryza sativa* L.) production. *Advance research Journa of Crop Improvement*, **8**(1): 36-44.

Putnam, A. R. and De Frank, J. 1983. Use or Phytotoxic plant residues for selective weed control. *Crop Protection* **2**: 173-81.

Radford, P. J. 1967. Growth analysis formulae- their use and abuse. *Crop Science*, **7**: 171-175.

Rahman, M., Juraimi, A. S., Suria, J. A. S. M., Man, A. B. and Anwar, P. 2011. Response of weed flora to different herbicides in aerobic rice system. *Scientific Research and Essays*, **7**(1): 12-23.

Rana, S.S. and Angiras, N.N. 1999. Influence of integrated weed management practices on weed competition for nutrients in puddle sown rice. *Indian Journal of Weed Science.*, **31**(3&4): 161-163.

Raju, R. A., and Reddy, M. N. 1999. Green manuring for sustainable rice *(Oryz:a sativa* L.) productivity in rice-rice system. *Journal of Farming Systems Research and Development*, **5**(1-2): 27-31.

Rao, A. N., Johnson, D. E., Sivaprasad, H., Ladha, J. K. and Mortimerr, A. M. 2007. Weed management in direct seeded rice. *Advances in Agronom.* **93**: 153-255.

Rawat, A., Chaudhary, C. S., Upadhyaya, V. B., and Jain, V. 2012. Efficacy of bispyribac-sodium on weed flora and yield of drilled rice. *Indian Journal of Weed Science*. **44**(3) 183-185.

Sanodiya, P., and Singh, M. K. 2018. Effect of live mulches, cover crops and herbicides on weed flora, Growth and yield of direct-seeded rice (*Oryza sativa*). *Indian Society of Agronomy*. **63**(1): 60-66.

Schomberg, H. H., Martini N., Diaz-Perez, J. C., Phatak S. C., Balkcom, K. S. and Bhardwaj, H. L. 2007. Potential for using Sunnhemp as a source of biomass and nitrogen for the Piedmont and Coastal Plain regions of the south-eastern USA. *Agronomy Journal*, **99**(6): 1448-1457.

Shah, Z., Rashid Ahmad, S., Hidavat, U and Rahaman, R 2011. Sustaining rice- wheat system through management of legumes effect of green manure legumes on rice yield and soil quality. *Pakistan Journal of Botany*, **43**(3):1569- 1574.

Sharif, A. and Chauhan, B. S. 2014. Performance of Different Herbicides in Dry Seeded Rice in Bangladesh. *The Scientific World Journal*, Article ID 729418, 14 pages.

Sharma, S. N. and Prasad, R. 1999. Effect or *Sesbania* green-manuring and rnungbean residue incorporation on productivity and nitrogen uptake of a rice-wheat cropping system. *Bioresource Technology*, **87**: 171-175.

Sindhu, P. V., Thomas, C. G. and Abraham, C. T. 2010. Seed bed manipulations for weed management in wet seeded rice. *Indian Journal of Weed Science,* **42** (3&4): 173-179.

Singh, M. and Singh R, P. 2010. Efficacy of herbicides under different methods of direct-seeded rice (*Oryza sativa*) establishments. *Indian Journal of Agricultural Sciences*, **80**(9): 815-819

Singh, V., Jat, M. L., Ganine, Z. A., Chauhan, B. S. and Gupta, R. K. 2016. Herbicide options for effective weed management in dry direct seeded rice under scented rice-wheat rotation of western Indo Gangetic Plains. *Crop Protection,* **81**: 168-76.

Singh, A. K., Singh, R. K., Kumar P., and Singh, S., 2013. Growth weed control and yield of direct-seeded rice as influenced by different herbicides. *Indian Journal of Weed Science*, **45**(4)**:** 235-238.

Singh, R., Pal, R., Singh, T., Singh A. P., Yadaw, S. and Singh. J. 2014. Management of weeds in direct-seeded rice by bispyribac-sodium. *Indian Journal of Weed Science,* **46**(2): 126-128.

Singh, S., Bhushan, L., Ladha, J. K., Gupta, R. K., Rao, A. N., and Sivaprasad, B. 2006. Weed management in dry seeded rice cultivated on furrow irrigated raised bed planting system. *Crop Protection*, **25**: 487-495.

Singh, S., Chhokar, R. S., and Gopal, R. 2009. *Integrated weed management: A key to success for direct-seeded rice in the Indo- Gangetic Plains*. In: JK Ladha, *et al*. editors. Integrated Crop and Resource Management in the Rice-Wheat System of South Asia, Los Banos, Philippines: *International Rice Research Institute*: 261–278.

Singh, S., Ladha, J, K., Gupta, R. K., Bhushan. L., Rao, A. N., Sivaprasad, B. and Singh, P. P. 2007. Evalution of mulching, intercropping with *Sesbania* and herbicide use for weed management in dry-seeded rice. *Crop Protection*, **26**: 518-524.

Singh. K. and Tripathi, H. P. 2007. Effect of nitrogen and weed-control practices oe performance of irrigated direct seeded rice *(Oryza sativa). Indian Journal of Agronomy*, **52**(3): 231-234.

Singh, R. K., Sharma, S. N., Singh, R. and Padey, M. D. 2002. Efficacy of methods of planting and weed control measures on nutrient removal by rice (*Oryza sativa* L.) and associated weeds. Crop Research **24**(3): 425.429.

Singh, M. and Singh, R.P. 2010. Influence of crop establishment and and weed management practices on yield and economics of direct seeded rice *(Oryza sativa* L.*). Indian Journal of Agronomy,* **55** (3): 224-229.

Singh, M. K. 2014. Competitiveness of rice cultivars under stale seed bed in dry direct seeded rice. *Indian Journal of Weed Sciences*, **45**(3): 171-174.

Singh, N.K., Singh, U.P., Sutaliya, J.M., Parihar, C.M. and Jat, S.L. 2012. Performance of direct seeded rice under different integrated and weed management and crop establishment practices in Indo-gangetic plains of India 3rd International Agronomy Congresson Agriculture Diversification, Climate Change Management and Livelihoods held at New Delhi, on November 26-30.

Singh, R., Pal, R., Singh, T., Singh, A.P., Yadav, S. and Singh, J. 2014. Management of weeds in direct-seeded rice by bispyribac-sodium. *Indian Journal Of Weed Science*, **46**(2). 126-128.

Singh, A., Singh, R. K., Kumar, P. and Sumita, S. 2014a.Growth, weed control and yield of direct-seeded rice as influenced by different herbicides. *Indian Journal of Weed Science*, **45**(4):235-238.

Smith, R. J. 1988. Weed thresholds in Southern U.S. rice, *Oryza sativa. Weed Technology* **2**:232-41.

Subbiah, B. V. and Asija, G. L. 1956. A rapid procedure for estimation of available nitrogen in soil. *Current Sciences*, **25**: 259-260.

Suria, A. S. M. J., Juraimi, A. S., Rahman, M. M., Man, A. B. and Selamat, A. 2011. Efficacy and economics of different herbicides in aerobic rice system. African Journal of Biotechnology, **10**(41): 8007-8022.

Teasdale, J. R., and Daughtry, C. S. R. 1993. Weed suppression by live and desiccated hairy vetch *(Vicia villosa). Weed Science*, **41**(2): 207-212.

Tomita, S., Nawata, E., Kano, Y., Nagata, Y., Noichana, C., Sributta, A. and Inamura, T. 2003. Differences in weed vegetation in response to cultivating methods and water conditions in rainfed paddy fields in northeast Thailand. *Weed Biology Management,* **3**: 117-127.

Tripathi, R. P., Sharma, P., and Singh, S. 2005. Tillage index: An approach to optimize tillage in rice-wheat system. *Soil Tillage Research*, **80**: 125-137.

Ullah, R., Aslam, Z., Khaliq, A., Zahir, Z., 2018, Sunflower residue incorporation suppresses weeds, enhances soil properties and seed yield of spring-planted mung bean. *Planta Daninha,* **36**: 1-14.

Unamma, R. P. A., L. S. O. Ene, S. O. Odurukwe, and T. Enyinnia. 1986. Integrated weed management for cassava intercropped with maize. *Weed Research,* **26**: 9–17.

Upsani, R. R. and Barla, S. 2014. Weed control methods in direct seeded rice uder medium land condition. *Journal of Crop and Weed*, **10**(2): 445-450

Valverde, B. E. 2005. The damage by weedy rice: Can feral rice remain undetected In *"Crop Ferality and Volunteerism"* (J B Gressel, Ed). pp 279-94 CRC Press, Boca Raton. FL, USA.

Walkey, A. and Black, I. A.1934. An examination of the detgaulf method of determining soil organic matter and proposed modification of chronic and titration methods. *Soil Science* **37**:29-30.

Walia, U. S., Singh, O., Nayyar, S. and Sindhu, V. 2008. Performance of post-emergence application of bicpyribac in dry-seeded rice. *Indian Journal of Weed Science,* **40*(***3-4): 157-160

Walia, U. S., Bhullar, M. S., Nayyar, Shelly and Walia, S. S. 2008. Control of complex weed flora of dry-seeded rice (*Oryza sativa* L.) with pre- and post-emergence herbicides. *Indian Journal of Weed Science*, **40**(3&4): 161- 164.

Walia, U. S., Singh, O., Nayyar, S. and Sindhu. V. 2008. Performance of post- emergence application of bispyribac in dry-seeded rice. *Indian Journal of Weed* Science, **40**: 157-160.

Walia, U.S., Gill, G., Walia, S.S. and Sindhu, A.S. 2012. Production of direct seeded rice (*Oryza sativa* L.*)* under differential planting densities and herbicides in central plains of Punjab*. Journal of Crop and Weed Science,* **7**(2): 1-5.

Walia, U. S., Walia, S. S., Sindhu, A. S. and Nayyar, S. 2012. Bioefficacy pre and post-emergence herbicides in direct seeded rice in Central Punjab. *Indian Journal of Weed Science.* **44**(1): 30-33.

Wang, K. H., Mc Sorley, R. and kokakus, Burelle, R. N. 2008. Cover crops and organic mulches for nematode, weed, and plant health management. *Nematology* **10**: 211-242.

Wang, K. H., Mc Sorley, R., A. J. Marshall and Gallaher, R. N. 2004. Nematode community changes following decomposition or *Crotalaria juncea* amendment in littebags. *Applied Soil Ecology***, 27**: 31-45**.**

Wang, Y. S., Law, F. H. Wong, Y. C. and Chen, Y. L. 1993. Effects of paraquat on soil properties and on the growth of rice and corn seedlings. *Life Science***, 17** (3): 116-121.

Wilson, M. F. and A. E. Bell. 1979. Amino acids and related compounds as inhibitors of lettuce growth. *Phytochemistry*, **18**: 1883–1884.

Weir, T. L., Park, S. and Vivanco, J. M. 2004. Biochemical and physiological mechanisms mediated by allelochemicals. *Plant Biology*, **7**: 472-479.

Yadav, D.B., Kamboj, B.R Yadav,A., Malik.R.K. and Gill, G. 2011. Optimization or ground cover by green manure cover crops before no-till direct seeded and mechanically transplanted rice in rice-wheat system. *Enviromenrt and Ecology,* **29**(4): 1755—1759.

Yadav, D. B., Yadav, A. and Punia, S. S. 2014. Evaluation of bispyribac-sodium for weed control in transplanted rice. *Indian Journal of Weed Science,* **41**(1&2): 23-27.

Yadav, D. B., Yadav, A., Malik, R, K. and GiIl, G. 2007. Efficacacy of penoxsulam and azimusulfuron for post emergence weed control in direct seeded rice. *Weed Science* held at CCS HAU, Hisar, 2-3 Novemher, 92.

Yaduraju, N. T. and Mishra, J. S. 2005. Sedges in rice culture and their management In *“Direct Seeding or Rice and Weed Management in the Irri gated Rice- Wheat Cropping System of the IndoGangetic Plains"* Singh, Y., Singh, G., Singh, V. P., Singh, P., Hardy, B., Johnson, D. E. Mortimer, M. (Eds) Directorate of Experiment Station, G B Pant University of Agriculture and Technology, Pantnagar, India.

Yadvinder, S., Bijay,S., and Khind, C. S. 1992. Nutrient transformations in soil amended with green manures. *Advances of Soil Sciences,* **20:** 217-229.

APPENDIX

Appendix -I

Standard Meteorological Weekly data of Agrometeorology Observatory for the Year 2019

Week (1)	Date & month (2)	Rainfall (mm) (3)	Rainy days (4)	RH Max. (5)	RH Min. (6)	Max Temp (^{0}C) (7)	Min Temp (^{0}C) (8)
24	11-17 Jun	11.6	1	51	29	41.1	23.7
25	18-24	8.8	2	53	38	36.7	23.9
26	25-1 July	3.8	1	52	21	41.7	25.4
27	2-8	13.2	1	67	47	38.9	**27.5**
28	9-15	94.8	4	88	63	32.9	25.2
29	16-22	1.2	0	79	60	34.4	26.3
30	23-29	170.6	5	90	73	32.3	26.1
31	30-5 Aug	50.2	2	86	68	32.7	26.2
32	6-12	23.0	2	87	70	34.1	27.2
33	13-19	131.1	4	86	68	32.7	26.2
34	20-26	9.4	1	84	58	34.6	25.8
35	27-2 Sep	2.0	0	88	61	35.2	26.7
36	3-9	9.0	2	85	62	34.6	25.6
37	10-16	3.0	1	87	63	35.0	25.9
38	17-23	62.8	2	89	61	32.2	23.0
39	24-30	93.4	2	93	76	29.7	23.1
40	1-7 Oct	21.4	2	89	65	28.8	18.8
41	8-14	0.0	0	86	52	30.5	18.6
42	15-21	9.2	1	87	52	29.2	17.3
43	22-28	0.0	0	85	44	29.3	14.5
44	29-4 Nov	0.0	0	90	52	28.0	15.8
45	5-11	51.8	2	83	52	25.4	13.0

Appendix-II

Fixed cost of cultivation in Riceduring *Kharif*2019

S. No.	Input	Quantity/ha	Unit	Rate (Rs./unit)	Total cost (Rs./ha)
1.	Land preparation	20	Kanal (500 m^2)	250	5,000.00
2.	Pre sowing Irrigation	1	Man days	325	325
3.	Seed				
	Basmati-370	40	kg	40	1600.00
4.	Sowing	1	ha	1500	1500.00
5.	Irrigation (nine irrigations)	2	Man days	325	5850
6.	Fertilizer				
	Urea	48	kg	6.40	307.20
	DAP	44	kg	24.00	1056
	MOP	17	kg	16.00	272
7.	Fertilizer application (1^{st}& 2^{nd} top dressing)	2	Man days	325	1300.00
8.	Plant protections (Tilt)	1	Liter	1400/liter	1400
9.	Fungicide application (Tilt)	2	Man days	325	650
10.	Harvesting and threshing	20	Man days	325	6500.00
11.	Miscellaneous	-	-	-	1000.00
12.	Total Fixed cost	-	-	-	26,760.20

Appendix-III

Variable cost for green manuring and stale seed bed

Green manure crop/stale seed bed	Input	Quantity/ha	Unit	Rate (Rs./unit)	Total cost (Rs./ha)
Cowpea	Seed	40	kg	80	3200.00
	Sowing	1	Mandays	325	325
	Irrigation	2	Mandays	325	650
	Incorporation	1	ha	2000	2000
				Total	**6175**
Dhaincha	Seed	60	kg	60	3600.00
	Sowing	1	Mandays	325	325
	Irrigation	2	Mandays	325	650
	Incorporation	1	ha	2000	2000
				Total	**6575**
Sunnhemp	Seed	50	kg	100	5000.00
	Sowing	1	Mandays	325	325
	Irrigation	2	Mandays	325	650
	Incorporation	1	ha	2000	2000
				Total	**7975**
Stale Seed bed	Weed Incorporation	1	ha	2000	**2000**

Appendix-IV

Herbicidal treatment wise variable cost of cultivation (Rs/ha)

Treatment details		**Particulars**		**Rate (Rs./unit)**	**Total (Rs./ha)**
		Product quantity	**Unit**		
Pendimethalin 1 kg/ha as pre-emergence	Pendimethalin	3.33	Liter	450/liter	1498.5
	Herbicide application	02	Mandays	325	650.00
	Total				2148.5
Bispyribac-sodium 25 g/ha at 25 Days after sowing	Bispyribac-sodium	250	ml	800/100 ml	2000
	Herbicide application	02	Mandays	325	650.00
	Total				2650.00
Pendimethalin 1 kg/ha as pre-emergence *fb*bispyribac-sodium 25 g/ha at 25 Days after sowing	Pendimethalin	3.33	Liter	450/liter	1498.5
	Bispyribac-sodium	250	ml	800/100 ml	2000
	Herbicide application	04	Mandays	325	1300.00
	Total				4798.5
Weedy check	-	-	-	-	0.00

Appendix-V

Treatment wise cost of cultivation (Rs./ha)

Treatment details	Fixed cost (Rs./ha)	Variable cost (Rs./ha)		Total cost (Rs./ha)
		Green manuring	Herbicide	
Cowpea				
Pendimethalin 1 kg/ha as pre-emergence	26,760.20	6175	2148.5	35,083.70
Bispyribac-sodium 25 g/ha at 25 Days after sowing	26,760.20	6175	2650.00	35,585.20
Pendimethalin 1 kg/ha as pre-emergence *fb* bispyribac-sodium 25 g/ha at 25 Days after sowing	26,760.20	6175	4798.5	37,733.70
Weedy check	26,760.20	6175	0.00	32,935.20
Dhaincha				
Pendimethalin 1 kg/ha as pre-emergence	26,760.20	6575	2148.5	35,483.70
Bispyribac-sodium 25 g/ha at 25 Days after sowing	26,760.20	6575	2650.00	35,985.20
Pendimethalin 1 kg/ha as pre-emergence *fb* bispyribac-sodium 25 g/ha at 25 Days after sowing	26,760.20	6575	4798.5	38,133.70
Weedy check	26,760.20	6575	0.00	33,335.20
Sunnhemp				
Pendimethalin 1 kg/ha as pre-emergence	26,760.20	7975	2148.5	36,883.70

Bispyribac-sodium 25 g/ha at 25 Days after sowing	26,760.20	7975	2650.00	37,385.20
Pendimethalin 1 kg/ha as pre-emergence *fb* bispyribac-sodium 25 g/ha at 25 Days after sowing	26,760.20	7975	4798.5	39,533.70
Weedy check	26,760.20	7975	0.00	34,735.20
Stale Seed Bed				
Pendimethalin 1 kg/ha as pre-emergence	26,760.20	2000	2148.5	30,908.70
Bispyribac-sodium 25 g/ha at 25 Days after sowing	26,760.20	2000	2650.00	31,410.20
Pendimethalin 1 kg/ha as pre-emergence *fb* bispyribac-sodium 25 g/ha at 25 Days after sowing	26,760.20	2000	4798.5	33,558.70
Weedy check	26,760.20	2000	0.00	28,760.20

Appendix – VI

Total cost of cultivation

Treatments	Cost of Cultivation (Rs/ha)
Green manure	
Cowpea	35334.45
Dhaincha	35734.45
Sunnhemp	37134.45
Stale Seedbed	31159.45
Herbicides	
Pendimethalin 1 kg/ha as PE	34589.95
Bispyribac-sodium 25 g/ha at 25 DAS	35091.45
Pendimethalin 1 kg/ha as PE *fb* bispyribac-sodium 25 g/ha at 25 DAS	37239.95
Weedy check	32441.45

Sale price of produce

Variety	Grain (Rs./q)	Straw (Rs./q)
Basmati-370	3810	250

Appendix – VII

Dry biomass of different green manuring crops incorporated in soil before sowing

Green manure crops	kg/ha
Cowpea	3250
Sunnhemp	7920
Dhaincha	6100

Appendix – VIII

Effect of different green manuring and herbicide practices on nutrient concentration (%) in grain and straw

Treatments	Grain			Straw		
	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)
Green manure						
Cowpea	1.99	0.39	0.56	0.73	0.20	1.58
Sunnhemp	2.38	0.40	0.66	0.81	0.21	1.63
Dhaincha	2.33	0.40	0.63	0.77	0.20	1.61
Stale seedbed	1.86	0.38	0.60	0.79	0.21	1.60
Herbicides						
Pendimethalin 1 kg/ha as Pre emergence	2.09	0.42	0.65	0.81	0.20	1.63
Bispyribac-sodium 25 g/ha at 25 DAS	2.16	0.43	0.64	0.83	0.23	1.66
Pendimethalin 1 kg/ha as Pre emergence *fb* bispyribac-sodium 25 g/ha at 25 DAS	2.23	0.44	0.65	0.84	0.24	1.75
Weedy check	2.09	0.29	0.51	0.62	0.15	1.38

Appendix – IX

Effect of different green manuring and herbicide practices on nutrient concentration (%) in weeds at harvest

Treatments	**Nutrient concentration (%)**		
	N (%)	P (%)	K (%)
Green manure			
Cowpea	1.35	0.57	2.05
Sunnhemp	1.26	0.60	1.96
Dhaincha	1.32	0.60	1.98
Stale seedbed	1.40	0.63	2.11
Herbicides			
Pendimethalin 1 kg/ha as Pre emergence	1.23	0.50	1.98
Bispyribac-sodium 25 g/ha at 25 DAS	1.50	0.71	2.17
Pendimethalin 1 kg/ha as Pre emergence *fb* bispyribac-sodium 25 g/ha at 25 DAS	1.53	0.69	2.21
Weedy check	1.06	0.48	1.83

VITA

VITA

Name of the student	:	Shubham Jamwal
Fathers name	:	Sh. Dilbag Singh
Mothers name	:	Smt. Urmila Devi
Date of Birth	:	25-09-1996
Nationality	:	Indian
Permanent home address	:	VPO - Ser, Teh. - Jhandutta, Distt. – Bilaspur, Himachal Pradesh. Pin-174031

Educational Qualifications

Bachelors Degree	:	B.Sc. Agriculture
Percentage	:	80.22%
University	:	HNBGU, Srinagar Garhwal, Uttrakhand
Master's Degree	:	M. Sc. (Agronomy) Agriculture
OGPA	:	7.63/10
University	:	SKUAST-Jammu
Title of Master's thesis	:	**"Effect of Green Manuring and Herbicides on Weed Dynamics and Yield of Direct Seeded Rice"**

CERTIFICATE – IV

Certified that all the necessary corrections as suggested by the external examiners and the Advisory committee have been duly incorporated in the thesis entitled **"Effect of Green Manuring and Herbicides on Weed Dynamics and Yield of Direct Seeded Rice"** submitted by **Mr. Shubham Jamwal**, Registration No. **J-18-M-543**.

Dr. Ramphool Puniya
Junior Scientist (Agronomy)
AICRP-Weed Management
Major Advisor & Chairman Advisory Committee

Place: Jammu
Date: 04-12-2020

Head
Division of Agronomy