WEED MANAGEMENT FOR UPLAND RICE

BASILA Y.

(2018-11-027)

DEPARTMENT OF AGRONOMY

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR - 680 656

KERALA, INDIA

2020

WEED MANAGEMENT FOR UPLAND RICE

By

BASILA Y.

(2018-11-027)

THESIS

Submitted in partial fulfilment of the requirement for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF AGRONOMY

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR - 680 656

KERALA, INDIA

2020

DECLARATION

I, hereby declare that this thesis entitled **"WEED MANAGEMENT FOR UPLAND RICE"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Place: Vellanikkara

Date: 04/11/2020

Basila Y.

(2018-11-027)

CERTIFICATE

Certified that this thesis entitled **"WEED MANAGEMENT FOR UPLAND RICE"** is a record of research work done independently by Ms. Basila Y. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Place: Vellanikkara

Date: 04/11/2020

Dr. Anitha S.

(Major Advisor, Advisory Committee)

Professor and Head

Instructional Farm, Vellanikkara

CERTIFICATE

We, the undersigned members of the advisory committee of Ms. Basila Y., a candidate for the degree of **Master of Science in Agriculture** with major in Agronomy, agree that the thesis entitled **"WEED MANAGEMENT FOR UPLAND RICE"** may be submitted by Ms. Basila Y., in partial fulfilment of the requirement for the degree.

Dr. Anitha S.
(Chairman, Advisory Committee)
Professor and Head
Instructional Farm, Vellanikkara

Dr. Meera V. Menon
(Member, Advisory Committee)
Professor and Head (Agronomy)
College of Horticulture, Vellanikkara

Dr. Beena V. I.
(Member, Advisory Committee)
Assistant Professor (SS & AC)
College of Horticulture, Vellanikkara

Dr. Sreelakshmi K.
(Member, Advisory Committee)
Assistant Professor (Agronomy)
KVK, Palakkad

Acknowledgement

First of all I am grateful to The Almighty God Allah for successful completion of my research work.

I wish to express my sincere gratitude to my Major Advisor ***Dr. Anitha S.*** *Professor and Head, Instructional Farm, Vellanikkara, for her patience, guidance and encouragement throughout my filed work and preparation of thesis.*

I wish to express my deepest gratitude ***Dr. Meera V. Menon,*** *Professor and Head, Department of Agronomy, College of Horticulture, Vellanikkara and member of Advisory Committee for timely help and suggestions throughout my research work and course of study.*

I extend my sincere gratitude to ***Dr. C. George Thomas, Dr. P. Prameela*** *and* ***Dr. P. V. Sindhu,*** *Department of Agronomy for providing me with all necessary facilities and also for guidance and encouragement throughout my research work and course of study.*

I wish to show my gratitude to ***Dr. Beena V. I,*** *Assistant Professor (Soil Science and Agricultural Chemistry), College of Horticulture, Vellanikkara and member of Advisory Committee for the help and advice during my research work.*

My deep and sincere gratitude to ***Dr. Sreelakshmi K.*** *Assistant Professor (Agronomy) College of Horticulture, Vellanikkara and member of Advisory Committee for support, suggestions and timely help throughout the research work and course of study.*

I am greatly thankful to ***Dr. Syama S. Menon*** *and* ***Dr. Savitha Antony*** *Department of Agronomy, College of Horticulture, Vellanikkara for their support and kind guidance during the research work and course of study.*

I wish to express my sincere thanks to ***Mrs. Sreela*** *and* ***Mrs. Shyamala*** *of Agronomy Department, College of Horticulture, Vellanikkara for their sincere help and kind guidance throughout my laboratory analysis.*

I would like to express my sincere gratitude to all male and female labourers of Agronomy Farm, Vellanikkara for their immense help, support and assistance throughout my field work.

My sincere thanks to Jeena Mary, Anjali and Ajmal Fayique for their patience, timely help and kind cooperation.

I would like to thank my dearest friend, Minu Mariya Issac for her sincere support and help throughout my filed work and laboratory analysis and also during the course of my study.

I would like to thank my fellow classmates Mounisha J., Liz J Kappen, Th. Nengaparmoi and Somanatham Suhas for their help and support during the course of my study.

My deep and sincere gratitude to my seniors Durga C, Akhila C Thampi, Daly George,Thummu Venkateswara Reddy, Saravana Kumar, Sobha Rani, Vandana G. Pai, Arya,Vidhu Priyadarsini and all my other seniors and juniors from the Department of Agronomy for their support, help and kind guidance throughout my field work and laboratory analysis.

My special thanks to Mr. Sijith and Ms. Athira, Farm Officers. Agronomy Farm, Vellanikkara for their timely help and kind cooperation during my filed work.

I must express my sincere and deep gratitude to my parents, grandparents, uncles, aunts, cousins and my friends for their love, prayers, support and continuous encouragement for successful completion of my thesis.

Finally I wish to thank all who, directly or indirectly helped me for the completion of this thesis.

BASILA Y.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDIX

LIST OF ABBREVIATIONS

a.i	: active ingredient
@	: at the rate of
B:C	: Benefit Cost ratio
BSS	: Bright sunshine hours
BLWs	: Broad leaf weeds
cm	: centi metre
CGR	: Crop growth rate
DAS	: Days after sowing
DAT	: Days after transplanting
dS/m	: Deci Siemens per metre
EC	: Electrical Conductivity
EC	: Emulsifiable Concentration
et al	: and others
fb	: followed by
Fig	: Figure
g	: gram
HW	: Hand weeding
IRRI	: International Rice Research Institute
i.e	: that is
K	: Potassium
kg	: kilo gram

L	: Litre
LAI	: Leaf area index
m	: metre
m^2	: metre square
mm	: milli metre
mha	: million hectare
MSL	: Mean Sea Level
N	: Nitrogen
P	: Phosphorus
RBD	: Randomized Block Design
RGR	: Relative growth rate
SC	: Soluble Concentrate
SMBC	: Soil microbial biomass carbon
t/ha	: tonnes per hectare
WCE	: Weed Control Efficiency
WI	: Weed Index
WP	: Wettable Powder
°C	: Degree Celsius
%	: Percent

Introduction

1. INTRODUCTION

Rice (*Oryza sativa* L.) is an important staple food crop in India. Area under rice cultivation in India is about 38.42 mha with a production of 116.42 million tonnes and productivity of 3.03 t/ha (Indiastat, 2018-19). Rice can be grown in both wetland and upland conditions. In wetland, crop will be under flooded condition *i.e.*, there will be standing water throughout the crop growth period. Upland condition is poorly rainfed and there is no standing water during the entire crop stage. Major area of rice is under wetland condition, but nowadays farmers are shifting from wetland rice cultivation to direct seeded upland rice due to severe water scarcity, shortage of labourers and high labour cost. Upland rice is defined as rice which is grown in rainfed naturally well-drained soils of unbunded fields without surface water accumulation (IRRI, Philippines). In India area under upland rice cultivation is about 6.0 mha which is 13.5 % of total area under rice.

Rice is one of the most important food crops in Kerala and is cultivated mainly in three seasons *viz*., *Virippu*, *Mundakan* and *Puncha*. Area under rice in Kerala is 1.94 lakh hectares with a production of 5.21 lakh tonnes and an average productivity of 2.75 t/ha (Indiastat, 2018-19). In Kerala upland rice cultivation is known as *Modan* cultivation and crop is raised during *Virippu* season. Water requirement of rice is high, nearly 1200 mm, and 30 % of total water requirement is mainly for puddling and transplanting. Transplanting alone requires 240-250 man hours per hectare which increases the cost of production (Raj and Syriac, 2017). Hence upland rice cultivation is a better option to save water and labour. Chakraborti *et al*. (2017) found that there was a reduction of human labour to 45 % and tractor use to 55 % in upland rice.

Upland rice cultivation has many advantages, but the productivity of upland rice is very low as compared to wetland rice and is less than 1 t/ha. Moisture stress, weed infestation, poor soil fertility and incidence of pest and diseases are major problems associated with upland rice cultivation. Among these, weeds are considered to be the most serious problem as it causes reduction in yield and quality of produce. Low productivity of upland rice is due to severe weed infestation as aerobic soil conditions favours the weed growth (Kumar and Rana, 2013). Arunbabu and Jena (2018) reported loss of 94-97 % grain yield in upland rice due to weeds. Ramachandiran *et al.* (2013) reported that farmers in Asia were investing 190 man days/ ha for two to three hand weedings in a season. Heavy infestation of weeds in upland rice is mainly due to emergence of both crops and weeds simultaneously due to the absence of standing water in the field and are very difficult to control.

Weeds are highly competitive for light, space, water and nutrients which cause tremendous yield reduction and increase the cost of production. In upland rice cultivation, entire crop growth period is considered as critical period of weed competition. Hand weeding is the mostly adopted method of weed management in rice and is highly tedious and labour intensive. Chemical method of weed management is most effective and economical. Success of upland rice production depends upon how effectively weeds are managed. Hence effective and timely management of weeds is essential to achieve maximum productivity in upland rice. The experiment entitled "Weed management for upland rice" was carried out with the following objectives

1. To study the effect of weeds on growth and yield of upland rice
2. To develop cost effective weed management strategy for upland rice

Review of literature

2. REVIEW OF LITERATURE

Upland rice is infested with various types of grasses, broad-leaf weeds and sedges. Weeds are the most serious biological constraint and heavy weed infestation in upland rice reduces the grain yield and quality of rice. Puddling, flooding and transplanting practices in lowland rice reduce the early weed germination and weed infestation. Aerobic soil condition and alternate wetting and drying in upland rice favour the emergence of weeds. Therefore an effective weed management is essential to enhance productivity of upland rice.

2.1. Dominant weed species in upland rice

Weeds are undesired plants in the cropland, which are highly competitive to crops and cause yield reduction. Weeds can be classified into grasses, broad-leaf weeds and sedges based on morphology, and as annual, biennial and perennial based on life cycle.

Mimosa invisa, Cyperus rotundus and *Imperata cylindrica* are the major weed species in upland rice, which are very difficult to control (De Datta, 1981). According to Nair (2003), *Echinochloa colona, Echinochloa crus-galli* and *Cynodon dactylon* were the predominant grassy weeds. An experiment conducted at Bhubaneswar showed that dominant weed species in upland rice were *Digitaria ciliaris, Cyperus rotundus, Eleusine indica, Cynodon dactylon, Echinochloa colona, Paspalum scrobiculatum*, *Oldenlandia corymbosa, Ludwigia parviflora*, *Ageratum conyzoides*, *Borreria hispida*, *Celosia argentea*, *Eclipta alba*, *Cleome viscosa* and *Commelina benghalensis* and also reported that weeds in upland rice are constituted by 67 % monocot and 33 % dicot weeds (Mishra *et al*., 2006).

According to Ladu and Singh (2006), *Digitaria sanguinalis*, *Eleusine indica*, *Panicum repens, Paspalum conjugatum*, *Setaria glauca*, *Ageratum conyzoides*, *Amaranthus viridis*, *Borreria hispida* and *Mimosa pudica* were the major weeds grown in upland rice in Nagaland. Ramana *et al*. (2007) observed that both monocot and dicot weeds cause serious problem in upland rice cultivation. Among monocot weeds, *Echinochloa colona* and *Cyperus rotundus* were predominant and among dicot weeds, *Celosia argentea* was predominant. Mishra *et al*. (2009) observed that major weed flora in upland rice were *Digitaria ciliaris, Cynodon dactylon, Echinochloa colona, Eleusine indica, Ageratum conyzoides, Cleome viscosa* and *Cyperus rotundus.*

Chakraborti *et al*. (2017) found that *Digitaria sanguinalis, Cyperus iria, Amaranthus viridis, Oldenlendia corymbosa, Spilanthes acmella, Ludwigia parviflora, Cleome rutidosperma* and *Malvestrum coromandalianeum* as predominant weed species in upland rice in Tripura. Majhi *et al*. (2011) reported that weeds in upland rice were constituted by 59.5 % sedges, 24.6 % broad-leaf weeds and 15.9 % grasses, when observation was taken at 40 DAS in weedy check. Among broad-leaf weeds, *Cleome rutidosperma* and *Commelina benghalensis* and among sedges, *Cyperus rotundus* and *Cyperus iria* were major weeds in upland rice. Ismaila *et al*. (2011) found that weeds of upland rice constituted 30 % broad-leaf weeds, 63 % grasses and 7 % sedges.

Singh *et al*. (2013) listed *Eclipta alba, Trianthema portulacastrum, Cynotis auxiliaries, Digera arvensis, Euphorbia hirta, Phyllanthus niruri, Amaranthus viridis, Echinochloa colona, Echinochloa crus-galli, Eleusine indica, Dactyloctenium aegyptium, Paspalam* spp., *Cynodon dactylon, Digitaria sanguinalis, Cyperus rotundus, Cyperus iria* and *Fimbristylis miliacea* as dominant weed species in rainfed upland rice.

Major weeds associated with upland rice were *Cynodon dactylon, Cyperus rotundus, Cyperus iria, Echinochloa crus-galli, Echinochloa colona, Fimbristylis dichotoma* and *Phyllanthus niruri* (Bhurer *et al*., 2013). According to Kumar and Rana (2013), *Echinochloa colona, Digitaria sanguinalis, Commelina benghalensis, Ageratum conyzoides* and *Cyperus iria* were the most dominant weed species found in upland rice.

A field experiment conducted at Kolhapur showed that predominant weed species associated with rainfed upland rice cultivation were *Echinochloa colona, Cyperus rotundus, Parthenium hysterophorous, Mimosa pudica, Echinochloa crus-galli, Cynodon dactylon, Amaranthus viridis, Commelina benghalensis, Brachiaria* *eruciformis* and *Eclipta alba* (Rajendra, 2014). Dadsena *et al*. (2014) reported that major weed flora were *Digitaria ciliaris, Cyperus esculentus, Cyperus rotundus, Oldenlandia corymbosa, Ludwigia parviflora* and *Ageratum conyzoides* in upland rice. Among these weed species *Digitaria ciliaris* and *Oldenlandia corymbosa* were dominant.

Mutumba and Odongo (2015) found that weed infestation was severe in upland rice than lowland rice due to the absence of stagnant water in the field. Among grasses, broad-leaf weeds and sedges, broad-leaf weeds were dominant in upland rice. Roy (2016) reported *Echinochloa colona, Cynodon dactylon, Dactyloctenium aegyptium, Digitaria ciliaris, Eleusine indica, Cyperus iria* and *Cyperus rotundus as* major monocot weeds and *Acanthosepermum hispidum, Amaranthus viridis, Ageratum conyzoides, Borreria hispidia, Celosia argentea, Cleome viscosa, Croton sparsiflorus, Eclipta alba, Ludwigia parviflora, Oldenlandia corymbosa, Phyllanthus niruri, Commelina benghalensis* and *Scoparia dulcis* as major dicot weeds in upland rice. Among monocot weeds *Dactyloctenium aegyptium, Echinochloa colona, Cyperus iria and Digitaria ciliaris* were the dominant and among dicot weeds *Oldenlandia corymbosa, Ludwigia parviflora* and *Ageratum conyzoides* were dominant.

Kolleh (2016) reported that weeds infesting in rainfed upland rice were *Panicum maximum, Echinochloa colona, Cynodon dactylon, Cyperus rotundus, Cyperus esculentus, Mimosa pudica, Amaranthus retroflexus, Launaea* spp., and *Commelina benghalensis*. *Cyperus rotundus, Digitaria marginata, Echinochloa colona, Borreria articularis, Spilanthes acmella, Commelina benghalensis, Ageratum conyzoides, Euphorbia geniculata* and *Euphorbia hirta* were observed as weeds associated with upland rice in Karnataka (Dhanapal *et al*., 2018).

Goswami *et al*. (2018) observed that upland rice constituted 47.40 % broad-leaf weeds, 27.22 % grasses and 25.38 % sedges and also reported that occurrence of broad-leaf weeds was more as compared to the grasses and sedges throughout the growth period of rice. Gogoi and Deka (2019) found that *Cyperus rotundus, Cyperus* *iria, Cynodon dactylon* and *Ageratum conyzoides* were major weed flora in upland rice.

2.2. Critical period of weed competition in upland rice

Weeds are one of the major constraints which leads to yield reduction in upland rice. Productivity of upland rice is very low as compared to wetland rice and is mainly due to the heavy infestation of weeds. Weeds are highly competitive to upland rice for water, nutrients, light and space which causes tremendous yield reduction.

Critical period of weed competition is referred as the shortest time span during the crop growth in which occurrence of weeds results in highest economic loss or the period in which weeding results in highest crop yield. Critical period of weed competition is one third of the crop duration for most of the crops. For transplanted rice it is 15-45 DAS, and for upland rice, entire period of crop duration is considered as critical (Reddy and Reddy, 1992). Weeding should be carried out during the critical period of weed competition to obtain highest economic return.

Sahai *et al.* (1983) revealed that critical period of weed competition in upland rice was 15-45 DAS and weeds emerged during this period, which resulted in less grain production. Singh *et al.* (1987) conducted an experiment to study the critical period of weed competition in upland rice and reported that high weed density was observed at 15-30 DAS. Weedy condition up to 15 DAS resulted in highest yield loss and weed free condition up to 45 DAS resulted in highest grain yield. Crop weed competition in upland rice was reduced by two manual weedings before 40 DAS (Singh, 2012). Anwar *et al.* (2012) in his experiment studied the critical period of weed competition in upland rice and they found that critical period of weed competition was up to 6 WAS.

In upland rice, both crop and weeds emerged together at same time and competed for growth factors, which reduced the crop yield (Ramachandiran *et al.*, 2013). Toure *et al.* (2013) reported that critical period of weed competition in upland rice was 14-42 DAS. Raj and Syriac (2017) observed that weed free condition during 14-21 DAS resulted in highest grain yield in direct seeded rice. In upland rice cultivation initial 30 days were considered as critical period of weed competition (Arunbabu and Jena, 2018).

2.3. Effect of weeds on growth and yield of upland rice

According to Ladu and Singh (2006), long weedy condition resulted in lesser crop dry weight in upland rice. Unweeded control resulted in lesser number of panicles/m², grains/panicle and 1000 grain weight (Mishra *et al*., 2009). Presence of weeds in aerobic rice resulted in lesser number of tillers/m² (Daniel *et al*., 2012). Weedy condition in aerobic rice cultivation resulted in lesser number of tillers/m² (Prasuna and Rammohan, 2015).

According to Dadsena *et al.* (2014), dry matter production of rice recorded at different stages and yield attributing characters were found very less in unweeded plot as compared to herbicide treatments and hand weeded control. Roy (2016) revealed that lowest plant height, LAI, CGR, RGR, effective tillers/m², number of grains per panicle and crop dry matter at different stages of crop growth was recorded by unweeded plot due to severe competition of weeds.

In upland rice, 67 % of yield reduction was due to weed infestation and it depends on the type of weeds, intensity of weed infestation and stage of occurrence of weeds (De Datta, 1981). Weed free condition upto harvest resulted in higher grain yield and observed that weed occurrence during initial 15 days doesn't have any negative effect on yield of upland rice. Weedy condition from 30-60 DAS resulted in lesser grain yield (Ladu and Singh, 2006).

Ismaila *et al*. (2011) found that presence of weeds such as *Cynodon dactylon* and *Digitaria* resulted in reduced grain yield. Yield reduction due to weeds was 50 % in rainfed upland rice (Ramachandiran *et al*., 2013). Kumar and Rana (2013) reported that infestation of weeds throughout the stage resulted in 48 % grain yield reduction in rainfed direct seeded rice. The plot having heavy infestation of weeds resulted in lesser grain yield of 408.60 kg/ha (Mutumba and Odongo, 2015). Chakraborti *et al*. (2017) claimed that hand weeding thrice at 15, 30 and 40 DAS resulted in highest grain yield and straw yield. Loss of grain yield in upland rice due to weeds was about 94-97 % (Arunbabu and Jena, 2018).

2.4. Weed management in upland rice

Weeds are serious problem, which leads to tremendous yield reduction in upland rice. Hence timely and effective weed management is essential to sustain higher productivity in upland rice. Hand weeding is one of the traditional and effective method of weed management in rice, but it is very time consuming and results in increased cost of production. Hand weeding is very effective against annual weeds.

Green manuring is the practice of *in situ* incorporation of green manure crops especially leguminous crops like daincha, sunnhemp, cowpea, black gram *etc.* before flowering. It enhances physical, chemical and biological properties of the soil and also helps to control weeds during initial stages of crop by suppressing the weed growth. Even though green manuring has advantages there are also disadvantages to main crop. Hasanuzzaman (2019) reported that practice of green manuring results in competition for space, nutrients and other resources. Practice of green manuring can compete for water, nutrient, space, time and labour (IRRI, 1988).

Brown manuring is the practice of growing green manure crops in standing rice crop and it is killed and incorporated in to the soil by applying herbicide before flowering for manuring. After application of herbicide, a green manure crop turn to brown colour due to loss of chlorophyll and is known as brown manuring. 2, 4-D is the most commonly used post emergent herbicide for brown manuring. It enriches the soil physical and chemical properties by adding organic matter and helps to conserve soil moisture. It can smother weeds and can be considered as an effective method of weed control.

Chemical method of weed management is highly economical and cost effective. Oxyfluorfen can act as both pre and post emergent herbicide, which belongs to the family diphenyl ether. Mode of action is by inhibiting protoporphyrinogen oxidase, which is essential for the synthesis of chlorophyll and it can control grassy weeds as well as broad-leaf weeds. Pyrazosulfuron-ethyl is a selective pre-emergent herbicide, belonging to sulfonyl urea family. Mode of action is inhibition of acetolactate synthase, which can control grassy and broad-leaf weeds. Bispyribac sodium is a post-emergent herbicide, which belongs to family pyrimidinyl benzoate. It is a broad spectrum systemic herbicide, which can control all types of weeds in rice field and mode of action is inhibition of amino acid synthesis.

2.5. Effect of weed management practices on weed dry matter production, weed control efficiency (WCE) and weed index (WI)

Oikeh *et al.* (2004) suggested that two hand weedings at 2-3 weeks and 6-7 weeks after emergence of the weed is essential and second hand weeding should be done before panicle initiation and nitrogen top dressing. Perennial weeds are very difficult to control by hand weeding. Abraham *et al*. (2010) reported hand weeding was very effective for controlling annual weeds, but perennial weeds were very difficult to control. Less weed density and weed dry matter were recorded in upland rice cultivation, when hand weeding was done at 20, 40 and 60 DAS (Dhanapal *et al*., 2018).

Musthafa and Potty (2001) conducted an experiment to study the effect of *in situ* green manuring on weed control. Experiment consisted two levels of seed rate (cowpea @ 15 and 30 kg/ha) and reported that *in situ* green manuring resulted in less weed biomass as compared to control plot and among different levels of seed rate, higher seed rate resulted in least weed biomass, indicating that reduction in weed growth is mainly due to the smothering effect of cowpea. According to Mishra *et al*. (2009), lesser weed density was observed by the pre-emergent application of butachlor *fb in situ* incorporation of cowpea *fb* mechanical weeding. Less weed density and weed dry matter production was recorded when *Sesbania* intercropped with upland rice (Majhi *et al*, 2011). Intercropping with green manure crops resulted in less weed density and weed dry matter due to less competition of weeds to space, nutrients, water and light in early stage (Barla *et al*., 2016). Green manuring with cowpea is an effective method of weed control by its smothering effect. Intercropping with cowpea reduces space between plants and suppresses the growth of weeds there by reducing weed population and dry matter production (Arunbabu and Jena, 2018).

In a study by Mishra *et al*. (2009), highest WCE (86.20 %) at 60 DAS was observed when hand weeding was done twice at 25 and 45 DAS and highest WCE at harvest was noticed under pre-emergence application of butachlor 1.0 kg/ha *fb* incorporation of cowpea *fb* mechanical weeding. Majhi *et al*. (2011) found that intercropping of *Sesbania* in upland rice resulted in highest WCE at 40 DAS and hand weeding twice resulted in highest WCE (91.20 %) at 60 DAS. Highest WCE (83.82 %) was obtained when hand weeding done thrice at 20, 40 and 60 DAS (Rajendra, 2014).

Iliger *et al*. (2017) reported that broad-leaf weeds could effectively be controlled by brown manuring. According to Seema *et al*. (2014), brown manuring could effectively control the weeds and enhance nutrient availability. Brown manuring of *Sesbania* with 2, 4-D is an effective method of weed control and also add nutrients to the soil (Arunbabu and Jena, 2018). Practice of brown manuring reduced the weed density in cereal crops (Maitra and Zaman, 2017). Rice with *Sesbania* brown manuring resulted in minimum grass weeds as compared to rice without brown manuring (Ansari *et al*., 2017).

At 30 and 60 DAS, total dry matter production of weeds were found less in rice with brown manuring as compared to rice alone in direct seeded rice (Kumari, 2016). Rice with practice of brown manuring resulted in less weed density and dry matter in direct seeded rice (Kumari and Kaur, 2016). Application of pretilachlor followed by brown manuring resulted in minimum weed dry matter production, high WCE and low WI (Maity and Mukherjee, 2011). Brown manuring of cowpea resulted in defoliation, which act as mulch and reduces the weed population by smothering the weeds in rice (Nagargade *et al*., 2018).

Poddar *et al*. (2014) reported that application of oxyfluorfen @ 400 g/ha resulted in less weed density and weed biomass. Pre-emergence application of oxyfluorfen @ 0.15 kg a.i/ha at 0-6 DAS could control all types of weeds in upland rice for 3-4 weeks (KAU, 2016). Priya *et al.* (2017a) found that oxyfluorfen application @ 250 g/ha *fb* hand weeding at 45 DAS could reduce weed density, weed dry matter and increase grain and straw yield in transplanted rice. Reshma *et al.* (2015) reported that pre-emergent application of oxyfluorfen @ 0.15 kg a.i/ha *fb* hand weeding at 20 DAS resulted in highest WCE (89.43 %), least WI (8.85 %), weed count and weed dry matter in aerobic rice. Porwal (1999) revealed that application of oxyfluorfen at 0.2 kg/ha resulted in higher WCE (96.50 %).

Pre-emergent application of pyrazosulfuron-ethyl 0.02-0.03 kg a.i/ha on 6-9 DAS can effectively control all types of weeds for 3-4 weeks (KAU, 2016). According to Chopra and Nisha (2003), application of pyrazosulfuron-ethyl at 20 and 25 g/ha reduced weed density and weed dry matter production in transplanted rice. Saini (2003) reported that pyrazosulfuron application resulted in lesser weed dry matter production. Mondal *et al.* (2005) reported that application of pyrazosulfuron-ethyl as pre-emergence could effectively control all types of weeds in transplanted rice. Pal *et al.* (2012) reported that application of pyrazosulfuron-ethyl at 42.0 g/ha could effectively control gasses, broad-leaf weeds and sedges and recorded higher grain yield.

According to Jabran *et al.* (2012), highest WCE was observed when bispyribac sodium was applied as post emergent and was found very effective for controlling grasses, broad-leaf weeds and sedges. According to Kumar *et al.* (2013), bispyribac sodium @ 30 g/ha resulted in less weed count and weed dry matter. Application of bispyribac sodium in rainfed direct seeded rice resulted in highest WCE, lowest WI and could effectively control *Digitaria sanguinalis*, *Commelina benghalensis* and *Cyperus iria* and it was very effective for controlling grasses and sedges (Kumar and Rana, 2013). Application of bispyribac sodium as post-emergence could effectively control weeds in aerobic rice cultivation (Mahajan *et al.*, 2009).

Application of bispyribac sodium 0.025 kg a.i/ha as post-emergence herbicide at 15-20 DAS could control all types of weeds (KAU, 2016). Application of pendimethalin *fb* bispyribac sodium *fb* manual weeding resulted in lesser weed population and higher WCE (Roy, 2016). According to Sumekar *et al.* (2018), application of bispyribac sodium @ 100-150 ml/ha at 7-10 DAS resulted in less weed dry weight. Bispyribac sodium could effectively control grasses, BLWs and sedges due to its broad spectrum activity (Arunbabu and Jena, 2018).

Prashanth *et al.* (2016) conducted an experiment to study the effect of different doses of bispyribac sodium on weed control and nutrient uptake by weeds and rice in transplanted conditions and reported that application of bispyribac sodium @ 25 g/ha at 15 DAT resulted in minimum weed population and dry matter production. Among different herbicides applied in direct seeded rice, bispyribac sodium treated plot resulted in highest WCE (90.50 %) and grain yield was 3.61 t/ha in direct seeded rice (Hussain *et al.*, 2008). Ramprakash *et al.* (2015) found that application of bispyribac sodium at 25.0 g a.i/ha resulted in better WCE in direct seeded rice. Application of bispyribac sodium as post-emergence herbicide *fb* hand weeding at 30 DAS resulted in lesser weed dry matter production and higher WCE in direct seeded rice (Sangara *et al.*, 2018).

2.6. Effect of weed management practices on growth and yield of rice

According to Singh and Gosh (1992), hand weeding at 15 and 30 DAS resulted in highest grain yield in rainfed upland rice. Hand weeding at 20 and 40 DAS resulted in highest number of effective tillers/m², number of grains per panicle, 1000 grain weight and grain yield as compared to herbicide treatments and weedy check (Dadsena *et al.*, 2014). According to Rajendra (2014), hand weeding thrice at 20, 40 and 60 DAS resulted in highest grain yield in upland rice.

Highest dry matter production and grain yield was recorded from brown manuring treatment in direct seeded aerobic rice (Seema *et al.*, 2014). Kumari (2016) revealed that plant height and number of effective tillers observed at 30, 60, 90 DAS and at harvest was higher under brown manuring treated plot in direct seeded rice and also resulted in higher grain yield, straw yield and HI. Green manure incorporation could contribute higher tiller production (Latt *et al.*, 2009). Practice of green manuring increased the leaf area index at initial stage due to high nitrogen content in rice plants and decreased at later stage due to less availability of nitrogen (Islam *et al*., 2019).

Hand-weeded control resulted in highest grain yield (3889 kg/ha) and was on par with oxyfluorfen followed by HW at 20 DAS (3500 kg/ha) in aerobic rice (Reshma *et al*., 2015). Application of oxyfluorfen resulted in higher dry matter production of rice under direct seeded lowland condition (Panda *et al*., 2016). Application of oxyfluorfen resulted in highest grain yield and was on par with hand weeded control (Abraham *et al*., 2010). According to Priya *et al*. (2017a), oxyfluorfen application @ 250 g/ha *fb* hand weeding at 45 DAS could increase grain and straw yield in transplanted rice. Hand weeding at 20 and 40 DAS resulted in highest grain yield and was on par with pre-emergent application of oxyfluorfen 0.20 kg/ha *fb* hand weeding at 40 DAS (Laskar *et al.,* 2005). Highest number of productive tillers per m² was recorded in the plot treated with oxyfluorfen *fb* hand weeding at 20 DAS.

Application of pyrazosulfuron-ethyl @ 20 and 25 g/ha resulted in higher grain yield, which was on par with weed-free check in transplanted rice (Chopra and Nisha, 2003). According to Saini (2003), pyrazosulfuron application resulted in higher grain yield due to improved growth and yield parameters due to minimum weed growth. Application of pyrazosulfuron-ethyl resulted in higher grain yield (6266 kg/ha) in transplanted rice (Ramesha *et al.,* 2017).

Jabran *et al*. (2012) observed that highest grain yield was obtained from bispyribac sodium treated plot, which was on par with hand weeded control. Application of bispyribac sodium @ 30 g/ha resulted in highest grain yield and was 7.9 % higher than farmers practice (Ramachandiran *et al*., 2013). According to Dhanapal *et al*. (2018), application of pendimethalin 1kg/ha *fb* bispyribac sodium @ 25 g/ha *fb* hand weeding at 45 DAS resulted in highest grain yield which was on par with hand weeding at 20, 40 and 60 DAS and was very cost effective. Sumekar *et al*. (2018) reported that application of bispyribac sodium @ 100-150 ml/ha at 7-10 DAS resulted in highest grain yield.

A field experiment was conducted by Prashanth *et al.* (2016) to study the effect of different doses of bispyribac sodium on weed control and nutrient uptake by weeds and rice in transplanted condition and reported that application of bispyribac sodium 25 g/ha at 15 DAT resulted in highest grain yield and straw yield. The highest number of grains/ panicle, maximum test weight and grain yield was recorded by bispyribac sodium salt @ 250 ml/ha as post-emergence at 15 DAS *fb* HW at 30 DAS (Sangara *et al.*, 2018).

Application of pyrazosulfuron-ethyl followed by bispyribac sodium resulted in higher HI in direct seeded upland rice (Roy, 2016). Prasuna and Rammohan (2015) reported that application of pretilachlor or pendimethalin *fb* bispyribac sodium resulted in higher plant height, LAI, number of tillers, number of panicles and panicle weight, which was on par with hand-weeded control in aerobic rice cultivation.

2.7. Effect of weed management practices on nutrient uptake by weeds and rice

Weeds are generally competing with crops for moisture, light, space, nutrients and other growth factors. Weed infestation removes considerable amount of applied nutrients from the soil. According to Parameswari and Srinivas (2014) weedy check removed higher quantities of N, P and K by weeds and lower N,P and K uptake by rice and straw.

According to Madhukumar *et al.* (2013), highest nutrient uptake by crop was recorded by hand weeded control (N-77.81, P-13.20 and K-57.30 kg/ha) under aerobic rice cultivation. Dadsena *et al.* (2014) reported that highest uptake of N, P and K by rice was obtained from hand weeded control where hand weeding was done twice in direct seeded upland rice. Highest N, P and K uptake by rice in both grain and straw were observed when hand weeding was done thrice at 20, 40 and 60 DAS and weedy condition resulted in highest N, P and K removal by weeds (Rajendra, 2014). Chakraborti *et al.* (2017) reported that hand weeding thrice at 15, 30 and 40 DAS resulted in more uptake of N, P and K by rice. Jagtap *et al.* (2018) revealed that hand weeding at 20, 40 and 60 DAS resulted in higher uptake of N, P and K by rice as compared to weedy control. Hand weeding at 20 and 45 DAS resulted in lesser removal of nutrients by weeds and nutrient losses from the field was minimum under hand weeded plot under aerobic rice cultivation (Gowda *et al*., 2009).

Kumaran *et al*. (2015) observed that application of bispyribac sodium 10 % SC @ 40 g/ha resulted in less removal of N, P and K by weeds at all stages of observation. Application of bispyribac sodium @ 35 g/ha on 15 DAT observed less removal of nutrients by weeds and higher uptake by transplanted rice (Prashanth *et al*., 2016). Nitrogen uptake by plants was found higher under green manure treatment (Latt *et al*., 2009).

2.8. Effect of weed management practices on nutrient status of the soil

Weeds are highly competitive to nutrients and heavy infestation of weeds results in depletion of soil N, P and K (Ramachandiran *et al*., 2013). Sylvestre and Murthy (2018) reported that unweeded plot resulted in less available N, P and K in aerobic rice. Rajendra (2014) observed that application of different herbicides does not have any significant effect on available N, P and K on soil, but higher value was recorded in weed free plot as compared to the other treatments. Hand weeding at 20 and 45 DAS resulted in lesser removal of nutrients by weeds and nutrient losses from the field was minimum under hand weeded plot under aerobic rice cultivation (Gowda *et al*., 2009).

Green manuring enriches the soil by nitrogen fixation which helps to increase the nutrient uptake by plants (Arunbabu and Jena, 2018). According to Kumar *et al*. (2011), green manuring increased the organic carbon content in the soil and among different treatments such as 100 % NPK + green manure, 75 % NPK + green manure, 50 % NPK + green manure and 50 % NPK + FYM, the highest value of organic carbon was recorded in 75 % NPK + green manure. Green manure treated plots showed high organic carbon as compared to control plot (NPK alone). Brown manuring improved the physical and chemical properties of soil such as porosity, water holding capacity, organic carbon and also accelerated the soil microbial activity (Maitra and Zaman, 2017).

Application of bispyribac sodium 10 % SC with different doses (10, 15, 20, 25 and 40g a.i/ha) does not show any significant changes in soil chemical properties in direct seeded rice (Ramprakash *et al*., 2015). Baboo *et al*. (2013) reported that application of herbicides like butachlor, pyrazosulfuron, paraquat and glyphosate decreased the organic carbon content in the soil.

2.9. Effect of weed management practices on soil microbial biomass carbon

Microorganisms play an important role in decomposition and nutrient transformation, which thereby improves the soil fertility and plant growth. Herbicide application can either enhance or decrease the microbial population, which depends on the type of soil, time of application and quantity or dose of the herbicides. Improper and higher dose of herbicide application can have negative effects on growth and development of microorganisms. Sometimes degraded products of herbicide can act as nutrient source for microbial growth and accelerate the multiplication of microbes.

Herbicides at recommended level of dose does not inhibit the microbial population and growth. However, application of herbicides with higher dose would adversely affect soil microbial growth. Soil microbial biomass carbon depends on the time and quantity of herbicide application (Subhani *et al*., 2000). Haney *et al*. (2000) reported that glyphosate application does not show negative effect on soil microbial biomass carbon. Glyphosate can either accelerate or decrease the soil microbial biomass carbon and it depends on the type of soil, time of application and quantity applied.

Das *et al*. (2003) observed that application of oxyfluorfen and oxadiazone does not show any inhibitory effect on phosphate solubilizing microorganisms in rice field and moreover application of these herbicides accelerated the microbial population up to 30 days. Combined effect of degradation of herbicides and release of growth promoting substances from the roots during flowering stage act as source of nutrients for the growth of microbial population. Lupwayi *et al*. (2003) reported that soil microbial biomass carbon was unaffected by the single application of herbicides at recommended rate and soil microbial biomass carbon was decreased during the application of herbicides and after one or two weeks it became normal as previous.

Gupta and Joshi (2009) found that the application of 2,4-D inhibit the activity of soil microbes and higher soil biomass carbon was recorded in control. Soil microbial biomass carbon was related to the concentration of herbicides applied, as concentration increases, the amount of soil microbial biomass carbon decreases. Glyphosate application does not change the microbial population and soil microbial biomass carbon was higher as compared to both control and 2,4-D application. Mondal *et al*. (2011) reported that microbial population was decreased by the application of pyrazosulfuron-ethyl and is due to the inhibitory effect of herbicide on soil microbes. Baboo *et al*. (2013) studied the effect of butachlor, pyrazosulfuron-ethyl, paraquat and glyphosate on soil microbial biomass carbon and found that application of herbicides significantly decreased the soil microbial biomass carbon upto 28 days after herbicide application.

A study was carried out by Silva *et al*. (2014) to investigate the effect of sulfentrazone, oxyfluorfen and isoxaflutole application on soil microbial biomass carbon in forest soil and soil analysis was done at 5, 20 and 70 days after application of herbicides. They found that application of sulfentrazone reduced the soil microbial biomass carbon in sandy soil, however application of all three herbicides in clayey soil increased the soil microbial biomass carbon at 20 days after application and decreased at 70 days after application. Saha *et al*. (2015) conducted an experiment in peanut soil in Junagadh to investigate the effect of pendimethalin and oxyfluorfen application on soil microbial biomass carbon. The experiment consisted of half recommended rate, normal recommended rate and double recommended rate of two herbicides and result showed that application of both herbicides at all doses stimulated the growth of microorganism as compared to control.

Ramalakshmi *et al*. (2017) observed that application of herbicides, pyrazosulfuron-ethyl, bensulfuron methyl, pretilachlor and bispyribac sodium at recommended rate in rice decreased the soil microbial population initially and after that increased the microbial population due to degradation of herbicide, which act as a nutrient source for the growth of microorganisms. Amritha and Devi (2017) conducted a pot culture experiment to study the effect of herbicides on soil microbial biomass carbon. The experiment consisted of two pre-emergence herbicides pendimethalin and oxyfluorfen and two post-emergence herbicides bispyribac sodium and cyhalofop butyl. The result of the study indicated that the application of herbicides decreased the soil microbial activity up to 30 days after the application of herbicides and it was low at the time of harvest due to reduction in moisture content. They also reported that, soil microbial carbon is positively related with organic matter content in the soil, which indicates that the soil microbial biomass carbon is high in soil rich in organic matter.

A study was carried out by Priya *et al.* (2017b) at TNAU Coimbatore to investigate the effect of herbicides on soil microbial activity. Experiment consists of herbicides, bispyribac sodium, metamifop, almix, clincher and wetter at different doses and reported that herbicide application does not have any inhibitory effect on soil microbial population. The microbial population was less immediately after the application of herbicides due to herbicidal toxicity and it recovered to the normal level after few days of herbicide application. A study was carried out by Dubey *et al.* (2018) at Bihar Agricultural University in India to study the effect of herbicides on soil microbial population in direct seeded rice and showed that application of bispyribac sodium and pendimethalin stimulated the growth of actinomycetes and does not affect the soil bacterial population growth. Actinomycetes population was high in herbicide treatment plot as compared to weedy check and weed free plot.

2.10. Economics

Hand weeding is highly labour required method of weed control and it results in less B:C ratio due to high labour cost, which increases the cost of production (Dhanapal *et al.*, 2018). Hand weeding is highly laborious and costlier than other methods, nearly 190 man days/ha is needed for hand weeding twice (Ramachandiran *et al.*, 2013). Ramana *et al.* (2007) found that even though weed free plot recorded higher grain yield under upland condition, additional labour requirement and higher labour cost for hand weeding resulted in less net return and B:C ratio.

Incorporation of green manure resulted in higher net return as compared to treatments without green manure. It was due to weeding along with uprooting and incorporation of green manure which was done together to lower the cost of production as compared to other treatments which required two hand weedings (Kumar *et al*., 2011). Incorporation of green manure crops like daincha, sunnhemp and black gram resulted in highest gross return, net return and B:C ratio which was on par with hand weeding twice at 20 and 40 DAS in direct seeded rice (Barla *et al*., 2016). Higher B:C ratio was recorded by rice with brown manuring as compared to sole rice crop in direct seeded rice (Kumari, 2016).

Highest net benefit was recorded in bispyribac sodium treated plot in direct seeded rice (Hussain *et al*., 2008). Highest net return was obtained from treatment receiving bispyribac sodium at 30 kg/ha in rainfed direct seeded rice (Kumar and Rana, 2013). Reshma *et al*. (2015) found that oxyfluorfen @ 0.15kg a.i/ha *fb* hand weeding at 20 DAS resulted in highest B:C ratio in aerobic rice. Practice of oxyfluorfen at 0.20 kg/ha + HW recorded higher B:C ratio (Laskar *et al.,* 2005). Application of oxadiargyl *fb* bispyribac sodium resulted in highest B:C ratio (Roy, 2016). Highest net return (Rs. 26010) was obtained by the application pendimethalin (1.0 kg/ha) @ 2 DAS *fb* bispyribac sodium (25 g/ha) at 20 DAS (Chakraborti *et al*., 2017).

Materials and Methods

3. MATERIALS AND METHODS

A field experiment entitled "Weed management for upland rice" was carried out during June 2019 to September 2019 (*Virippu* season) at the Agronomy Farm, College of Horticulture, Vellanikkara. This chapter deals with the materials used and methods followed for conducting the experiment.

3.1. General details

3.1.1. Experimental site

A field experiment was carried out at Agronomy Farm, College of Horticulture, Vellanikkara, located at 10° 31′ N latitude and 76° 13′ E longitude at an altitude of 40.3 m above MSL.

3.1.2. Climate and weather conditions

The important meteorological parameters recorded during the experimental period are presented in Appendix I.

3.1.3. Soil characters

The experiment was carried out in soil with sandy loam texture and it was acidic in nature. The pre-experimental status of the soil is presented in Table 3.1.

3.1.4. Variety

Vaisakh, medium duration (117-125 days) rice variety was selected as test variety. It is moderately resistant to blue beetle, stem borer and whorl maggot. It can also withstand moisture stress and is highly suitable for upland rice cultivation. A local variety of cowpea was used for *in situ* green manuring and brown manuring in upland rice.

Table 3.1. Pre-experimental status of the soil

Particular	Value	Method used
Chemical composition		
pH	4.77	pH meter (Jackson, 1958)
EC	0.61	Electrical Conductivity meter (Jackson, 1958)
Organic carbon (%)	1.41	Chromic acid wet digestion method (Walkley and Black, 1934)
Available N (kg/ha)	176.4	Alkaline permanganate method (Subbiah and Asija, 1956)
Available P_2O_5 (kg/ha)	135.76	Ascorbic acid reduced molybdo-phosphoric blue colour method (Bray and Kurtz,1945; Watanabe and Olsen,1965)
Available K_2O (kg/ha)	171.64	Neutral Normal NH_4OAC extract method using flame photometer (Jackson, 1958)
Soil microbial biomass carbon(μg/g soil)	38.36	Fumigation extraction method (Jenkinson and Powlson, 1976)

3.1.5. Season

The crop was grown in *Virippu* season from June 2019 to September 2019. The crop duration was 113 days.

3.1.6. Cropping history of the experimental site

Table 3.2. Cropping history of the experimental site

Year	***Kharif***	***Rabi***	**Summer**
2016	Amorphophallus		
2017	Cowpea	Turmeric	
2018	Cowpea	Turmeric	

3.2. Experimental details

3.2.1. Treatments

The field experiment was carried out at Agronomy Farm, College of Horticulture, Vellanikkara during *Virippu* season (2019). The experiment was laid out in Randomized Block Design (RBD) with eight treatments and three replications. The treatments consisted of four herbicides in combination with green manuring of cowpea *in situ* and hand weeding. The herbicides used are given in Table 3.3.

Table 3.3. Herbicides used in the experiment

Herbicide	Trade name, formulation and dose	Application time
Oxyfluorfen	Goal 23.5 EC, 0.15 kg a.i/ha	Pre emergence, on the day of sowing
Pyrazosulfuron-ethyl	Saathi 10 WP, 0.03 kg a.i/ ha	Pre emergence, on 6 DAS
Bispyribac sodium	Nominee gold 10 SC, 0.025 kg a.i/ha	Post emergence, on 20 DAS
2,4-D	Fernoxone 80 WP, 1.0 kg a.i/ha	Post emergence, on 25 DAS

The treatments details are given below

Table 3.4. Treatments

T_1	Brown manuring (Cowpea) by application of 2,4-D 80 WP @ 1.0 kg/ha, 25 DAS
T_2	*In situ* green manuring (Cowpea), 25 DAS
T_3	Oxyfluorfen 23.5 EC @ 0.15 kg/ha on the day of sowing *fb* hand weeding at 30 DAS
T_4	Oxyfluorfen 23.5 EC @ 0.15 kg/ha on the day of sowing *fb* bispyribac sodium 10 SC @ 0.025 kg/ha, 20 DAS
T_5	Pyrazosulfuron-ethyl 10 WP @ 0.03 kg/ha, 6 DAS *fb* hand weeding at 30 DAS
T_6	Pyrazosulfuron-ethyl 10 WP @ 0.03 kg/ha, 6 DAS *fb* bispyribac sodium 10 SC @ 0.025 kg/ha, 20 DAS
T_7	Hand weeded control
T_8	Unweeded control

Lay out of the experiment

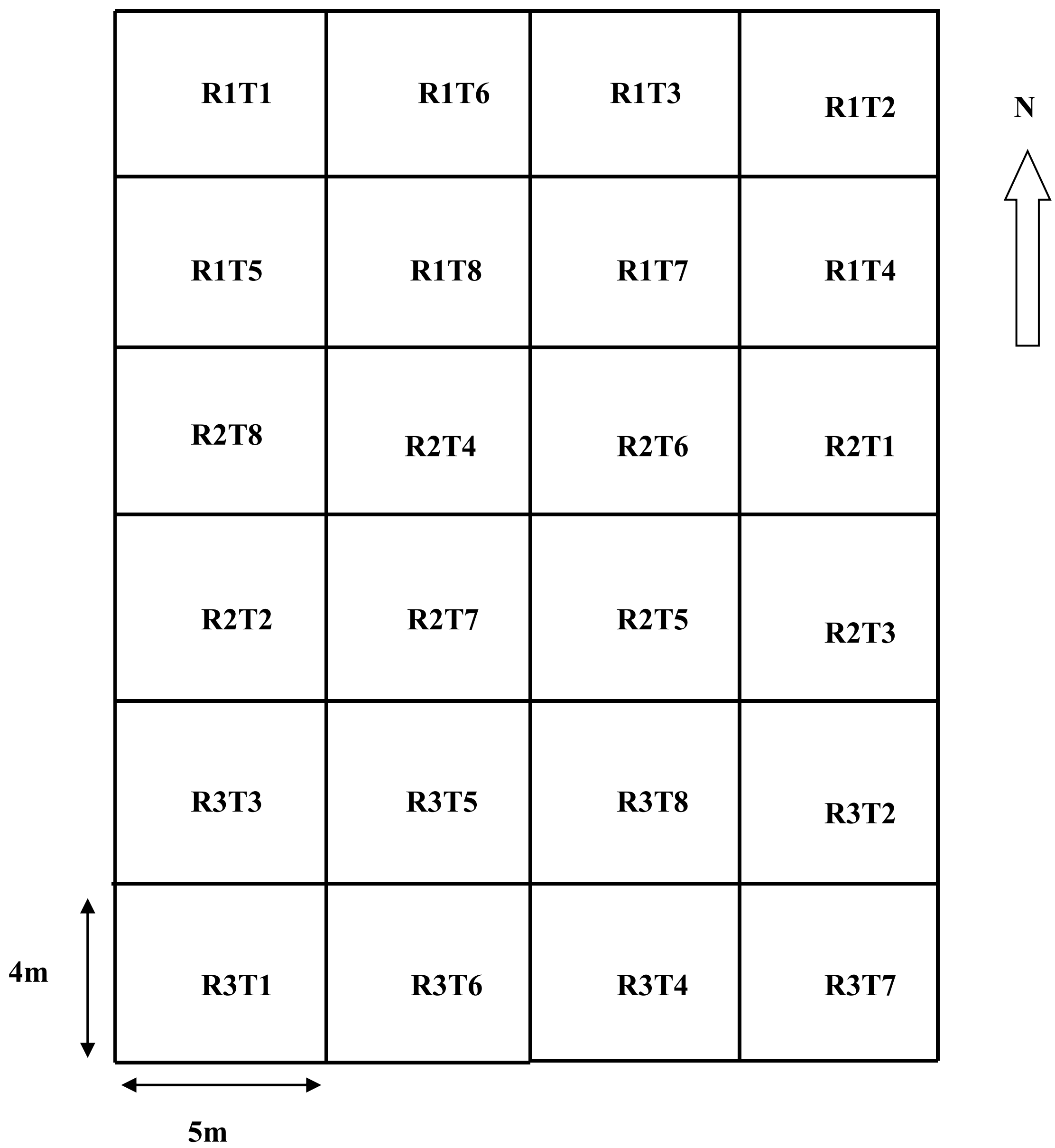

Figure 3.1 Lay out of the experiment

Design: RBD

Treatments: 8

Replications: 3

Plot size: 5m × 4m

3.3. Field operations

The various field operations performed during experiment are given below.

3.3.1. Land preparation

Field was ploughed by tractor. Weeds and previous crop residues were removed and leveled. Lay out was done and uniform flat beds of size of 5m×4m were prepared for each treatment.

3.3.2. Application of lime, FYM and fertilizers

Lime was applied @ 350 kg/ha, two weeks before sowing due to acidic nature of the soil. FYM was applied @ 5.0 t/ha, one week before the sowing. Fertilizers were applied as urea, rajphos and muriate of potash at the rate of 50: 35: 35 N, P_2O_5 and K_2O kg/ha. Full dose of P_2O_5 was applied basally. N was applied in two splits, ⅓rd at one week after sowing and ⅓rd at tillering stage and remaining ⅓rd to be applied at panicle initiation stage, was skipped to avoid lodging due to excessive vegetative growth. K_2O was applied as two equal splits, ½ at one week after sowing and ½ at panicle initiation stage.

3.3.3. Sowing

Paddy seeds were dibbled @ 80 kg/ha at a spacing of 20×10 cm. Cowpea seeds were also dibbled in alternate rows in T_1 and T_2 treatments for brown manuring and *in situ* green manuring.

3.3.4. Thinning and gap filling

Thinning and gap filling was done one week after sowing to maintain plant population

3.3.5. Herbicide application

Application of oxyfluorfen 23.5 EC @ 0.15 kg/ha was done on the day of sowing in T_3 and T_4 treatments and was applied @ 0.64 kg/ha. Pyrazosulfuron-ethyl

10 WP @ 0.03 kg/ha was sprayed at 6 DAS in T_5 and T_6 treatments and was applied @ 0.30 kg/ha. Application of bispyribac sodium 10 SC @ 0.025 kg/ha was done at 20 DAS in T_4 and T_6 treatments and was applied @ 0.25 kg/ha. Herbicide application was done during evening with a knapsack sprayer fitted with a flood jet nozzle using 500 L water per hectare as spray volume.

3.3.6. *In situ* green manuring and brown manuring

In T_2 treatment *in situ* green manuring was done by uprooting the cowpea plants and placed between the rows. Brown manuring was done by spraying of 2, 4-D in T_1 treatment and was applied @ 1.25 kg/ha. *In situ* green manuring and brown manuring were done at 25 DAS.

3.3.7. Hand weeding

Hand weeding was done at 30 DAS in T_3 and T_5 treatments. T_7 was maintained as hand weeded control where hand weedings were done at 15, 30 and 45 DAS and T_8 was maintained as unweeded control.

3.3.8. Plant protection measures

Dead heart symptom was observed in rice and spraying of Fame (4 ml/10 L) was done against stem borer incidence.

3.3.9. Harvesting and threshing

Crop was harvested during last week of September after attaining physiological maturity. Crop from each plot was harvested and threshed separately. Fresh weight of both grain and straw were recorded. Grain and straw were sun dried to reduce moisture content. Finally dry weight of both grain and straw were recorded and expressed in kg/ha.

Plate 1. Field preparation

Plate 2. Sowing

Plate 3. Experimental field at 1 WAS

Plate 4. Herbicide spray

Plate 5. Experimental field at 20 DAS

Plate 6. Rice + cowpea intercropping

Plate 7. ***In situ*** **green manuring of cowpea (uprooting of cowpea)**

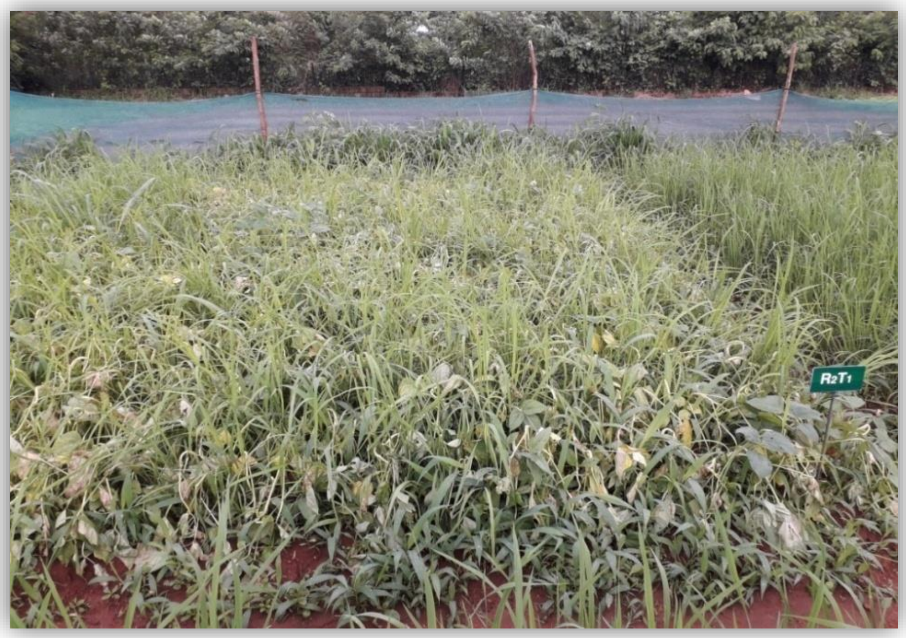

Plate 8. Brown manuring of cowpea

3.4. Observations recorded

3.4.1. Biometric observations on crops

Biometric observations were recorded at 30, 60 DAS and at harvest

a) Plant height

Five hills were selected randomly from each plot and tagged with a ribbon. Height was measured in centimetre (cm) from the ground to the tip of leaf and average values were computed.

b) Number of tillers/hill

Five hills were selected randomly from each plot and tagged. Number of tillers was counted from each hill and average values were computed.

c) Leaf area index

The maximum length and width of third leaf was recorded from tagged hills. From each hill, ten leaves were selected and average values were worked out. Total number of leaves per hill was counted. Leaf area was calculated using the formula

$$\textbf{Leaf area} = \textbf{length} \times \textbf{breadth} \times \textbf{k}$$

Where k is leaf area constant and is the ratio of actual leaf area to the apparent leaf area

Leaf area index (LAI) was calculated using the formula suggested by Watson (1952)

$$\textbf{LAI} = (\textbf{Leaf area per hill})/(\textbf{Ground area occupied by hill})$$

d) Dry matter production

From each plot, three plants were uprooted randomly. Soil particles were removed and plants were air dried for 24 hours. The plants were kept in brown paper cover and dried in hot air oven at 80 °C to constant weight. Dry weight of the plants were recorded and expressed in kg/ha.

3.4.2. Yield and yield attributes

Yield and yield attributes were recorded at harvest

a) Days to 50 % flowering

Number of days taken for 50 % flowering was recorded for each plot during the experiment.

b) Number of hills/m²

Number of hills/m² was recorded by quadrate method. A quadrate of 1m×1m was thrown and number of hills within the quadrate was counted.

c) Number of panicles/hill

Five hills were randomly selected from each plot. Number of panicles per hill was counted and average was taken.

d) Number of grains/panicle

Five panicles were randomly selected from each plot. Filled grains and chaffed grains were separated and percentage filled grain was calculated using following formula

$$\text{Percentage filled grain} = \frac{\text{Total number of grains} - \text{chaffed grain}}{\text{Total number of grains}} \times 100$$

e) 1000 grain weight

One thousand bold and healthy grains were selected from each plot and weight was recorded.

f) Grain and straw yield

Grain yield and straw yield were recorded from each plot after harvesting, threshing and winnowing and expressed in kg/ha.

g) Harvest index

Harvest index was calculated using the following formula

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}}$$

Where Economic yield = grain yield and Biological yield = Grain yield + straw yield

3.4.3. Observation on weeds

Weed observations were recorded at 20 and 45 DAS

a) Weed species composition

A quadrat of 0.5 m × 0.5 m (0.25 m²) was used and different weed species present within the quadrat were identified. Four spots were selected randomly from each plot.

b) Weed count

A quadrat of 0.5 m × 0.5 m (0.25 m²) was used for taking weed count. Four spots were selected randomly from each plot. Weeds present within the quadrat were categorized into grasses, broad-leaf weeds and sedges and counted separately. Total number of weeds was obtained by adding grasses, broad-leaf weeds and sedges.

c) Weed dry matter production

A quadrat of 0.5 m × 0.5 m (0.25 m²) was used and four spots were selected randomly from each plot by throwing quadrat. Weeds present within the quadrate were uprooted, soil particles were removed and air dried. Air dried plants were kept in brown paper cover and dried in hot air oven at 80 °C to constant weight. It was expressed in g/m^2.

d) Weed control efficiency (WCE)

WCE was calculated by following formula suggested by Mani and Goutham (1973) and expressed in percent.

$$\text{WCE} = \frac{\text{WDMP in unweeded control} - \text{WDMP in teated plot}}{\text{WDMP in unweeded plot}} \times 100$$

Where WDMP is weed dry matter production at 20 and 45 DAS

e) Weed index (WI)

Weed index was calculated by following formula given by Gill and Kumar (1969) and expressed in percent.

$$\text{WI} = \frac{\text{Grain yield of hand weeded control} - \text{Grain yield of treatment plot}}{\text{Grain yield of hand weeded control treatment}} \times 100$$

3.4.4. Plant analysis

N, P and K uptake by crops were analysed at 30, 60 DAS and at harvest. N, P and K removal by weeds were analysed at 20 and 45 DAS.

a) Nutrient uptake by crop and weeds

Samples of paddy and weed (composite of grasses, broad-leaf weeds and sedges) were taken from each plot. Samples were cleaned, air dried and kept in hot air oven for drying by keeping samples inside brown paper bags. Dried samples were ground and nutrient contents N, P and K were estimated by microkjeldhal method, diacid extract method using spectrophotometer and diacid extract method using flame photometer respectively. Nutrient uptake by crop and weeds were calculated by multiplying nutrient content with dry matter and it was expressed in kg/ha.

3.4.5. Soil analysis

Representative soil samples from five sites were collected and pooled for pre-experimental analysis. Soil samples from each plot were collected separately for post-experimental analysis. Soil samples were taken from randomly selected spots using a spade by digging ‘V' shaped hole at a depth of 15 cm. Successive quartering was done to reduce the size of the sample. Shade dried samples were transformed to polybag and labeled properly. For soil microbial biomass carbon, samples were not subjected to shade drying.

a) pH

pH was measured using pH meter. Soil and water were taken in the ratio of 1: 2.5 and stirred well. pH of the sample was read by immersing electrode of the pH meter in soil water suspension.

b) EC

EC was measured by EC meter. Soil and water were mixed in the ratio of 1: 2.5 and suspension was stirred well. EC of the sample was read by immersing electrode in soil water suspension.

c) Organic carbon

Organic carbon present in the soil was found by Walkley and Black method (1934) and it was expressed in percentage.

d) Available N, P and K

Available N was estimated by alkaline permanganate method, P was estimated by bray extraction and photoelectric calorimetry and K was estimated by flame photometry.

e) Soil microbial biomass carbon (SMBC)

Soil microbial biomass carbon was estimated by fumigation extraction method and it was calculated using the formula given below

$$\mathbf{SMBC = (E_{CF} - E_{CNF}) \div K_{EC}}$$

Where E_{CF} = Total weight of extractable C in the fumigated soil sample

E_{CNF} = Total weight of extractable C in the non-fumigated soil sample

K_{EC} = Efficiency of extraction of microbial biomass carbon (0.25 ± 0.05)

3.5. Cost – Benefit analysis

Benefit cost ratio was calculated by dividing the gross return with cost of cultivation. Gross return was calculated from grain yield and straw yield from the respective treatments. Prevailing price for grain and straw in the market were considered. Cost of cultivation from each treatment was calculated by taking into account field preparation cost, input cost, labour cost, extra treatment cost *etc.* and it was expressed in rupees per ha.

3.6. Data analysis

Data obtained from the experiment were analysed statistically by applying "analysis of variance" as per randomized block design with the help of online statistical package "OP" stat (Sheoran *et al.*, 1998).

Results

4. RESULTS

A field experiment entitled "Weed management for upland rice" was carried out during 2019 (*Virippu* season) at Agronomy Farm, College of Horticulture, Vellanikkara. Treatments were analysed statistically and results are presented in this chapter.

4.1. Observation on weeds

4.1.1. Predominant weed species observed in experimental field

Twenty two different weed species were identified and classified into grasses, broad-leaf weeds and sedges.

a) Grass weeds

Dominant grass weed species observed were *Echinochloa colona*, *Digitaria sanguinalis, Eleusine indica, Panicum maximum, Setaria* spp., and *Brachiaria* spp.

b) Broad leaf weeds

Broad-leaf weeds dominated under upland condition were *Alternanthera bettzickiana, Mitracarpus hirtus, Euphorbia hirta, Euphorbia geniculata, Ludwigia perennis, Scoparia dulcis, Ageratum conyzoides, Phyllanthus amara, Cleome burmannii, Commelina benghalensis, Lindernia crustacea, Catharanthus pusillus, Trianthema portulacastrum, Mollugo disticha* and *Hemidesmus indicus.*

c) Sedges

Cyperus iria was the only sedge observed in the experimental field.

4.1.2. Weed count

Effect of various weed management practices on weed count recorded at 20 and 45 DAS are presented in Table 4.1.

At 20 DAS, grasses, broad-leaf weeds and sedges were influenced significantly by the treatments. Among the various treatments, hand-weeded control resulted in lowest grass weed count (15.66), which was on par with oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS (31.66). Highest grass weed count was recorded in unweeded control (238.00), followed by application of pyrazosulfuron-ethyl on 6 DAS *fb* bispyribac sodium on 20 DAS (153.00) and which was found on par with pyrazosulfuron-ethyl on 6 DAS *fb* hand weeding at 30 DAS (133.00). Application of oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS resulted in significantly less broad-leaf weed count (22.00) and was on par with hand-weeded control (39.33). Significantly higher broad-leaf count was observed in unweeded control (239.00) followed by *in situ* green manuring on 25 DAS (145.00) and pyrazosulfuron-ethyl on 6 DAS *fb* bispyribac sodium on 20 DAS (144.33). Brown manuring on 25 DAS resulted in significantly higher sedges count (5.42) and was on par with unweeded control (5.14). Lesser sedges count was observed in oxyfluorfen on the day of sowing *fb* bispyribac sodium 20 DAS, pyrazosulfuron-ethyl on 6 DAS *fb* hand weeding at 30 DAS and pyrazosulfuron-ethyl on 6 DAS *fb* bispyribac sodium on 20 DAS.

Total weed count at 20 DAS was found affected by treatments. Among the various treatments, application of oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS (58.00) resulted in minimum weed count which was on par with hand-weeded control (59.00). Unweeded control resulted in significantly higher total weed count (503.00), followed by pyrazosulfuron-ethyl on 6 DAS *fb* bispyribac sodium on 20 DAS (297.33) and was on par with brown manuring on 25 DAS (259.00).

Weed count at 45 DAS was influenced significantly by various treatments. Lowest grass weed count was observed in hand-weeded control (2.33) and was on par with oxyfluorfen on the day of sowing *fb* bispyribac sodium on 20 DAS (19.33) and oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS (19.66). Highest grass weed count was observed in the treatment, pyrazosulfuron-ethyl on 6 DAS *fb* bispyribac sodium on 20 DAS (120.66) followed by brown manuring on 25 DAS (79.00). Among the different treatments, lowest broad-leaf weeds was observed in brown manuring on 25 DAS (13.66), which was on par with pyrazosulfuron-ethyl on

6 DAS *fb* hand weeding at 30 DAS (19.00) and oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS (24.66). Unweeded control resulted in higher broad-leaf weeds count (90.66). Maximum number of sedge weed count was observed in the treatment, oxyfluorfen on the day of sowing *fb* bispyribac sodium on 20 DAS (2.30) which was on par with *in situ* green manuring on 25 DAS (2.15). Lesser sedges count was observed in brown manuring at 25 DAS, oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS, pyrazosulfuron-ethyl at 6 DAS *fb* hand weeding at 30 DAS and pyrazosulfuron-ethyl on 6 DAS *fb* bispyribac sodium on 20 DAS.

Total weed count at 45 DAS was significantly affected by various treatments and among the different treatments oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS resulted in lowest weed count (44.33), which was on par with oxyfluorfen on the day of sowing *fb* bispyribac sodium on 20 DAS (56.00). Highest total weed count was observed in unweeded control (169.00).

4.1.3. Weed dry matter production

Data on the effect of various treatments on weed dry matter production at 20 and 45 DAS are given in Table 4.2.

Weed dry matter production at 20 DAS and 45 DAS were influenced significantly by the treatments. At 20 DAS, lesser weed dry matter accumulation was recorded in hand-weeded control (5.80 g/m^2), which was on par with application of oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS (5.87 g/m^2) and oxyfluorfen on the day of sowing *fb* bispyribac sodium on 20 DAS (9.07 g/m^2). At 45 DAS, lesser weed dry matter accumulation was recorded in hand-weeded control (3.33 g/m^2) and was on par with oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS (3.60 g/m^2) and pyrazosulfuron-ethyl on 6 DAS *fb* HW at 30 DAS (6.66 g/m^2). Significantly higher weed dry matter accumulation was recorded in unweeded control (79.40 g/m^2 at 20 DAS and 256.33 g/m^2 at 45 DAS) followed by pyrazosulfuron-ethyl on 6 DAS *fb* bispyribac sodium on 20 DAS (34.66 g/m^2 at 20 DAS and 120 g/m^2 at 45 DAS).

4.1.4. Weed control efficiency

Effects of treatments on weed control efficiency are given in Table 4.3.

WCE at 20 DAS and 45 DAS were influenced significantly by various treatments. At 20 DAS, application of oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS (92.60 %) resulted in maximum WCE followed by hand-weeded control (92.55 %). Application of oxyfluorfen on the day of sowing *fb* bispyribac sodium on 20 DAS resulted in WCE of 88.56 %. At 45 DAS, better WCE was recorded in hand-weeded control (98.69 %), which was similar to the treatment, oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS (98.58 %) followed by pyrazosulfuron-ethyl on 6 DAS *fb* hand weeding at 30 DAS (97.39 %). Brown manuring on 25 DAS resulted in WCE of 71.02 % and 54.09 % at 20 and 45 DAS respectively. *In situ* green manuring resulted in WCE of 86.14 % and 67.53 % at 20 and 45 DAS.

Application of oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS recorded better WCE at both stages of observation. Pyrazosulfuron-ethyl on 6 DAS *fb* hand weeding at 30 DAS recorded better WCE at 45 DAS.

4.1.5. Weed index

Data on weed index as influenced by various treatments are presented in Table 4.3.

Weed index was influenced significantly by various treatments. Among the different weed management practices, significantly lowest weed index was recorded from oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS (5.02 %) followed by pyrazosulfuron-ethyl on 6 DAS *fb* hand weeding at 30 DAS (10.35 %).

Table 4.1. Effect of treatments on weed count (no. /m²) at 20 and 45 DAS

Treatments	Weed count at 20 DAS				Weed count at 45 DAS			
	Grass	**Broad-leaf weeds**	***Sedges**	**Total weed count**	**Grass**	**Broad - leaf weeds**	***Sedges**	**Total weed count**
Brown manuring (Cowpea) by application of 2,4-D 80 WP @ 1.0 kg/ha , 25 DAS	100.66	128.66	5.42 (28.66)	259.00	79.00	13.66	1.00 (0.00)	92.667
In situ green manuring (Cowpea), 25 DAS	65.33	145.00	4.08 (15.66)	226.00	53.33	62.66	2.15 (3.66)	120.33
Oxyfluorfen 23.5 EC @ 0.15 kg/ha on the day of sowing *fb* hand weeding at 30 DAS	31.66	22.00	2.01 (4.00)	58.00	19.66	24.66	1.00 (0.00)	44.33
Oxyfluorfen 23.5 EC @ 0.15 kg/ha on the day of sowing *fb* bispyribac sodium 10 SC @ 0.025 kg/ha, 20 DAS	68.33	50.66	1.00 (0.00)	119.00	19.33	32.33	2.30 (4.33)	56.00
Pyrazosulfuron -ethyl 10 WP @ 0.03 kg/ha, 6 DAS *fb* hand weeding at 30 DAS	133.00	70.66	1.00 (0.00)	210.33	39.66	19.00	1.00 (0.00)	58.66
Pyrazosulfuron -ethyl 10 WP @ 0.03 kg/ha, 6 DAS *fb* bispyribac sodium 20 DAS	153.00	144.33	1.00 (0.00)	297.33	120.66	42.33	1.00 (0.00)	163.00
Hand weeded control	15.66	39.33	2.23 (4.00)	59.00	2.33	73.33	1.73 (2.00)	76.00
Unweeded control	238.00	239.00	5.14 (26.00)	503.00	77.66	90.66	1.27 (0.66)	169.00
SE (m)	**11.06**	**8.66**	**0.34 (2.63)**	**13.43**	**6.20**	**3.96**	**0.08 (0.30)**	**13.22**
CD (0.05)	**33.87**	**26.52**	**1.06 (8.01)**	**41.14**	**19.00**	**12.14**	**0.25 (0.93)**	**40.50**

***$\sqrt{x}$ + 0.5 transformed values, original values in parenthesis**

Table 4.2. Effect of treatments on weed dry matter production (g/m^2) at 20 and 45 DAS

Treatments	Weed dry matter production (g/m^2)	
	20 DAS	**45 DAS**
Brown manuring (Cowpea) by application of 2,4-D 80 WP @ 1.0 kg/ha , 25 DAS	23.00	117.66
In situ green manuring (Cowpea), 25 DAS	11.00	84.00
Oxyfluorfen 23.5 EC @ 0.15 kg/ha on the day of sowing *fb* hand weeding at 30 DAS	5.87	3.60
Oxyfluorfen 23.5 EC @ 0.15 kg/ha on the day of sowing *fb* bispyribac sodium 10 SC @ 0.025 kg/ha, 20 DAS	9.07	31.53
Pyrazosulfuron -ethyl 10 WP @ 0.03 kg/ha, 6 DAS *fb* hand weeding at 30 DAS	29.33	6.66
Pyrazosulfuron-ethyl 10 WP @ 0.03 kg/ha, 6 DAS *fb* bispyribac sodium 10 SC @ 0.025 kg/ha, 20 DAS	34.66	120.00
Hand weeded control	5.80	3.33
Unweeded control	79.40	256.33
SE (m)	**3.60**	**9.52**
CD (0.05)	**11.02**	**29.18**

Table 4.3. Effect of treatments on WCE (%) and WI (%)

Treatments	WCE (%)		WI (%)
	20 DAS	45 DAS	
Brown manuring (Cowpea) by application of 2,4-D 80 WP @ 1.0 kg/ha , 25 DAS	71.02	54.09	62.18
In situ green manuring (Cowpea), 25 DAS	86.14	67.53	65.33
Oxyfluorfen 23.5 EC @ 0.15 kg/ha on the day of sowing *fb* hand weeding at 30 DAS	92.60	98.58	5.02
Oxyfluorfen 23.5 EC @ 0.15 kg/ha on the day of sowing *fb* bispyribac sodium 10 SC @ 0.025 kg/ha, 20 DAS	88.56	87.76	12.81
Pyrazosulfuron -ethyl 10 WP @ 0.03 kg/ha, 6 DAS *fb* hand weeding at 30 DAS	63.05	97.39	10.35
Pyrazosulfuron -ethyl 10 WP @ 0.03 kg/ha, 6 DAS *fb* bispyribac sodium 10 SC @ 0.025 kg/ha, 20 DAS	56.33	52.66	42.34
Hand weeded control	92.55	98.69	-
Unweeded control	-	-	78.04

4.2. Biometric observation of crop

4.2.1. Plant height

Observation on plant height was recorded at 30, 60 DAS and at harvest. The results obtained are given in Table 4.4.

The plant height at 30, 60 DAS and at harvest were found unaffected by various treatments.

4.2.2. Number of tillers per hill

Observation on number of tillers per hill at 30, 60 and at harvest are presented in Table 4.5.

At 30 and 60 DAS number of tillers per hill was influenced significantly by various treatments. At 30 DAS, oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS produced significantly higher number of tillers per hill (13.00) and was on par with oxyfluorfen on the day of sowing *fb* bispyribac sodium on 20 DAS (12.33). Lowest number of tillers per hill was recorded in brown manuring on 25 DAS (6.33).

At 60 DAS, highest number of tillers per hill was observed in oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS (13.33) and was on par with *in situ* green manuring on 25 DAS (12.33) and hand-weeded control (11.66). Unweeded control produced significantly lowest number of tillers per hill (7.00), which was inferior to all other treatments. At harvest, number of tillers per hill was not affected by treatments.

Application of oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS recorded highest number of tillers per hill at 30 and 60 DAS.

Table 4.4. Effect of treatments on plant height (cm)

Treatments	**30 DAS**	**60 DAS**	**At harvest**
Brown manuring (Cowpea) by application of 2,4-D 80 WP @ 1.0 kg/ha , 25 DAS	71.49	121.66	152.33
In situ green manuring (Cowpea), 25 DAS	73.04	133.40	155.00
Oxyfluorfen 23.5 EC @ 0.15 kg/ha on the day of sowing *fb* hand weeding at 30 DAS	70.43	138.90	153.06
Oxyfluorfen 23.5 EC @ 0.15 kg/ha on the day of sowing *fb* bispyribac sodium 10 SC @ 0.025 kg/ha, 20 DAS	69.54	140.60	151.86
Pyrazosulfuron-ethyl 10 WP @ 0.03 kg/ha, 6 DAS *fb* hand weeding at 30 DAS	61.16	134.30	158.66
Pyrazosulfuron-ethyl 10 WP @ 0.03 kg/ha, 6 DAS *fb* bispyribac sodium 10 SC @ 0.025 kg/ha, 20 DAS	63.82	134.66	156.57
Hand weeded control	63.36	137.16	163.10
Unweeded control	70.25	132.46	145.68
SE (m)	**-**	**-**	**-**
CD (0.05)	**NS**	**NS**	**NS**

Table 4.5. Effect of treatments on number of tillers/hill

Treatments	30 DAS	60 DAS	At harvest
Brown manuring (Cowpea) by application of 2,4-D 80 WP @ 1.0 kg/ha , 25 DAS	6.33	8.00	5.48
In situ green manuring (Cowpea), 25 DAS	10.00	12.33	6.13
Oxyfluorfen 23.5 EC @ 0.15 kg/ha on the day of sowing *fb* hand weeding at 30 DAS	13.00	13.33	7.86
Oxyfluorfen 23.5 EC @ 0.15 kg/ha on the day of sowing *fb* bispyribac sodium 10 SC @ 0.025 kg/ha, 20 DAS	12.33	9.66	7.40
Pyrazosulfuron-ethyl 10 WP @ 0.03 kg/ha, 6 DAS *fb* hand weeding at 30 DAS	10.33	8.00	6.92
Pyrazosulfuron-ethyl 10 WP @ 0.03 kg/ha, 6 DAS *fb* bispyribac sodium 10 SC @ 0.025 kg/ha, 20 DAS	9.00	8.00	6.13
Hand weeded control	10.00	11.66	7.13
Unweeded control	10.33	7.00	5.31
SE (m)	**0.64**	**0.69**	**-**
CD (0.05)	**1.98**	**2.13**	**NS**

4.2.3. Leaf area index

Data on leaf area index at 30, 60 DAS and at harvest are given in Table 4.6.

Leaf area index at 30 DAS was not affected by various treatments. Leaf area index was influenced significantly by treatments at 60 DAS and harvest.

At 60 DAS, oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS resulted in significantly higher LAI (6.20), which was closely followed by oxyfluorfen on the day of sowing *fb* bispyribac sodium 10 SC at 20 DAS (5.98). Unweeded control had lowest LAI (4.03). At harvest, significantly higher LAI was recorded in oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS (4.54), which was on par with oxyfluorfen on the day of sowing *fb* bispyribac sodium at 20 DAS (4.35), pyrazosulfuron-ethyl on 6 DAS *fb* bispyribac sodium at 20 DAS (3.91), pyrazosulfuron-ethyl on 6 DAS *fb* hand weeding at 30 DAS (3.87) and hand-weeded control (3.17). Unweeded control recorded lowest LAI (2.04).

Application of oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS resulted in higher LAI and unweeded control resulted in lowest LAI.

4.2.4. Dry matter production

Data on effect of weed management practices on dry matter production of rice are given in Table 4.7.

At 30 DAS, treatments did not show any significant effect on dry matter production. Treatments had significant effect on dry matter production at 60 DAS and at harvest. At 60 DAS, among the treatments, significantly higher value was recorded by hand-weeded control (17,000 kg/ha) and was on par with oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS (15,666 kg/ha), oxyfluorfen on the day of sowing *fb* bispyribac sodium on 20 DAS (15,666 kg/ha) and pyrazosulfuron-ethyl on 6 DAS *fb* bispyribac sodium on 20 DAS (15,666 kg/ha). Unweeded control resulted in significantly lower dry matter production (8,500 kg/ha).

At harvest, pyrazosulfuron-ethyl on 6 DAS *fb* hand weeding at 30 DAS produced highest dry matter production (23,000 kg/ha) and was on par with oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS (20,500 kg/ha). Lowest dry matter production was observed in brown manuring on 25 DAS (10,500 kg/ha).

4.3. Yield and yield attributes

4.3.1. Days to 50 % flowering

Days to 50 % flowering did not show any significant effect due to treatments. 50 % flowering was observed on 76th day for all the treatments.

4.3.2. Number of hills/m²

Observations recorded on number of hills/m² as influenced by various treatments are given by Table 4.8.

Number of hills/m² was found significantly by various treatments. Oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS produced significantly higher number of hills/m² (32.33), which was on par with all treatments except brown manuring on 25 DAS and unweeded control.

4.3.3. Number of panicles/hill

Data on the effect of treatments on number of panicles per hill is provided in Table 4.8.

No significant difference was observed on number of panicles per hill by various weed management practices.

Table 4.6. Effect of treatments on leaf area index

Treatments	30 DAS	60 DAS	At harvest
Brown manuring (Cowpea) by application of 2,4-D 80 WP @ 1.0 kg/ha , 25 DAS	3.02	4.65	2.45
In situ green manuring (Cowpea), 25 DAS	3.62	4.90	2.68
Oxyfluorfen 23.5 EC @ 0.15 kg/ha on the day of sowing *fb* hand weeding at 30 DAS	4.10	6.20	4.54
Oxyfluorfen 23.5 EC @ 0.15 kg/ha on the day of sowing *fb* bispyribac sodium 10 SC @ 0.025 kg/ha, 20 DAS	4.80	5.98	4.35
Pyrazosulfuron -ethyl 10 WP @ 0.03 kg/ha, 6 DAS *fb* hand weeding at 30 DAS	3.44	4.95	3.81
Pyrazosulfuron -ethyl 10 WP @ 0.03 kg/ha, 6 DAS *fb* bispyribac sodium 10 SC @ 0.025 kg/ha, 20 DAS	2.86	4.30	3.91
Hand weeded control	3.51	5.02	3.17
Unweeded control	3.18	4.03	2.04
SE (m)	**-**	**0.04**	**0.44**
CD (0.05)	**NS**	**0.14**	**1.37**

Table 4.7. Effect of treatments on dry matter production of rice (kg/ha)

Treatments	30 DAS	60 DAS	At harvest
Brown manuring (Cowpea) by application of 2,4-D 80 WP @ 1.0 kg/ha , 25 DAS	1,833	14,166	10,500
In situ green manuring (Cowpea), 25 DAS	2,333	12,500	11,550
Oxyfluorfen 23.5 EC @ 0.15 kg/ha on the day of sowing *fb* hand weeding at 30 DAS	2,833	15,666	20,500
Oxyfluorfen 23.5 EC @ 0.15 kg/ha on the day of sowing *fb* bispyribac sodium 10 SC @ 0.025 kg/ha, 20 DAS	2,833	15,666	17,333
Pyrazosulfuron -ethyl 10 WP @ 0.03 kg/ha, 6 DAS *fb* hand weeding at 30 DAS	2,666	15,500	23,000
Pyrazosulfuron -ethyl 10 WP @ 0.03 kg/ha, 6 DAS *fb* bispyribac sodium 10 SC @ 0.025 kg/ha, 20 DAS	3,000	15,666	14,333
Hand weeded control	3,000	17,000	13,333
Unweeded control	2,333	8,500	12,500
SE (m)	**-**	**1,177.88**	**1,577.37**
CD (0.05)	**NS**	**3,607.34**	**4,830.82**

4.3.4. Number of grains per panicle

Data on number of grains per panicle are presented in Table 4.8.

Treatments did not show any significant effect on number of grains per panicle.

4.3.5. Percentage filled grain

Data on the effect of various treatments on percentage filled grain are given in Table 4.8.

No significant difference was observed among treatments on percentage filled grain.

4.3.6. 1000 grain weight

Data on 1000 grain weight are presented in the Table 4.8.

No significant effect was observed among various treatments on 1000 grain weight.

4.3.7. Grain yield

Data on effect of various treatments on grain yield are depicted in Table 4.9.

Grain yield was influenced significantly by various weed management practices. Among the treatments, hand-weeded control produced significantly higher grain yield (2888 kg/ha), which was 78.05 % greater than unweeded control, and was on par with oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS (2743 kg/ha), which was 76.89 % greater than unweeded control, pyrazosulfuron-ethyl on 6 DAS *fb* hand weeding at 30 DAS (2589 kg/ha) and oxyfluorfen on the day of sowing *fb* bispyribac sodium on 20 DAS (2518 kg/ha). Brown manuring on 25 DAS recorded grain yield of 1,092 kg/ha and *in situ* green manuring recorded grain yield of 1,001 kg/ha. Lowest grain yield was recorded in unweeded control (634 kg/ha), which was inferior to all other treatments.

4.3.8. Straw yield

Straw yield as influenced by various treatments are presented in Table 4.9.

Straw yield was influenced significantly by various treatments. Oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS (5898 kg/ha) produced higher straw yield, which was on par with pyrazosulfuron-ethyl on 6 DAS *fb* hand weeding at 30 DAS (5886 kg/ha) and hand-weeded control (5415 kg/ha). Brown manuring on 25 DAS recorded straw yield of 1,748.40 kg/ha and *in situ* green manuring recorded straw yield of 2,210 kg/ha. Unweeded control resulted in significantly lower straw yield (943 kg/ha).

4.3.9. Harvest index

Harvest index as influenced by various treatments is given in Table 4.9.

Harvest index was influenced significantly by various treatments. Unweeded control resulted in highest harvest index (0.40), which was on par with brown manuring on 25 DAS (0.39), oxyfluorfen on the day of sowing *fb* bispyribac sodium on 20 DAS (0.37) and hand weeded control (0.34). Significantly lower harvest index was recorded in pyrazosulfuron- ethyl on 6 DAS *fb* bispyribac sodium on 20 DAS (0.29).

Table 4.8. Effect of treatments on number of hills/m², number of panicles/hill, number of grains per panicle, percentage filled grain (%) and 1000 grain weight (g)

Treatments	No. of hills per m^2	No. of panicles per hill	No. of grains per panicle	Percentage filled grain (%)	1000 grain weight (g)
Brown manuring (Cowpea) by application of 2,4-D 80 WP @ 1.0 kg/ha , 25 DAS	22.33	4.83	140.68	69.55	30.19
In situ green manuring (Cowpea), 25 DAS	27.66	3.66	155.93	68.57	29.65
Oxyfluorfen 23.5 EC @ 0.15 kg/ha on the day of sowing *fb* hand weeding at 30 DAS	32.33	6.33	159.33	78.98	28.75
Oxyfluorfen 23.5 EC @ 0.15 kg/ha on the day of sowing *fb* bispyribac sodium 10 SC @ 0.025 kg/ha, 20 DAS	31.00	5.20	111.80	82.98	29.53
Pyrazosulfuron-ethyl 10 WP @ 0.03 kg/ha, 6 DAS *fb* hand weeding at 30 DAS	30.66	6.00	107.46	80.96	28.38
Pyrazosulfuron-ethyl 10 WP @ 0.03 kg/ha, 6 DAS *fb* bispyribac sodium 10 SC @ 0.025 kg/ha, 20 DAS	25.33	5.06	122.00	91.12	30.86
Hand weeded control	32.00	4.80	123.93	88.08	29.56
Unweeded control	17.00	3.95	102.26	54.83	30.81
SE (m)	**2.64**	**-**	**-**	**-**	**-**
CD (0.05)	**8.10**	**NS**	**NS**	**NS**	**NS**

Table 4.9. Effect of treatments on grain yield, straw yield (kg/ha) and harvest index

Treatments	**Grain yield (kg/ha)**	**Straw yield (kg/ha)**	**HI**
Brown manuring (Cowpea) by application of 2,4-D 80 WP @ 1.0 kg/ha , 25 DAS	1,092	1,748	0.39
In situ green manuring (Cowpea), 25 DAS	1,001	2,210	0.30
Oxyfluorfen 23.5 EC @0.15 kg/ha on the day of sowing *fb* hand weeding at 30 DAS	2,743	5,898	0.31
Oxyfluorfen 23.5 EC @ 0.15 kg/ha on the day of sowing *fb* bispyribac sodium 10 SC @ 0.025 kg/ha, 20 DAS	2,518	4,212	0.37
Pyrazosulfuron-ethyl 10 WP @ 0.03 kg/ha, 6 DAS *fb* hand weeding at 30 DAS	2,589	5,886	0.30
Pyrazosulfuron-ethyl 10 WP @ 0.03 kg/ha, 6 DAS *fb* bispyribac sodium 10 SC @ 0.025 kg/ha, 20 DAS	1,665	4,108	0.29
Hand weeded control	2,888	5,415	0.34
Unweeded control	634	943	0.40
SE (m)	**155.19**	**426.70**	**0.02**
CD (0.05)	**475.28**	**1,306.82**	**0.07**

4.4. Nutrient uptake

4.4.1. N, P and K uptake by rice

Effect of treatments on uptake of N, P and K by rice at 30, 60 DAS and at harvest are presented in Table 4.10.

Uptake of nutrients by rice was significantly affected by various weed management practices at all stages of observation. At 30 DAS, hand-weeded control resulted in significantly highest N uptake (113.75 kg/ha) and was on par with oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS (108.79 kg/ha), oxyfluorfen on the day of sowing *fb* bispyribac sodium on 20 DAS (99.45 kg/ha) and pyrazosulfuron-ethyl on 6 DAS *fb* bispyribac sodium 20 DAS (95.33 kg/ha). Brown manuring on 25 DAS resulted in lowest N uptake (44.63 kg/ha). Highest P uptake was observed in pyrazosulfuron-ethyl on 6 DAS *fb* bispyribac sodium on 20 DAS (7.60 kg/ha), which was on par with oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS (7.20 kg/ha), pyrazosulfuron-ethyl on 6 DAS *fb* hand weeding at 30 DAS (7.19 kg/ha) , hand-weeded control (7.18 kg/ha), *in situ* green manuring on 25 DAS (6.29 kg/ha) and oxyfluorfen on the day of sowing *fb* bispyribac sodium on 20 DAS (6.10 kg/ha). Brown manuring at 25 DAS (2.82 kg/ha) resulted in significantly lowest P uptake. Among the treatments, highest K uptake by rice was obtained from pyrazosulfuron-ethyl on 6 DAS *fb* bispyribac sodium on 20 DAS (57.43 kg/ha), which was on par with oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS (54.59 kg/ha) and hand-weeded control (51.34 kg/ha). Lowest K uptake was observed in brown manuring at 25 DAS (30.78 kg/ha) and was on par with *in situ* green manuring on 25 DAS (33.02 kg/ha).

At 60 DAS, uptake of N was significantly highest under oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS (400.16 kg/ha), which was on par with oxyfluorfen on the day of sowing *fb* bispyribac sodium 20 DAS (393.83 kg/ha). Lowest uptake of N by rice was recorded in unweeded control (185.20 kg/ha). Among the treatments, brown manuring on 25 DAS resulted in highest P uptake (37.54 kg/ha) and pyrazosulfuron-ethyl on 6 DAS *fb* hand weeding at 30 DAS (32.78 kg/ha) was the second best treatment, which was on par with oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS (32.39 kg/ha). Unweeded control resulted in lowest P uptake (10.64 kg/ha). Significantly highest K uptake was recorded in oxyfluorfen on the day of sowing *fb* bispyribac sodium on 20 DAS (307.87 kg/ha), which was found on par with hand-weeded control (283.71 kg/ha) and oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS (264.73 kg/ha). Lowest K uptake by rice was observed under *in situ* green manuring on 25 DAS (98.56 kg/ha), which was on par with unweeded control (139.44 kg/ha).

At harvest, among the different treatments, oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS resulted in highest N uptake (435.16 kg/ha) which was on par with pyrazosulfuron-ethyl on 6 DAS *fb* hand weeding at 30 DAS (419.70 kg/ha) and hand-weeded control (388.50 kg/ha). Unweeded control resulted in lowest N uptake (103.75 kg/ha) which was on par with brown manuring at 25 DAS (124.60 kg/ha) and *in situ* green manuring at 25 DAS (175.28 kg/ha). Highest P uptake was observed under oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS (23.47 kg/ha), which was on par with oxyfluorfen on the day of sowing *fb* bispyribac sodium on 20 DAS (22.91 kg/ha). Hand-weeded control (7.27 kg/ha) resulted in lowest P uptake and was on par with unweeded control (7.90 kg/ha). Pyrazosulfuron-ethyl on 6 DAS *fb* hand weeding at 30 DAS resulted in significantly highest K uptake (429.79 kg/ha. Lowest uptake of K was observed under unweeded control (167.92 kg/ha).

At 30, 60 DAS and harvest, treatment receiving oxyfluorfen on the day of sowing *fb* HW at 30 DAS resulted in higher N uptake by rice. At 30 DAS, application of pyrazosulfuron- ethyl on 6 DAS *fb* bispyribac sodium on 20 DAS resulted in higher P and K. At 60 DAS, brown manuring on 25 DAS resulted in higher P uptake and oxyfluorfen on the day of sowing *fb* bispyribac sodium on 20 DAS resulted in higher K uptake. At harvest higher P uptake by rice was recorded in oxyfluorfen on the day of sowing *fb* HW at 30 DAS. Pyrazosulfuron-ethyl on 6 DAS *fb* hand weeding showed higher K uptake by rice at this stage.

Table 4.10. Effect of treatments on uptake of N, P and K by rice (kg/ha)

Treatments	N			P			K		
	30 DAS	**60 DAS**	**At harvest**	**30 DAS**	**60 DAS**	**At harvest**	**30 DAS**	**60 DAS**	**At harvest**
Brown manuring (Cowpea) by application of 2,4-D 80 WP @ 1.0 kg/ha , 25 DAS	44.63	264.25	124.60	2.82	37.54	16.50	30.78	223.15	173.00
In situ green manuring (Cowpea), 25 DAS	70.21	243.12	175.28	6.29	25.20	16.96	33.02	98.56	217.71
Oxyfluorfen 23.5 EC @ 0.15 kg/ha on the day of sowing *fb* hand weeding at 30 DAS	108.79	400.16	435.16	7.20	32.39	23.47	54.59	264.73	251.95
Oxyfluorfen 23.5 EC @ 0.15 kg/ha on the day of sowing *fb* bispyribac sodium 10 SC @ 0.025 kg/ha, 20 DAS	99.45	393.83	263.37	6.10	25.90	22.91	45.57	307.87	270.27
Pyrazosulfuron-ethyl 10 WP @ 0.03 kg/ha, 6 DAS *fb* hand weeding at 30 DAS	76.33	316.54	419.70	7.19	32.78	10.30	45.49	252.40	429.79
Pyrazosulfuron-ethyl 10 WP @ 0.03 kg/ha, 6 DAS *fb* bispyribac sodium 10 SC @ 0.025 kg/ha, 20 DAS	95.33	259.50	284.16	7.60	32.12	14.58	57.43	256.35	233.50
Hand weeded control	113.75	276.33	388.50	7.18	31.14	7.27	51.34	283.71	252.73
Unweeded control	68.26	185.20	103.75	5.56	10.64	7.90	40.07	139.44	167.92
SE (m)	**8.40**	**21.16**	**27.54**	**0.69**	**1.54**	**1.65**	**2.55**	**23.97**	**17.74**
CD (0.05)	**25.72**	**64.83**	**84.36**	**2.11**	**4.73**	**5.06**	**7.82**	**73.43**	**54.35**

4.4.2. N, P and K removal by weeds

Data on N, P and K removal by weeds as influenced by various treatments are given in Table 4.11.

Nutrient removal by weeds at 20 and 45 DAS were influenced significantly by various weed management practices. At 20 and 45 DAS, highest N and K removal by weeds was observed in unweeded control. At 20 DAS, lowest N and K removal by weeds were observed on oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS which was on par with hand-weeded control and oxyfluorfen on the day of sowing *fb* bispyribac sodium 10 SC on 20 DAS, brown manuring at 25 DAS and *in situ* green manuring at 25 DAS. P removal was highest under unweeded control (2.68 kg/ha) and lowest P removal by weeds was recorded by hand-weeded control (0.17 kg/ha) and was on par with oxyfluorfen on the day of sowing *fb* bispyribac sodium on 20 DAS (0.27 kg/ha), oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS (0.36 kg/ha), *in situ* green manuring on 25 DAS (0.43 kg/ha), pyrazosulfuron-ethyl on 6 DAS *fb* hand weeding at 30 DAS (0.73 kg/ha) and brown manuring on 25 DAS (0.94 kg/ha).

At 45 DAS, lowest N, P and K removal by weeds was observed in hand-weeded control which was on par with oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS. P removal was highest under brown manuring on 25 DAS (5.65 kg/ha) and on par with unweeded control (5.44 kg/ha). Lowest P removal by weeds was observed in hand-weeded control (0.14 kg/ha) which was on par with pyrazosulfuron-ethyl on 6 DAS *fb* hand weeding at 30 DAS (0.25 kg/ha), oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS (0.26 kg/ha) and oxyfluorfen on the day of sowing *fb* bispyribac sodium on 20 DAS (0.60 kg/ha).

4.5. Post experimental status of soil chemical properties and SMBC

4.5.1. pH

Effects of different weed management practices on soil pH after the experiment are given in Table 4.12.

No significant difference was found in pH due to various treatments. The values were almost similar for all treatments.

4.5.2. Electrical conductivity

Data on EC after the experiment are presented in the Table 4.12.

Treatments did not show any significant effect on soil EC. The values were almost same for all treatments.

4.5.3. Organic carbon

Data on organic carbon as influenced by various treatments are provided in Table 4.12.

Organic carbon was influenced significantly by treatments. Highest organic carbon content was recorded in brown manuring on 25 DAS (1.47 %) which was on par with unweeded control (1.40 %), *in situ* green manuring on 25 DAS (1.38 %), oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS (1.34 %) and pyrazosulfuron-ethyl on 6 DAS *fb* bispyribac sodium on 20 DAS (1.22 %). Lowest value of organic carbon was recorded in oxyfluorfen on the day of sowing *fb* bispyribac sodium at 20 DAS and was on par with hand-weeded control.

4.5.4. Soil microbial biomass carbon

SMBC as influenced by various treatments are given in Table 4.12.

SMBC was influenced significantly by various treatments. Highest value was observed in brown manuring at 25 DAS (235.10 µg/g of soil) which was on par with pyrazosulfuron-ethyl on 6 DAS *fb* bispyribac sodium on 20 DAS (205.26 µg/g of soil). Lowest value was observed in hand-weeded control (69.18 µg/g of soil), which was on par with unweeded control (94.93 µg/g of soil).

Table 4.11. Effect of treatments on uptake of N, P and K by weeds (kg/ha)

Treatments	20 DAS			45 DAS		
	N	**P**	**K**	**N**	**P**	**K**
Brown manuring (Cowpea) by application of 2,4-D 80 WP @ 1.0 kg/ha , 25 DAS	4.20	0.94	2.34	35.53	5.65	24.34
In situ green manuring (Cowpea), 25 DAS	6.19	0.43	1.50	14.69	4.82	13.08
Oxyfluorfen 23.5 EC @ 0.15 kg/ha on the day of sowing *fb* hand weeding at 30 DAS	2.07	0.36	0.72	1.23	0.26	0.60
Oxyfluorfen 23.5 EC @ 0.15 kg/ha on the day of sowing *fb* bispyribac sodium 10 SC @ 0.025 kg/ha, 20 DAS	2.09	0.27	1.24	11.33	0.60	3.45
Pyrazosulfuron -ethyl 10 WP @ 0.03 kg/ha, 6 DAS *fb* hand weeding at 30 DAS	10.22	0.73	5.39	2.08	0.25	1.14
Pyrazosulfuron -ethyl 10 WP @ 0.03 kg/ha, 6 DAS *fb* bispyribac sodium 10 SC @ 0.025 kg/ha, 20 DAS	10.98	1.01	6.12	46.36	2.55	15.27
Hand weeded control	2.73	0.17	1.38	1.04	0.14	0.56
Unweeded control	32.62	2.68	12.89	88.31	5.44	53.15
SE (m)	**1.97**	**0.22**	**0.49**	**3.87**	**0.78**	**1.07**
CD (0.05)	**6.03**	**0.69**	**1.52**	**11.86**	**2.39**	**3.29**

Table 4.12. Post-experimental status of pH, EC, organic carbon and SMBC

Treatments	pH	EC (dS/m)	Organic carbon (%)	SMBC (µg/g of soil)
Brown manuring (Cowpea) by application of 2,4-D 80 WP @ 1.0 kg/ha , 25 DAS	5.20	0.33	1.47	235.10
In situ green manuring (Cowpea), 25 DAS	5.09	0.35	1.38	102.03
Oxyfluorfen 23.5 EC @ 0.15 kg/ha on the day of sowing *fb* hand weeding at 30 DAS	5.08	0.37	1.34	126.92
Oxyfluorfen 23.5 EC @ 0.15 kg/ha on the day of sowing *fb* bispyribac sodium 10 SC @ 0.025 kg/ha, 20 DAS	4.90	0.38	0.53	101.81
Pyrazosulfuron-ethyl 10 WP @ 0.03 kg/ha, 6 DAS *fb* hand weeding at 30 DAS	5.19	0.39	0.92	121.33
Pyrazosulfuron-ethyl 10 WP @ 0.03 kg/ha, 6 DAS *fb* bispyribac sodium 10 SC @ 0.025 kg/ha, 20 DAS	4.96	0.35	1.22	205.26
Hand weeded control	4.93	0.35	0.65	69.18
Unweeded control	5.16	0.34	1.40	94.93
SE (m)	**-**	**-**	**0.14**	**10.15**
CD (0.05)	**NS**	**NS**	**0.44**	**31.10**
Pre experimental status of the soil	**4.77**	**0.61**	**1.41**	**38.36**

4.5.4. Available N, P and K

Table 4.13. Represents data on available N, P and K after the experiment.

Available N content of the soil after the experiment was not influenced by weed management practices.

Weed management practices showed significant effect on available P and K after the experiment. Oxyfluorfen on the day of sowing *fb* bispyribac sodium on 20 DAS (89.59 kg/ha) resulted in highest available P content, which was on par with brown manuring on 25 DAS (83.22 kg/ha) and oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS (80.44 kg/ha). Pyrazosulfuron-ethyl on 6 DAS *fb* bispyribac sodium on 20 DAS resulted in lowest available P (55.39 kg/ha), which was on par with pyrazosulfuron-ethyl on 6 DAS *fb* hand weeding at 30 DAS (66.50 kg/ha).

Among the treatments, hand-weeded control resulted in significantly higher available K (163.97 kg/ha) which was on par with pyrazosulfuron-ethyl on 6 DAS *fb* hand weeding at 30 DAS (147.71 kg/ha). Lowest available K in soil was recorded in unweeded (85.17 kg/ha) control, which was on par with *in situ* green manuring on 25 DAS.

4.6. Economic analysis

Cost of cultivation, gross return, net return and B:C ratios of the experiment are given in Table 4.14.

Among the different treatments, oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS resulted in highest gross return (Rs. 130308/- per ha), net return (Rs. 85628/- per ha) and B:C ratio (2.91), which was closely followed by pyrazosulfuron-ethyl on 6 DAS *fb* hand weeding at 30 DAS, which resulted in gross return of Rs. 126199/- per ha, net return of Rs.70267/- per ha and B:C ratio of 2.87. Hand-weeded control resulted in B:C ratio of 2.19. Lowest B:C ratio was recorded from unweeded control (0.74).

Table 4.13. Post-experimental status of available N, P and K in soil (kg/ha)

Treatments	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
Brown manuring (Cowpea) by application of 2,4-D 80 WP @ 1.0 kg/ha , 25 DAS	210.00	83.22	134.43
In situ green manuring (Cowpea), 25 DAS	222.60	75.60	103.11
Oxyfluorfen 23.5 EC @ 0.15 kg/ha on the day of sowing *fb* hand weeding at 30 DAS	247.80	80.44	125.70
Oxyfluorfen 23.5 EC @ 0.15 kg/ha on the day of sowing *fb* bispyribac sodium 10 SC @ 0.025 kg/ha, 20 DAS	222.60	89.59	112.72
Pyrazosulfuron -ethyl 10 WP @ 0.03 kg/ha, 6 DAS *fb* hand weeding at 30 DAS	222.60	66.50	147.71
Pyrazosulfuron -ethyl 10 WP @ 0.03 kg/ha, 6 DAS *fb* bispyribac sodium 10 SC @ 0.025 kg/ha, 20 DAS	180.60	55.39	135.55
Hand weeded control	205.80	75.80	163.97
Unweeded control	193.20	76.31	85.17
SE (m)	**-**	**4.25**	**9.13**
CD (0.05)	**NS**	**13.02**	**27.98**
Pre-experimental status of the soil	**176.40**	**135.76**	**171.64**

Table 4.14. Effect of treatments on economics of cultivation

Treatments	Cost of cultivation (Rs./ha)	Gross return (Rs./ha)	Net return (Rs./ha)	B:C ratio
Brown manuring (Cowpea) by application of 2,4-D 80 WP @ 1.0 kg/ha , 25 DAS	36772	45880	9108	1.24
In situ green manuring (Cowpea), 25 DAS	36400	48142	11742	1.32
Oxyfluorfen 23.5 EC @ 0.15 kg/ha on the day of sowing *fb* hand weeding at 30 DAS	44680	130308	85628	2.91
Oxyfluorfen 23.5 EC @ 0.15 kg/ha on the day of sowing *fb* bispyribac sodium 10 SC @ 0.025 kg/ha, 20 DAS	40055	107602	67547	2.68
Pyrazosulfuron-ethyl 10 WP @ 0.03 kg/ha, 6 DAS *fb* hand weeding at 30 DAS	43937	126199	82261	2.87
Pyrazosulfuron-ethyl 10 WP @ 0.03 kg/ha, 6 DAS *fb* bispyribac sodium 10 SC @ 0.025 kg/ha, 20 DAS	39312	84379	123691	2.14
Hand weeded control	59000	129267	70267	2.19
Unweeded control	35000	25917	-9082	0.74

Discussion

5. DISCUSSION

A field experiment entitled "Weed management for upland rice" was conducted at Agronomy Farm, College of Horticulture, Vellanikkara to study the effect of weeds on growth and yield of upland rice and to develop a cost effective weed management strategy for upland rice. Important results of the study are discussed under the following sections.

5.1. Effect of treatments on weed control

Weeds are a serious problem in upland rice and cause drastic reduction in yield. Weeds will emerge simultaneously with crop and compete for soil moisture, nutrients, light and space under direct seeded upland situation, which negatively affect the growth and yield attributing characters and finally lead to reduction of yield. Hence for achieving higher productivity effective and timely weed control is essential.

From the study, twenty-two different weed species were identified in the experimental field (grasses-6, BLWs-15 and sedges-1). Among grassy weeds, *Setaria* spp., *Digitaria sanguinalis, Echinochloa colona, Eleusine indica, Panicum maximum* and *Brachiaria* spp. were dominant. *Alternanthera bettzickiana, Lindernia crustacea, Mollugo disticha, Ludwigia perennis, Ageratum conyzoides, Mitracarpus hirtus, Euphorbia hirta, Euphorbia geniculata, Scoparia dulcis, Phyllanthus amara, Cleome burmannii, Commelina benghalensis, Catharanthus pusillus, Trianthema portulacastrum* and *Hemidesmus indicus* were identified as broad-leaf weeds and *Cyperus iria* was the only sedge identified in the experimental field.

Weed count, weed dry matter production, weed control efficiency (WCE) and weed index (WI) were significantly affected by various treatments.Weed count at all the stages of observation was influenced by weed management practices (Fig. 5.1 & Fig. 5.2). Hand-weeded control resulted in lowest grass weed count, which may be due to regular control of weeds by weeding thrice, which produced an almost weed-free situation. This treatment was on par with oxyfluorfen applied on the day of sowing *fb* HW at 30 DAS and it might be due to prevention of germination of weeds during initial crop growth by the application of oxyfluorfen as pre-emergence herbicide. Highest grass weed count was recorded in unweeded control, followed by pyrazosulfuron-ethyl on 6 DAS *fb* bispyribac sodium on 20 DAS. Bhurer *et al*. (2013) reported that lesser number of weeds/m² were recorded from weed-free plot. Lowest broad-leaf count was recorded under oxyfluorfen on the day of sowing *fb* HW at 30 DAS and hand-weeded control, which might be due to ability of herbicides to inhibit the germination of weeds and hand weeding which prevented the growth of weeds. Highest broad-leaf count was recorded from unweeded control. Sedge count was very less as compared to grass and broad-leaf weeds. At 20 DAS, higher sedge count was recorded under brown manuring on 25 DAS and unweeded control. At 45 DAS, higher sedge weed count was recorded in plots receiving oxyfluorfen on the day of sowing *fb* bispyribac sodium on 20 DAS and *in situ* green manuring on 25 DAS. Lesser total weed count was observed under oxyfluorfen on the day of sowing *fb* HW at 30 due to its broad spectrum activity as it can control all types of weeds in rice. Application of oxyflourfen @ 0.15 kg/ha *fb* HW at 20 DAS resulted in minimum number of grass, broad-leaf weeds and sedges at all stages of observation in aerobic rice (Reshma *et al.,* 2015). Application of oxyfluorfen @ 400 g/ha resulted in lesser weed population and dry matter production (Poddar *et al.,* 2014). Highest total weed count was recorded under unweeded control, where weeds were not controlled by any method. Weedy-check recorded higher number of weeds/m² (Bhurer *et al*., 2013).

Weed dry matter production at 20 DAS and 45 DAS were influenced by the treatments (Fig. 5.3). Weed dry matter accumulation was increased from 20 DAS to 45 DAS in all the treatments, except oxyfluorfen on the day of sowing *fb* HW at 30 DAS, pyrazosulfuron-ethyl on 6 DAS *fb* HW at 30 DAS and hand-weeded control. Lesser weed dry matter accumulation was recorded in hand-weeded control, which was closely followed by oxyfluorfen on the day of sowing *fb* HW at 30 DAS and reduction was 92.60 % at 20 DAS and 98. 58 % at 45 DAS over unweeded control. At 45 DAS, pyrazosulfuron-ethyl on 6 DAS *fb* HW at 30 DAS was the second best treatment after oxyfluorfen on the day of sowing *fb* HW at 30 DAS. Lesser weed dry matter accumulation in hand weeded control might be due to regular control of weeds by hand-weeding thrice. Lowest weed dry matter production by oxyfluorfen on the day of sowing *fb* HW at 30 DAS and pyrazosulfuron-ethyl on 6 DAS *fb* HW at 30 DAS, might be due to timely application of pre-emergence herbicide and its broad spectrum action to control grasses and BLWs and also hand-weeding which resulted in less weed infestation. Dadsena *et al*. (2014) reported that hand-weeded control resulted in minimum weed dry matter production in direct-seeded upland rice. Hand weeding at 20, 40 and 60 DAS resulted in less weed density and weed dry matter in upland rice (Dhanapal *et al*., 2018). Poddar *et al*. (2014) observed that application of oxyfluorfen @ 400 g/ha resulted in less weed biomass. Priya *et al*. (2017a) suggested that oxyfluorfen application @ 250 g/ha *fb* hand weeding at 45 DAS could reduces weed density, weed dry matter and increase grain and straw yield in transplanted rice. Saini (2003) reported that pyrazosulfuron application resulted in lesser weed dry matter production. *In situ* green manuring and brown manuring resulted in lesser weed dry matter production as compared to unweeded control and it can be an effective biological method for controlling weeds. In the case of *in situ* green manuring reduction in weed dry matter production was 86. 14 % at 20 DAS and 67.22 % at 45 DAS and for brown manuring reduction was 71.03 % at 20 DAS and 54.09 % at 45 DAS over unweeded control. It might be due to smothering effect of cowpea during initial crop growth stage that reduced the weed infestation. Both at 20 DAS and 45 DAS, higher weed dry matter accumulation was recorded in unweeded control, followed by pyrazosulfuron-ethyl on 6 DAS *fb* bispyribac sodium on 20 DAS. It might be due to ineffective control of weeds. Under direct-seeded upland rice system, weedy check reported higher weed biomass (Dadsena *et al*., 2014). Similar result has been found by Chakraborti *et al*. (2017).

WCE was influenced by various treatments (Fig. 5.4). Oxyfluorfen on the day of sowing *fb* HW at 30 DAS resulted in better WCE at both stages of observation which was equally effective as hand-weeded control. At 45 DAS, pyrazosulfuron-ethyl on 6 DAS *fb* HW at 30 DAS recorded better WCE. This might be due to reduction in weed biomass by broad spectrum activity of herbicides, which controlled grasses and broad-leaf weeds very effective as well as timely control of weeds by HW at 30 DAS. Reshma *et al*. (2015) observed that application of oxyfluorfen @ 0.15 kg a.i/ha as pre-emergence followed by hand weeding at 20 DAS resulted in highest WCE (89.43 %) in aerobic rice. Porwal (1999) revealed that application of oxyflourfen at 0.2 kg/ha recorded higher WCE (96.50 %). According to Chopra and

Nisha (2003), application of pyrzosulfuron-ethyl resulted in reduction in weed density and weed dry matter production. At 20 DAS, brown manuring resulted in WCE of 71.02 % and *in situ* green manuring resulted in WCE of 86.14 %. It might be due to smothering effect of cowpea that resulted in less weed infestation during early stage of crop growth. At 45 DAS, WCE was found less as compared to all other treatments, which might be due to lack of any weed control measures at later stages of crop growth.

WI was significantly affected by various treatments (Fig 5.6). Oxyfluorfen on the day of sowing *fb* HW at 30 DAS resulted in lowest WI, followed by pyrazosulfuron-ethyl on 6 DAS *fb* HW at 30 DAS and oxyfluorfen on the day of sowing *fb* bispyribac sodium on 20 DAS. It might be due to better control of weeds, which resulted in minimum weed dry matter production. Similar result was obtained by Reshma *et al*. (2015) in the case of oxyfluorfen, who reported pre-emergence application of oxyfluorfen followed by hand weeding at 20 DAS resulted in less weed index (8.85 %) in aerobic rice cultivation. Pyrazosulfuron-ethyl at 15 g/ha could effectively control broad leaf weeds in direct seeded rice (Choudhary and Dixit, 2018). Application of bispyribac sodium in rainfed direct seeded rice recorded lowest WI (Kumar and Rana, 2013). Unweeded control resulted in higher WI and it might be due to higher weed pressure and lesser WCE. Dadsena *et al.* (2014) reported higher WI in unweeded plot under direct seeded upland rice. Even though brown manuring and *in situ* green manuring recorded better WCE at 20 DAS WI was found higher and it might be due to lack of herbicide application or hand weeding at critical period of weed competition.

Application of oxyfluorfen on the day of sowing *fb* HW at 30 DAS was equally effective as hand weeded control at 20 and 45 DAS and resulted in lesser weed count, dry matter production, WI and high WCE. Application of pyrazosulfuron-ethyl on 6 DAS *fb* HW at 30 DAS resulted in lesser weed dry matter production, lesser WI and high WCE at 45 DAS. *In situ* green manuring and brown manuring resulted in reduction in weed dry matter production and high WCE at early stages of crop growth as compared to unweeded control, but it was not effective as herbicide application.

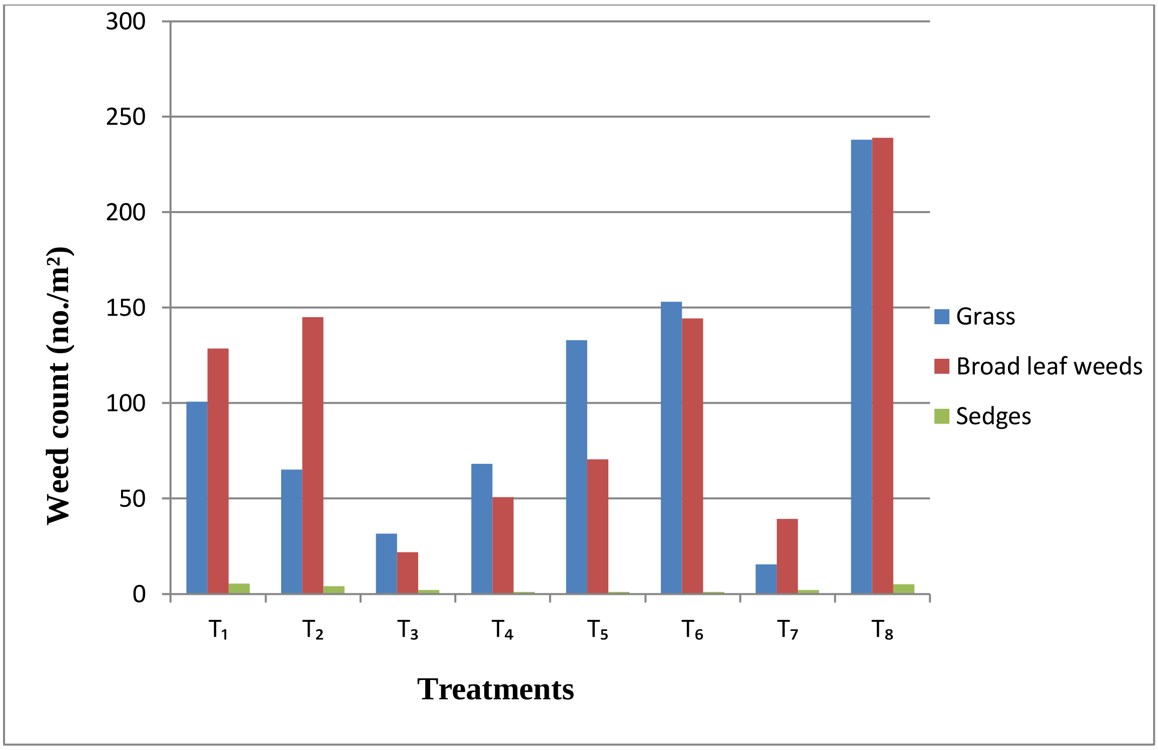

Figure 5.1. Effect of treatments on weed count (no./m^2) at 20 DAS

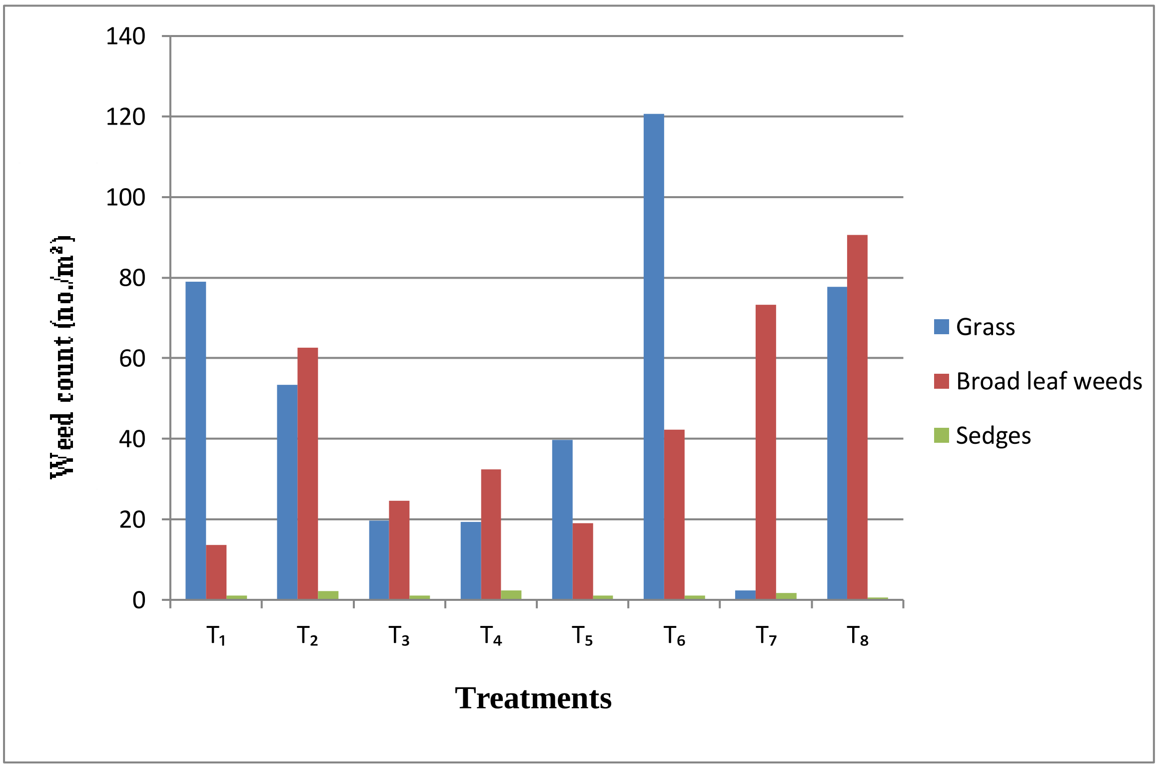

Figure 5.2. Effect of treatments on weed count (no./m^2) at 45 DAS

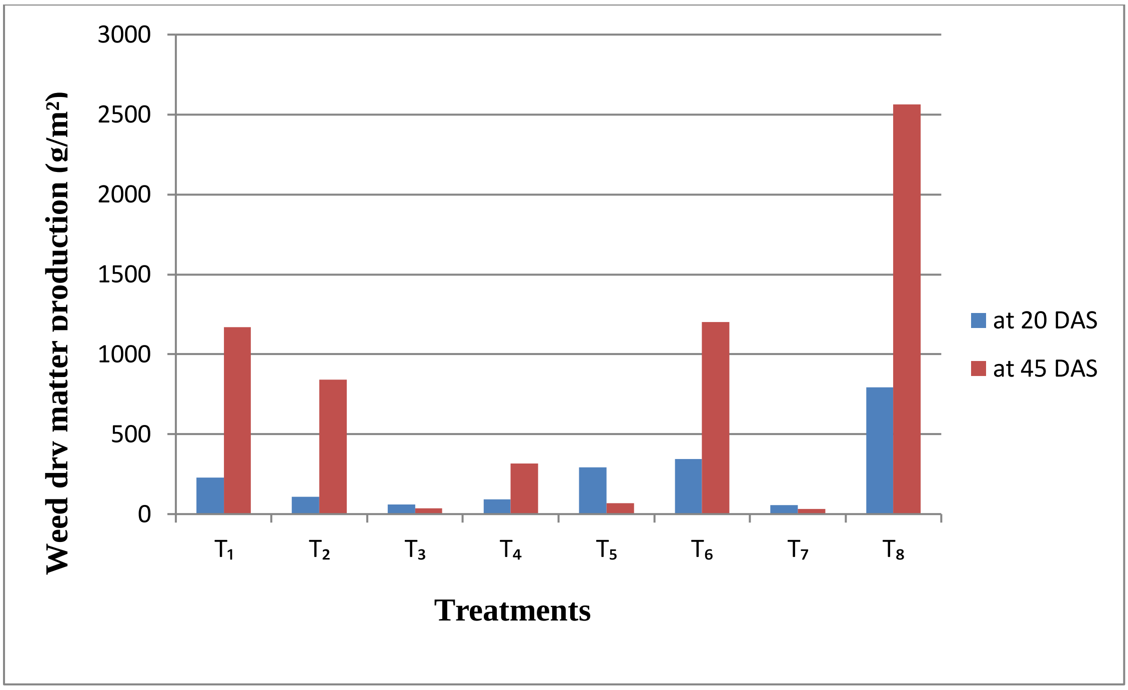

Figure 5.3. Effect of treatments on weed dry matter production (g/m^2)

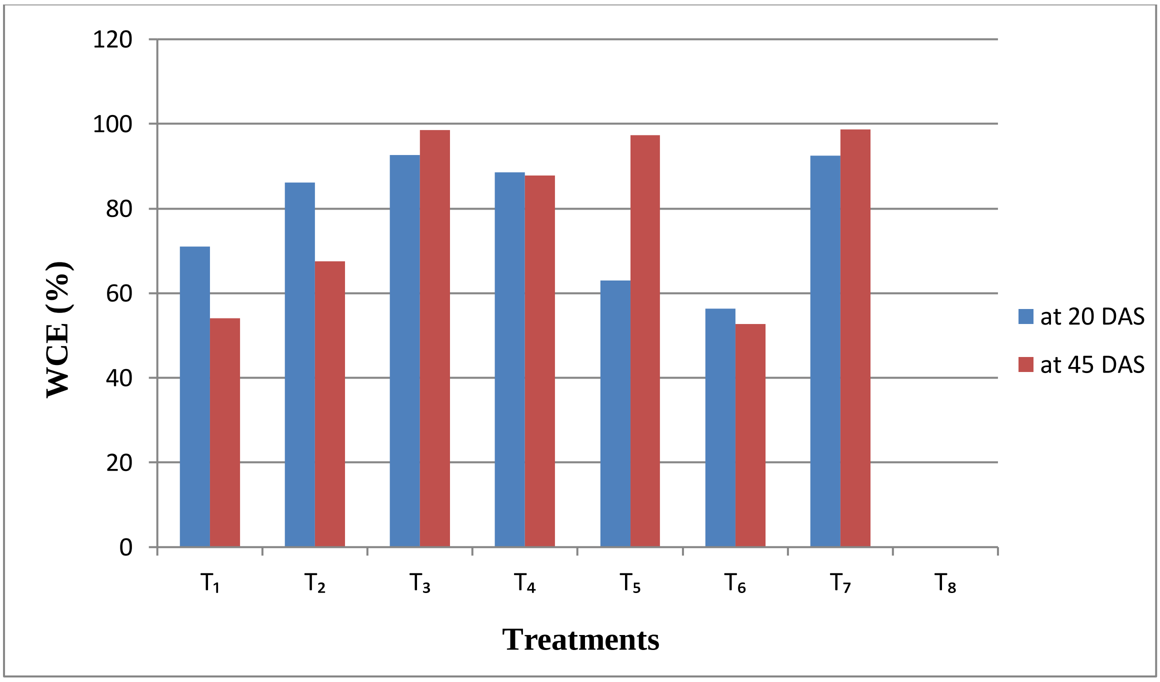

Figure 5.4. Effect of treatments on weed control efficiency (%)

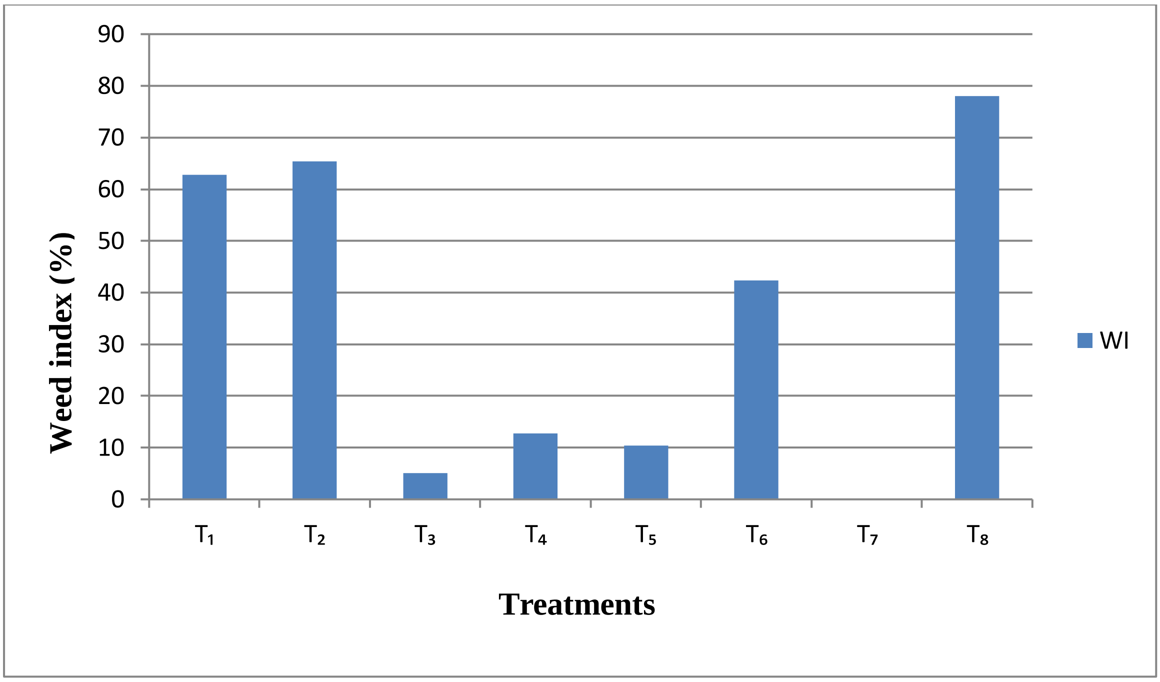

Figure 5.5. Effect of treatments on weed index (%)

5.2. Effect of treatments on growth and productivity of rice

Grain yield and straw yield in upland rice were influenced significantly by various weed management practices (Fig 5.9). Among the different treatments, hand-weeded control resulted in higher grain yield, closely followed by oxyfluorfen on the day of sowing *fb* HW at 30 DAS. Hand-weeded control and oxyfluorfen on the day of sowing *fb* HW at 30 DAS resulted in 355.52 % and 332.64 % higher yield over unweeded control. Hand-weeding thrice resulted in better growth and yield attributing characters due to less weed competition by regular control of weeds in upland rice. The increased grain yield in oxyfluorfen on the day of sowing *fb* HW at 30 DAS might be due to reduction in weed count, weed dry matter production, WI and higher WCE, which contributed to better growth and yielding attributing characters. Application of oxyfluorfen *fb* HW at 30 DAS resulted in higher number of tillers/hill and number of hills/m^2 (Fig. 5.6 & Fig. 5.7) and increased yield attributing characters, which may be due to reduction in weed competition and was reflected in growth and yield parameters. Highest number of tillers per hill might be due to lesser weed infestation and competition during the crop growth, which may increase the number of tillers per hill. Reshma *et al*. (2015) revealed that in aerobic rice cultivation, application of oxyfluorfen *fb* HW at 20 DAS resulted in higher number of productive tillers/m^2 and also reported that hand-weeded control resulted in highest grain yield (3889 kg/ha) and was on par with oxyfluorfen followed by HW at 20 DAS (3500 kg/ha) in aerobic rice (Reshma *et al*., 2015). Hand-weeded control resulted in highest grain yield and was on par with pre-emergence application of oxyfluorfen 150 g/ha in transplanted rice (Abraham *et al*., 2010). Unweeded control resulted in lesser grain yield and recorded 78.05 % yield reduction in upland rice. It might be due to heavy infestation of weeds and high competition of weeds for nutrients and other resource. Lowest grain yield of 1075 kg/ha was recorded in unweeded control in direct-seeded upland rice (Roy, 2016). De Datta (1981) reported 67 % yield reduction due to weed infestation in upland rice. *In situ* green manuring and brown manuring resulted in 57.89 % and 72.23 % higher yield over unweeded control, but it was not effective as herbicide treatments and it might be due to competition for space and nutrients as concurrent emergence of cowpea and weeds along with rice seedlings during initial stage of crop growth may have negatively influenced the growth and yield parameters. Hasanuzzaman (2019) reported that practice of green manuring resulted in competition for space, nutrients and other resources.

Oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS resulted in highest straw yield followed by pyrazosulfuron-ethyl on 6 DAS *fb* HW at 30 DAS. It might be due to effective control of all types of weeds from initial stage of crop growth which might have led to better crop growth and dry matter production (Fig. 5.8). Lower straw yield was obtained from unweeded control and it was mainly due to uncontrolled weed growth. Roy (2016) found that weedy check recorded less straw yield (2250 kg/ha) in upland rice cultivation. Same result has been obtained by Dadsena *et al.* (2014) also who reported that straw yield from weedy check was very less (1810 kg/ha) under upland condition. Harvest index was found affected by various treatments (Fig. 5.10). Unweeded control recorded highest HI and it might be due to less production of straw. Lowest HI was recorded by pyrazosulfuron-ethyl on 6 DAS *fb* bispyribac sodium on 20 DAS and it may be due to lesser grain yield. According to Priya *et al.* (2017a), oxyfluorfen application @ 250 g/ha *fb* HW at 45 DAS could increase grain and straw yield in transplanted rice. Treatment receiving application of pyrazosulfuron-ethyl followed by bispyribac sodium resulted in higher grain and straw yield (Roy, 2016).

Oxyfluorfen on the day of sowing *fb* HW at 30 DAS resulted in highest number of tillers per hill and number of hills/m^2. Highest grain yield was recorded by oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS, which was almost equal to hand-weeded control. Weed competition resulted in 78.05 % yield reduction in upland rice. Oxyfluorfen 23.5 EC on the day of sowing *fb* hand weeding at 30 DAS resulted in highest straw yield followed by pyrazosulfuron-ethyl 10 WP on 6 DAS *fb* HW at 30 DAS. Brown manuring and *in situ* green manuring resulted in grain yield and straw yield higher than unweeded control. Even though practice of *in situ* green manuring and brown manuring was not effective as herbicide application, it can be considered as better weed management strategy in upland rice.

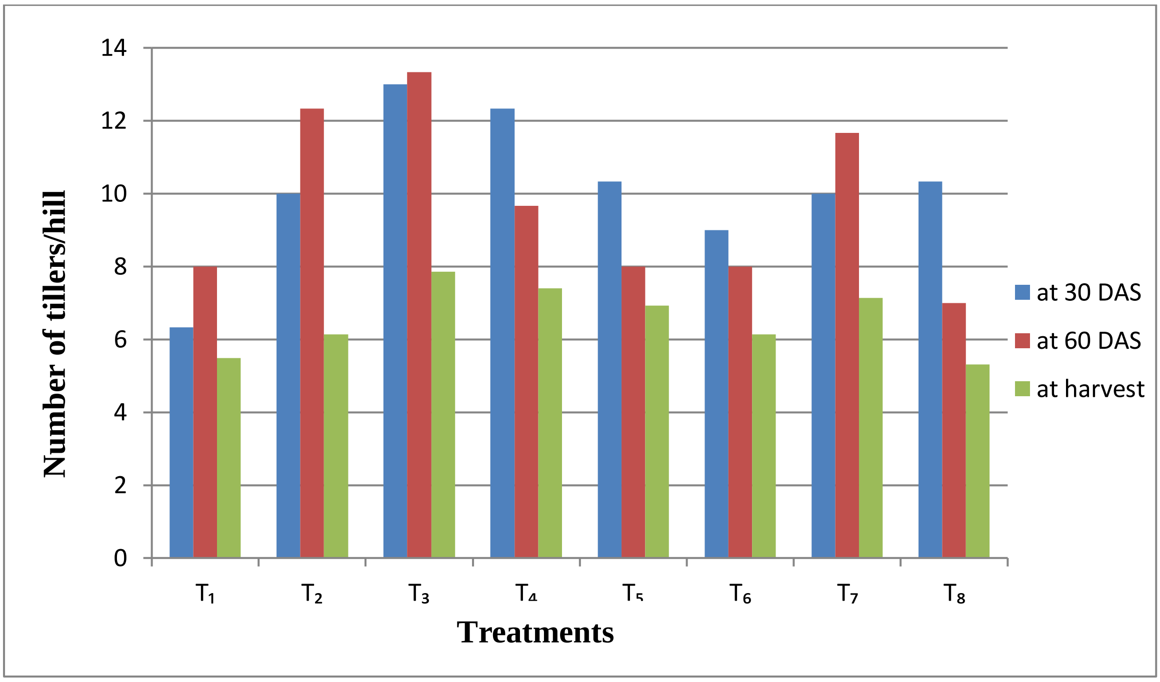

Figure 5.6. Effect of treatments on number of tillers/hill

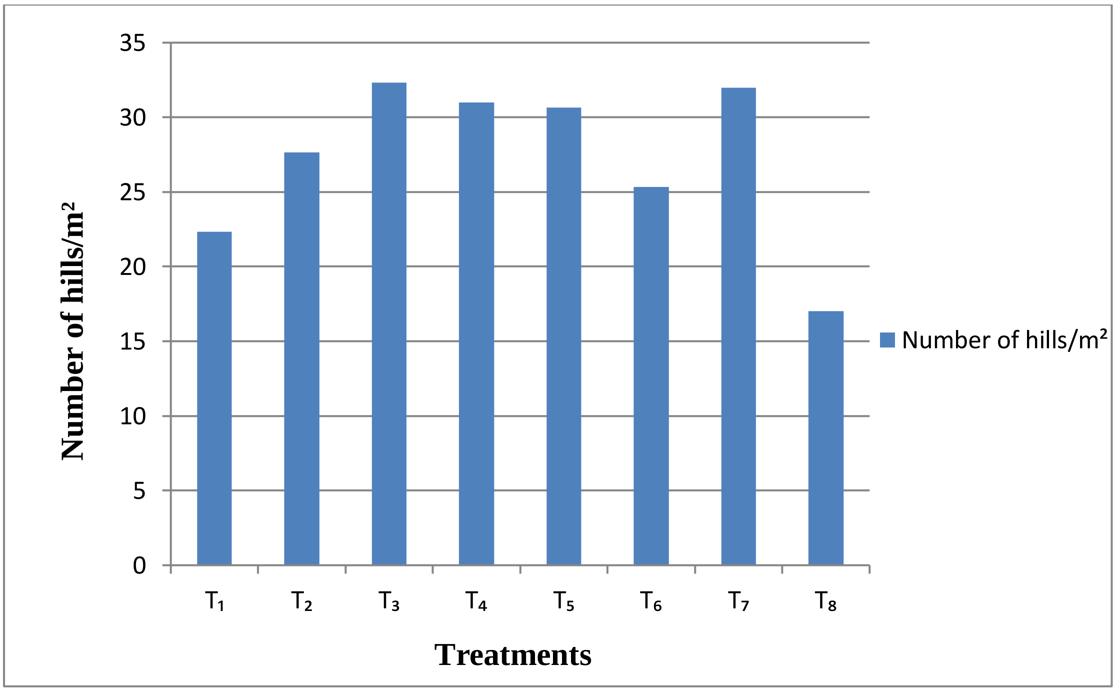

Figure 5.7. Effect of treatments on number of hills/m²

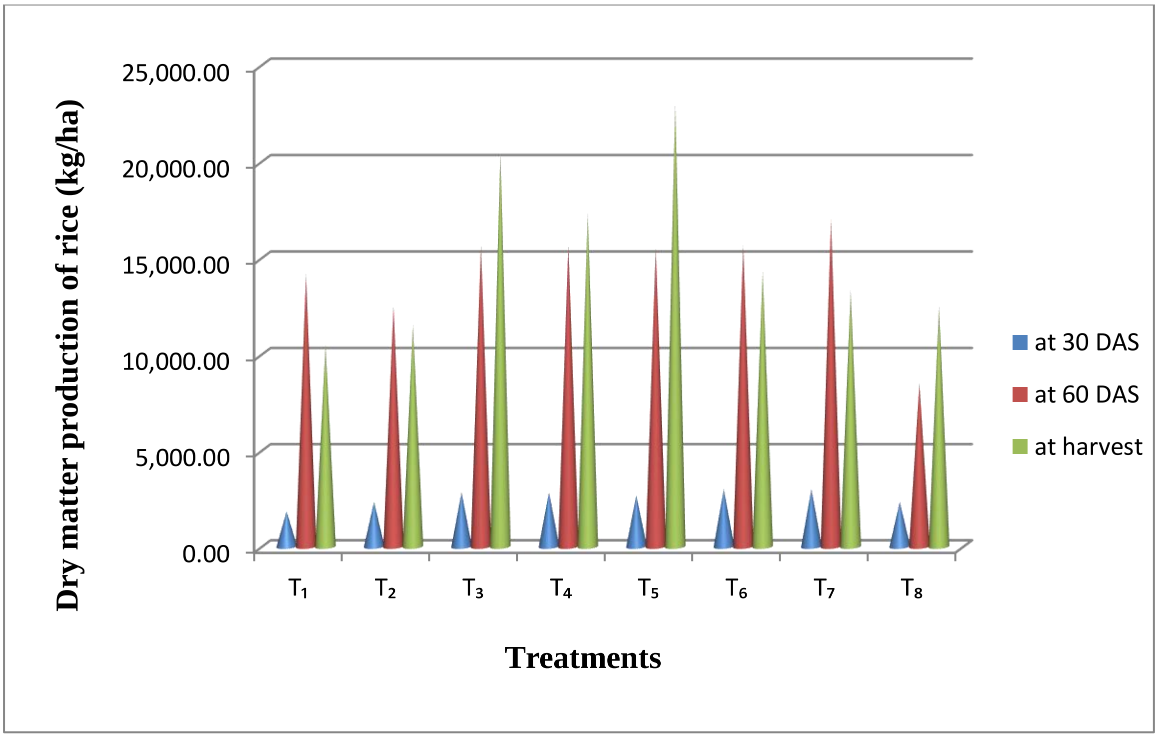

Figure 5.8. Effect of treatments on dry matter production of rice (kg/ha)

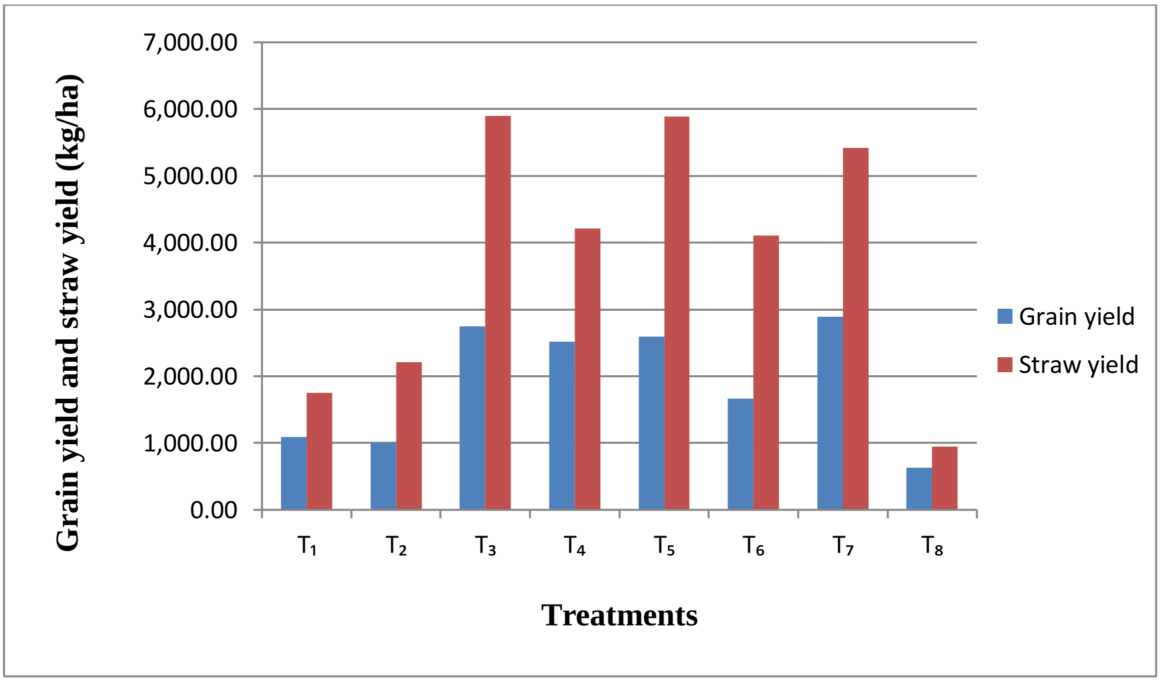

Figure 5.9. Effect of treatments on grain yield and straw yield (kg/ha)

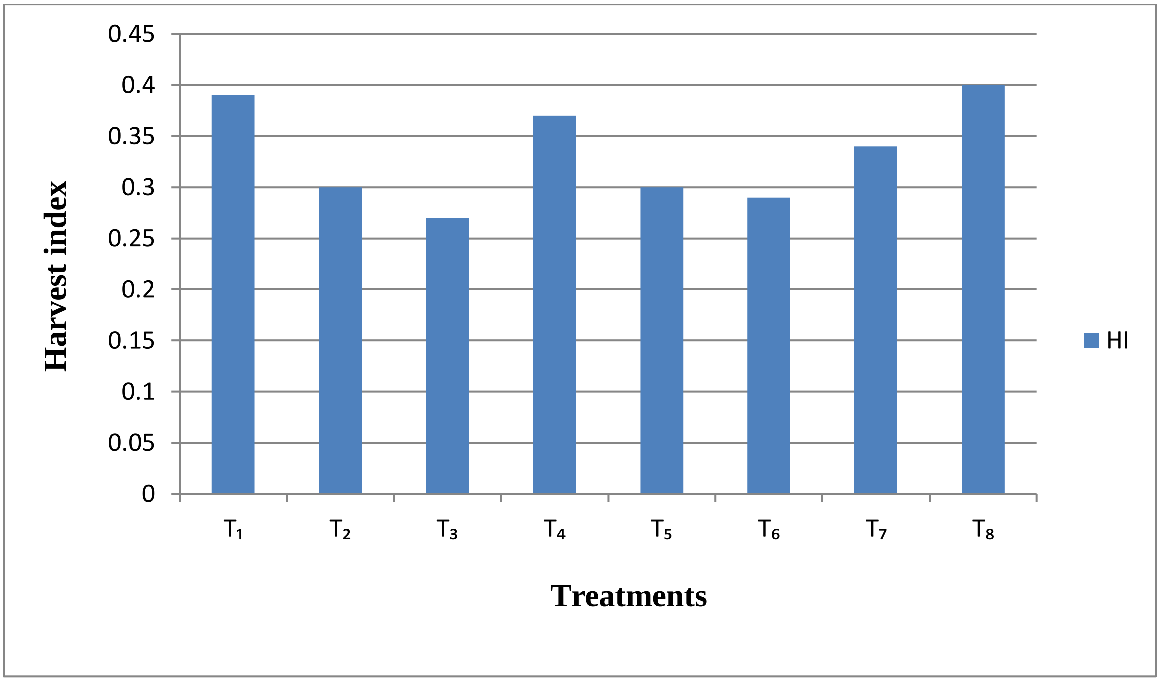

Figure 5.10. Effect of treatments on harvest index

5.3. Effect of treatments on nutrient uptake

Nutrient uptake by rice was influenced significantly by various weed management practices (Fig. 5.11, Fig. 5.12 and Fig 5.13). At 30 DAS, hand weeded control resulted in higher N uptake by rice, which was closely followed by oxyfluorfen on the day of sowing *fb* HW at 30 DAS. At 60 DAS and at harvest, oxyfluorfen on the day of sowing *fb* HW at 30 DAS resulted in higher N uptake by rice. At 30 DAS, higher P uptake by rice was recorded by pyrazosulfuron-ethyl on 6 DAS *fb* bispyribac sodium on 20 DAS, which was closely followed by oxyfluorfen on the day of sowing *fb* HW at 30 DAS. At 60 DAS, brown manuring and at harvest, oxyfluorfen on the day of sowing *fb* HW at 30 DAS resulted in higher P uptake by rice. At 30 DAS, higher K was recorded under pyrazosulfuron-ethyl on 6 DAS *fb* bispyribac sodium on 20 DAS. At 60 DAS, oxyfluorfen on the day of sowing *fb* bispyribac sodium on 20 DAS and at harvest, pyrazosulfuron-ethyl on 6 DAS *fb* HW at 30 DAS resulted in higher K uptake by rice. It might be due to better weed management practices, which contributed favourable condition for crop growth, which resulted in higher vegetative growth and high nutrient uptake as it was a product of dry matter production and nutrient content. Lowest uptake of N, P and K by rice was observed under unweeded control due to lesser dry matter production of rice, higher weed count and weed dry matter accumulation during initial stage of crop growth as weeds were not controlled and competed for nutrients and other resources that inhibited the growth of rice. Similar result has been obtained by Dadsena *et al.* (2014) as weedy check recorded lesser uptake of N, P and K by rice at harvest under upland condition. Less nutrient uptake by crop was recorded in weedy check (Chakraborti *et al.*, 2017). Madhukumar *et al.* (2013) also reported same result as lowest uptake of nutrients by crop was recorded by unweeded control (N- 9.76, P- 1.13 and K- 5.40 kg/ha) under aerobic system of rice cultivation.

Nutrient removal by weeds was significantly affected by various weed management practices. Among the different treatments, oxyfluorfen on the day of sowing *fb* HW at 30 DAS resulted in lowest N, P and K removal by weeds, which was similar as that of hand weeded control. It might be due to lesser weed dry matter accumulation and high WCE as a result of better management of weeds. Poddar *et al.*

(2014) suggested that application of oxyfluorfen resulted in less weed density and weed biomass. Highest N, P and K removal by weeds was observed in unweeded control due to higher weed dry matter production. Sunil *et al*. (2011) found similar results that highest removal of nutrients by weeds was recorded under unweeded control in aerobic rice cultivation.

Among the various treatments, oxyfluorfen on the day of sowing *fb* HW at 30 DAS resulted in higher N uptake by rice at all stages of observation. At 30 DAS, application of pyrazosulfuron-ethyl on 6 DAS *fb* bispyribac sodium on 20 DAS resulted in higher P and K uptake by rice. At 60 DAS, brown manuring resulted in higher P and oxyfluorfen on the day of sowing *fb* bispyribac sodium on 20 DAS resulted in higher K uptake by rice. At harvest, oxyfluorfen on the day of sowing *fb* HW at 30 DAS resulted in higher P and pyrazosulfuron-ethyl on 6 DAS *fb* HW at 30 DAS resulted in higher K uptake by rice. Application of oxyfluorfen on the day of sowing *fb* HW at 30 DAS resulted in lowest N, P and K removal by weeds, which was similar as that of hand-weeded control.

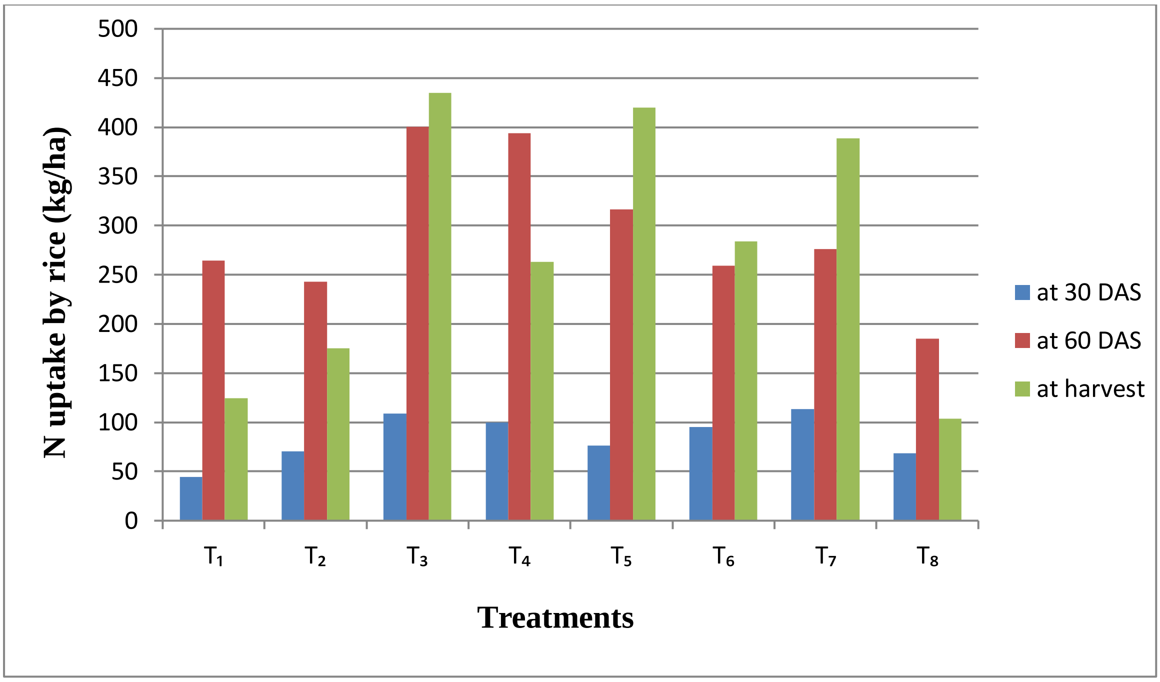

Figure 5.11. Effect of treatments on uptake of N by rice (kg/ha)

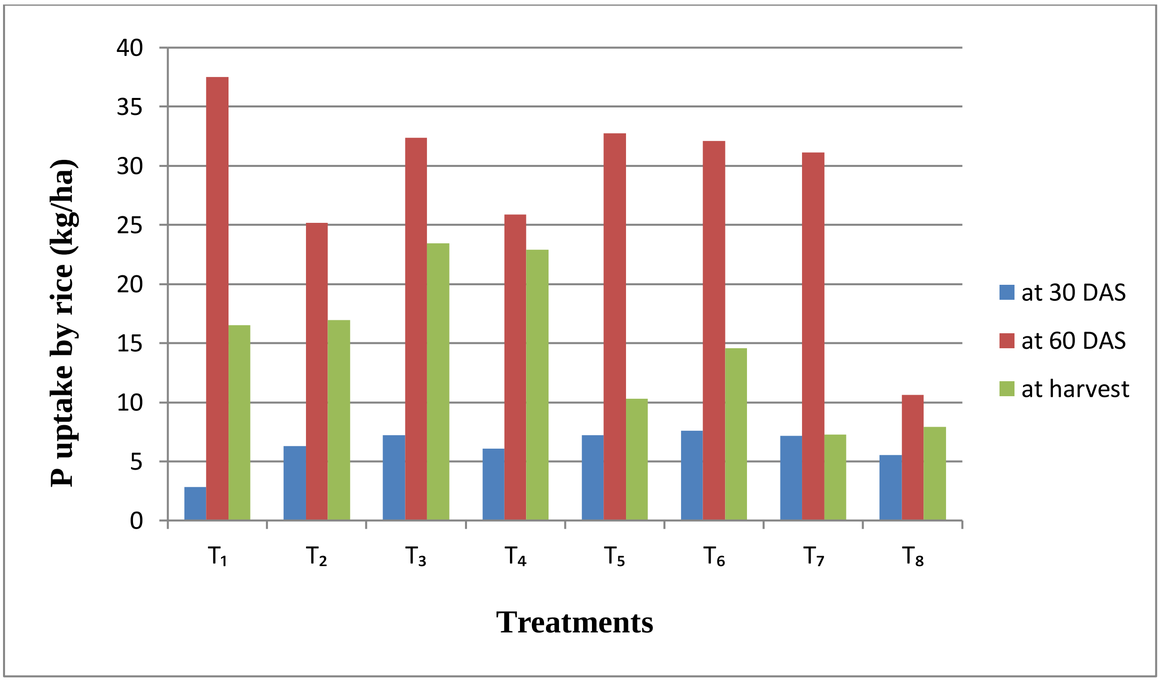

Figure 5.12. Effect of treatments on uptake of P by rice (kg/ha)

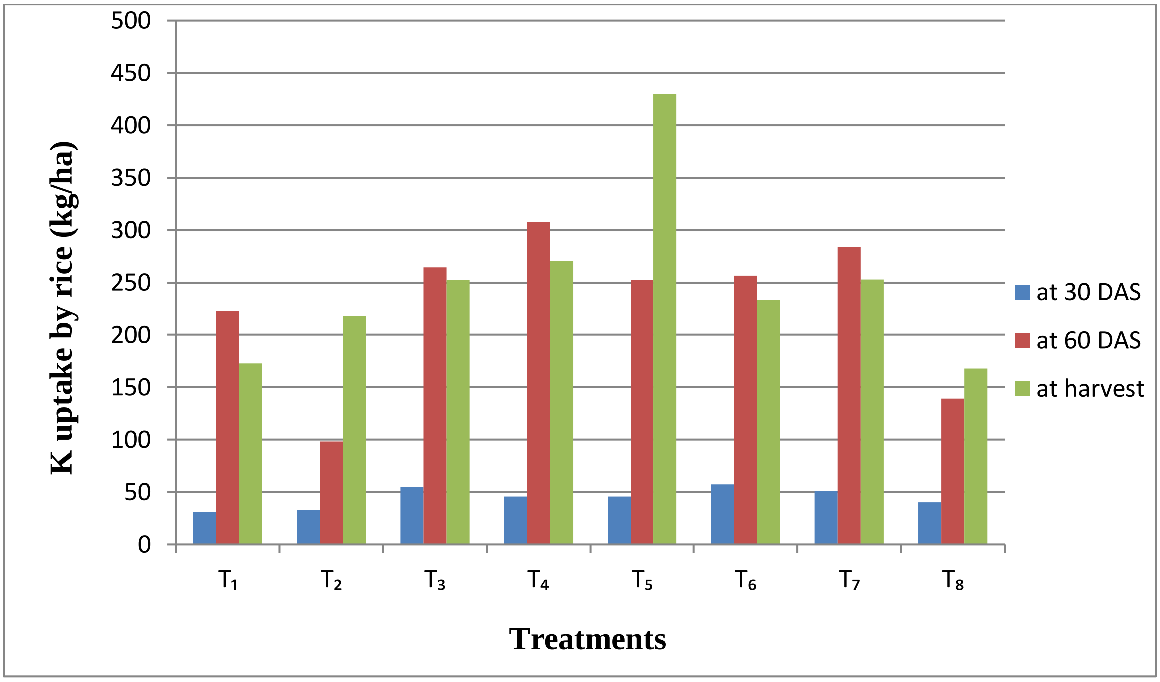

Figure 5.13. Effect of treatments on uptake of K by rice (kg/ha)

5.4. Effect of treatments on soil nutrient status

pH, EC and available N were found unaffected by various treatments. Organic carbon, soil microbial biomass carbon (SMBC) and available P and K were influenced significantly by treatments.

Higher organic carbon was recorded in brown manuring and was on par with *in situ* green manuring (Fig. 5.14). It may be because decomposition of cowpea added more organic matter, which could increase organic carbon in the soil. Maitra and Zaman (2017), obtained similar result under practice of brown manuring, which improved the organic carbon and also accelerated the soil microbial activity. According to Kumar *et al.* (2011), practice of green manuring increased the organic carbon content in the soil. Oxyfluorfen on the day of sowing *fb* bispyribac sodium on 20 DAS resulted in lowest value for organic carbon due to less activity of soil microbes on decomposition process due to the application of herbicides. Amritha and Devi (2017) reported that application of pre-emergence herbicides, pendimethalin and oxyfluorfen and post-emergence herbicides, bispyribac sodium and cyhalofop butyl decreased the soil microbial activity up to 30 days after the application of herbicides and it was low at the time of harvest. Baboo *et al.* (2013) reported application of herbicides like butachlor, pyrazosulfuron, paraquat and glyphosate decreased the organic carbon in the soil.

Soil microbial biomass carbon was affected by treatments (Fig. 5.15). SMBC was higher under brown manuring on 25 DAS and pyrazosulfuron-ethyl on 6 DAS *fb* bispyribac sodium on 20 DAS. Decomposition of cowpea and herbicide (2,4-D) degradation could enhance the microbial population. Higher SMBC under pyrazosulfuron-ethyl on 6 DAS *fb* bispyribac sodium on 20 DAS may be due to degradation of herbicides, which could act as nutrients for microbial growth. Ramalakshmi *et al.* (2017) reported that application of herbicides, pyrazosulfuron-ethyl and bispyribac sodium at recommended rate in rice decreased the soil microbial population initially and after that microbial population was increased due to degradation of herbicide, which acted as a nutrient source for the growth of microorganisms. Hand-weeded and unweeded control recorded lowest value for

SMBC and it might be due to lack of nutrient source for microbial growth. Dubey *et al*. (2018) reported actinomycetes population was high in herbicide treatment plot as compared to weedy check and weed free plot.

Available P and K in soil were affected by different weed management practices (Fig. 5.16). Highest available P was found under oxyfluorfen on the day of sowing *fb* bispyribac sodium on 20 DAS, brown manuring on 25 DAS and oxyfluorfen on the day of sowing *fb* HW at 30 DAS. Better weed management practices might have contributed to lesser weed dry matter production and resulted in less removal of nutrients by weeds from the soil. Application of bispyribac sodium @ 35 g/ha 15 days after transplanting caused less removal of nutrients by weeds (Prashanth *et al*., 2016). Similar result was obtained in the case of brown manuring as practice of brown manuring with *Sesbania* could supply N up to 35 kg/ha (Singh *et al*., 2013). Pyrazosulfuron-ethyl on 6 DAS *fb* bispyribac sodium on 20 DAS resulted in lowest available P. It might be due to higher weed count, weed dry matter production and less WCE in pyrazosulfuron-ethyl on 6 DAS *fb* bispyribac sodium on 20 DAS treated plot which was higher in weed count and dry matter production next to unweeded control. Highest available K was under hand-weeded control and pyrazosulfuron-ethyl on 6 DAS *fb* HW at 30 DAS. Pyrazosulfuron-ethyl on 6 DAS *fb* HW at 30 DAS resulted in lesser weed dry matter production and higher WCE. A reduced competition from weeds must have contributed to lesser removal of nutrients by weeds. Unweeded control and *in situ* green manuring on 25 DAS resulted in lowest available K. It might be due to high weed dry matter production, which took up more nutrients from the soil in unweeded control plot and more weed growth in *in situ* green mauring plot due to lack of any control measure during later stage of crop growth. Weeds are highly competitive in nutrient uptake and heavy infestation of weeds resulted in depletion of soil N, P and K (Ramachandiran *et al*., 2013). Highest N, P and K removal by weeds was recorded in unweeded check under aerobic rice cultivation (Madhukumar *et al*., 2013).

Among the various treatments, brown manuring resulted in higher organic carbon and SMBC which had influence on physical and chemical properties of soil. Oxyfluorfen on the day of sowing *fb* bispyribac sodium on 20 DAS resulted in higher available N and P and pyrazosulfuron-ethyl on 6 DAS *fb* HW at 30 DAS resulted in highest available K.

5.5. Effect of treatments on economics of upland rice

Among the various treatments, application of oxyfluorfen on the day of sowing *fb* HW at 30 DAS recorded highest gross return, net return and B:C ratio, which was closely followed by pyrazosulfuron-ethyl on 6 DAS *fb* HW at 30 DAS. Better weed management practices decreased the weed dry matter production and increased WCE, which resulted in better growth and yield parameters of upland rice. Higher gross return and reduced cost of cultivation in both the treatments resulted in higher B:C ratio. Reshma *et al*. (2015) revealed that oxyfluorfen @ 0.15 kg a.i/ha *fb* HW at 20 DAS resulted in higher net income and B:C ratio in aerobic rice. Rana *et al.* (2018) reported that application of pyrazosulfuron-ethyl at different doses resulted in higher net return and B:C ratio as compared to weed free and weedy check. Lowest B:C ratio was recorded from unweeded control due to lack of any weed control measure. Heavy weed infestation resulted in lesser gross return due to lesser grain yield and straw yield. Similar result has been found by Dhanapal *et al*. (2018).

Economic analysis revealed that application of oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS resulted in highest gross return, net return and B:C ratio, which was closely followed by pyrazosulfuron-ethyl on 6 DAS *fb* hand weeding at 30 DAS.

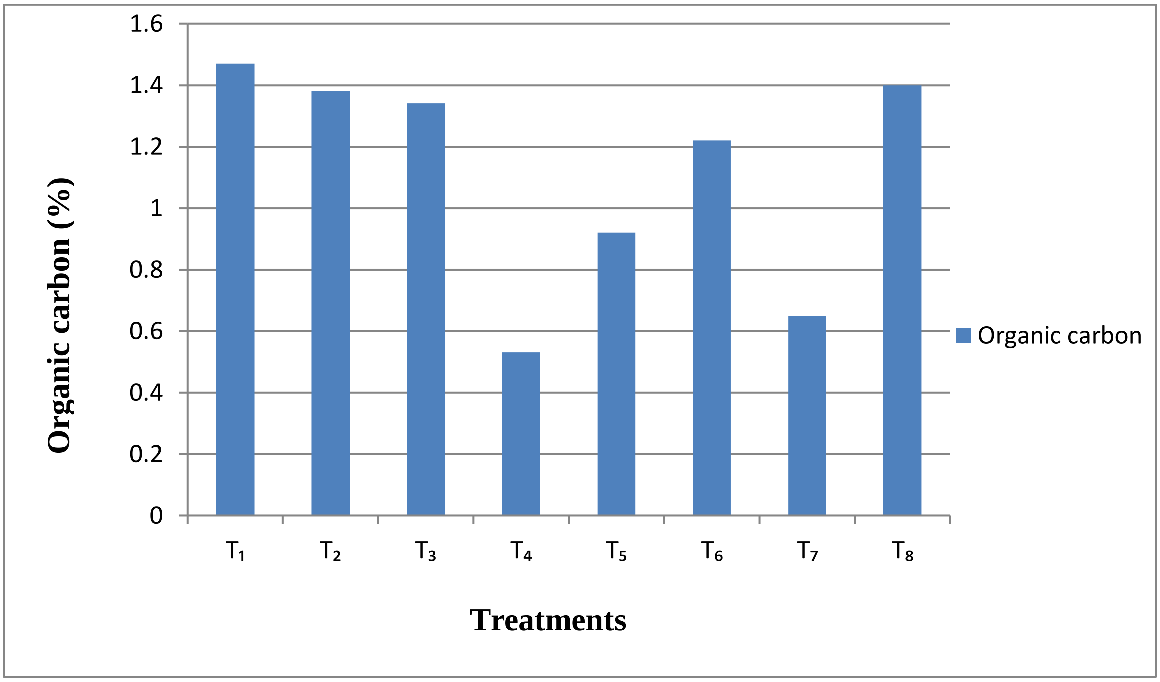

Figure 5.14. Post-experimental status of organic carbon (%) as affected by treatments

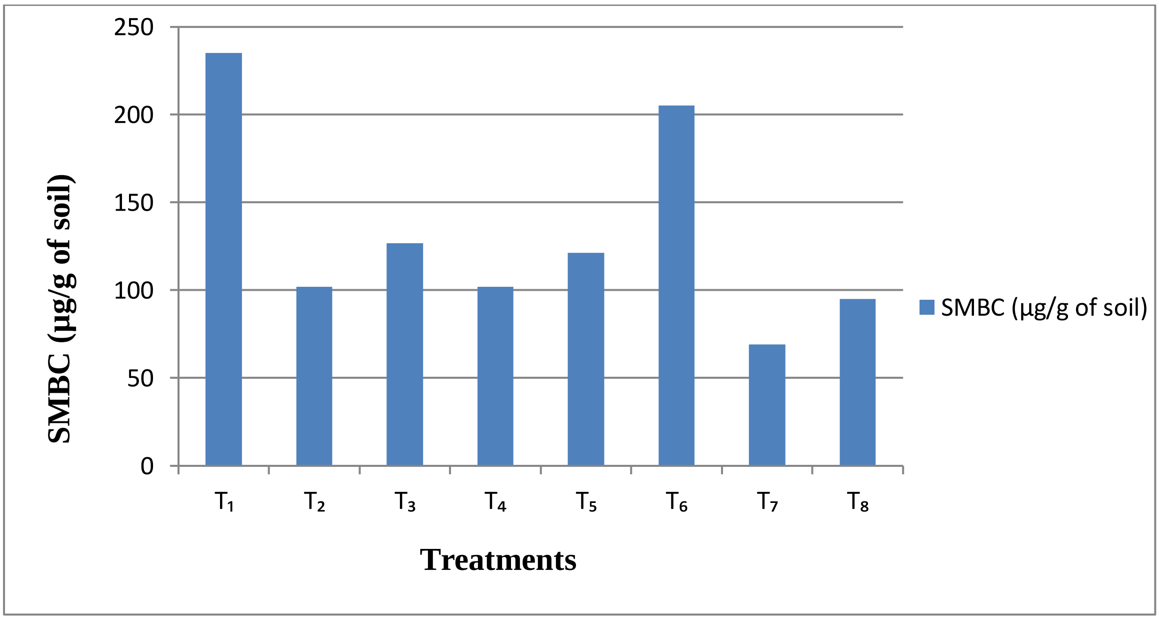

Figure 5.15. Post-experimental status of SMBC (µg/g of soil) as influenced by treatments

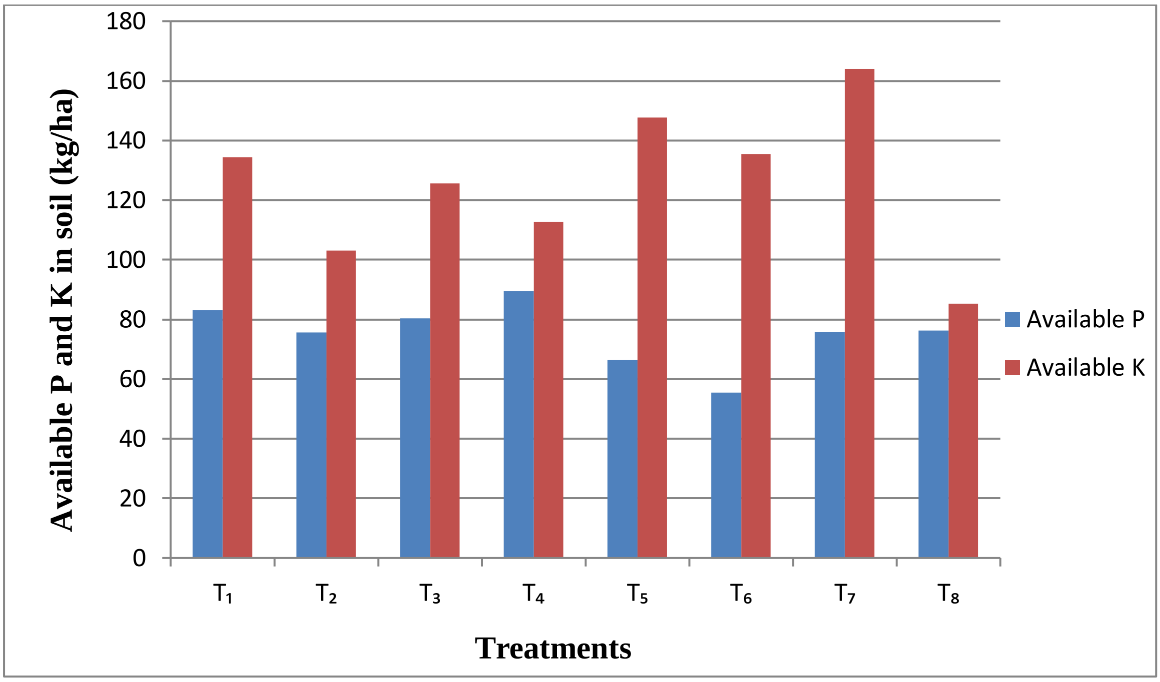

Figure 5.16. Post-experimental status of available P and K in soil (kg/ha) as affected by treatments

Summary

6. SUMMARY

A field experiment entitled "Weed management for upland rice" was conducted with the objective to develop cost effective weed management strategy for upland rice at Agronomy Farm, College of Horticulture, Vellanikkara from 11 June 2019 to 28 September 2019. The experiment consisted of eight treatments T_1: brown manuring (cowpea) by application of 2,4-D on 25 DAS, T_2: *in situ* green manuring (cowpea), on 25 DAS, T_3: oxyfluorfen on the day of sowing *fb* HW at 30 DAS, T_4: oxyfluorfen on the day of sowing *fb* bispyribac sodium on 20 DAS, T_5: pyrazosulfuron-ethyl 10 WP on 6 DAS *fb* HW at 30 DAS, T_6: pyrazosulfuron-ethyl 10 WP on 6 DAS *fb* bispyribac sodium on 20 DAS, T_7: hand weeded control and T_8: unweeded control in RBD with three replications. The salient findings from the experiment are summarised below.

❖ Twenty-two different weed species were identified in the experimental field. Dominant grass weed species observed were *Echinochloa colona, Digitaria sanguinalis, Eleusine indica, Panicum maximum, Setaria* spp., and *Brachiaria* spp. Dominant broad leaf weeds were *Alternanthera bettzickiana, Mitracarpus hirtus, Euphorbia hirta, Euphorbia geniculata, Ludwigia perennis, Scoparia dulcis, Ageratum conyzoides, Phyllanthus amara, Cleome burmannii, Commelina benghalensis, Lindernia crustacea, Catharanthus pusillus, Trianthema portulacastrum, Mollugo disticha* and *Hemidesmus indicus. Cyperus iria* was the only sedge observed in the experimental field.

❖ Hand weeding thrice resulted in 92.55 % and 98.69 % reduction in weed dry matter production at 20 and 45 DAS respectively. Application of oxyfluorfen on the day of sowing *fb* HW at 30 DAS was equally effective as hand weeded control and resulted in lesser weed count, weed dry matter, weed index and high weed control efficiency. Application of pyrazosulfuron-ethyl on 6 DAS *fb* hand weeding at 30 DAS resulted in lesser dry matter production and better WCE at 45 DAS.

- *In situ* green manuring and brown manuring resulted in reduction in weed dry matter production and high WCE at early stages of crop growth as compared to unweeded control, but it was not effective as herbicide application.

- Application of oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS resulted in maximum WCE (92.60 % at 20 DAS and 98.58 % at 45 DAS). Application of pyrazosulfuron-ethyl on 6 DAS *fb* hand weeding at 30 DAS resulted in better WCE of 97.39 %.

- Lowest weed index was recorded in the treatment receiving oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS (5.02 %) followed by pyrazosulfuron-ethyl 10 WP on 6 DAS *fb* hand weeding at 30 DAS (10.35 %).

- Application of oxyfluorfen on the day of sowing *fb* HW at 30 DAS resulted in highest number of tillers per hill and number of hills/m^2.

- Hand weeded control resulted in significantly higher grain yield (2888 kg/ha) and was on par with oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS (2743 kg/ha) and pyrazosulfuron-ethyl 10 WP on 6 DAS *fb* hand weeding at 30 DAS (2589 kg/ha).

- Weed competition resulted in 78.05 % yield reduction in upland rice.

- Oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS resulted in highest straw yield (5898 kg/ha) and was on par with pyrazosulfuron-ethyl 10 WP on 6 DAS *fb* hand weeding at 30 DAS (5886 kg/ha) and hand weeded control (5415 kg/ha). Unweeded control resulted in significantly lower straw yield (943 kg/ha).

- Brown manuring and *in situ* green manuring resulted in grain yield and straw yield higher than unweeded control, but it was not effective as herbicide application.

- Oxyfluorfen on the day of sowing *fb* HW at 30 DAS resulted in higher N uptake by rice at all stages of observation and higher P uptake at harvest. At 30 DAS, pyrazosulfuron-ethyl on 6 DAS *fb* bispyribac sodium on 20 DAS resulted in higher P and K uptake by rice. At 60 DAS, brown manuring resulted in higher P and oxyfluorfen on the day of sowing *fb* bispyribac sodium on 20 DAS resulted in higher K uptake by rice. At harvest, pyrazosulfuron-ethyl on 6 DAS *fb* HW at 30 DAS recorded higher K uptake by rice.

- N, P and K removal by weeds were less in oxyfluorfen on the day of sowing *fb* HW at 30 DAS and hand weeded control.

- Brown manuring resulted in higher organic carbon and soil microbial biomass carbon.

- Higher soil N and P availability was observed in plots sprayed with oxyfluorfen on the day of sowing *fb* bispyribac sodium on 20 DAS and higher soil K availability was in pyrazosulfuron-ethyl on 6 DAS *fb* HW at 30 DAS.

- *In situ* green manuring and brown manuring resulted in better WCE, grain yield and straw yield higher than unweeded control and resulted in highest organic carbon and soil microbial biomass carbon, which had significant influence on physical and chemical properties of the soil, but it was not effective as herbicide application. It can also be considered as a good management practice.

- Economic analysis revealed that application of oxyfluorfen on the day of sowing *fb* hand weeding at 30 DAS was the most profitable with highest gross return (Rs. 130308/- per ha), net return (Rs. 85628/- per ha) and B:C ratio (2.91), closely followed by pyrazosulfuron-ethyl on 6 DAS *fb* hand weeding at 30 DAS, which recorded gross return of Rs. 126199/- per ha, net return of Rs.70267/- per ha and B: C ratio of 2.87. Unweeded control resulted in loss with the B:C ratio (0.74).

Application of oxyfluorfen 23.5 EC @ 0.15 kg/ha on the day of sowing *fb* HW at 30 DAS resulted in better reduction in weed dry matter, increased weed control efficiency, grain yield and B:C ratio, which was on par with pyrazosulfuron-ethyl 10 WP @ 0.03 kg/ha, 6 DAS *fb* HW at 30 DAS. Hence either of these pre-emergence herbicides followed by one hand weeding at 30 DAS can be recommended for a cost effective weed management in upland rice.

References

7. REFERENCES

Abraham, C. T., Prameela, P. and Lakshmi, M. P. 2010. Efficacy of oxyfluorfen for weed control in transplanted rice. *J. Crop Weed* 6(2): 67-71.

Amritha, K. and Devi, K. M. D. 2017. Effect of pre and post emergence herbicides on microbial biomass carbon and dehydrogenase activity in soils. *J. Trop. Agric*. 55(1): 114-118.

Ansari, M. H., Yadav, R. A., Siddiqui, M. Z., Ansari, M. A. and Khan, N. 2017. Efficacy of *Sesbania* brown manuring and weed management approaches to improve the production and weed control efficiency in transplanted rice. *J. Crop Weed.* 13(1): 142-150.

Anwar, M. P., Juraimi, A. S., Samedani, B., Puteh, A. and Man, A. 2012. Critical period of weed control in aerobic rice. *Sci. World J*. 2012: 1-9.

Arunbabu, T. and Jena, S. N. 2018. Weeds and progressive weed management techniques in rice (*Oryza sativa*. L.): a review. *Bull. Environ. Pharmacol. Life Sci*. 7((2): 108-117.

Baboo, M., Pasayat, M., Samal, A., Kujur, M., Maharana, K. J. and Patel, A. K. 2013. Effect of four herbicides on soil organic carbon, microbial biomass-C, enzyme activity and microbial populations in agricultural soil. *Int. J. Res. Environ. Sci. Technol*. 3(4): 100-112.

Barla, S., Upasani, R. R., Pandey, A. C. and Kumar, S. S. 2016. Weed management through green manuring in direct seeded rice (*Oryza sativa*) under medium land condition at East Singhbhum District of Jharkhand, India. *Ecol. Environ. Conserv*. 22(4): 227-230.

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.). *Agron. J. Nepal*. 3: 53-63.

Bray R.H. and Kurtz, L. T. 1945. Determination of total, organic, and available forms of phosphorus in soils. *Soil Sci.* 59(1): 39-46.

Chakraborti, M., Duary, B. and Datta, M. 2017. Effect of weed management practices on nutrient uptake by direct seeded upland rice under Tripura condition. *Int. J. Curr. Microbiol. Appl. Sci.* 6(12): 66-72.

Chopra, N. K. and Nisha, C. 2003. Effect of doses and stages of application of pyrazosulfuron ethyl on weeds in transplanted rice. *Indian J. Weed Sci.* 35(1&2): 27-29.

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

Dadsena, T., Talla, A. and Mishra, M. 2014. Effect of weed management practices on weed parameters, yield and nutrient uptake of direct seeded upland rice. *Ann. Plant Soil Res.* 16(4): 294-299.

Daniel, P. S. J., Poonguzhalan, R., Mohan, R. and Suburayalu, E. 2012. Weed management for enhanced production of aerobic rice. *Indian J. Weed Sci.* 44(4): 270–273.

Das, A. C., Debnath, A. and Mukherjee, D. 2003. Effect of the herbicides oxadiazon and oxyfluorfen on phosphates solubilizing microorganisms and their persistence in rice fields. *Chemosphere* 53: 217-221.

De Datta, S. K. 1981. *Principles and practices of rice production*. International Institute of Rice Research Institute, Philippines, 642p.

Dhanapal, G. N., Sanjay, M. T., Nagarjun, P. and Sandeep, A. 2018. Integrated weed management for control of complex weed flora in direct seeded upland rice under Southern transition zone of Karnataka. *Indian J. Weed Sci.* 50(1): 33-36.

Dubey, S. K., Kumar, A., Singh, M., Singh, A. K., Tyagi, S. and Kumar, V. 2018. Effect of six herbicides on soil microbial population and yield in direct seeded rice. *J. Pharmacogn. Phytochem.* 4: 83-87.

Gill, J. S. and Kumar,V. 1969. "Weed Index" A new method for reporting weed control trials. *Indian J. Agron.* 14: 96-98.

Gogoi, B. and Deka, J. 2019. Effect of integrated weed management on direct seeded upland rice under rainfed conditions of Assam. *J. Crop Weed* 15(2): 132-143.

Goswami, G., Deka, N. C. and Ojha, N. J. 2018. Weed dynamics and yield of direct seeded upland autumn rice (*Oryza sativa* L.) varieties as influenced by integrated weed and nutrient management practices. *Indian J. Agric. Res.* 52 (2): 133-139.

Gowda, P. T., Govindappa, M., Murthy, K. N. K., Shankaraiah, C. and Jnanesha, A. C. 2009. Effect of herbicides and cultural treatments on uptake of major nutrients by crop and weeds under aerobic rice cultivation. *J. Crop Weed* 5(1): 326-329.

Gupta, D. and Joshi, M. 2009. Changes in microbial biomass and phosphatase activity exposed to 2, 4-D and glyphosate. *J. Environ. Res. Dev.* 3(3): 663-669.

Haney, R. L., Senseman, S. A., Hons, F. M. and Zuberer, D. A. 2000. Effect of glyphosate on soil microbial activity and biomass. *Weed Sci.* 48: 89-93.

Hasanuzzaman, M. 2019. Agronomic Crops: Vol. 2: Management Practices. Springer Nature, 652p.

Hussain, S., Ramzan, M., Akhter, M. and Aslam, M. 2008. Weed management in direct seeded rice. *J. Anim. Plant Sci.* 18(2&3): 86-88.

Iliger, M. D., Sutar, R., Chogatapur, S.V. and Parameshwarareddy, R. 2017. Effect of brown manuring on soil properties, weed density, grain yield and economics of different crops. *Adv. Res*. 12(6): 1-11.

Indiastat, 2018-19. State wise area and production of cereals and millets in India [online].https://www.indiastat.com/agriculturedata/2/cerealsandmillets/963995/rice/17194/stats.aspx.

IRRI (International Rice Research Institute) 1988. Green Manuring in Rice Farming. International Rice Research Institute, Philippines, 379p.

Islam, M. M., Urmi, T. A., Rana, S. M., Alam, A. S. and Haque, M. M. 2019. Green manuring effects on crop morpho-physiological characters, rice yield and soil properties. *Physiol. Mol. Biol. Plants.* 25(1): 303-312.

Ismaila, U., Kolo, M. G. M., Gbanguba, U. A. 2011. Efficacy and profitability of some weed control practices in upland rice (*Oryza sativa* L.) at Badeggi, Nigeria. *Am. J. Exp. Agric*. 1(4): 174-186.

Jabran, K., Ehsanullah, Hussain, M., Farooq, M., Babar, M., Dogan, M. N. and Lee, D. 2012. Application of bispyribac-sodium provides effective weed control in direct-planted rice on a sandy loam soil. *Weed biol. Manag*. 12: 136-145.

Jackson, M. L. 1958. *Soil Chemical Analysis.* (Indian Reprint, 1976), Prentice Hall of India, New Delhi, 478p.

Jagtap, D. N., Pawar, P. B., Sutar M. W., Jadhav, M. S., Pinjari, S. S. and Meshram, N. A. 2018. Effect of weed management practices on kharif rice- a review. *J. Res. Weed Sci.* 1(2): 37-47.

Jenkinson, D. S. and Powlson, D. S. 1976. The effects of biocidal treatments on metabolism in soil-V. A method for measuring soil biomass. *Soil Biol. Biochem*. 8: 209-213.

KAU (Kerala Agricultural University) 2016. *Package of Practices Recommendations: Crops* (15th Ed.). Kerala Agricultural University, Thrissur, 392p.

Kolleh, D. S. 2016. Upland rice growth and yield response to weed management practices under rainfedconditions. M. Sc. (Ag) thesis, Sokoine University of Agriculture, Tanzania, 111p.

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

Kumar, S. and Rana, S. S. 2013. Bioefficacy of bispyricbac-sodium for weed control in direct seeded rice. *Pesticide Res. J.* 25(2): 123-127.

Kumar, S., Rana, S. S., Chander, N. and Ramesh. 2013. Mixed weed flora management by bispyribac-sodium in transplanted rice. *Indian J. Weed Sci.* 45(3): 151-155.

Kumaran, S. T.,Kathiresan, G., Arthanari, P. M., Chinnusamy, C. and Sanjivkumar, V. 2015. Efficacy of new herbicide (bispyribac sodium 10% SC) against different weed flora, nutrient uptake in rice and their residual effects on succeeding crop of green gram under zero tillage. *J. Appl. Nat. Sci.* 7(1): 279-285.

Kumari, S. 2016. Integrated weed management in direct seeded rice (*Oryza sativa* L.) with brown manuring and herbicides. M. Sc. (Ag) thesis, Punjab Agricultural University, Ludhiana, 114p.

Kumari, S. and Kaur, T. 2016. Effect of brown manuring and herbicides on growth, nitrogen uptake and weed dynamics in direct seeded rice (*Oryza sativa* L.). *Int. J. Bio-resource Stress Manag.* 7(6):1249-1254.

Ladu, M. and Singh, M. K. 2006. Crop-weed competition in upland direct seeded rice under foot hill conditions of Nagaland. *Indian J. Weed Sci.* 38(1&2): 131-132.

Laskar, H., Singh, M. K. and Longkumer, L. T. 2005. Economics of integrated weed management in rice based intercropping under rainfed conditions of Nagaland. *Indian J. Weed Sci.* 37(1&2): 111-113.

Latt, Y. K., Myint, A. K., Yamakawa, T. and Ogata, K. 2009. The effects of green manure (*Sesbania rostrata*) on the growth and yield of rice. *J. Fac. Agric. Kyushu Univ*. 54 (2): 313-319.

Lupwayi, N. Z., Harker, K. N., Clayton, G. W., Turkington, T. K., Rice, W. A. and O'Donovan, J. T. 2003. Soil microbial biomass and diversity after herbicide application. *Can. J. Plant Sci*. 677-685.

Madhukumar, V., Murthy, K. N. K., Sanjay, M. T., Prashanth, R. and Sunil, C. M. 2013. Economics and crop weed competition for nutrients in aerobic rice (*Oryza sativa* L.) as influenced by weed control practices. *Plant Arch.* 13(2): 731-734.

Mahajan, G., Chauhan, B. S. and Johnson, D. E. 2009. Weed management in aerobic rice in north western Indo-gangetic plains. *J. Crop Improv.* 23: 366-382.

Maitra, S. and Zaman, A. 2017. Brown manuring, an effective technique for yield sustainability and weed management of cereal crops: a review. *Int. J. Bioresource Sci*. 4(1): 1-5.

Maity, S. K. and Mukherjee, P. K. 2011. Effect of brown manuring on grain yield and nutrient use efficiency in dry direct seeded kharif ice (*Oryza sativa* L.). *Indian J. Weed Sci.* 43 (1&2): 61-66.

Majhi, S., Thakur, R., Upasani, R. R., Pal, S. K. and Singh, M. K. 2011. Effect of integrated weed management on the productivity of direct seeded upland rice (*Oryza sativa*) in eastern India. *SAARC J. Agric.* 9(1): 23-28.

Mani, V. S. and Gautham, K. G. 1973. Chemical weed control-effective and economical. *Indian Farming* 22: 191-198.

Mishra, G. C., Rath, A. K., Rath, B. S., Sahoo, J. and Mohapatra, P. K. 2006. Weed management in direct seeded rice under rainfed upland eco-system. *J. Crop. Weed*. 2(2): 52-57.

Mishra, S. S., Mishra, M. M., Mishra, K. N., Kar, B. C., and Mohanty, S. K. 2009. Integrated weed management in upland rice under eastern and south eastern coastal plain zone of Orissa. *Indian J. Weed Sci*. 41(1&2): 106-108.

Mondal, D. C., Hossain, A. and Duary, B. 2005. Effect of pyrazosulfuron-ethyl on weeds and yield of transplanted rice under lateritic belt of West Bengal. *Indian J. Weed Sci.* 37 (3&4): 263-264.

Mondal, S., Kuiry, S. C., Ghosh, G. K., Biswas, P. K. and Malik, G. C. 2011. Effects of pyrazosulfuron-ethyl on soil microbial biomass carbon and ammonification in a lateritic soil of West Bengal. *J. Crop Weed* 7(2): 155-158.

Musthafa, K. and Potty, N. N. 2001. Effect of *in situ* green manuring on weeds in rice. *J. Trop. Agric*. 39: 172-174.

Mutumba, G. M. and Odongo, P. 2015. Effects of weeds on yield in upland and lowland rice growing system, Uganda. *AshEse J. Biol. Sci.* 1(1): 1-8.

Nagargade, M., Singh, M. K. and Tyagi, V. 2018. Ecologically sustainable integrated weed management in dry and irrigated direct-seeded rice. *Adv. Plant Agric. Res.* 8(4): 319-331.

Nair, S. S. 2003. Integrated weed management in upland rice. M. Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, 140p.

Oikeh, S. O., Nwilene, F. E., Agunbiade, T. A., Oladimeji, O., Ajayi, O., Semon, M., Tsunematsu, H. and Samejima, H. 2004. *Growing Upland Rice: A Production Handbook*. Africa Rice Center (WARDA), Africa, 44p.

Pal, S., Ghosh, R. K., Banerjee, H., Kundu, R. and Alipatra, A. 2012. Effect of pyrazosulfuron-ethyl on yield of transplanted rice. *Indian J. Weed Sci.* 44(4): 210-213.

Panda, R. K., Sahoo, P., Jena, S. N. and Muduli, K. C. 2016. Physiological indices to yield variation under rice-weed competition in direct seeded lowland condition. *Oryza* 53(3): 316-322.

Parameswari, Y. S. and Srinivas, A. 2014. Influence of weed management practices on nutrient uptake and productivity of rice under different methods of crop establishment. *J. Rice Res.* 7 (1&2): 77-86.

Poddar, R., Ghosh, R. K., Paul, T. and Bera, S. 2014. Weed management through oxyfluorfen in direct seeded rice and its impact on soil micro-organisms and succeeding crops. *Ann. Agric. Res.* 35(3): 337-342.

Porwal, M. K. 1999. Weed management through herbicides in direct drilled upland rice in rainfed situations of southern Rajasthan. *Indian J. Weed Sci.* 31(3&4): 196-198.

Prashanth, R., Murthy, K. N. K., Kumar, V. M., Murali, M. and Sunil, M. 2016. Bispyribac-sodium influence on nutrient uptake by weeds and transplanted rice. *Indian J. Weed Sci.* 48(2): 217-219.

Prasuna, J. G. and Rammohan, J. 2015. Effect of weed management practices on growth and yield attributes of aerobic rice. *J. Crop Weed* 11(1): 229-231.

Priya, R. S., Chinnusamy, C., Arthanari, P. M. and Janaki, P. 2017a. Pre-emergence herbicide of oxyfluorfen on weed control in transplanted rice. *Int. J. Chem. Stud.* 5(5): 271-275.

Priya, R. S., Chinnusamy, S., Arthanari, P. M. and Janaki, P. 2017b. Microbial and dehydrogenase activity of soil contaminated with herbicide combination in direct seeded rice (*Oryza sativa* L.). *J. Entomol. Zool. Stud.* 5(15): 1205-1212.

Rajendra, M. S. 2014. Integrated weed management in upland rice (*Oryza sativa* L.). M.Sc. (Ag) thesis, Mahatma Phule Krishi Vidyapeeth, Maharashtra, 136p.

Raj, S. K. and Syriac, E. K. 2017. Weed management in direct seeded rice: A review. *Agric. Rev.* 38 (1): 41-50.

Ramachandiran, K., Balasubramanian, R. and Babu, R. 2013. Weed management in aerobic rice - a review. *Agric. Rev.* 34(2): 121-128.

Ramalakshmi, A., Arthanari, P. M. and Chinnusamy, C. 2017. Effect of pyrasosulfuron ethyl, bensulfuron methyl, pretilachlor and bispyribac sodium on soil microbial community and soil enzymes under rice-rice cropping system. *Int. J. Curr. Microbiol. Appl. Sci. 6*(12): 990-998.

Ramana, A. V. Naidu, G. J. and Murthy, K. V. R. 2007. Integrated weed management in rainfed upland rice (*Oryza sativa*). *Indian J. Agron.* 52 (4): 311-314.

Ramesha, Y. M., Kumar, M. A., Bhanuvally, M., and Gaddi, A. K. 2017. Bio-efficacy of pyrazosulfuron ethyl 10% WP against weeds in transplanted rice. *J. Appl. Nat. Sci. 9*(3): 1844-1847.

Ramprakash, T., Madhavi, M., Yakadri, M. and Srinivas, A. 2015. Bispyribac sodium persistence in soil, plant and grain in direct seeded rice and its effect on soil properties. *Nat. Environ. Pollut. Technol.* 14(3): 605- 609.

Rana, A., Rana, M. C., Rana, S. S., Sharma, N. and Kumar, S. 2018. Weed control by pyrazosulfuron-ethyl and its influence on yield and economics of transplanted rice. *Indian J. Weed Sci.* 50(4): 309-314.

Reddy, T.Y. and Reddy, G. H. S. 1992. *Principles and Practices of Agronomy*. Kalyani publishers, Ludhiana, 527p.

Reshma, R. S., Pillai, P. S. and Sansamma, G. 2015. Efficacy and economics of weed management strategies in aerobic rice (*Oryza sativa* L.). *Curr. Adv. Agric. Sci.* 7(1): 73-75.

Roy, J. B. B. 2016. Weed dynamics and yield of direct seeded upland rice (*Oryza sativa* L.) under integrated weed management practices. M. Sc. (Ag) thesis, Orissa University of Agriculture and Technology, Bhubaneswar, 87p.

Saha, A., Bhaduri, D., Pipariya, A., Jain, N. K. and Basak, B. B. 2015. Behaviour of pendimethalin and oxyfluorfen in peanut field soil: effects on soil biological and biochemical activities. *Chem. Ecol.* 31(6): 550-566.

Sahai, B., Bhan, V. M. and Balyan, R. S. 1983. Weed emergence and competition in drilled upland rice in India. *Trop. Pest Manag*. 29(2): 125-128.

Saini, J. P. 2003. Efficacy of pyrazosulfuron-ethyl against mixed weed flora in transplanted rice. *Pestic. Res. J.* 15(2): 157-159.

Sangara, R., Ninama, A., Singh, A. P., Devendra and Mahajan, R. 2018. Evaluation of different weed management practice on growth and yield attributing characters of rice under direct seeded rice system. *J. Pharmacogn. Phytochem*. 1: 454-458.

Seema, Krishna, M., Devi, T. T. M. 2014. Effect of nitrogen and weed management on nutrient uptake by weeds under direct seeded aerobic rice. *Bioscan* 9(2): 535-537.

Sheoron, O. P., Tonk, D. S., Kaushik, L. S., Hasija, R. C., and Pannu, R. S. 1998. *Statistical Software Package for Agricultural Research Workers*. CCSHAU, Hisar, 139p.

Silva, G. S., Melo, C. A. D., Fialho, C. M. T., Santos, L. D. T., Costa, M. T. and Silva, A. A. 2014. Impact of sulfentrazone, isoxaflutole and oxyfluorfen on the microorganisms of two forest soils. *Soil Plant Nutr*. 73(3): 292-299.

Singh, G., Yadav, S. R. and Singh, D. 1987. Crop/weed competition studies in upland rice. *Trop. Pest Manag*. 33(1): 19-21.

Singh, M. K. 2012. Weed management in upland rice. *Oryza* 49(1): 1-9.

Singh, R. S. and Gosh, D. C. 1992. Effect of cultural practices on weed management in rainfed upland rice. *Trop. Pest Manag.* 38(2): 119-121.

Singh, T., Lal, B. and Satapathy, B. S. 2013. Weed management in paddy. *Popular Kheti*. 1(2): 10-15.

Subbiah, B.V. and Asija, G. L. 1956. A rapid procedure for assessment of available nitrogen in soils. *Curr. Sci.* 31: 196-260.

Subhani, A., El-ghamry, M. A., Changyong, H. and Jianming, X. 2000. Effects of pesticides (herbicides) on soil microbial biomass carbon – a review. *Pakist. J. Biol. Sci*. 3(5): 705-709.

Sumekar, Y., Riswandi, D., Widayat, D., Umiyati, U. and Kurniadie, D. 2018. The impact of bispyribac sodium herbicide on weed control and rice (*Oryza sativa* L.) yield. *Int. J. Agric. Sci*. 10(16): 7008-7010.

Sunil, C. M., Shekara, B. G., Ashoka, P., Murthy, K. N. K., Mahantesh, V. and Madhukumar, V. 2011. Effect of integrated weed management practices on nutrient uptake in aerobic rice. *Res. Crops*. 12(3): 629-632.

Sylvestre, H. and Murthy, K. N. K. 2018. Influence of weed management practices on soil microbial populations, soil nutrient status and biological yield of aerobic rice (*Oryza sativa* L.). *J. Soil Biol. Ecol.* 38(1&2): 120-129.

Toure, A., Sogbedji, J. M. and Gumedzoe, Y. M. D. 2013. The critical period of weed interference in upland rice in northern Guinea savanna: Field measurement and model prediction. *Afr. J. Agric. Res.* 8(7): 1748-1759.

Walkley, A. and Black, I. A. 1934. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Sci.* 37(1): 29-38.

Watanabe, F.S. and Olsen, S. R. 1965. Test of an ascorbic acid method for determining phosphorus in water and $NaHCO_3$ extracts from soil. *Soil Sci. Soc. Am. J.* 29(6): 677-678.

Watson, D. J. 1952. The physiological basis of variation in yield. *Adv. Agron*. 4: 101-145.

Abstract

WEED MANAGEMENT FOR UPLAND RICE

BASILA Y.

2018-11-027

Abstract of the Thesis

Submitted in partial fulfilment of the requirement for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF AGRONOMY

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR - 680 656

KERALA, INDIA

2020

ABSTRACT

Rice is one of the principal food crops in Asia and can be grown in wetland and upland conditions. Upland rice is grown in rainfed, naturally well drained soils with bunded or unbunded fields without surface water accumulation. Moisture stress, weed infestation, poor soil fertility and incidence of pests and diseases are major problems in upland rice cultivation. Among these, weeds are considered to be most serious. Hence an effective and timely control of weed is essential to achieve higher productivity in upland rice. Field experiment was conducted at Agronomy Farm, College of Horticulture, Vellanikkara from June 2019 to September 2019 to develop cost effective weed management strategy for upland rice. The experiment was laid out in RBD with eight treatments and three replications. Treatments were T_1: Brown manuring (Cowpea) by application of 2,4-D on 25 DAS, T_2: *In situ* green manuring (Cowpea), on 25 DAS, T_3: Oxyfluorfen on the day of sowing *fb* HW at 30 DAS, T_4: Oxyfluorfen on the day of sowing *fb* bispyribac sodium on 20 DAS, T_5: Pyrazosulfuron on 6 DAS *fb* HW at 30 DAS, T_6: Pyrazosulfuron ethyl on 6 DAS *fb* bispyribac sodium on 20 DAS, T_7: Hand weeded control and T_8: Unweeded control.

Dominant grass weed species observed were *Echinochloa colona, Digitaria sanguinalis, Eleusine indica, Panicum maximum, Setaria* spp, and *Brachiaria* spp. Dominant broad-leaf weed species were *Alternanthera bettzickiana, Mitracarpus hirtus, Euphorbia hirta, Euphorbia geniculata, Ludwigia perennis, Scoparia dulcis, Ageratum conyzoides, Phyllanthus amara, Cleome burmannii, Commelina benghalensis, Lindernia crustacea, Catharanthus pusillus, Trianthema portulacastrum, Mollugo disticha* and *Hemidesmus indicus. Cyperus iria* was the only sedge observed in the experimental field.

Lowest weed dry matter production was recorded in hand-weeded control at 20 and 45 DAS. Application of oxyfluorfen *fb* HW at 30 DAS was as effective as hand weeded control and resulted in lesser weed count, weed dry matter, weed index and high weed control efficiency. Application of oxyfluorfen *fb* HW at 30 DAS resulted in maximum WCE of 92.60 % at 20 DAS and 98.58 % at 45 DAS. Lowest weed index was resulted from oxyfluorfen *fb* HW at 30 DAS (5.02 %) and was on par

with pyrazosulfuron-ethyl on 6 DAS *fb* HW at 30 DAS (10.35 %). *In situ* green manuring and brown manuring resulted in significant reduction in weed dry matter production and high WCE at early stages of crop growth as compared to unweeded control, but it was not as effective as herbicide application.

Application of oxyfluorfen *fb* HW at 30 DAS resulted in highest number of tillers per hill, leaf area index and number of hills/m². Hand-weeded control resulted in significantly higher grain yield (2888 kg/ha) and was on par with application of oxyfluorfen *fb* HW at 30 DAS (2743 kg/ha) and pyrazosulfuron-ethyl *fb* HW at 30 DAS (2589 kg/ha). Weed competition resulted in 78.05 % yield reduction in upland rice. Oxyfluorfen *fb* HW at 30 DAS resulted in highest straw yield (5898 kg/ha), which was on par with pyrazosulfuron-ethyl *fb* HW at 30 DAS (5886 kg/ha) and hand-weeded control (5415 kg/ha). Unweeded control resulted in significantly lower grain yield (634 kg/ha) and straw yield (943 kg/ha).

Application of oxyfluorfen *fb* HW at 30 DAS resulted in higher N uptake by rice at all stages of observation and higher P uptake at harvest. At 30 DAS, application of pyrazosulfuron-ethyl *fb* bispyribac sodium resulted in higher P and K uptake by rice. At 60 DAS, the treatment brown manuring resulted in higher P uptake and application of oxyfluorfen *fb* bispyribac sodium resulted in higher K uptake by rice. At harvest, application of pyrazosulfuron-ethyl *fb* HW at 30 DAS resulted in higher K uptake by rice. Less N, P and K removal by weeds was observed in treatments oxyfluorfen *fb* HW at 30 DAS and hand-weeded control. Brown manuring resulted in higher organic carbon and soil microbial biomass carbon. Higher soil N and P availability was recorded in plots sprayed with oxyfluorfen *fb* bispyribac sodium and higher soil K availability was in pyrazosulfuron-ethyl on 6 DAS *fb* HW at 30 DAS.

Application of oxyfluorfen 23.5 EC @ 0.15 kg/ha on the day of sowing *fb* HW at 30 DAS resulted in higher gross return, net return and B: C ratio, which was on par with pyrazosulfuron-ethyl 10 WP @ 0.03 kg/ha on 6 DAS *fb* hand weeding at 30 DAS. Hence, either of these pre-emergence herbicides followed by one hand weeding at 30 DAS can be recommended for a cost effective weed management in upland rice.

Appendix

Appendix 1. Weather parameters during the cropping period

Standard week	Relative humidity (%)	Maximum temperature (°C)	Minimum temperature (°C)	Rainfall (mm)	BSS hours	Evaporation (mm)
23	79	34.2	23.8	052.5	5.9	3.4
24	88	30.3	23.0	153.1	1.8	2.0
25	87	31.1	22.6	111.2	2.3	2.4
26	83	32.2	24.5	007.8	4.3	2.9
27	86	30.9	23.5	150.5	2.6	3.1
28	83	31.3	22.8	088.2	3.0	2.4
29	89	29.5	22.1	324.7	2.3	1.9
30	86	29.3	21.1	089.0	1.9	1.9
31	85	31.4	23.8	022.2	3.9	2.6
32	94	27.2	20.9	532.0	0.3	1.1
33	86	30.0	22.2	172.5	1.0	1.7
34	80	29.8	21.4	120.8	1.5	2.4
35	90	29.4	21.6	177.1	1.2	1.7
36	89	30.3	21.7	206.9	1.5	2.2
37	86	31.4	22.3	075.2	3.5	2.6
38	83	31.7	21.9	067.2	4.2	2.8
39	81	32.3	21.8	022.6	4.8	2.7