ECOFRIENDLY MANAGEMENT OF WEEDS IN RICE

By

SINDHU, P.V.

THESIS
submitted in partial fulfilment of the
requirement for the degree of

Doctor of Philosophy in Agriculture

Faculty of Agriculture
Kerala Agricultural University

Department of Agronomy
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR-680 656
KERALA, INDIA

2008

DECLARATION

I, hereby declare that the thesis entitled **"ECOFRIENDLY MANAGEMENT OF WEEDS IN 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.

Vellanikkara

Date: 18.4.08 SINDHU, P.V.

CERTIFICATE

Certified that the thesis entitled **"ECOFRIENDLY MANAGEMENT OF WEEDS IN RICE"** is a record of research work done independently by Ms. Sindhu, P.V. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship or fellowship to her.

Vellanikkara

Date:18.4.2008

Dr. C. George Thomas

(Chairperson, Advisory Committee)

Professor of Agronnomy

College of Horticulture

Vellanikkara

CERTIFICATE

We, the undersigned members of the advisory committee of **Ms. Sindhu, P.V. (2004-21-01)** a candidate for the degree of **Doctor of Philosophy in Agriculture**, with major field in Agronomy, agree that the thesis entitled **"ECOFRIENDLY MANAGEMENT OF WEEDS IN RICE"** may be submitted by Ms. Sindhu,P.V. in partial fulfilment of the requirement for the degree.

Dr. C. George Thomas
(Chairman, Advisory Committe)
Professor
Department of Agronomy
College of Horticulture
Vellanikkara.

Dr. C.T. Abraham
Professor and Head
Deaprtment of Agronomy
College of Horticulture
Vellanikkara

Dr. U. Jaikumaran
Professor and Head
Agricultural Research Station
Mannuthy

Mr. S. Krishnan
Assistant Professor (SS)
Department of Agricultural
Statistics College of
Horticulture, Vellanikkara.

Dr. T. Girija
Professor
AICRP on Weed Control,
College of Horticulture, Vellanikkara.

External Examiner

ACKNOWLEDGEMENTS

It is with great respect and devotion I place on record my deep sense of gratitude and indebtedness to my major advisor **Dr. C. George Thomas**, Professor, Department of Agronomy, for his sustained and valuable guidance, constructive suggestions, unfailing patience, friendly approach, constant support and encouragement during the conduct of this research work and preparation of the thesis. I gratefully acknowledge his knowledge and wisdom which nurtured this research project in the right direction, without which the success of this endeavor would not have been possible.

No words can truly express my profound thankfulness and indebtedness to **Dr. C.T. Abraham**, Professor and Head, Department of Agronomy and member of my Advisory Committee, for his unstinted support and guidance in the conduct of field experiments and constructive criticism as well as valuable suggestions and critical scrutiny of the manuscript. It is his benevolence and encouragement which helped me complete this work on time.

I am deeply indebted to **Dr. U. Jaikumaran**, Professor and Head, Agricultural Research Station, Mannuthy and member of my Advisory Committee for his unbounded support and valuable suggestions, and for providing me the facilities for the conduct of field experiments at the station.

I am extremely delighted to place on record my profound sense of gratitude to **Mr. S. Krishnan**, Assistant Professor (SS), Department of Agricultural Statistics and member of my Advisory Committee for his support, critical comments and valuable advice during the preparation of this manuscript.

I am deeply obliged to **Dr. T.Girija**, Professor, AICRP on Weed Control and member of my Advisory Committee, for the generous and timely help she has always accorded to me during the course of this study.

It is with great pleasure I record my heartfelt gratitude and sincere thanks to **Dr. Meera V Menon**, Associate Professor, Department of Agronomy for the wholehearted support and co operation rendered throughout the course of my study.

My sincere thanks are due to **Dr. P.S. John, Dr. Mercy George, Dr. P. Pameela, Dr. K.E. Savithri.** and **Dr. Jose Mathew**, Department of Agronomy for the valuable help and advice rendered during the course of my study.

I am thankful to **Dr. K.A. Mariyam**, Department of Soil Science and Agricultural Chemistry for sincere help during chemical analysis, and to **Dr. K.M. Durga Devi**, Associate Professor, AICRP on Weed Control for her support and encouragement.

Let me express my sincere thanks to **Sri. C.P.Nandakumar**, Farm Officer, AICRP on Weed Control for his whole hearted co-operation and assistance always accorded to me during the course of investigation.

I am extremely thankful to **Sri. Kesavaraj**, Kulapully house, Purathur, Alappad and to his labourers for their co-operation and support during the conduct of field experiments.

I wish to express my sincere gratitude to Deepthy, Santhosh, Devi chechi, Seenath Karthikettan, Joshy and Rajesh for their sincere help, timely suggestions and encouragement which gave me enough mental strength to get through all tedious circumstances.

I am happy to place on record my sincere thanks to my seniors and juniors of Dept. of Agronomy for their unstinted help and support during the course of this study.

The award of the Senior Fellowship of the KAU is thankfully acknowledged.

I am deeply indebted to my husband, as without his moral support, blessings and affection this would not have been a success.

I am at a loss for words to express my heartfelt gratitude to my Achan, Chettan, Chechi, Ammu and Appu for their constant encouragement and silent prayers throughout the course of study.

Words can't express my soulful gratitude to my Amma for her selfless sacrifice, boundless patience and unflagging interest throughout the period of my course. **I am affectionately dedicating this thesis to her**.

Finally, I bow my head before ***THE ALMIGHTY*** whose blessings enabled me to undertake this venture successfully.

SINDHU, P.V.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

Introduction

1. INTRODUCTION

Weeds are major factors that decide the success of crop production. Competition from weeds for various growth factors causes severe stress on crops. Sustainable production strategies involve the use of improved cultivars under integrated crop management system in which the inputs are optimized for yield, profitability and environmental impact. An integrated cropping system utilizes best management practices to achieve the most profitable and environmentally sound yield level. An important component of integrated crop management is Integrated Weed Management (IWM) involving various chemical and non - chemical methods based on the biology and competitive behaviour of both crops and weeds.

Several time tested weed management strategies are followed by farmers. However, labour intensive traditional methods especially hand weeding, though non-chemical, are no longer effectively done. Non availability of labour in time, cost involved, drudgery of hand weeding, etc. are the major reasons. At the same time, weeding if not done in time, may cause severe yield losses. Although herbicides have come to stay as a farmer friendly practice, numerous doubts have been raised about the sustainability of continued use of herbicides. It is feared that the over dependence and over use of herbicides create undesirable environmental problems. Of late, there has been a concerted move to reduce the use of chemicals in agriculture as a part of Good Agricultural Practices (GAPS). This is reflected in the increased interest in non - chemical methods of weed control.

The most important non-chemical weed control is centered on land preparation, fertilizer management and water management. Plant spacing or seeding rate, crop rotation, cultivars used and preventive practices are also important. Careful preparation of land provides weed free conditions at planting. The method of land preparation influences the occurrence of weeds (Sankaran and De Datta, 1985). Stale seed bed technique in dry seeded upland rice involves the removal of successive weed flushes before planting. The dry - seeded rice crop may be sown with minimum soil disturbances after the emerged weeds have been controlled. The size of subsequent germinating weed cohorts would be minimized because most weeds in the favorable zone for germination have already been controlled (Moody and Mukhopadhy, 1982). Renu (1999) reported that stale seed bed technique is an efficient tool for the management of *Sacciolepis interrupta* in semi-dry rice. This practice was found to be economically viable also. In wet seeded rice too, there is immense scope for the adoption of stale seed bed (John and Mathew, 2001). In such areas, simple flooding is enough to control the germinated weeds. In *Kuttanad* and *Kole* areas, several rice farmers started practicing stale seed bed technology. However, scientific studies on the practice are lacking.

Plant density is an important factor deciding the yield. Seeding rate in direct seeded rice and plant spacing in transplanted rice determine the rice stands or rice plant density per unit area. This, in turn, determines the amount of canopy created to help rice to shade and compete with weeds. Increased spacing between or within rows increases light penetration into the canopy, which enhances weed growth. In the light of the above, it is thought necessary to develop and refine techniques for non-chemical weed management in rice by integrating stale seed bed techniques and plant density which can give maximum weed control efficiency coupled with better grain yield.

Hand weeding or weeding by a rotary weeder called cono weeder is the only recommended practice for the control of weeds in the recent much publicized method of rice cultivation, SRI (System of Rice Intensification) originated from Madagascar. Proponents of SRI claim high yield compared to conventional methods. Therefore, it is thought necessary to study the impact of plant density in SRI system also.

Having considered all the above aspects, the study was planned with the following objectives

1. Survey and documentation of various weed management practices followed by rice farmers
2. To standardise the stale seed bed technique and subsequent cultural practices for semi-dry and wet-seeded rice.
3. To assess the influence of plant stands on crop weed competition in transplanted rice

Review of literature

2. REVIEW OF LITERATURE

A major impediment in the successful cultivation of rice in the tropics is the heavy infestation of weeds, which compete with the crop to such an extent that the crop gets smothered by weeds. Herbicides are used extensively in rice production for the control of weeds. However, increased awareness about the potential hazards of over use of herbicides put greater pressure on researchers to reorient their research towards non-chemical and non-hazardous means of weed management.

Intensity of weed problems in different rice production systems and their influence on rice yield and possibilities of weed management through non - chemical methods are reviewed in this Chapter.

2.1. Weed spectrum in rice culture

Rice is either direct seeded or transplanted. Direct seeded rice is grown under both rainfed and flooded conditions. Transplanted rice is cultivated normally under flooded condition. Weed spectrum and intensity differ according to the method under which the rice crop is grown (Smith and Moody, 1979).

The distribution of weeds in paddy fields is largely determined by environmental factors modified by competition from rice. Many weeds have wide range of environmental tolerance and a broad geographical distribution; some species occur in man made habitats far outside their normal range (Kim and Park, 1996). About 350 species in more than 150 genera and 60 plant families have been reported as weeds of rice (De Datta, 1977; Barret and Seaman, 1980). According to Smith (1981), Poaceae is the most important weed family accounting for more than 80 species of weeds in rice. Cyperaceae ranks second in abundance with more than 50 species (Holm *et al.* 1977). Azmi and Baki (2002) identified 78 weed species belonging to 53 genera and 33 families in the rice-growing areas of Peninsular Malaysia, of these, 16 species were grasses, 35 broad-leaved weeds, 20 sedges and 7 aquatic weeds.

According to Rao *et al.* (2007), 1800 species of plants are reported as weeds in rice. Among them, weeds belonging to Cyperaceae and Poaceae are predominant. Adoption of direct seeding has resulted in a change in the relative abundance of weed species in particular those of *Echinochloa* spp., *Ishaemum rugosum*, *Cyperus difformis* and *Fimbristylis miliacea*.

Ahmed (1981) reported *Echinochloa colona*, *Eleusine indica*, *Cyperus iria* and *Fimbristylis littoralis* as major weeds of rice. According to Smith (1983), important weeds associated with rice on a worldwide scale are *Echinochloa crusgalli*, *Cyperus difformis*, *Cyperus iria*, *Eleusine indica*, *Fimbristylis littoralis*, *Iscaemum rugosum*, *Monochoria vaginalis* and *Sphenochlea zeylanica*.

2.1.1. Weed spectrum in upland and semi dry rice

In upland rice culture, weeds are major constraints limiting yield. The cost of weed control is high in upland rice production. The weed problem in upland rice is more serious as compared to transplanted rice. Estimated yield losses in upland direct sown rice accounts for about 70 to 80 per cent (Balasubramaiyam and Palaniappan, 2001) as against 30 to 40 per cent in transplanted rice (Bhan, 1994).

Many reports point out the predominance of grassy weeds in rice culture. According to Moody (1989), grassy weeds were predominant in upland rice and about 140 species were observed in South and South East Asian countries. Of these *Dactyloctenium aegyptium*, *Digitaria* spp., *Echinichloa colona*, *Eluesine indica*, *Imperata cylindrical* and *Rottboellia cochinchinensis* were important on a global basis. Moody (1996) reported *Ageratum conyzoides*, *Amaranthus viridis*, *Commelina benghalensis*, *Digitaria* spp., *Rottboellia cochinchinensis* as the major weed species in upland rice. According to Karim *et al*. (2004) *Oryza rufipogon* (weedy rice), *Echinochloa* spp., *Leptochloa chinensis*, *Fimbristylis miliacea* (L) and *Limnocharis flava* (L.) were the major upland rice weeds in Malaysia.

In semi-dry rice too, grasses and sedges constituted the major part of weed flora. The grasses reported were *Isachne miliacea*, *Sacciolepis interrupta* and *Echinochloa colona*. Among sedges, *Cyperus iria* was the most predominant (Jayasree, 1987, Palaikudy, 1989, Suja and Abraham, 1991). The main upland rice weeds reported from West Bengal included *Echinochloa colona*, *Cyperus rotundus*, and *Cyperus iria* (Pandey and Bhan, 1964)

Nair *et al*. (1979) found *Cynodon dactylon*, *Cyperus iria*, *Cyperus difformis*, *Amarathus viridis*, *Ageratum conyzoides*, *Tridax procumbens*, and *Phyllanthus niruri* as the widely prevalent weeds in the rice fields of Mannuthy. According to Sudhakara and Nair (1976) predominant weed species in rice under semi dry system of rice culture were *Echinochloa crusgalli*, *E. colona*, *Ishaemum rugosum*, *Cyperus* spp., *Marsilia quadrifolia* and *Eicchornia crassipes*.

Cyperus iria, *Digitaria ciliaris*, *Phyllanthus niruri* were prominent in upland drilled rice (Trivedi *et al*. 1986). Choudhari and Pradhan (1988) reported *Ageratum conyzoides*, *Commelina benghalensis*, *Echinochloa crusgalli*, *Cynodon dactylon*, *Cyperus rotundus* and *Cyperus difformis* as major semi - dry rice weeds of Bihar.

Varughese (1996) reported *Isachne miliaceae*, *Cyperus* spp., *Echinochloa colona*, *Sacciolepis interrupta*, *Oryza sativa* var *fatua*, *Monochoria vaginalis* and *Ludwigia parviflora* as the major weeds of Onattukkara during Kharif season. After a detailed survey of the central zone of Kerala, where semi - dry rice is prevalent, Thomas *et al*. (1997) reported the dominance of 40 weed species. The first ten weeds according to their ranking based on density and frequency were *Isachne miliacea*, *Sacciolepis interrupta*, *Eriocaulon quinquangulare*, *Ludwigia perennis*, *Ammania baccifera*, *Cyperus albomarginatus*, *Dopatricum junceeum*, *Eriocaulon cuspidatum*, *Echinochloa colona* and *Cyperus haspen*. Thomas and Abraham (1998) reported the predominance of grass weeds in semi - dry system and rated *Sacciolepis interrupta* as the major weeds, which requires special attention.

2.1.2. Weed spectrum in wet - seeded rice

Moody (1983) reported that weed competition is greater in wet-seeded rice than transplanted rice. This is because of the similarities in age and morphological characters of grassy weeds and rice seedlings. According to Moorthy and Dubey (1978), 90 per cent of the weeds in wet seeded rice were sedges.

Nair *et al.* (1974) reported presence of *Echinochloa crusgalli*, *Cyperus* spp., *Fimbristylis miliacea* and *Monochoria vaginalis* as major weeds in direct wet sown fields of Pattambi. According to Joy *et al*. (1991), the weed flora in wet seeded rice in Kerala at 40 DAS consisted of 22 per cent grasses, 40 per cent sedges and 32 per cent broad leaf weeds. At 55 DAS, the weed flora consisted of 37 per cent grasses, 33 per cent sedges and 30 per cent broad leaf weeds (Joy *et al.* 1993). At CRRI, Cuttack, Moorthy (1980) observed *Cyperus difformis*, *Scirpus mucronatus*, *Fimbristylis miliacea*, *Echinochola colona*, *Sphenochlea zeylanica* and *Ludwigia parviflora* as the major species of weeds of wet - sown rice.

In the order of importance, the major weed species observed in wet - seeded rice at IRRI were *Paspalum distichum*, *Monochoria vaginalis*, *Sphenochlea zeylanica*, *Echinochloa glabrescens* and *Cyperus difformis* (Mabbayad and Moody, 1984).

Allard and Zoschke (1990) reported *Echinochloa spp*., *Leptochloa chinensis*, *Cyperus* sp., *Fimbristylis miliacea*, *Scirpus* sp., *Monochoria vaginalis* and *Ludwigia aodscendens* as major weeds infesting wet - sown rice in SE Asia. Moorthy and Manna (1982) reported that the weed flora in puddled rice composed of *Fimbristylis miliacea*, *Cyperus difformis* and *Scirpus supines*. Vaishya *et al*. (1992) reported that the dominant weed flora in puddle rice at Faizabad, UP, consisted of *Echinochola colona*, *Echinochola crusgalli*, *Fimbristylis milaceae*, *Cyperus spp*., *Ammania baccifera*, *Eclipta alba*, *Alternanthera sessilis* and *Ceaselia axillaris*.

Joseph (1986) reported a high population of 56.8 *Scirpus supines*/m^2 in wet - sown rice at 40 DAS in Kerala. This was followed by *Cyperus difformis* and *Cyperus iria* accounting for 43.4 per cent of the total weed population. John and Sadanadan (1989) identified *Cyperus iria*, *Cyperus difformis*, *Fimbristylis miliacea*, *Monochoria vaginalis*, *Ludwigia parviflora*, *Sphenochlea zeylanica*, *Marsilia quadrifoliata* and *Lindernia* sp. as major weeds of puddle low land rice at Moncompu. Reports of Sreedevi and Thomas (1993) suggest that the sedges and broad leaved weeds constituted the major part of the weed flora in direct sown puddle rice in Kerala; with few grasses. Similar results were reported by Mohankumar *et a*l. (1996) and according to them the predominant weed species were *Schoenoplectus lateriflorus*, *Monochoria vaginalis* and *Ludwigia perrenis*.

2.1.2. Weed spectrum in transplanted rice

Transplanting is an important operation, which reduces weed population since the crop has an additional advantage due to its age. The clean field operation for transplanting helps in reducing weed germination (Reddy and Reddy, 1991).

More than 300 species and 100 genera belonging to more than 60 plant families have been reported as weeds in transplanted rice field of China. The dominant weed species of transplanted rice include *Echinochloa crusgalli*, *Scirpus planiculmis*, *Sagittaria pygmaea*, *Potamogeton distinctus*, *Paspalum distichum*, *Cyperus serotinus*, *Leptochloa chinensis*, *Monochoria chinensis*, *Cyperus difformis* and *Scirpus juncoides* (Ze - Pu Zhang, 1996). Baki and Md. Khir (1983) repoted *Monochoria vaginalis*, *Ludwigia adscendens*, *Fimbristylis miliacea*, *Scirpus grossus*, *Limnocharis flava*, *Leersia hexandra* and *Cyperus haspan* as major weeds of transplanted paddy fields of Malaysia based on their value.

Malik and Moorthy (1996) suggests *Echinochloa crusgalli*, *Echinochloa colona*, *Paspalum distichum*, *Cyperus iria*, *Ishaemum rugosum*, *Eragrostis japonica*, *Dactyloctenium aegyptium*, *Leptochloa chinesis*, *Saggitaria guayanensis*, *Cyperus difformis*, *Fimbristylis tenera*, *Eclipta alba* and *Ludwigia perennis* as major weed flora of transplanted rice of South Asia. According to Zafar (1988) *Echinochloa crusgalli*, *Cynodon dactylon*, *Digitaria sp*., *Cyperus sp*., *Fimbristylis miliacea*, *Eclipta alba*, *Sagittaria* sp., *Scirpus* sp. and *Monochoria vaginalis* were the important weeds of transplanted rice of Pakistan.

Gosh and Singh (1996) identified *Echinochloa crusgalli*, *Echinochloa colona*, *Digitaria filiformis*, *Ludwigia purpuria*, *Marsiliea quadrifolia* and *Cyperus* sp. as predominant weed species of transplanted rice in Ranchi. According to Phogat and Pandey

(1998) *Leptochloa chinensis*, *Echinochloa crusgalli*, *Eclipta alba* and *Cyperus iria* were the major weeds of transplanted rice in New Delhi. As per Nanjappa and Krishnamurthy (1980), important weeds of rice fields of Bangalore were grasses like *Echinochloa crusgalli, Echinochloa colona,Panicum repens,* sedges like *Cyperus difformis, Cyperus irria*, and broad leaf weeds like *Marsilia quadrifolia* and *Jussieea repens*.

Mukherjee and Singh (2005) reported *Echinochloa crusgalli*, *Echinochloa colona*, *Cynodon dactylon*, *Cyperus rotundus*, *Cyperus difformis*, *Fimbrystylis miliacea*, *Amaranthus viridis*, *Ludwigia parvifloa* and *Ammania baccifera* as major weeds of transplanted paddy fields of Varanasi. Weed species considered as most important in paddy fields of Tamil Nadu were *Echinochloa colona* and *Echinochloa crusgalli* among grasses; *Cyperus iria*, *Cyperus difformis*, *Fimbrystylis miliacea* and *Scirpus* spp. among sedges *Ammania baccifera*, *Brachiaria* spp., *Cynotis axillaris*, *Eclipta alba*, *Ludwigia parvifloa*, *Marsilea quadrifolia*, *Monochoria vaginalis*, *Rotala densifloa* and *Sphaeranthus indica* among broad leaf weeds (Venkataraman and Gopalan, 1995).

According to Jacob *et al*. (2005) the predominant weed species observed in the transplanted paddy fields of Instructional Farm, College of Agriculture, Vellayani were *Echinochloa colona*, *Echinochloa crusgalli* and *Leersia hexandra* among grasses, *Cyperus iria* and *Cyperus difformis* among sedges and *Ludwigia parviflora* and *Monochoria vaginalis* among broad leaf weeds.

2.2 Crop - weed competition in rice

Weeds rank next to drought stress in reducing yield and quality of upland rice. High competitive ability of most weeds is due to their C4 nature with higher photosynthetic ability than rice, which is a C3 species (Matsunaka, 1983). Kim and Moody (1989) also reported the competitive advantage of weeds over rice due to their C4 nature. Yield loss caused by uncontrolled weeds in upland rice could lead to total crop loss (Akobundu and Fagade, 1978; Ampong – Nyarko and De Datta, 1991).

Yield reduction due to weeds in rice can vary from 15 to 20 per cent in transplanted rice, 30 to 35 per cent in wet seeded rice and over 50 to 60 per cent in upland rice (Smith, 1968). According to De Datta (1981) weeds grown in rice plots reduces yield as much as 30 per cent in transplanted rice, 45 per cent in rain fed low land direct seeded rice and 67 per cent in upland rice. In India, yield loss due to unchecked weed competition was reported to be 43 to 83 per cent (Pillai and Rao, 1974).

According to Jiang (1989), grasses are the most dominant weeds during the early crop season, while sedges and broadleaved weeds dominate later in the season. Grassy weeds are most influential in reducing rice grain yield followed by broad-leaf weeds and sedges (De Datta *et al*. 1968).

Smith (1964) studied influence of *Echinochloa crusgalli*, *Sesbania exaltala*, *Aeschynomene virginica* and *Heteranthera limosa* and found that *Echinochloa crusgalli* and *Heteranthera limosa* lowered rice yields early in the season. Although they emerged with rice, the other two species competed more effectively late in the season.

2.2.1. Critical period of crop weed competition

Critical period for weed control is generally defined as the time span between the beginning of the crop cycle when weeds present must be removed and the point after which weed growth no longer affects the crop yield (Nieto *et al*., 1974). Critical period of crop weed competition is the shortest time span during the crop growth when weeding results in highest economic returns. The critical period of crop weed competition is around 30 days for most of the crops (Reddy and Reddy, 1991).

The precise time and duration of critical period depends on many factors such as the weed flora, growth characteristics of the rice plant and the weeds, cultural practices and environmental factors (Moody, 1977). Clements (1970) identified two critical periods for transplanted rice. The first are between 4 and 6 weeks after transplanting then corresponds to the period of maximum tillering which causes greatest damage by reducing the number of panicles. The second is during 12th week or early ripening stage, which reduces the grain weight.

Studies indicate that the full impact of weed competition occurs during the early growing seasons. According to Sharma *et al*. (1977), in direct-seeded upland rice, yield reductions due to weed competition ranged from 42 to 65% in field experiments conducted in eastern Utter Pradash and the most critical period, when crop losses due to weed competition were most severe, ranged from 10 to 20 days after emergence.

Weed competition during the first 15 days after sowing had no significant effect on grain yield of upland rice (Singh *et al*., 1987). Weeds emerging in between 15 DAS and 45 DAS will compete with the crop, resulting in substantial yield reduction. Ali and Sankaran (1984) reported that the critical period of crop weed competition in upland rice is for a period up to 60 DAS. However, Varshney (1985) reported a period of 40 DAS. Weed free period up to 60 days is essential for getting good yields in dry sown rice (Sankaran and De Datta, 1985). Thomas and Abraham (1998) stated that the critical period is from 15 to 45 days after sowing.

The first 30-40 days is considered to be the critical period for crop weed competition in direct seeded rice (Sharma *et al.* 1977; Tewari and Singh, 1991). However, Singh *et al*. (1991) reported that removal of weeds as late as 70 days after transplanting increased the paddy yield significantly in transplanted rice. According to Arai (1967), the transplanted crop has an initial growth advantage and so weeds are less detrimental than direct seeded rice. While reviewing various research works on crop weed competition in rice, Zimdahl (1980) concluded that the first 20 days after emergence was the critical period of crop weed competition in rice.

2.2.2. Growth and yield as affected by weed competition

Sreedevi (1979) reported a reduction in plant height due to severe weed infestation in semi - dry rice. Kumar (1984) observed that the height of rice plants in weedy check was more than that in herbicide treated plots in the beginning; however, subsequently this trend was reversed with plants in the weedy check having a short stature than those in the herbicide treated plots. Decrease in plant height due to competitive stress in unweeded plots was reported by many researchers (Noda *et al*. 1968., Jayasree, 1987, Palaikudy, 1989). According to Suja and Abraham (1991), high weed density and severe weed competition reduced the plant height and crop dry matter production.

Crops under competitive stress produced fewer vegetative and panicle bearing tillers. They also manifested smaller panicles, delayed heading and increased plant height (Noda *et al*, 1968).

Chakraborthy (1973) and Balaswamy and Kondap (1988), recorded reduction in dry matter production in rice due to weed competition. Patel *et al*. (1985) reported a negative correlation of crop dry matter with weed dry weight. Singh *et al*. (1987) observed higher rate of dry matter production of weeds in unweeded plots during 15 to 30 days. The crop dry matter production was higher in plots where a hand weeding or pre - emergence herbicide was applied (Palaikudy, 1989). In general, rice dry matter yield would be reduced by 1 kg for every kg of weeds produced in the same area (Ampong – Nyarko and De Datta, 1991). According to Moody (1988), rice yield is inversely related to weed dry matter.

The loss of rice yield due to weeds ranged from 10 to 70 per cent (Mani *et al*. 1968, Shetty, 1973). Pillai and Rao (1974) estimated a yield reduction of 30 to 35 per cent in direct seeded rice under puddle condition. Sankaran and De Datta (1985) after reviewing the reports of many Indian workers reported a yield reduction of 32 to 86 per cent in upland rice due to uncontrolled weed growth. According to Okafor and De Datta (1974), grain yield of drilled and broadcast upland rice was reduced by 43 and 41 per cent due to competition from *Cyperus rotundus*.

The extent of decline in the yield of rice due to weeds has been reported between 94 to 100 per cent (Mukhopadhyay *et a*l. 1972). Regression studies by Singh and Dash (1988) showed that an increase in dry weight of weeds at the rate of 1 g/m^2 decreased the grain yield of rice by 0.0074 t ha^{-1}. A yield loss of 73 to 86 per cent due to uncontrolled weed growth was reported by AICRP - WC (1992). Incidence of *Echinochloa* for a period of 4 weeks reduced rice yield by 40 per cent in upland direct seeded rice (Mandal, 1990).

Twenty *Echinochloa crusgalli*/m^2 competing from the 7 to 14 days after emergence in Philippine low land rice reduced yield up to 20 per cent and 40 plants/m^2 reduced yield up to 40 per cent. However, there was no further reduction from 60, 80 or 100 plants/m^2 (Lubigan and Vega, 1971). Swain *et al*. (1975), proposed a linear relationship between rice yield and duration of *Cyperus difformis* competition. He observed a yield reduction of 64.4 kg ha^{-1} for each day of competition up to tillering in high fertile soils, but only 27.9 kg ha^{-1} under low fertile conditions.

2.2.3. Nutrient removal by weeds

Weeds accumulate more nitrogen in direct - sown rice than the crop indicating severe competition for nitrogen throughout the upland rice growing season (Chakraborthy, 1973 and Singh and Sharma, 1984). Chang (1973) found that barnyard grass removes more nutrients from soil than *Monochoria*. The yield loss due to barnyard grass at low and high soil fertility levels were 80 per cent and 88.8 per cent and from *Monochoria* was 64.6 per cent and 58.9 per cent. Similar findings were also reported by Chisaka (1977). The nutrient concentration in weeds far exceeds the associated crop. Weeds are severe competitors for nutrients than for water (Loomis, 1958).

The demand for nutrients was in the order of K>N>P by crop and weed. Weeds removed 24 kg N, 7.5 kg P_2O_5 and 30.5 kg K_2O per hectare in an unweeded check (Varughese, 1978). Many rice weeds have nutrient uptake similar to that of rice, but have higher nutrient use efficiency. Nanjappa (1975) and Sahai and Bhan (1982) reported significant correlation between nutrient uptake by the crop and weeds. The ability of weed species to utilize available nutrients better than crop species can also provide an advantage to the farmer while competing for water and light (Carlson and Hill, 1986).

Echinochloa crusgalli bears a morphological similarity to rice and because rice roots are disturbed through all soil layers, competition for N was more vigorous between rice and *Echinochloa crusgalli*. Dotzenko *et al.* (1969) reported that rate and time of N fertilization affected weed population and thus number of weed seeds produced. Okafor and De Datta (1976) found that increasing N in rice benefited *Cyperus rotundus* more than the crop, leading to a reduction in rice grain yield. Weed dry weight and N uptake by weeds are positively correlated (Singh and Dash, 1988). Potassium deficiency primarily results in stunting. However, weeds seem to be insensitive to low soil K and do not respond to added K (Buchanan and Hoveland, 1973).

Moorthy and Mittra (1990) reported N, P and K removal of 19.4—33.7 kg ha^{-1}, 1.5— 1.8 kg ha^{-1} and 17.4 — 3 3.7 kg ha^{-1} respectively from soil by weeds. Weeds when allowed to compete with crop depleted 25.8, 3.65 and 21.83 kg N, P_2O_5 and K_2O per hectare (Ramamoorthy, 1991).

Weeds compete severely for nutrients and depending upon the intensity of weed growth, the depletion may be up to 86.5 kg N, 12.4 kg P and 134.5 kg K per hectare and in addition 61, 15, 2523 and 166 g per hectare each of Zn, Cu, Fe and Mn respectively (Malik and Moorthy, 1996). In West Bengal, an aquatic weed *Chara* sp. produced about 1060 kg ha^{-1} dry matter and removed 21.1 kg ha^{-1} N causing a reduction in rice yield up to 40 per cent (Guha, 1991).

2.2. Non chemical methods of weed management in rice

Studies on cultural control methods are not extensive as studies on chemical control and are conducted mostly in tropical Asia, where direct or indirect cultural methods are the major practices (Baltazar and De Datta, 1992). The over dependence and over use of herbicides in agriculture has created undesirable effects like development of herbicide resistance, herbicide residues and environmental pollution. This resulted in greater pressure on farmers to reduce the use of herbicides, and there is a need to concentrate on non chemical means of weed management (Hosmani and Meti, 1993).

Akobundu (1987) states that “cultural weed management includes all aspects of good husbandry used to minimize weed interference with crops”. He includes hand weeding, mechanical weeding, tillage, burning, flooding, mulching and crop rotation as examples of cultural weed management. According to Bhan (1983), Mabbayad and Moody (1984) and Sarkar and Moody, 1983, water management, land preparation, cultivar, seeding rate, plant spacing, fertilizer management, crop rotation etc, can be designed to suppress weed growth as well as to enhance rice growth and its competitive ability against weeds.

The earliest ways of weed control in transplanted rice were cultural methods (Matsunaka, 1983). Researchers propose that transplanting and growing rice in submerged conditions are probably the first two traditional steps towards weed control (De Datta, 1989). In spite of being labour intensive, hand weeding is still the most common direct weed control method in tropical Asia, using bare hands and hand tools (De Datta, 1974).

Direct cultural methods include removal of weeds by hand, with weeding tools, or with mechanical implements. Pulling weeds by hands is the best way to control the weeds and in olden times was the only direct method of controlling weeds in rice. It takes about 200 to 500 manhours in two to three operations to weed one hectare of rice by hand (De Datta, 1974). Hand weeding is effective when the weeds are at the seedling stage, but ineffective when the weeds are established (Kukula, 1985). In a study conducted at the Bangladesh Rice Research Institute Regional Station, Comilla, during three rice growing seasons, Islam and Molla (2001) found that two hand weeding or one hand weeding plus herbicides can be recommended where labour is available. Otherwise, only herbicides should be used to make weeding economical and rice production profitable.

Despite major advantages in chemical control, hand removal of weeds still remains to be the most practical method of weed control in many developing countries. Although back breaking and laborious, hand weeding is quite effective if employed at the right time. Two aspects are important in hand weeding, the number of hand weedings to be done and interval between two hand weedings. The number of hand weedings depends on crop growth, weed growth and critical period of crop-weed competition (Hooda, 2002). In a study conducted in Kerala, Jacob and Syriac (2003) found that hand weeding twice was effective but significantly inferior to other treatments in reducing weed competition in transplanted scented rice.

Mechanical weeding is done with human or engine powered inter row cultivators or rotary weeders. It takes about 50 to 60 manhours to weed one hectare of rice field by mechanical weeding (Parthasarathy and Negi, 1977). However, it is practical only in row seeded rice and does not remove weeds within or close to the rice hills, which can still cause marked reduction in yield (De Datta, 1981). Push type rotary weeders are difficult to use because they must be moved back and forth and do not work well if the soil is too dry, if weeds are too big or if flood water is too deep (Moody, 1991). Parida (2002) reported an improved and modified IRRI cono-weeder for wet field condition. According to him, with the use of this weeder, 60 per cent of time could be saved in comparison to manual weeding. There is 60 per cent savings in the cost of weeding.

2.3.1. Stale seed bed techniques

Careful preparation of land provides weed free conditions at planting. The method of land preparation influences the incidence of weeds (Sankaran and De Datta, 1985). Stale seed bed technique in dry seeded upland rice involves the removal of successive weed flushes before planting. Chemical (Paraquat or Glyphosate), mechanical and manual methods may be used for the control of weeds. The dry seeded rice crop may be sown with minimum soil disturbance after weeds have been controlled. The size of subsequent germinating weed cohorts will be minimized because most weeds in the favorable zone for germination have already been controlled (Moody and Mukhopadhy, 1982).

Parker and Dean (1976) suggested stale seedbed technique as a useful tool for control of red rice in rice culture. According to Ampong – Nyarko and De Datta (1991) and Thomas and Abraham (1998) reduction of weeds in semi - dry rice culture is possible by practicing stale seed bed technique.

Stale seed bed is described as a planting system that does not use tillage immediately prior to planting. Tillage is usually performed immediately after crop harvest or any time before the next cropping season begins, when soil moisture and environmental conditions allow field operations (Shaw, 1996). Many weed seeds in the germination zone germinate and emerge before planting. Foliar herbicides applied to control existing vegetation at planting will eliminate these weeds without additional tillage to bring up new seed; fewer weeds will be present later in the season (Shaw, 1996). He also found that the stale seed bed approach was economically viable and agronomically feasible. According to Jhonson and Mullinix (1998), stale seed beds shallow tilled two times had fewer weeds and higher yield than stale seedbed treated with glyphosate.

Yaduraju and Mani (1987) observed that stale seed bed preparation had no effect on broad leaf weeds in wheat. However, both cultural and chemical treatments were equally effective in wild oat growth up to 6 weeks after sowing. The stale seed bed technique consists of loosening the soil in order to achieve an almost optimal gaseous environment around buried seeds to satisfy the light requirements considered essential for germination of photoblastic seeds (Hartman and Nezadal, 1990).

Hosmani (1991) observed that the weed intensity is low in late sown Kharif crops than early sown Kharif crops. Similarly, in years when frequent pre - monsoon showers are received the weed intensity is lower as it favours weed germination and subsequent destruction by tillage operation before sowing the crop. Reducing tillage or using shallow tillage results in rapid depletion of seed bank (Yenish *et al*. 1992).

IRRI (1979) reported reduction in weed growth by practicing stale seed bed techniques. Almamum *et al*. (1986) suggests stale seed bed technique as the most and widely used means of weed control in Iraq. Stale seed bed is the most practical and widely used means of weed control in Iraq. In Egypt, stale seed bed was recommended in mechanically transplanted and machine drilled rice to reduce weed pressure. Paraquat @

0.6 kg ha^{-1} at three days before planting was used when weeds had reached three leaf stage. Shallow hoeing was recommended before drilling rice (Hassan and Rao, 1996).

The usefulness of stale seed bed method in preventing successive flushes before seeding was reported in dry - seeded rice in India (Mukhopadhyay, 1987 and Moorthy, 1992). Moorthy (1992) also reported that cultivated stale seed bed was superior to chemical stale seed bed involving spraying of Paraquat @ 1.0 kg ha^{-1} on existing weeds before sowing rice. However, Renu (1999) reports that the stale seed bed with Paraquat is better than stale seed bed with hoeing. She suggested that stale seedbed technique was a useful tool for management of all weeds including *Sacciolepis* in rice.

Work conducted at CRRI, Cuttack indicated that appropriate land preparation and sowing in a stale seed bed can be effectively used in integrated weed management systems (Chandra *et al*., 1991; Moorthy, 1992). The crop under stale seed bed had significantly higher yield attributing characters such as plant height, effective tillers per plant and ear length, owing to reduced weed stress (Yadav *et al*. 1995). According to Saikia and Pathak (1993), the stale seedbed suppressed the weeds better than the conventional method and allowed the crop to attain height.

Integration of stale seed bed with herbicides was found to be superior to other seed bed manipulations, in wheat. This combination gave better yield and weed control efficiency (Kumar *et al*., 2002).

Lonsbary *et al*. (2003) observed stale seed bed in combination with herbicides as a superior integrated weed management tool compared to conventional weed management tools. He also suggested that the optimum timing of stale seed bed preparation as 20 to 30 days before planting. According to Sharma *et al*. (2004), stale seedbed preparation is better than traditional seed bed preparation for weed control in direct dry seeded rice in India.

False seed beds were shown to contribute to a decrease in soil weed seed reserve (Rasmussen, 2004). According to Benvenute and Macchia (2006) possibility of forcing germination through stale seed bed appears to be one of the most promising strategies especially with low competitiveness and/or the presence of non row crops that limit the chances of successful non chemical control in post emergence period. Riemens *et al*. (2007) reported that the stale seed bed technique in combination with mechanical control of emerging weeds can reduce the weed population during crop growth as effectively as chemical weed control.

2.3.2. Row spacing and seeding rate

Seeding rate in direct seeded rice and plant spacing in transplanted rice determine the rice stands or rice plant density per unit area. This, in turn, determines the amount of canopy created to help rice to shade and compete with weeds. Increased spacing between or within rows increases light penetration in to the canopy which enhances the weed growth. Dry weight of weeds have been shown to decrease corresponding to increase in seed rate from 50 to 250 kg ha^{-1} (Moody, 1977)

Godel (1935) recognized the value of higher seeding rates of cereals for reducing weed competition. Singh *et al*. (1983) indicated that yield of waterlogged rice can be potentially increased if more seedlings are planted per hill at a spacing closer than normal practices. Increasing crop density by using higher seed rate, narrower row spacing and closer plant spacing (within a row) are important weed management techniques as they enhance crop competitiveness by suppressing or smothering weeds (Rao, 2000).

Moyer *et al*. (1991) investigated the effects of both row spacing and seed rate. When crops are planted at wider spacing because of more number of plants within the rows greater inter specific competition would have occurred as compared to closer spacing (Johri and Singh, 1991). Although individual hills under wide spacing showed superior growth and yield contributing characters than that under closer spacing, the grain yield per unit area was greater in the latter than in the former as a result of more number of productive tillers per unit area (Gupta and Sharma, 1991). According to Younie and Tylor (1995), sowing the crop at narrow row spacing increases the rate of crop growth and ground cover. However, increasing the seed rate provided better weed suppression than narrowing the row spacing.

Gosh and Singh (1996) reported that reduction in plant density by 25 per cent enhanced weed infestation but had no effect on grain yield. In cereals, increasing the seed rate can be effective in suppressing the weeds (Korres and Williams, 1997: Sodhi and Dhaliwal, 1998). Higher seed rate and closer spacing produced more yield than normal seed rate and wider spacing (Dhiman *et al*. 1985). Dry matter of weeds decreased as row spacing decreased

2.4. System of Rice Intensification (SRI)

The system of rice intensification (SRI) is a type of rice cultivation suitable for water scarce areas, originated in the Ansirabe region at about 1500 m altitude in Madagascar. This system was developed by Henri de Laulanie, a Jesuit priest, who worked with farming communities in Madagascar from 1961 until his death in 1995. By 1984, he had assembled the set of practices that now constitute SRI (Laulanie, 1993).

SRI, however, remained unknown to the rest of the world until 1994. In 1994, an Integrated Conservation and Development Project (ICDP), around Ranomafana National Park, Madagascar, made it possible for Tefy Saina, an NGO to begin working with the Cornell International Institute for Food, Agriculture and Development (CIIFAD) under the leadership of Norman Uphoff. This partnership that began with a view to increasing the yield on lowland rice fields and weaning farmers away from slash-and-burn cultivation enabled the spread of SRI initially in Madagascar and the rest of the world (Prasad, 2006). According to Uphoff, (2004) at present, apart from Madagascar, this method is in practice in 18 additional countries ranging from China to Peru, with average yields from SRI in the 7-8 t ha^{-1} range, and with yields over 15 t ha^{-1} reported from at least four countries beyond Madagascar. The three main features of SRI are: single rice seedlings should be transplanted quickly when young, rice seedlings should be spaced widely apart and most importantly that the rice fields should be kept moist but not flooded (Surridge, 2004).

There are claims and counter claims regarding the success of SRI compared to conventional rice farming practices. The first trials validating the methods outside Madagascar were done in 1999, in China and Indonesia, and have now been validated in 22 countries. In countries such as Laos, Nepal and Thailand, 'the SRI effect' was not very evident initially. In other countries, such as Cambodia, Cuba, Gambia and Sierra Leone, very dramatic results were claimed. The Agency for Agricultural Research and Development (AARD) in Indonesia was amongst the earliest organizations that sought to promote SRI in collaboration with CIIFAD, deciding in 2002 after three years of evaluations to make it part of a new integrated crop management (Rabenandrasana 1999; Uphoff, 2003; Berkelaar 2001; Stoop *et al*., 2002).

As SRI does not require application of agrochemicals such as fertilizers or pesticides, the SRI farmers have claimed that their cost of production is usually half of the conventional system. According to Batuvitage (2006), SRI farming method produces greater grain yield compared to commonly used conventional transplanting and broadcasting systems in Srilanka.

The positive effects of SRI on rice production and water saving in Tamil Nadu was reported by Thiyagarajan (2002). According to Vishnudas (2006), there was an increase in the yield up to 65 per cent to 80 per cent and profit increase ranged from 50 per cent to 100 per cent. Improvement in grain yields of rice by the adoption of SRI methods have been reported by many workers (Uphoff, 2003; Singh and Talati, 2005; Vijayakumar *et al*., 2006 and Sinha and Talati, 2007)).

Nissanka and Bandara (2004) attributed the higher grain yield production in SRI farming system to the vigorous and healthy growth, development of more number of productive tillers and leaves ensuring greater resource use efficiency in the SRI compared to conventional transplanting and broadcasting system.

In a review, Stoop *et al*. (2002) concluded that under SRI, the basic crop production factors—time, space, water, plant nutrients and labour need to be considered simultaneously and that response might result largely from synergistic effects. According to Wang *et al*. (2003), SRI significantly increased root activity, increased soluble sugars, non-protein nitrogen and proline contents of leaf, dry matter translocation per centage from vegetative organs to grains and quality significantly. Rice yield, however, was limited by low tiller number and panicle number of plant population.

Although, most initial reports were in favour of SRI, many of the current reports from replicated trails are not in favour of SRI. Phenomenal yield increase as reported in popular writings were lacking in scientific studies.

Experiments conducted in three locations in China, comparing yields in the conventional systems and in SRI managed systems, revealed that SRI has no inherent advantage over conventional systems and that of the original reports of extra ordinary high yields are likely to be the consequence of error (Sheehy *et al*., 2004). Mosser and Barret

(2003) found that SRI is difficult for most of the farmers to practice because the method requires significant additional labour input at the time of the year when liquidity is low and labour effort is already high. According to Barret *et al*. (2004), the increased estimated yield risk associated with SRI would nonetheless make it unattractive to many farmers within the standard range of relative risk aversion.

In a study by Mc Donald *et al.* (2006) using 40 site-years of SRI versus conventional best management practices (BMP), except from one set of experiments in Madagascar where SRI more than doubled rice productivity with respect to BMP, they found no evidence of a systematic or even occasional yield advantage of this magnitude elsewhere. None of the 35 other experimental records demonstrated yield increases that exceeded BMP by more than 22 per cent. Excluding the Madagascar examples, the typical SRI outcome was negative, with 24 of 35 site-years demonstrating inferior yields to best management and a mean performance of –11per cent.

Kumar *et al*. (2005) from trails at Indian Agricultural Research Institute, New Delhi, could not record any additional yield advantage for SRI than conventional system. According to Latif *et al*. (2005), SRI did not increase rice yields when it was compared with existing best management practices. The increased labour demand and poor economic performance make it unattractive to farmers. Joseph *et al*. (2007) reported that single plant yield was more in SRI method; it was less when the plot as a whole was taken. The number of plants in SRI would be one third of normal plants. While comparing yield performance of rice under different systems of management they found that under well-managed conditions the normal package of practices recommendations would be more useful in terms of cost of production and profitability.

Considering the strengths and weaknesses of the system of rice intensification methods, Zheng *et al*. (2004) suggested a modified SRI method with three seedlings per hill in a triangular pattern, application of herbicides before transplanting, addition of chemical fertilizers, and mid season drainage to SRI fields to avoid excessive tillering. Similar modifications were also suggested by the scientists of Tamil Nadu Agricultural University (TNAU, 2007). They suggested planting of 16-18 day old seedlings at a closer spacing of around 20 cm x 20 cm and application of chemical fertilizers. These practices are almost similar to the package of practices recommendations of Kerala Agricultural University (KAU, 2007).

Materials & Methods

3. MATERIALS AND METHODS

The field trials of the present research programme were conducted during 2005 to 2007 at two locations viz., Agricultural Research Station (ARS), Mannuthy and in farmer's field at Alappad in the *Kole* lands of Thrissur district. The details of materials used and methods adopted in the conduct of the trials are presented in this Chapter.

3.1 General details

Location

The Agricultural Research Station, Mannuthy is located at $10^{0}31^{1}$ latitude and $76^{0}13^{1}$ longitude and is at an altitude of 40.29 m above sea level. Alappad *kole* is located at $75^{0}58^{1}$ latitude and $76^{0}11^{1}$ longitude and 1 m below sea level.

Climate and weather conditions

The experimental site enjoys a typical humid tropical climate. The mean weekly averages of the important meteorological parameters observed during the experimental period are presented in Appendices 1, 2, 3 and 4.

Soil

Soil type of the Agricultural Research Station, Mannuthy is laterite sandy loam of the Oxisol group with an acidic pH of 5.5. The *Kole* land soils are clayey in texture with pH 5.0 and belongs to Inceptisol group. The physico chemical characteristics of the soils of the experimental fields are presented in Table 1.

Table 1. Physico-chemical properties of the soil

Particulars	Experiment location		Method used
	ARS, Mannuthy	Alappad *Kole*	
A. Particle size analysis			
Sand (%)	53.8	20.15	Hydrometer method (Piper, 1966)
Silt	23.9	21.54	
Clay	20.9	56.31	
Bulk density (g cc^{-3})	1.45	1.23	
B. Chemical composition			
Organic C (%)	0.52	1.2	Walkley and Black's rapid filtration method(Jackson, 1958)
Available N (kg ha^{-1})	296	1500	Alkaline permanganate method (Subbiah and Asija, 1956)
Available P (kg ha^{-1})	59	17	Bray – 1 Extractant Ascorbic acid reductant method (Jackson, 1958)
Available K (kg ha^{-1})	100	125	Neutral normal Ammonium acetate extract using flame photometer (Jackson, 1958)
pH (1:2.5 soil water ratio)	5.5	5.0	Jackson, 1958

Cultivar used

The rice cv.Jyothy, a red kernelled, short duration cultivar of 110-120 days duration was used for the trials. The cultivar is suitable for direct seeding and transplanting during both first (Virippu) and second (Mundakan) crop seasons. It is tolerant to BPH and rice blast disease, moderately susceptible to sheath blight and capable of yielding over 8 tons under favorable situations and moderately good yields under adverse conditions.

Cropping history of the experimental site

The experimental site at the Agricultural Research Station is a double crop wet land paddy, where a semi - dry crop is taken during April - May to August- September and a transplanted crop during September - October to December - January every year. The land is either left fallow or under vegetable cultivation during summer season.

In the Alappad *Kole*, the experimental field is a single cropped land, where rice is grown during September - October to February - March. The land remains submerged during the rest of the year.

3.2 Experiment details

Experiment I. Survey and documentation of weed management practices followed by rice farmers

Palakkad, *Kole*, Pokkali and Kuttanad regions were selected for the study since they are the major rice farming areas of Kerala.

A questionnaire was prepared for the survey and the English version of the interview schedule was translated to Malayalam for direct personal interview with the farmers.

In Palakkad district, Alathur, Mannarghat, Chittoor, Ottappalam and Palakkad taluks were chosen for the survey. Survey area of *Kole* lands included upper (Adat and Puzhakkal) and lower (Alappad and Manakkody) *Koles*. Both upper and lower Kuttanad region were covered under this study. Pokkali rice growing tracts in Ernakulam district were the study areas for Pokkali rice.

Experiment II. Stale seed bed techniques suited for semi - dry and wet - seeded rice

A. Semi - dry rice

The trial was conducted at ARS, Mannuthy during the first crop season of 2006 and 2007. Trial was laid out in split plot with four seed bed treatments assigned to main plots, six weed control methods in sub plots and three replications.

Gross plot size: 6m X 5m
Border : 0.5m on all sides
Sampling area : 1 m strip along the 6m side inside the border area
Net plot size : 4m X 4m

The treatments included were

Main plot treatments: Seed bed treatments (4)

1. Normal dry dibbling
2. Stale seed bed for 7 days (after land preparation) followed by shallow hoeing and seeding

Plate 1. Field view of stale seed bed for dry seeding

Plate 2. Field view of stale seed bed for wet seeding

3. Stale seed bed for 14 days with two shallow hoeings (one on 7th day and second on 14th day)
4. Stale seed bed for 14 days with one shallow hoeing on 14th day

Sub Plot treatments: Weed control methods (6)

1. No weeding (Maintaining plots as such)
2. Hand weeding twice at 20 and 40 DAS
3. Pre - emergence spray of Pretilachlor (Rifit 50 EC) @ 0.75 kg ha^{-1} followed by hand weeding at 40 DAS
4. Cono weeding at 20 DAS + one hand weeding at 40 DAS
5. Cono weeding at 20 and 40 DAS
6. Concurrent growing of rice and cowpea and *in situ* green manuring at 30 DAS

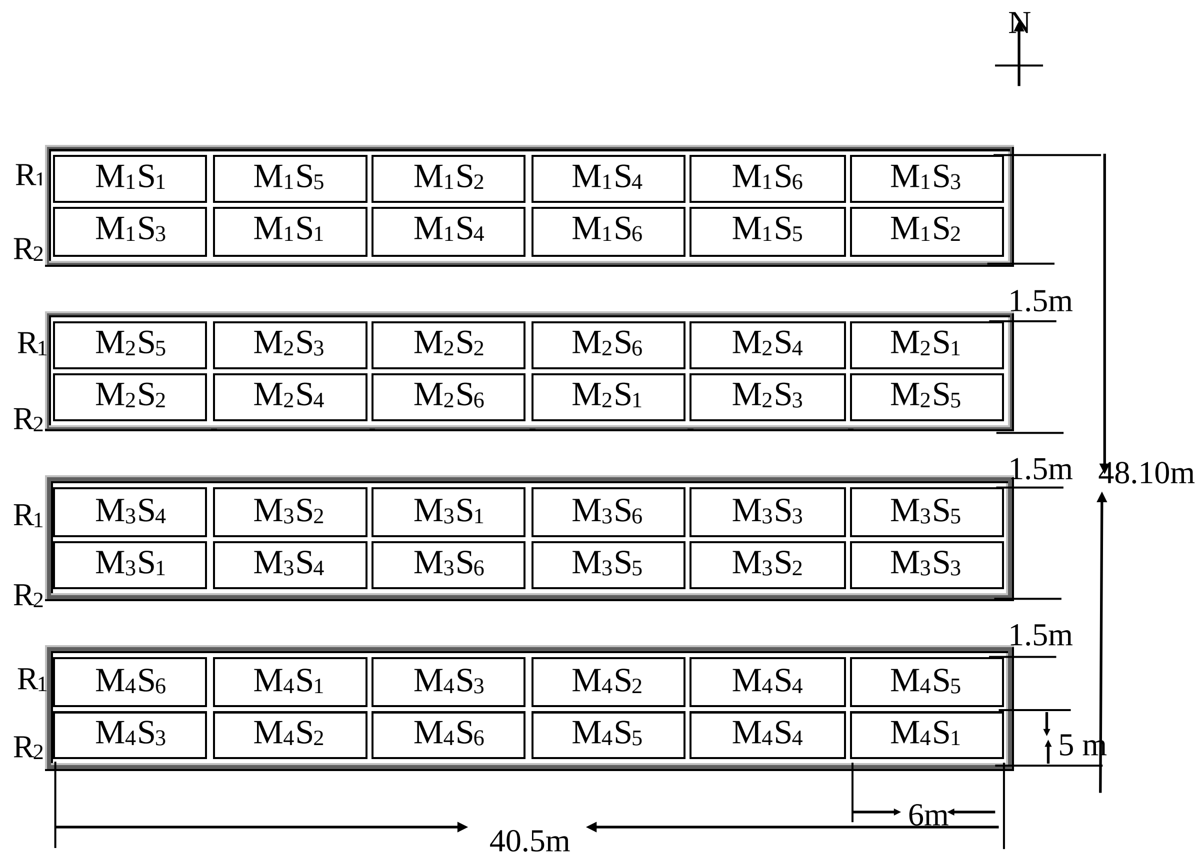
Land preparation

The experimental area was ploughed well and given tillage as per the main plot treatments (Plate 1). The sub plots of 5m X 4m were prepared by constructing bunds of 30 cm width and 30 cm height. Irrigation/drainage channels were provided after every two rows. In the stale seed bed plots the germinated weeds were destroyed by shallow hoeing on 7th and 14th day as per the treatments.

In the treatment 'normal dry dibbling,' seed bed was prepared on the same day of sowing. In all main plot treatments, sowing was done on the same day by adjusting the dates of preparing stale seed beds. The stale seed bed for 14 days was prepared first. After 7 days, stale seed bed for 7 days was prepared and at the end of stale seed bed period in main plot treatments, normal seed bed was prepared and sowing of weeds was done on the same day.

The layout of the field and treatment allocation is given in Figure 1.

Figure.1. Lay out plan of the experiment on “Stale seed bed techniques suited for dry - seeded rice”



Main plot treatments

M_1 Normal dry dibbling

M_2 Stale (7 days)

M_3 Stale (14 days + 2 hoeings)

M_4 Stale (14 days + 1 hoeing)

Sub plot treatments

S_1 No weeding

S_2 Hand weeding (20 and 40 DAS)

S_3 Rifit + Hand weeding (40 DAS)

S_4 Cono weeding (20 DAS) + Hand weeding (40 DAS)

S_5 Cono weeding (20 and 40 DAS)

S_6 Cowpea concurrent growing

Crop culture

The crop was dry dibbled @ 80 kg ha^{-1} at a spacing of 15 cm X 10 cm. A strip of 1 m width along the 5m side on one end of the plot was left as sampling area leaving a plot size of 4m X 4m.

General practices for the semi - dry rice culture, except that of weed control, were followed in all treatments. The pre - emergence herbicides Pretilachlor (Rifit 50EC) @ 0.75 kg ha^{-1} or Pretilachlor + safener (Sofit 30 EC) @ 0.45 kg ha^{-1} were sprayed in respective plots on 3^{rd} day after sowing. The herbicides, as per treatments were applied uniformly on the soil surface with a knapsack sprayer fitted with a flat fan nozzle. Quantity of spray fluid used was 300 l ha^{-1}.

Fertilizer management and plant protection measures were done as per the package of practices recommendations of KAU (KAU, 2002). Details of field operations are given in Appendix 5.

B) Wet - seeded rice

Experiment on stale seed bed techniques suited for wet land rice was conducted in the field of Mr. Kesavaraj, Kulappully house, Purathur, in Alappad *Kole* lands of Thrissur district during the Mundakan season of 2005 and 2006. The experiment was laid out in split plot with three seed bed treatments as main plots, five weed control methods as sub plots and three replications. The treatments included

Main plot treatments: Seed bed treatments (3)

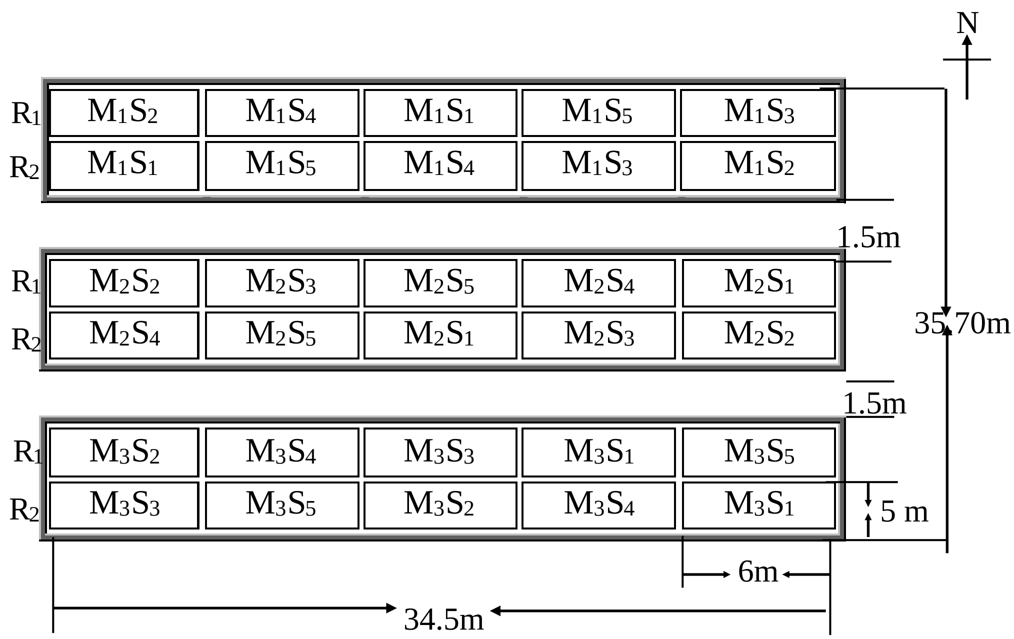
1. Normal wet sowing (line sowing)
2. Stale seed bed for 7 days (by keeping the field drained and destruction of weeds by letting in water on 7th day)
3. Stale seed bed for 14 days (by keeping the field drained and destruction of weeds by letting in water on 14th day)

Sub plot treatments: Weed control methods (5)

1. No weeding
2. Hand weeding at 20 DAS
3. Pre - emergence spray of Pretilachlor + safener (Sofit 30 EC) @ 0.45 kg ha^{-1} at 3 DAS.
4. Cono weeding at 20 DAS
5. Concurrent growing of rice and Daincha and *in situ* green manuring on 30 DAS

Gross plot size: 6m X 5m
Border : 0.5m on all sides
Sampling area : 1 m strip along the 6m side inside the border area
Net plot size : 4m X 4m

Figure.2. Lay out plan of the experiment on "Stale seed bed techniques suited for wet seeded rice"



Main plot treatments

M_1 Normal wet sowing

M_2 Stale (7 days)

M_3 Stale (14 days

Sub plot treatments

S_1 No weeding

S_2 Hand weeding at 20 DAS

S_3 Sofit

S_4 Cono weeding at 20 DAS

S_5 Daincha

The experimental design was split plot with three replications. The plot size adopted was 20 m^2 (5m X 4m). The experimental area was ploughed, puddled and levelled and stale seed beds were prepared as per treatments by draining the field (Plate 2). After the stale seed bed period weed seedlings were destroyed by allowing water to stand for 10 days. On the 10^{th} day of flooding, water was drained from the plots and the normal seed bed was prepared.

Line sowing of pre - germinated paddy seeds was done using a manually operated combined seed drill (green manure cum rice seed drill marketed by *Raidco*). Water was again let in on the fifth day and the depth of water was gradually increased and maintained at 5cm. The lay out and treatment allocation is given in Figure 2.

In plots with daincha, the seeds of daincha were sown on the same day of sowing rice. Except for weed management, all other management practices were done as per the recommendations of Kerala Agricultural University (KAU, 2007).

Experiment III. Crop weed competition in transplanted rice: Influence of plant stand

The investigation was laid out in split plot design with two main plots and four sub plots, replicated thrice. The lay out and allocation of treatments is given in Figure 3.

Gross plot size: 6m X 5m
Border : 0.5m on all sides
Sampling area : 1 m strip along the 6m side inside the border area
Net plot size : 4m X 4m

The following treatments were included in the experiment

Main plots

1. Weeded
2. Unweeded

Sub plots (spacing)

1. 10 cm X 10 cm (Management as per POP)
2. 20 cm X 10 cm (Management as per POP)
3. 30 cm X 30 cm (Management as per POP)
4. 30 cm X 30 cm (Management as per SRI techniques)
5. 30 cm X 30 cm (Management as per modified SRI)

The main plot was ploughed, puddled and levelled. Plots of 5m X 4m were demarcated by preparing bunds of 30 cm width and height. In POP managed plots, 20 day old seedlings were transplanted at two seedlings per hill, at a spacing of 10 cm X 10 cm, 20 cm X 10 cm and 30 cm X 30 cm. Fertilisers to supply NPK @90:45:45 kg ha^{-1} were applied. N and K fertilizers were applied in three equal splits at land preparation, maximum tillering and panicle initiation stages. Full P was applied as basal. In weeded plots two hand weedings were done, at 20 DAT and second at 40 DAT. The plots were kept under 5 cm standing water.

In plots managed under SRI, 10 day old seedlings were transplanted at a spacing of 30 cm X 30 cm @ one seedling per hill. The planting was done in puddled field with no standing water. Groundnut cake (@ 1286 kg ha^{-1}) was applied fully as basal. Frequent watering and dewatering of field was done, so as to get saturated soil moisture. In weed free SRI managed plots, weeding was done with the help of cono weeder from 10 days after transplanting to panicle initiation stage (4 times).

In modified SRI, instead of groundnut cake, NPK @ 90:45:45 kg ha^{-1} was applied as urea, Rajphos and muriate of potash and weeds were controlled by spraying Cyhalofop butyl (Clincher10% EC) @ 0.08 kg $aiha^{-1}$ at 15 DAT and Chlorimuron ethyl 10% + Metsulfuron methyl 10% (Almix 20WP) @ 4g ai ha^{-1} + 0.2% surfactant at 20 DAT.

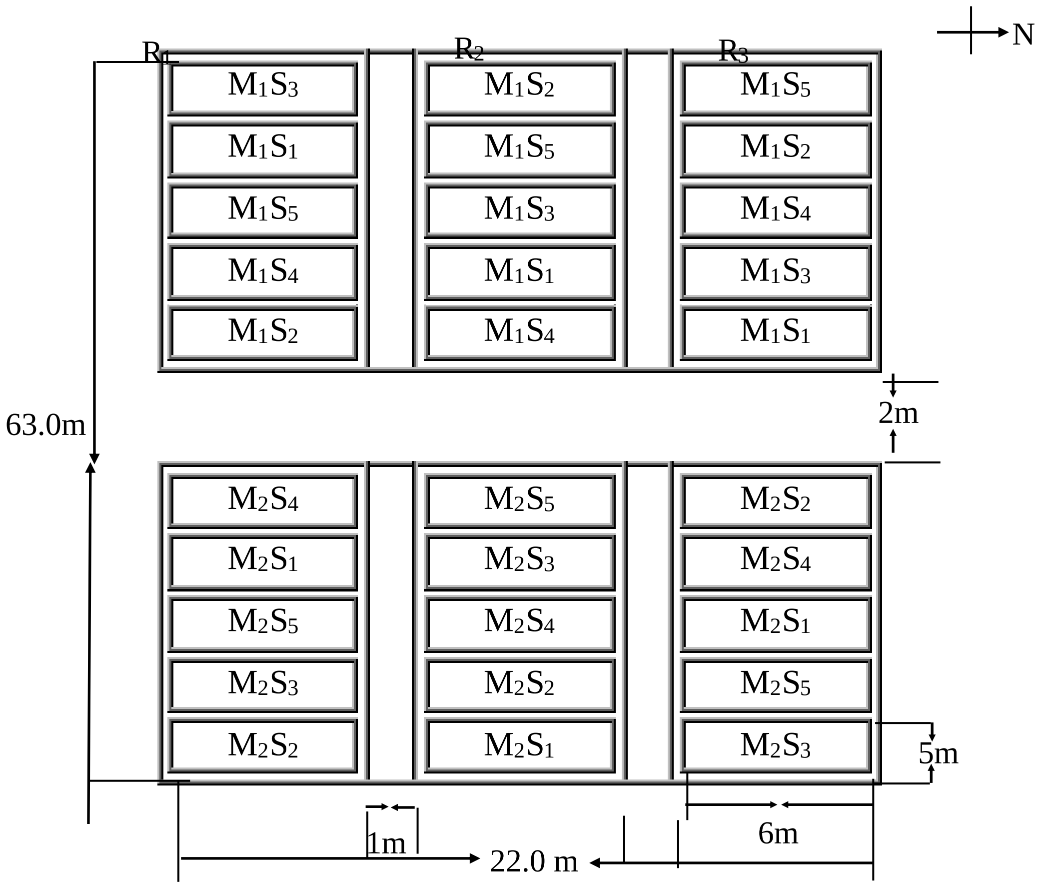
Weeded plots managed as per POP were kept weed free by giving two hand weedings, one at 20 DAT and second at 40 DAT.

Harvesting

The crop was harvested at maturity. Plants in the border rows on the four sides were harvested and removed and were not included in the net plot yield.

Threshing was done on the same day and fresh yields of grain and straw were recorded. Moisture per centage of three samples of grain were worked out and grain yield was recorded at 12 per cent moisture level. The straw from each net plot was sun dried and the weight was recorded.

Figure.3. Lay out plan of the experiment on
"Crop - weed competition in transplanted rice: Influence of plant stand"



Main plot treatments

M_1 Weeded

M_2 Unweeded

Sub plot treatments

S_1 10 cm X 10 cm (POP)

S_2 20 cm X 10 cm (POP)

S_3 30 cm X 30 cm (POP)

S_4 30 cm X 30 cm (SRI

S_5 30 cm X 30 cm (Modified SRI)

3.3 Observations recorded

3.3.1. Biometric observations

A. Plant characters

Plant height

Height of ten plants was measured from ground level to the tip of the longest leaf at maximum tillering and panicle initiation stages. At harvest, it was measured from ground level to the tip of the longest panicle and expressed in centimeters.

Tiller production

The number of tillers per hill and in one square metre area of each of the experimental plot at maximum tillering, panicle initiation and harvest were counted and recorded.

Dry matter production

Five plants pulled out for observation at each stage were initially sun dried and then oven dried at 80 ± 5^{0}C and the above ground weight was recorded. Dry matter production was computed for each treatment and expressed as kg ha^{-1}.

Number of panicles

The number of panicles per hill and in one square metre area of each plot were counted and recorded.

Panicle length

Length of 10 panicles randomly collected from plants was measured and the average was worked out and expressed in centimetre.

Number of filled grains per panicle

Grains collected from randomly selected ten plants were separated into filled grains and chaff. The average number of filled grains for single panicle was then worked out.

Thousand grain weight

One thousand grains were counted from the produce of each plot and their weight was recorded in grams.

Grain and straw yield

The crop was harvested from each net plot area, threshed, winnowed and weight of straw and grain was recorded separately and expressed as kg ha^{-1}.

B. Observations on weeds

Weed count

The observations on weeds were taken from the sampling strip using a 50 cm X 50 cm (0.25 m^2) quadrat. The quadrat was placed at random inside the sampling strip and samples were taken from two places in each plot. They were further separated into grasses, sedges and broad leaf weeds and reported as number/m^2.

Dry matter production of weeds

The weeds collected from the quadrat were uprooted, air dried and then oven dried at 80 $\pm$5^{o}C and dry weight was recorded in g m^{-2}.

3.3.2. Physiological studies

Leaf area index (LAI)

Ten plants were selected randomly at each time. The maximum width (W) and length (L) of all the leaves of the middle tillers were measured and leaf area per tiller was worked out using the formula

Leaf area = L X W X 0.68 at 15 DAS and L X W X 0.75 at 45 DAS (Gomez, 1972)

Using this, leaf area per plant was worked out.

Leaf area per plant = Total leaf area of middle tiller X Total number of tillers

$$\text{LAI} = \frac{\text{Sum of leaf area of 10 sample plants } (m^2)}{\text{Area of land covered by 10 plants } (m^2)}$$

Relative growth rate (RGR)

RGR indicates the increase in dry weight per unit of original dry weight over any specific time interval (Fischer, 1921). This was calculated using the formula

$$\text{RGR} = \frac{I_n W_2 - I_n W_1}{t_2 - t_1}$$

Where I_n - logarithm at base e (natural logarithm)

W_2 - final dry weight

W_1- initial dry weight

t_2 - period (time) of final observation

t_1- period (time) of previous observation

RGR is expressed as g g^{-1} day^{-1}

Chlorophyll content

Chlorophyll content of index leaf (Yoshida *et a*l., 1972) was extracted using DMSO and estimated colorimetrically in a Spectronic-20- spectrophotometer at maximum tillering and panicle initiation stages (Barnes *et al*., 1990).

3.3.3. Chemical analysis

Soil

Initial and final status of major nutrients in soil were estimated. Soil samples collected, dried, powdered and passed through 2 mm sieve were used for analyzing the status of major nutrients *viz*., organic carbon, available N, available P and available K using standard procedures as shown in Table 1.

Plant

The N, P and K content of rice plants and major weeds were analyzed by standard procedures (Jackson, 1958). The total uptake of N, P and K were calculated as the product of the content of these nutrients and the plant dry weight and expressed in kg ha^{-1}.

Nitrogen content

Total N content of plant samples was determined by the Micro Kjeldhal distillation method.

Phosphorus content

Plant sample was digested in a diacid mixture and the P content was determined by Vanadomolybdophosphoric yellow colour method. Intensity of color was read using Spectronic 20 spectrophotometer at 420 nm.

Potassium content

Potassium content in the diacid digest was estimated using EEL Flame photometer.

3.4. Benefit: cost ratio of treatments

The prevailing labour charge in the locality, cost of inputs, and extra treatment costs were taken together and gross expenditure was computed and expressed in rupees per hectare. The price of paddy and that of straw at current local market prices were taken as total receipts for computing gross return and expressed in rupees per hectare. Benefit: cost ratio was worked out by dividing the gross return with total expenditure per hectare.

3.5. Data analysis

Data were subjected to analysis of variance using the statistical package 'MSTAT - C' (Freed, 2006). Data on weed count and weed biomass, which showed wide variation were subjected to square root transformation ($\sqrt{x} + 0.5$) to make the analysis of variance valid (Gomez and Gomez, 1984). Multiple comparisons among treatment means, where the F test was significant (at 5% level) were done with Duncan's Multiple Range Test (DMRT).

Results

4. RESULTS

4.1. Survey and documentation of weed management practices followed by rice farmers

4.1.1. Palakkad district

The area surveyed included five thaluks viz., Alathur, Mannarghat, Chittoor, Ottappalam and Palakkad. The major rice based farming system followed in the district is Rice – Rice- Fallow/summer vegetables/pulses.

Method of crop establishment

Dry seeding is the major crop establishment method during Virippu season with the exception of Chittoor thaluk, where transplanting is predominant. However, during Mundakan season, transplanting is the major practice in all the five thaluks (Table 2).

Table 2. Method of crop establishment during Virippu and Mundakan seasons in Palakkad district

Location	Virippu			Mundakan		
	Dry seeding	Wet seeding	Transplanting	Dry seeding	Wet seeding	Transplanting
Alathur	28*	0	2	0	10	20
Mannarghat	26	2	2	0	10	25
Chittoor	2	10	18	0	10	20
Ottappalam	25	5	0	0	12	18
Palakkad	12	10	8	0	18	12

*No. of farmers (out of 30)

Major weeds of the region

Dominant weeds found in the rice fields with their scientific and local names are presented in Table 3.

Table 3. Major weeds in rice fields of Palakkad district

Location	Local name	Scientific name
Alathur	Polla pullu	*Sacciolepis interrupta*
	Kavada	*Echinochloa* spp.
	Varinellu	*Oryza rufipogon*
	Manjakkora	*Cyperus iria*
	Mangu	*Fimbristylis miliacea*
	Vayalchulli	*Amischophacelus axillaris*
	Neergrambu	*Ludwigia perennis*
Mannarghat	Polla	*Sacciolepis interrupta*
	Kavada	*Echinochloa* spp.
	Muthanga	*Cyperus rotundus*
	Mangu	*Fimbristylis miliacea*
	Pongankala	*Sphenoclea zeylanica*
	Pacha payal	*Chara* spp.
Chittoor	Kavada	*Echinochloa* spp
	Kuthiravalli	*Leptochloa chinensis*
	Mangu	*Fimbristylis miliacea*
	Manjakora	*Cyperus iria*
	Neergrambu	*Ludwigia perennis*
	Nagapolla	*Limnocharis flava*
Ottappalam	Kavada	*Echinochloa* spp.
	Polla pullu	*Sacciolepis interrupta*
	Muthanga	*Cyperus rotundus*
	Manjakora	*Cyperus iria*
	Neergrambu	*Ludwigia perennis*
Palakkad	Kavada	*Echinochloa* spp.
	Polla pullu	*Sacciolepis interrupta*
	Muthanga	*Cyperus rotundus*
	Manjakora	*Cyperus iria*
	Mangu	*Fimbristylis miliacea*
	Neergrambu	*Ludwigia perennis*

Pre- planting weed control practices

Summer plouging is the major pre-planting weed control practice in the district. Although, the main aim of burning is not weed control, it is practiced by a sizeable number of farmers. A few farmers also sow cowpea or daincha as a green manure, which is also a weed control method. However, the number of farmers raising daincha or cowpea before rice crop is less (Table 4).

Table 4. Major pre- planting weed control practices

	Alathur	Mannarghat	Chittoor	Ottappalam	Palakkad
Summer ploughing	25*	26	20	25	28
Burning	10	12	2	13	15
Stale seed bed (plough)	0	0	0	0	0
Stale seed bed (Flooding)	0	0	0	0	0
Growing Cowpea or daincha	2	5	8	3	5
Herbicide	1	0	2	0	0

*No. of farmers (out of 30)

Major post planting weed control practices

Among the various post planting weed control practices, physical methods (hand pulling) was the major one. Hand weeding was practiced by all the rice farmers of the district (Table 5). Chemical weed control using herbicides was the next major one. Only three farmers from Chittoor followed mechanical methods using cono weeder.

Table 5. Major post planting weed control operations

	Alathur	Mannarghat	Chittoor	Ottappalam	Palakkad
Cultural methods	2*	1	5	1	1
Physical methods (hand pulling)	30	30	27	30	30
Mechanical methods	0	0	3	0	0
Chemical methods	25	20	23	20	22

*No. of farmers (out of 30)

Table 6. Major herbicides used by the farmers with their time of application and average dose

Location	**Name**	**Average dose/acre**	**Time of application**	**No. of farmers (out of 30)**
Alathur	Rifit Fernoxone Almix	1L 400-500g 4g	0-5DAS 20-25 DAS/DAT 20-23 DAS/DAT	20 10 5
Mannarghat	Fernoxone Rifit	500g 1.5L	20-30 DAS/DAT 0-4 DAS	25 5
Chittoor	Rifit Fernoxone Butachlor	1L 500g 500ml	0-5DAS 20-25 DAS/DAT 3-10 DAS	12 5 10
Ottappalam	Rifit Fernoxone Almix	1L 400-500g 4g	0-5DAS 20-30DAS/DAT 18-20 DAS/DAT	20 10 4
Palakkad	Rifit Fernoxone Butachlor	1L 500g 500ml	0-5DAS 20-25 DAS/DAT 3-10 DAS	12 15 15

Herbicide use

Rifit (Pretilachlor), Butachlor (Butachlor), Fernoxone (2,4-D) and Almix (Chlorimuron ethyl 10% + Metsulfuron methyl 10%) were the major herbicides used by the farmers of Palakkad district. Average dosage, time of application and number of farmers using these chemicals are presented in Table 6.

Details of hand weeding

Labour requirement for weeding one acre of paddy is presented in Table 7. In general, Virippu season consumes more labourers for weeding. In general, 20-25 labourers are required for hand weeding one acre of rice in Virippu season and 15-20 labourers in Mundakan season. The labour usage for weeding is the lowest in Chittoor thaluk, mainly because of transplanting during both the seasons. .

Table 7. Number of labourers utilized for weeding one acre of rice

Location	Virippu		Mundakan	
	I[st] weeding	II[nd] weeding	I[s]t weeding	II[nd] weeding
Alathur	10	12	10	10
Mannarghat	15	10	10	5
Chittoor	2	2	2	1
Ottappalam	15	10	10	8
Palakkad	12	10	10	5

4.1.2. Thrissur *Kole* lands

Survey area of *Kole* lands included upper (Adat and Puzhakkal) and lower (Alappad and Manakkody) *Koles*. The existing cropping system of lower K*ole* is water fallow – water fallow- rice (late Mundakan) and upper *Kole* is water fallow – rice – fallow.

Method of crop establishment

Wet seeding is the major crop establishment method followed by farmers of *Kole* lands. Out of 30 farmers surveyed, 25 farmers of upper *Kole* and 20 farmers of lower K*ole* adopted wet seeding (Table 8).

Table 8. Method of crop establishment in *Kole* lands of Thrissur district

Location	Dry seeding	Wet seeding	Transplanting
Upper K*ole*	0	25	5
Lower K*ole*	0	20	10

*No. of farmers (out of 30)

Major weeds of the region

Dominant weeds in rice with their scientific and local names are given in Table 9.

Pre- planting weed control practices

Out of 30 farmers surveyed, 15 farmers of upper K*ole* and 12 farmers of lower *Kole* practiced summer ploughing. Burning the field during summer was adopted by five farmers of upper *Kole*. Stale seed bed (flooding) is in practice at lower *Kole* (Table 10).

Major post planting weed control practices

Most farmers of *Kole* land region apply herbicides for the control of weeds. Hand pulling is the next major weed control option of the farmers (Table 11).

Herbicide use

Clincher (Cyhalofop butyl), Almix (Chlorimuron ethyl 10% + Metsulfuron methyl 10%) and fernoxone (2,4-D) were the major herbicides used by the farmers of *Kole* lands. Average dosage, time of application and number of farmers using these chemicals are presented in Table 12.

Table 9. Major weeds in rice fields of *Kole lands*

Location	**Local name**	**Scientific name**
	Kavada	*Echinochloa* spp.
	Varinellu	*Oryza rufipogon*
	Muthanga	*Cyperus* spp.
	Mangu	*Fimbristylis miliacea*
	Neergrambu	*Ludwigia perennis*
Lower *Kole*	Pongankala	*Sphenoclea zeylanica*
	Kulavazha	*Eiichornia crassipes*
	African payal	*Salvinia molesta*
	Karimkoovalam	*Monochoria vaginalis*
	Neyyambal	*Nymphaea nouchali*
	Kakkapoovu	*Lindernia crustacea*
	Kavada	*Echinochloa* spp.
	Varinellu	*Oryza rufipogon*
	Naringa	*Isachne miliacea*
	Muthanga	*Cyperus rotundus*
	Mangu	*Fimbristylis miliacea*
	Karimkoovalam	*Monochoria vaginalis*
	Vazhapadathi	*Commelina benghalensis*
Upper *Kole*	Nagapola	*Limnocharis flava*
	Pongankala	*Sphenoclea zeylanica*
	Neergrambu	*Ludwigia perennis*
	Randila kala	*Sphenoclea zeylanica*
	Padarppan kala	*Lindernia crustacea*
	African payal 50	*Salvinia molesta*
	Nalilakodiyan	*Marsilia quadrifoliata*

Table 10. Major pre-planting weed control practices in *Kole* lands

	Upper *Kole*	Lower *Kole*
Summer ploughing	15*	12
Burning	5	0
Stale seed bed (plough)	0	0
Stale seed bed (Flooding)	0	5
Growing cowpea or daincha	2	0
Herbicide	5	5

*No. of farmers (out of 30)

Table 11. Major post planting weed control operations in *Kole* lands

	Upper *Kole*	Lower *Kole*
Cultural methods	2*	0
Physical methods (hand pulling)	15	18
Mechanical methods	0	0
Chemical methods	25	28

*No. of farmers (out of 30)

Table 12. Major herbicides used by the farmers of *Kole* lands with their time of application and average dosage

	Name	Average dose/acre	Time of application	No. of farmers (out of 30)
Upper *Kole*	Clincher	500ml	15-18 DAS	25
	Almix	8g	18-20 DAS	18
	Fernoxone	750g	25-28 DAS	10
Lower *Kole*	Clincher	600ml	15-20 DAS	28
	Almix	8g	20 DAS	20
	Fernoxone	1kg	25-30 DAS	8

Details of hand weeding

On an average, 15 female labourers are required for first weeding one acre of rice in upper *Kole* and 12 labourers in lower *Kole* (Table 13).

Table 13. Number of labourers involved in weeding one acre of rice in *Kole* lands

Average number of labourers per acre		
	I^{st} weeding	II^{nd} weeding
Upper *Kole*	15	2
Lower *Kole*	12	2

4.1.3. Pokkali lands

Study area included Pokkali rice growing tracts in Ernakulam district. The existing cropping system is rice flowed by prawn culture.

Method of crop establishment

In situ sowing of seeds in the mounds followed by dismantling of seedlings is the system of crop establishment in Pokkali region. For preparing *in situ* nurseries mounds of 1 m base and 0.5 m height are formed. This facilitates the washing down of the dissolved salts from the surface of the mounds, which were ultimately removed from the field by tidal action. When the soil and weather conditions become favourable for sowing, the mounds in the field are raked and top levelled. The sprouted seeds are sown on top of the mounds, which act as an *in situ* nursery. When the seedlings reach a height of 40-45 cm (30-35 days), the mounds are cut into pieces with a few seedlings, which are uniformly spread in the field.

Major weeds of the region

Dominant weeds in rice fields with their scientific and local names are provided in Table 14.

Table 14. Major rice weeds of *Pokkali* region

Local name	Scientific name
Kamanda	*Echinochloa* spp.
Kuthiravalli	*Diplachne fusca*
Manjapullu	*Cyperus* spp.

Pre- planting weed control methods

None of the farmers of *Pokkali* rice tract adopts pre planting weed control measures since the field is under prawn cultivation during the previous season.

Post planting weed control practices

The only weed control method in the *Pokkali* rice region is hand weeding.

Details of hand weeding

On an average 15 female labourers were utilized for weeding one acre.

4.1.4. Kuttanad

Both upper and lower *Kuttanad* region were covered under this study. The major cropping system of lower *Kuttanad* is rice – fallow - fallow and upper *Kuttanad* is fallow – rice – fallow.

Method of crop establishment

Wet seeding is the major crop establishment method followed by farmers of lower and upper *Kuttanad* region. A few farmers also practiced transplanting (Table 15).

Major weeds of the region

Dominant weeds in rice fields with their scientific and local names are given in Table16.

Table 15. Method of crop establishment in *Kuttanad* region

Location	Dry seeding	Wet seeding	Transplanting
Upper *Kuttanad*	0	26	4
Lower *Kuttanad*	0	28	2

*No. of farmers (out of 30)

Pre- planting weed control practices

Most of the farmers of both lower and upper *Kuttanad* region practice summer ploughing. Field burning is also an important pre planting operation here. All the farmers adopt stale seed bed (Flooding) as a weed control measure. (Table17).

Major post planting weed control practices

Majority of farmers of *Kuttanad* region apply herbicides for the control of weeds. Hand pulling is the next major weed control option of the farmers (Table18).

Table16. Major weeds of *Kuttanad*

Location	**Local name**	**Scientific name**
Lower *Kuttanad*	Kavada	*Echinochloa* spp.
	Varinellu	*Oryza rufipogon*
	Manjakala	*Cyperus iria*
	Mangu	*Fimbristylis miliacea*
	Kulavazha	*Eichornia crassipes*
	African payal	*Salvinia molesta*

Upper *Kuttanad*	Kavada	*Echinochloa spp.*
	Varinellu	*Oryza rufipogon*
	Muthanga	*Cyperus rotundus*
	Chekka	*Cyperus spp.*
	Kuda	*Eleiocolon hispidon*
	African payal	*Salvinia molesta*
	Kulavazha	*Eichornia crassipes*

Table17. Major pre-planting weed control practices

	Upper *Kuttanad*	Lower *Kuttanad*
Summer ploughing	28	30
Burning	24	25
Stale seed bed (plough)	0	0
Stale seed bed (Flooding)	30	30
Growing Cowpea or daincha	10	2
Herbicide	5	3

*No. of farmers (out of 30)

Table18. Major post planting weed control operations in *Kuttanad*

	Upper *Kuttanad*	Lower *Kuttanad*
Cultural methods	0*	0
Physical methods (hand pulling)	15	19
Mechanical methods	0	0
Chemical methods	28	25

*No. of farmers (out of 30)

Herbicide use

Clincher (Cyhalofop butyl) and Fernoxone (2,4-D) were the major herbicides used by the farmers of *Kuttanad* region. Average dosage, time of application and number of farmers using these chemicals are presented in Table19.

Table19. Major herbicides used by the farmers with their time of application and average dose

	Name	Average dose/acre	Time of application	No. of farmers (out of 30)
Upper *Kuttanad*	Clincher Fernoxone	500ml 500g	20 DAS 18-20 DAS	25 10
Lower *Kuttanad*	Clincher Fernoxone	500ml 1kg	15-20 DAS 20-25 DAS	28 8

Details of hand weeding

In upper *Kuttanad*, six labourers are needed for first weeding and 10 labourers for second weeding. However, in lower *kuttanad* the labourers needed for weeding one acre of paddy field is five and eight respectively for first and second weeding (Table20).

Table 20. Number of labourers engaged in weeding one acre of rice in *Kuttanad*

Average number of labourers per acre		
	Ist weeding	IInd weeding
Upper *Kuttanad*	6	10
Lower *Kuttanad*	5	8

4.2. Stale seed bed techniques suited for dry seeded rice

4.2.1. Studies on weeds

Weed population

Weeds observed in the experimental field were mainly those found in uplands. Grasses were predominant and the major ones were *Echinochloa colona*, *Digitaria ciliaris*, *Cynodon dactylon*, *Eleusine indica*, *Panicum repens* and *Dactyloctenium aegyptium*. Predominant broad leaf weeds were *Celosia argentia*, *Alternanthera sessilis*, *Commelina benghalensis* and *Aeschynomene indica*. *Cyperus rotundus* and *Cyperus difformis* were the major sedges.

Total population of weeds

Influence of seed bed preparation on germination and further growth of weeds at 20 DAS during 2006 and 2007 is presented in Table 21. The data on total population of weeds clearly indicates that the stale seed bed technique was superior in reducing the population of weeds in semi dry rice culture upto 20 DAS over normal seed bed. Among the stale seed bed plots, stale seed bed for 14 days with two hoeings was superior.

Except for pretilachlor sprayed and cowpea grown plots, significant variation with respect to total weed count was not observed among sub plot treatments at this stage. Spraying of pretilachlor in plots with stale seed bed for 14 days (two hoeings) was the best treatment, which gave significant reduction in the population of weeds. Pre emergence spraying of pretilachlor in stale seed bed for 14 days (one hoeing) or concurrent growing of cowpea in stale seed bed for 14 days (two hoeing) plots were equally effective.

Total population of weeds at 40 DAS was found to be the lowest in stale seed bed for 14 days with two hoeings (Table 22). During 2006, stale seed bed for 14 days with one hoeing and stale seed bed for 7 days were at par. Whereas in 2007, stale seed bed for 14 days with one hoeing was significantly superior to stale seed bed for 7 days. Among sub plot treatments, concurrent growing of cowpea significantly lowered the total weed count. Unweeded plots recorded the highest weed population. Combination of cowpea with all four main plot treatments significantly lowered the weed growth during both years. Total population of weeds was the highest in unweeded plots of normal seed bed followed by that in stale seed bed for 7 days.

At harvest, total population of weeds was lower in stale seed bed for 14 days with two hoeings in 2006. This treatment was on a par with stale seed bed for 14 days with one hoeing. Weed population was the highest in normal seed bed (Table 23). During 2006, significant reduction in the population was noticed in cowpea grown plots, closely followed by pretilachlor + hand weeding, but the latter showed superiority during 2007.

Stale seed bed plots with pre - emergence spraying of pretilachlor followed by hand weeding recorded significantly lower population of weeds at harvest stage of 2006. During 2007 *in situ* green manuring in stale seed bed for 14 days with two hoeing showed lower counts and was on a par *with* pretilachlor + hand weeding in stale seed bed for 7 days and stale seed bed for 14 days (two hoeings).

Population of grass weeds

The data on the number of grasses at 20 DAS during 2006 and 2007 are presented in Table 24. During both years, the population of grasses was the lowest in stale seed bed for 14 days with two hoeings on 7th and 14th day. Stale seed bed for 14 days with one hoeing was the next best treatment in increasing the population of grasses than normal seed beds.

Table 21. Effect of treatments on total population of weeds at 20 DAS (Number m^{-2})

Main plot / Sub plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	23.26^{*a} (540.53)	20.95^{a} (438.67)	15.19^{cd} (230.24)	13.16^{b} (173.33)	9.77^{ghi} (94.95)	6.63^{ef} (44.00)	14.41^{cd} (207.15)	9.53^{c} (90.67)	15.66^{a} (244.74)	12.57^{a} (186.67)
HW(20 and 40)	20.62^{b} (424.68)	20.99^{a} (442.67)	13.71^{cde} (187.46)	13.85^{b} (192.00)	9.17^{hi} (83.59)	7.23^{ef} (52.00)	13.53^{de} (182.56)	9.55^{c} (90.67)	14.26^{b} (202.85)	12.91^{a} (194.33)
Pretilachor + HW	10.34^{ghi} (106.42)	7.49^{def} (56.00)	8.19^{ij} (66.58)	6.73^{ef} (45.33)	3.60^{l} (12.46)	3.33^{h} (10.67)	5.69^{k} (31.88)	5.73^{fg} (33.33)	6.96^{d} (47.94)	5.82^{b} (36.33)
CW(20)+HW (40)	20.86^{b} (434.64)	21.45^{a} (460.00)	13.22^{def} (174.27)	13.23^{b} (174.67)	11.72^{efg} (136.86)	7.73^{de} (60.00)	11.95^{efg} (142.30)	10.60^{c} (112.00)	14.44^{b} (208.01)	13.25^{a} (201.67)
CW(20 and 40)	21.33^{ab} (454.47)	21.21^{a} (452.00)	15.40^{cd} (236.66)	13.26^{b} (176.00)	9.36^{hi} (87.11)	6.91^{ef} (48.00)	13.42^{de} (179.60)	9.73^{c} (94.67)	14.88^{ab} (220.91)	12.78^{a} (192.67)
Cowpea	15.85^{c} (250.72)	9.12^{cd} (82.67)	11.87^{efg} (140.40)	6.32^{ef} (40.00)	6.45^{jk} (41.10)	4.51^{gh} (20.00)	11.09^{fgh} (122.49)	5.91^{efg} (34.67)	11.32^{c} (127.64)	6.47^{b} (44.33)
Main plot mean	18.71^{a} (349.56)	16.87^{a} (322.00)	12.93^{b} (166.68)	11.09^{b} (133.56)	8.35^{d} (69.22)	6.06^{d} (39.11)	11.68^{c} (135.92)	8.51^{c} (76.00)		

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

Table 22. Effect of treatments on total population of weeds at 40 DAS (Number m^{-2})

Sub plot \ Main plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	20.69^{*a} (427.58)	22.67^{a} (513.33)	14.66^{b} (214.42)	16.65^{b} (277.33)	11.85^{cde} (139.92)	10.96^{cde} (120.00)	12.81^{c} (163.60)	11.04^{cde} (121.33)	15.00^{a} (224.50)	15.33^{a} (258.00)
HW(20 and 40)	11.09^{def} (122.49)	9.78^{defgh} (96.00)	10.64^{efg} (112.71)	7.92^{i} (62.67)	8.64^{ij} (74.15)	8.35^{hi} (69.33)	9.22^{hij} (84.51)	9.03^{fghi} (81.33)	9.90^{c} (97.51)	8.77^{c} (77.33)
Pretilachor + HW	6.27^{k} (38.81)	11.96^{c} (144.00)	8.62^{ij} (73.80)	11.68^{c} (138.67)	8.80^{ij} (76.94)	6.05^{jk} (37.33)	9.67^{ghi} (93.01)	8.96^{ghi} (81.00)	8.34^{d} (69.06)	9.66^{b} (100.33)
CW(20)+HW (40)	11.79^{cde} (138.50)	11.26^{cd} (126.67)	11.01^{defg} (120.72)	10.35^{cdefg} (106.67)	7.94^{j} (62.54)	7.65^{ij} (58.67)	10.15^{fgh} (102.52)	9.19^{efghi} (84.00)	10.22^{bc} (103.95)	9.61^{b} (94.00)
CW(20 and 40)	12.34^{cd} (151.78)	10.86^{cdef} (118.67)	10.54^{efgh} (110.59)	10.39^{cdefg} (108.00)	8.57^{ij} (72.94)	8.89^{ghi} (78.67)	11.18^{def} (124.49)	10.27^{cdefg} (105.33)	10.66^{b} (113.14)	10.10^{b} (102.67)
Cowpea	4.76^{l} (22.61)	5.78^{kl} (33.33)	4.24^{l} (17.48)	4.22^{lm} (17.33)	4.22^{l} (17.31)	3.51^{m} (12.00)	4.92^{l} (23.71)	4.37^{klm} (18.67)	4.53^{e} (20.02)	4.47^{d} (20.33)
Main plot mean	11.16^{a} (124.05)	12.05^{a} (172.00)	9.95^{b} (98.50)	10.20^{b} (118.44)	8.34^{c} (69.06)	7.57^{d} (62.67)	9.66^{b} (92.82)	8.81^{c} (82.00)		

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

Table 23. Effect of treatments on total population of weeds at harvest (Number m^{-2})

Main plot / Sub plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	19.70*[a] (387.59)	16.63[a] (276.00)	14.83[b] (219.43)	12.39[b] (153.33)	10.67[c] (113.35)	7.15[d] (50.67)	11.57[c] (133.36)	9.82[c] (97.33)	14.19[a] (200.86)	11.50[a] (144.33)
HW(20 and 40)	7.04[fg] (49.06)	5.93[defg] (34.67)	6.51[fgh] (41.88)	5.03[fgh] (25.33)	5.31[hij] (27.70)	5.30[efgh] (28.00)	5.28[hij] (27.38)	6.00[defg] (36.00)	6.04[cd] (35.98)	5.57[c] (31.00)
Pretilachor + HW	7.75[def] (59.56)	4.51[gh] (20.00)	5.19[hij] (26.44)	3.93[h] (16.00)	4.94[hij] (23.90)	4.06[h] (16.00)	4.04[j] (15.82)	4.43[gh] (20.00)	5.48[de] (29.53)	4.24[c] (18.00)
CW(20)+HW (40)	7.03[fg] (48.92)	5.28[efgh] (28.00)	7.50[ef] (55.75)	5.55[defgh] (30.67)	5.80[ghi] (33.14)	5.15[efgh] (26.67)	5.41[hij] (28.77)	.95[defg] (36.00)	6.44[c] (40.97)	5.48[c] (30.33)
CW(20 and 40)	9.10[d] (82.31)	6.75[de] (45.33)	8.80[de] (76.94)	6.74[de] (45.33)	8.09[def] (64.95)	6.02[defg] (36.00)	9.10[d] (82.31)	6.76[de] (45.33)	8.77[b] (76.41)	6.57[b] (43.00)
Cowpea	5.89[ghi] (34.19)	6.29[def] (40.00)	4.37[ij] (18.60)	5.17[efgh] (26.67)	4.76[ij] (22.16)	3.89[h] (14.67)	5.41[hij] (28.77)	4.80[fgh] (22.67)	5.11[e] (25.61)	5.04[c] (26.00)
Main plot mean	9.42[a] (88.24)	7.56[a] (74.00)	7.87[b] (61.44)	6.47[b] (49.56)	6.60[c] (43.06)	5.26[c] (28.67)	6.80[c] (45.74)	6.29[b] (42.89)		

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

Table 24. Effect of treatments on population of grasses at 20 DAS (Number m^{-2})

Sub plot \ Main plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeing		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	16.61*[a] (275.39)	15.85* (250.67)	7.83* (60.81)	7.85* (61.33)	4.88*[i] (23.31)	4.78*[gh] (22.67)	6.22*[efg] (38.19)	6.56*[de] (42.67)	8.89* (78.53)	8.76* (94.33)
HW(20 and 40)	16.09[a] (258.39)	15.95[a] (254.67)	6.94[defg] (47.66)	7.70[bc] (60.00)	5.15[hi] (26.02)	5.45[efg] (29.33)	7.08[cdef] (49.63)	6.64[bcde] (44.00)	8.82[a] (77.29)	8.93[a] (97.00)
Pretilachor + HW	5.42g[hi] (28.88)	4.51[gh] (20.00)	4.80[hi] (22.54)	3.66[hij] (13.33)	0.71[k] (0)	2.12[k] (4.00)	2.92[j] (8.03)	2.65[jk] (6.67)	3.46[c] (11.47)	3.24[c] (11.00)
CW(20)+HW (40)	16.66[a] (277.06)	15.89[a] (252.00)	7.51[cde] (55.90)	6.56[cde] (42.67)	5.98[efgh] (35.26)	4.88[fgh] (24.00)	6.83[cdefg] (46.15)	6.73[bcde] (45.33)	9.25[a] (85.06)	8.51[a] (91.00)
CW(20 and 40)	16.66[a] (277.06)	16.25[a] (264.00)	7.95[c] (62.70)	7.47[bcd] (56.00)	4.73[hi] (21.87)	4.04[hi] (16.00)	7.66[cd] (58.18)	5.92[ef] (34.67)	9.25[a] (85.06)	8.42[a] (92.67)
Cowpea	10.66[b] (113.14)	6.36[de] (40.00)	7.03[cdef] (48.92)	4.04[hi] (16.00)	4.20[ij] (17.14)	2.92[ijk] (8.00)	5.69[fghi] (31.88)	3.66[hij] (13.33)	6.90[b] (36.34)	4.25[c] (19.33)
Main plot mean	13.69[a] (186.92)	12.47[a] (180.22)	7.01[b] (48.64)	6.22[b] (41.56)	4.28[c] (17.82)	4.03[d] (17.33)	6.07[d] (36.34)	5.36[c] (31.11)		

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

Table 25. Effect of treatments on population of grasses at 40 DAS (Number m^{-2})

Sub plot \ Main plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	16.87*[a] (284.10)	18.04[a] (325.33)	10.75[b] (115.06)	11.34[b] (129.33)	7.70[cd] (58.79)	7.36[cd] (54.67)	8.53[c] (72.26)	7.67[c] (58.67)	10.96[a] (119.62)	11.10[a] (142.00)
HW(20 and 40)	6.34[def] (39.70)	6.23[cdef] (38.67)	6.34[def] (39.70)	5.53[defg] (30.67)	5.37[efgh] (28.34)	4.11[gh] (17.33)	6.34[def] (39.70)	5.44[defg] (29.33)	6.10[b] (36.71)	5.33[c] (29.00)
Pretilachor + HW	2.92[j] (8.03)	7.23[cd] (52.00)	3.51[ij] (11.82)	7.03[cd] (49.33)	6.03[efg] (35.86)	3.19[h] (10.67)	5.53[efgh] (30.08)	4.88[efgh] (24.00)	4.50[c] (19.75)	5.58[c] (34.00)
CW(20)+HW (40)	7.75[cd] (59.56)	7.08[cd] (50.67)	6.75[de] (45.06)	6.36[cde] (40.00)	4.90[fghi] (23.51)	4.12[gh] (18.67)	6.66[de] (43.86)	5.68[cde] (32.00)	6.52[b] (42.01)	5.81[bc] (35.33)
CW(20 and 40)	7.78[cd] (60.03)	7.55[c] (57.33)	6.61[de] (43.19)	6.61[cde] (44.00)	5.92[efg] (34.55)	5.89[cdefg] (34.67)	6.66[de] (43.86)	6.51[cde] (42.67)	6.74[b] (44.93)	6.64[b] (44.67)
Cowpea	4.76[ghi] (22.16)	5.78[cdefg] (33.33)	4.23[hij] (17.39)	4.22[gh] (17.33)	4.23[hij] (34.55)	3.51[h] (12.00)	4.92[fghi] (23.71)	4.37[fgh] (18.67)	4.53[c] (20.02)	4.47[d] (20.33)
Main plot mean	7.74[a] (59.41)	8.65[a] (92.89)	6.36[b] (39.95)	6.85[b] (51.78)	5.69[c] (31.88)	4.69[d] (24.67)	6.44[b] (40.97)	5.76[c] (34.22)		

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

Significant reduction in the population of grass weeds was obtained by the pre emergence spraying of pretilachlor during both years. Concurrent growing of cowpea with rice also reduced the population of grasses. Other sub plot treatments without any weed control measures till 20 DAS did not show any significant variation. Normal seed bed with all sub plot treatments produced higher population of grasses at this stage of observation compared to stale seed bed plots.

At 40 DAS, normal seed bed and stale seed bed for 14 days with two hoeings recorded the highest and lowest population of grasses respectively (Table 25). During 2006, stale seed bed for 14 days with one hoeing and stale seed bed for 7 days were at par, while in 2007, the former was superior.

Concurrent growing of cowpea recorded the least grass population at 40 DAS during 2006 and was on a par with pre - emergence spraying of pretilachlor. During 2007 also concurrent growing of cowpea was found to be the best treatment with the lowest population. During both years, unweeded plots showed the highest population. pretilachlor in combination with normal seed bed resulted in significant reduction in the grass population during 2006. This treatment was on a par with pretilachlor in 7 days stale seed bed, cowpea in stale seed bed either for 14 days (two hoeing) or 7 days. However, during 2007, pretilachlor in combination with stale seed bed for 14 days with two hoeing was on a par with cowpea under the same main plot treatment.

Influence of stale seed bed in decreasing the population of grasses continued up to harvest stage also (Table 26). Stale seed bed plots showed significantly lower population of grasses than normal seed bed. Pre emergence spraying of pretilachlor followed by hand weeding at 40 DAS was the best sub plot treatment, which reduced the grass population at harvest stage.

Table 26. Effect of treatments on population of grasses at harvest (Number m^{-2})

Main plot / Sub plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeing		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	16.13^{*a} (259.68)	12.93^{a} (166.67)	11.27^{b} (126.51)	10.66^{b} (113.33)	7.60^{cd} (57.26)	5.53^{def} (30.67)	8.42^{c} (70.40)	7.87^{c} (62.67)	10.86^{a} (117.44)	9.25^{a} (93.33)
HW(20 and 40)	5.15^{hijk} (26.02)	3.68^{ghi} (13.33)	4.22^{jkl} (17.31)	3.66^{ghi} (13.33)	3.71^{lmn} (13.26)	3.13^{hi} (9.33)	4.04^{klm} (15.82)	4.26^{efgh} (18.67)	4.28^{de} (17.82)	3.68^{c} (13.67)
Pretilachor + HW	5.79^{fgh} (33.02)	2.92^{hi} (8.00)	3.84^{lmn} (14.25)	2.45^{i} (8.00)	2.92^{mn} (8.03)	2.92^{hi} (8.00)	2.86^{n} (7.68)	2.86^{hi} (8.00)	3.85^{e} (14.32)	2.79^{d} (8.00)
CW(20)+HW (40)	5.25^{hij} (27.06)	4.43^{efgh} (20.00)	5.06^{hijk} (25.10)	3.13^{hi} (9.33)	4.04^{klm} (15.82)	3.66^{ghi} (13.33)	4.04^{klm} (15.82)	4.13^{efghi} (17.33)	4.60^{cd} (20.66)	3.84^{c} (15.00)
CW(20 and 40)	7.33^{de} (53.23)	6.14^{d} (37.33)	6.45^{efg} (41.10)	5.02^{defg} (25.33)	5.55^{gh} (30.30)	4.53^{defgh} (20.00)	6.83^{def} (46.15)	5.06^{defg} (25.33)	6.54^{b} (42.27)	5.19^{b} (27.00)
Cowpea	5.31^{hij} (27.70)	5.64^{de} (32.00)	4.37^{ijkl} (18.60)	5.17^{defg} (26.67)	4.76^{hijkl} (22.16)	3.89^{fghi} (14.67)	5.41^{ghi} (28.77)	4.53^{defgh} (20.00)	4.96^{c} (24.10)	4.81^{b} (23.33)
Main plot mean	7.50^{a} (55.75)	5.96^{a} (46.22)	5.87^{b} (33.96)	5.02^{b} (32.67)	4.77^{c} (22.25)	3.94^{c} (16.00)	5.27^{bc} (27.27)	4.79^{b} (25.33)		

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

Table 27. Effect of treatments on population of sedges at 20 DAS (Number m^{-2})

Main plot / Sub plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	5.19^{*def} (26.44)	4.76^{bc} (22.67)	5.80^{cde} (33.14)	4.50^{bc} (21.33)	6.09^{bcd} (36.59)	2.65^{def} (6.67)	7.48^{a} (55.45)	2.92^{def} (8.00)	6.44^{a} (40.97)	3.71^{a} (14.67)
HW(20 and 40)	3.13^{i} (9.30)	5.33^{ab} (28.00)	5.95^{bcd} (34.90)	5.31^{ab} (28.00)	5.95^{bcd} (34.90)	2.39^{def} (5.33)	6.64^{abc} (43.59)	2.41^{defg} (5.33)	5.42^{b} (28.88)	3.79^{a} (16.67)
Pretilachor + HW	5.89^{bcde} (34.19)	2.121^{defg} (4.00)	3.33^{hi} (10.59)	2.12^{defg} (4.00)	3.30^{hi} (10.39)	0.71^{g} (0)	3.13^{i} (9.30)	2.12^{defg} (4.00)	3.91^{c} (14.79)	1.77^{c} (3.00)
CW(20)+HW (40)	4.13^{fghi} (16.56)	6.23^{a} (38.67)	4.53^{efgh} (20.02)	3.66^{cd} (13.33)	7.23^{ab} (51.77)	2.65^{def} (6.67)	5.68^{cde} (31.67)	3.33^{cde} (10.67)	5.39^{b} (28.55)	3.97^{a} (17.33)
CW(20 and 40)	4.20^{fghi} (17.14)	3.40^{cde} (12.00)	5.68^{cde} (31.76)	3.66^{cd} (13.33)	5.37^{cdef} (28.34)	2.39^{def} (6.67)	6.03^{bcd} (35.86)	2.59^{def} (6.67)	5.32^{b} (27.80)	3.01^{b} (9.67)
Cowpea	5.62^{cde} (31.08)	0.71^{g} (0)	3.68^{ghi} (13.04)	1.65^{fg} (2.67)	3.13^{i} (9.30)	1.92^{efg} (4.00)	4.76^{defg} (22.16)	1.65^{fg} (2.67)	4.30^{c} (17.99)	1.48^{c} (2.33)
Main plot mean	4.69^{a} (21.50)	3.76^{a} (17.56)	4.83^{a} (22.83)	3.48^{a} (13.78)	5.18^{a} (26.33)	2.12^{b} (4.89)	5.62^{a} (31.08)	2.46^{b} (6.22)		

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

Table 28. Effect of treatments on population of sedges at 40 DAS (Number m^{-2})

Main plot / Sub plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	4.04*^{abcde} (15.82)	4.45^{bcde} (21.33)	4.38^{abcd} (18.68)	6.42^{a} (42.67)	5.56^{a} (30.41)	5.06^{ab} (25.33)	5.42^{a} (28.88)	3.99^{bcdefg} (16.00)	4.85^{a} (23.02)	4.98^{a} (26.33)
HW(20 and 40)	5.15^{ab} (26.02)	2.39^{ghi} (5.33)	5.15^{ab} (26.02)	1.92^{ij} (4.00)	2.86^{de} (7.68)	4.81^{bcd} (22.67)	3.66^{bcde} (12.90)	3.84^{bcdefgh} (14.67)	4.21^{ab} (17.02)	3.24^{b} (11.67)
Pretilachor + HW	2.65^{e} (6.52)	4.4^{bcdefg} (16.00)	2.92^{de} (8.03)	5.17^{ab} (26.67)	3.13^{cde} (9.30)	2.86^{efghi} (8.00)	4.76^{ab} (22.16)	5.03^{abc} (25.33)	3.37^{c} (10.86)	4.28^{a} (19.00)
CW(20)+HW (40)	4.05^{abcde} (15.90)	2.65^{fghi} (6.67)	4.76^{ab} (22.16)	3.33^{defghi} (10.67)	2.86^{de} (7.68)	2.92^{efghi} (8.00)	4.43^{abcd} (19.12)	3.40^{cdefghi} (12.00)	4.03^{bc} (15.74)	3.08^{b} (9.33)
CW(20 and 40)	5.27^{ab} (27.27)	2.92^{efghi} (9.33)	4.61^{abc} (20.75)	4.26^{bcdef} (18.67)	2.65^{e} (6.52)	2.18^{hij} (5.33)	5.42^{a} (28.88)	3.66^{bcdefgh} (13.33)	4.49^{ab} (19.66)	3.26^{b} (11.67)
Cowpea	0.71^{f} (0)	0.71^{j} (0)	0.71^{f} (0)	0.71^{j} (0)	0.71^{f} (0)	0.71^{j} (0)	0.71^{f} (0)	0.71^{j} (0)	0.71^{d} (0)	0.71^{c} (0)
Main plot mean	3.65^{a} (12.82)	2.86^{a} (9.78)	3.76^{a} (13.64)	3.64^{a} (17.11)	2.96^{b} (8.26)	3.09^{a} (11.56)	4.07a (16.06)	3.44^{a} (13.56)		

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

During 2006, stale seed bed for 14 days with one hoeing followed by pre - emergence spraying of pretilachlor and hand weeding reduced the population of grasses. This treatment was on a par with the same sub plot treatment combination with stale seed bed for 14 days with two hoeings, stale seed bed for 14 days with two hoeings followed by hand weeding twice at 20 and 40 DAS and cowpea in normal seed bed. During 2007, stale seed bed for 7 days followed by pretilachlor and hand weeding was the best treatment combination which significantly lowered the population of grasses.

Population of major sedges

During 2006 and 2007, at 20 DAS, seed bed preparation had significant influence on the population of sedges. Normal seed bed and stale seed bed for 7 days with one hoeing recorded maximum number of sedges. Stale seed beds for 14 days (with one or two hoeings) were at par. The lowest population during 2006 was noticed in plots with pre - emergence spraying of pretilachlor, which was closely followed by concurrent growing of cowpea. All other sub plot treatments were at par. However, in 2007 the pretilachlor sprayed and cowpea grown plots were statistically at par (Table 27).

Normal seed bed with no weeding facilitated the maximum build up of sedges. Pre mergence spraying of pretilachlor in stale seed bed for 14 days (two hoeings) showed the lowest count of sedges during 2006. Complete control of sedges up to 20 DAS was obtained with concurrent growing of cowpea in normal seed bed and by spraying pretilachlor in stale seed bed for 14 days.

Population of sedges at 40 DAS during 2006 and 2007 is presented in Table 28. Stale seed bed for 14 days with two hoeings was the only treatment which showed significantly lower counts of sedges at this stage during 2006. No significant variation could be observed among main plot treatments during 2007. Concurrent growing and *in situ* green manuring of cowpea at 30 DAS gave complete control of

Table 29. Effect of treatments on population of broad leaf weeds at 20 DAS (Number m^{-2})

Sub plot \ Main plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	15.46*[a] (238.51)	12.86[a] (165.33)	11.66[cd] (135.46)	9.54[b] (90.67)	5.92[ghi] (34.55)	3.84[fgh] (14.67)	10.54[cd] (110.59)	6.34[cde] (40.00)	10.90[a] (118.31)	8.14[b] (77.67)
HW(20 and 40)	12.48[b] (155.25)	12.58[a] (160.00)	10.11[cde] (101.71)	10.22[b] (104.00)	4.60[hi] (20.66)	4.13[fgh] (17.33)	9.40[de] (87.86)	6.45[cde] (41.33)	9.15[b] (83.22)	8.35[ab] (80.67)
Pretilachor + HW	6.56[ghi] (42.53)	5.59[def] (32.00)	5.80[ij] (33.14)	5.31[ef] (28.00)	1.45[l] (1.60)	2.65[h] (6.67)	3.87[k] (14.48)	4.70[efg] (22.67)	4.42[d] (19.04)	4.57[c] (22.33)
CW(20)+HW (40)	11.85[b] (139.92)	13.01[a] (169.33)	9.93[def] (98.10)	10.91[b] (118.67)	6.99[efg] (48.36)	5.42[ef] (29.33)	8.04[efg] (64.14)	7.48[c] (56.00)	9.20[b] (84.14)	9.21[a] (93.33)
CW(20 and 40)	12.64[ab] (159.27)	13.20[a] (176.00)	11.93[cd] (141.82)	10.28[b] (106.67)	6.09[hi] (36.59)	5.06[ef] (25.33)	9.25[de] (85.06)	7.31[cd] (53.33)	9.98[ab] (99.10)	8.95[ab] (90.33)
Cowpea	10.20[c] (103.54)	6.56[cde] (42.67)	8.77[efg] (76.41)	4.64[efg] (21.33)	3.89[jk] (14.63)	2.86[gh] (8.00)	8.24[fgh] (67.40)	4.37[fgh] (18.67)	7.77[c] (59.87)	4.61[c] (22.67)
Main plot mean	11.53[a] (132.44)	10.63[a] (124.22)	9.70[b] (93.59)	8.48[b] (78.22)	4.82[c] (22.73)	3.99[d] (16.89)	8.22[d] (67.07)	6.11[c] (38.67)		

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

Table 30. Effect of treatments on population of broad leaf weeds at 40 DAS (Number m^{-2})

Sub plot \ Main plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	11.22^{*a} (125.39)	12.93^{a} (166.67)	8.90^{b} (78.71)	10.07^{b} (105.33)	7.03^{cdefg} (48.92)	6.34^{efgh} (40.00)	7.83^{bcd} (60.81)	6.83^{cdefgh} (46.67)	8.75^{a} (76.06)	9.04^{a} (89.67)
HW(20 and 40)	7.52^{bcde} (56.05)	7.17^{cdefgh} (52.00)	6.86^{cdefg} (46.56)	5.30^{hi} (28.00)	6.09^{efgh} (36.59)	5.45^{ghi} (29.33)	5.67^{fgh} (31.65)	6.14^{efghi} (37.33)	6.53^{bc} (42.14)	6.02^{c} (36.67)
Pretilachor + HW	4.91^{h} (23.61)	8.65^{bc} (76.00)	7.37^{bcde} (53.82)	7.78^{cde} (62.67)	5.67^{fgh} (31.65)	4.34^{i} (18.67)	6.36^{defgh} (39.95)	5.64^{fghi} (32.00)	6.08^{c} (36.47)	6.60^{bc} (47.33)
CW(20)+HW (40)	7.83^{bcd} (60.81)	8.35^{cd} (69.33)	7.28^{cdef} (52.50)	7.51^{cdef} (56.00)	5.53^{gh} (30.08)	5.70^{fghi} (32.00)	6.22^{defgh} (38.19)	6.34^{efgh} (40.00)	6.71^{bc} (44.52)	6.97^{b} (49.33)
CW(20 and 40)	8.02^{bc} (63.82)	7.23^{cdefg} (52.00)	6.73^{cdefg} (44.79)	6.73^{defgh} (45.33)	5.67^{fgh} (31.65)	6.25^{efgh} (38.67)	7.20^{cdef} (51.34)	7.03^{efgh} (49.33)	6.91^{b} (47.25)	6.81^{bc} (46.33)
Cowpea	0.71^{i} (0)	0.71^{j} (0)	0.71^{i} (0)	0.71^{j} (0)	0.71^{i} (0)	0.71^{j} (0)	0.71^{i} (0)	0.71^{j} (0)	0.71^{d} (0)	0.71^{d} (0)
Main plot mean	6.70^{a} (44.39)	7.51^{a} (69.33)	6.31^{ab} (39.32)	6.35^{b} (49.56)	5.12^{c} (25.71)	4.80^{d} (26.44)	5.67^{b} (31.65)	5.45^{c} (34.22)		

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

sedges. Combination of this sub plot treatment with all four main plots was equally effective in managing the menace of sedges in semi dry rice culture. Unweeded control plots recorded the highest values.

Population of broad leaf weeds

Population of broad leaf weeds at 20 DAS was also influenced by seed bed preparation. Data in Table 29 reveal that stale seed bed (14 days with two hoeings) effectively lowered the population of broad leaf weeds. The population was almost half in this treatment as compared to stale seed bed for 14 days with one hoeing, which was the next best treatment. During both years, normal seed bed recorded the highest broad leaf weed population.

Among sub plot treatments, pre - emergence spraying of pretilachlor controlled the broad leaf weeds effectively with lowest counts in these plots. Concurrent growing of cowpea was also found to be effective in reducing the broad leaf weed population.

Pre - emergence spraying of pretilachlor in stale seed bed for 14 days with two hoeings reduced the problem of broad leaf weeds. The sub plot treatments which did not receive weed control measures as per treatment at this stage (hand weeding or cono weeding) in combination with normal seed bed recorded significantly higher population than their combination with stale seed bed treatment.

Observations on population of broad leaf weeds at 40 DAS indicate the effectiveness of stale seed bed technique in reducing the population of broad leaf weeds. Stale seed bed for 14 days with two hoeings gave successful control of these weeds (Table 30). Stale seed bed for 14 days with one hoeing was the next best treatment. Normal seed bed facilitated maximum build up of broad leaf weeds during both years.

Table 31. Effect of treatments on population of broad leaf weeds at harvest (Number m^{-2})

Main plot / Sub plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	11.30*[a] (127.19)	10.47*[a] (109.33)	9.67*[b] (93.01)	6.34*[b] (40.00)	7.51*[cd] (55.90)	4.38*[de] (20.00)	7.95*[c] (62.70)	5.87b*[c] (34.67)	9.11*[a] (82.49)	6.77*[a] (51.00)
HW(20 and 40)	4.60[efgh] (20.66)	4.67[cd] (21.33)	4.87[efg] (23.22)	3.46[def] (12.00)	3.87[fghi] (14.48)	4.34[de] (18.67)	3.46[ghi] (11.47)	4.20[de] (17.33)	4.20[c] (17.14)	4.17[b] (17.33)
Pretilachor + HW	5.17[efg] (26.23)	3.51[def] (12.00)	3.54[ghi] (12.03)	2.92[ef] (8.00)	4.04[fghi] (15.82)	2.92[ef] (8.00)	2.92[hi] (8.03)	3.46[def] (12.00)	3.92[c] (14.87)	3.20[c] (10.00)
CW(20)+HW (40)	4.45[efgh] (19.30)	2.92[ef] (8.00)	5.56[ef] (30.41)	4.59[cd] (21.33)	4.11[fghi] (16.39)	3.66[def] (13.33)	3.57[ghi] (12.24)	4.34[de] (18.67)	4.42[c] (19.04)	3.88[b] (15.33)
CW(20 and 40)	5.42[ef] (28.88)	2.86[fg] (8.00)	6.00[de] (35.50)	4.53[cd] (20.00)	5.92[de] (34.55)	3.99[def] (16.00)	6.04[de] (35.98)	4.53[cd] (20.00)	5.85[b] (33.72)	3.90[b] (16.00)
Cowpea	2.65[i] (6.52)	2.86[fg] (8.00)	0.71[j] (0)	0.71[h] (0)	0.71[j] (0)	0.71[h] (0)	0.71[j] (0)	1.45[gh] (2.67)	1.20[d] (0.94)	1.43[d] (2.67)
Main plot mean	5.60[a] (30.86)	4.50[a] (27.78)	5.06[ab] (25.10)	3.76[b] (16.89)	4.36[bc] (18.51)	3.34[b] (12.67)	4.11[c] (16.39)	3.97[ab] (17.56)		

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

Table 32. Effect of treatments on total dry weight of weeds at 20 DAS (g m^{-2})

Main plot / Sub plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	7.01*^{bc} (48.64)	6.85^{a} (46.39)	5.52^{bc} (29.97)	3.84^{b} (14.22)	4.85^{bcd} (23.02)	2.18^{ef} (4.28)	5.87^{bc} (33.96)	3.01^{d} (8.58)	5.81^{a} (33.26)	3.97^{a} (18.37)
HW(20 and 40)	7.06^{bc} (49.34)	6.86^{a} (46.84)	5.71^{bc} (32.10)	3.90^{b} (14.85)	5.08^{bcd} (25.31)	2.43^{e} (5.39)	6.10^{bc} (36.71)	3.04^{d} (8.79)	5.99^{a} (35.38)	4.06^{a} (18.97)
Pretilachor + HW	3.99^{bcd} (15.42)	2.27^{ef} (7.69)	3.85^{cd} (14.32)	1.98^{efg} (3.49)	1.44^{d} (1.57)	1.19^{i} (0.93)	3.51^{cd} (11.82)	1.64^{ghi} (2.22)	3.20^{b} (9.74)	1.77^{c} (2.83)
CW(20)+HW (40)	7.99^{ab} (63.34)	6.90^{a} (47.16)	5.01^{bcd} (24.60)	3.62^{bc} (12.64)	5.69^{bc} (31.88)	2.37^{e} (5.22)	6.02^{bc} (35.74)	3.21^{cd} (9.85)	6.18^{a} (37.69)	4.03^{a} (18.72)
CW(20 and 40)	11.20^{a} (124.94)	7.00^{a} (48.68)	5.32^{bcd} (27.80)	3.80^{b} (14.04)	4.73^{bcd} (21.87)	2.07^{efg} (3.82)	5.97^{bc} (35.14)	2.92^{d} (8.02)	6.80^{a} (45.74)	3.95^{a} (18.64)
Cowpea	4.14^{bcd} (16.64)	2.94^{d} (8.13)	3.95^{cd} (15.10)	2.00^{efg} (3.53)	3.20^{cd} (9.74)	1.48^{hi} (1.69)	4.58^{bcd} (20.48)	1.86^{fgh} (2.99)	3.97^{b} (15.26)	2.07^{b} (4.09)
Main plot mean	6.90^{a} (47.11)	5.47^{a} (33.65)	4.89^{b} (23.41)	3.19^{b} (10.46)	4.17^{b} (16.89)	1.95^{d} (3.56)	5.34^{ab} (28.02)	2.61^{c} (6.74)		

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

The lowest broad leaf weed population was noticed in plots with *in situ* green manuring of cowpea. This was followed by pre - emergence spraying of pretilachlor in 2006 and hand weeding in 2007. Unweeded plots recorded the highest population.

Stale seed bed for 14 days with one hoeing showed the lowest population of broad leaf weeds at harvest stage of 2006 (Table 31). This was on a par with stale seed bed for 14 days with two hoeings. However, during 2007, stale seed bed for 14 days with two hoeings was on a par with stale seed bed for 7 days with one hoeing.

Among the sub plot treatments, *in situ* green manuring of cowpea lowered the broad leaf weed population during both years. In 2006, hand weeding at 20 and 40 DAS, pretilachlor at 3 DAS followed by hand weeding at 40 DAS and cono weeding at 20 DAS followed by hand weeding at 40 DAS were at par. Pretilachlor followed by hand weeding showed significantly lower broad leaf count during 2007.

In situ green manuring of cowpea in stale seed bed plots gave successful control of broad leaf weeds. Combination of no weeding with normal seed bed recorded the highest count, followed by unweeded plots of stale seed bed for 7 days.

Total dry matter production of weeds

Total dry matter production of weeds at 20 DAS during 2006 and 2007 is given in Table 32. Maximum accumulation of dry matter by weeds at 20 DAS was observed in normal seed beds. Lower dry weight of weeds at this stage was observed in stale seed bed for 14 days with two hoeings. Only pretilachlor spray and concurrent growing of cowpea could reduce weed dry weight at this stage, with lower values in pretilachlor sprayed plots. Pretilachlor in combination with stale seed bed for 14 days with two hoeings caused significant reduction in the dry weight of weeds. Combination of normal seed bed with all the sub plot treatments showed higher values for total weed dry weight at 20 DAS.

Table 33. Effect of treatments on total dry weight of weeds at 40 DAS (g m^{-2})

Sub plot \ Main plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	10.35*[a] (106.62)	15.92[a] (252.83)	9.45[b] (88.80)	11.45[b] (130.99)	7.06[de] (49.34)	7.47[cdef] (55.44)	7.87[c] (61.44)	7.63[cde] (57.79)	8.68[a] (74.84)	10.62[a] (124.26)
HW(20 and 40)	7.39[cd] (54.11)	6.386[defg] (47.04)	6.17[fg] (37.57)	5.56[h] (30.61)	5.49[ij] (29.64)	5.57[h] (30.59)	5.99[ghi] (35.38)	6.20[fgh] (38.03)	6.26[b] (38.69)	6.05[c] (36.57)
Pretilachor + HW	3.02[l] (8.62)	8.30[c] (69.12)	4.95[k] (24.00)	7.98[cd] (64.53)	5.24[jk] (26.96)	4.14[i] (17.23)	5.64[hij] (31.31)	5.99[gh] (36.11)	4.71[c] (21.68)	6.60[bc] (46.75)
CW(20)+HW (40)	7.78[c] (60.03)	7.89[cd] (62.13)	6.64[ef] (43.59)	7.20[cdefg] (51.41)	5.34[jk] (28.02)	5.30[h] (27.89)	6.27[fg] (38.81)	6.35[efgh] (39.84)	6.51[b] (41.88)	6.69[b] (45.32)
CW(20 and 40)	7.60[c] (57.26)	7.59[cde] (57.65)	6.20[fg] (37.94)	7.14[cdefg] (50.64)	5.53[hij] (30.08)	6.23[fgh] (38.37)	6.05[gh] (36.10)	7.12[cdefg] (50.27)	6.35[b] (39.82)	7.02[b] (49.23)
Cowpea	2.50[m] (5.75)	4.12[i] (16.67)	2.36[m] (5.07)	3.03[ij] (8.67)	2.32[m] (4.88)	2.53[j] (6.00)	2.60[lm] (6.26)	3.13[ij] (9.33)	2.44[d] (5.45)	3.20[d] (10.17)
Main plot mean	6.44[a] (40.97)	8.45[a] (84.24)	5.96[b] (35.02)	7.06[b] (56.14)	5.16[c] (26.31)	5.21[d] (29.25)	5.74[b] (32.45)	6.07[c] (38.56)		

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

Table 34. Effect of treatments on total dry weight of weeds at harvest (g m^{-2})

Main plot / Sub plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	10.40*^{a} (107.66)	17.60^{a} (309.33)	9.40^{b} (87.86)	13.27^{b} (176.00)	7.02^{d} (48.78)	7.57^{d} (56.80)	7.87^{c} (61.44)	10.43^{c} (109.87)	8.67^{a} (74.67)	12.22^{a} (163.00)
HW(20 and 40)	5.09^{fgh} (25.41)	6.15^{defgh} (37.33)	4.45^{hi} (19.30)	5.29^{ghi} (28.00)	3.12^{lm} (9.23)	5.48^{fghi} (29.87)	3.54^{jkl} (12.03)	6.30^{defgh} (39.73)	4.05^{c} (15.90)	5.80^{c} (33.73)
Pretilachor + HW	5.65^{fg} (31.42)	4.69^{hi} (21.60)	3.40^{jklm} (11.06)	4.09^{i} (17.60)	3.22^{klm} (9.87)	4.25^{i} (17.60)	3.20^{klm} (9.74)	4.60^{hi} (21.60)	3.87^{c} (14.48)	4.41^{d} (19.60)
CW(20)+HW (40)	4.97^{gh} (24.20)	5.63^{efghi} (32.00)	3.99^{ijk} (15.42)	5.27^{efghi} (32.53)	4.07^{ij} (16.06)	5.4f^{ghi} (29.33)	3.29^{jklm} (10.32)	6.22^{defgh} (39.47)	4.08^{c} (16.15)	5.75^{c} (33.33)
CW(20 and 40)	5.79^{ef} (33.02)	7.28^{de} (52.80)	6.48^{de} (41.49)	7.10^{def} (50.40)	5.53^{fg} (30.08)	6.35^{defgh} (40.00)	5.71^{fg} (32.10)	7.12^{def} (50.40)	5.88^{b} (34.07)	6.96^{b} (48.40)
Cowpea	4.04^{ij} (15.82)	6.77^{defg} (46.40)	2.99^{lm} (8.44)	5.66^{efghi} (32.00)	2.66^{m} (6.58)	4.25^{i} (17.60)	3.66^{jkl} (12.90)	5..20^{ghi} (26.67)	3.34^{d} (10.66)	5.47^{c} (30.67)
Main plot mean	5.99^{a} (35.38)	9.15^{a} (83.24)	5.12^{b} (25.71)	7.52^{b} (56.09)	4.27^{c} (17.73)	5.69^{d} (31.87)	4.54^{c} (20.11)	6.96^{c} (47.96)		

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

Table 35. Effect of treatments on dry weight of grasses at 20 DAS (g m^{-2})

Main plot / Sub plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	5.46*[a] (29.31)	6.17[a] (37.60)	2.84[bc] (7.57)	3.11[b] (9.20)	1.85[cde] (2.92)	1.96[ghi] (3.40)	2.29[bcd] (4.74)	2.62[cdef] (6.40)	3.11[a] (9.17)	3.47[a] (14.15)
HW(20 and 40)	5.70[a] (31.99)	6.21[a] (38.20)	2.53[bcd] (5.90)	3.06[bc] (9.00)	1.93[cde] (3.22)	2.21[fgh] (4.40)	2.58[bcd] (6.16)	2.65[bcdef] (6.60)	3.19[a] (9.68)	3.53[a] (14.55)
Pretilachor + HW	2.02[cde] (3.58)	1.86[hi] (3.00)	1.82[cde] (2.81)	1.56[ijk] (2.00)	0.71[f] (0)	1.05[l] (0.60)	1.22[ef] (0.99)	1.22[kl] (1.00)	1.44[c] (1.57)	1.42[c] (1.65)
CW(20)+HW (40)	5.90[a] (34.31)	6.19[a] (37.80)	2.73[bc] (6.95)	2.62[cdef] (6.40)	2.21[bcde] (4.38)	2.00[ghi] (3.60)	2.50[bcd] (5.75)	2.69[bcde] (6.80)	3.34[a] (10.66)	3.37[a] (13.65)
CW(20 and 40)	5.39[a] (28.55)	6.33[a] (39.60)	2.88[bc] (7.79)	2.97[bcd] (8.40)	1.79[cde] (2.70)	1.70[ij] (2.40)	2.78[bc] (7.23)	2.38[efg] (5.20)	3.21[a] (9.80)	3.34[a] (13.90)
Cowpea	3.24[b] (10.00)	2.55[def] (6.00)	2.57[bcd] (6.10)	1.70[ij] (2.40)	1.62[def] (2.12)	1.30[jkl] (1.20)	2.11[cde] (3.95)	1.56[ijk] (2.00)	2.39[b] (5.21)	1.78[b] (2.90)
Main plot mean	4.62[a] (20.84)	4.88[a] (27.03)	2.56[b] (6.05)	2.50[b] (6.23)	1.69[c] (2.36)	1.70[d] (2.60)	2.25[b] (4.56)	2.19[c] (4.67)		

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

Total dry weight of weeds recorded at 40 DAS is presented in Table 33. The data clearly explains the superiority of stale seed bed technique over normal seed bed in managing the weed problem in semi dry rice culture. The stale seed bed for 14 days with two hoeings was the best method for reducing the weed dry matter accumulation. Among the sub plot treatments, concurrent growing of cowpea was the best treatment.

Reduction in the dry weight of weeds was observed under *in situ* green manuring of cowpea combined with stale seed bed (14 days) with two hoeings. This was on a par with cowpea grown in combination with the other three main plot treatments.

Total dry matter accumulation by weeds at harvest stage was significantly reduced by the adoption of stale seed bed for 14 days with two hoeings as compared to normal seed bed (Table 34). The normal seed bed contributed to the highest dry matter accumulation.

Among the sub plot treatments, cowpea and pretilachlor significantly lowered the weed dry weight during 2006 and 2007 respectively. Cono weeding twice was not effective in reducing weed dry matter accumulation during both years. Combination of stale seed bed for 14 days (two hoeings) with *in situ* green manuring of cowpea significantly lowered the total dry weight of weeds. Normal seed bed combined with no weeding manifested severe weed problem and recorded the highest dry weight.

Dry weight of grass weeds

Dry matter production of grasses at 20 DAS as affected by the seed bed preparation and weed control methods is presented in Table 35. Main plot treatments showed significant differences in dry weight of grasses with the least dry weight in stale seed bed for 14 days (two hoeings). Among the sub plot treatments, which received weed control measures at this stage (pretilachlor spray and concurrent growing of cowpea), pre emergence spraying of pretilachlor caused significant reduction in the

Table 36. Effect of treatments on dry weight of grasses at 40 DAS (g m^{-2})

Main plot / Sub plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	7.19*[a] (51.20)	12.77[a] (162.67)	6.51[b] (41.88)	8.04[b] (64.67)	5.12[d] (25.71)	5.23[cd] (27.33)	5.83[c] (33.49)	5.45[c] (29.33)	6.16[a] (37.45)	7.87[a] (71.00)
HW(20 and 40)	4.63[e] (20.94)	4.44[cdef] (19.33)	4.16[efgh] (16.81)	3.94[defg] (15.33)	3.73[hi] (13.41)	2.95[gh] (8.67)	4.29[efg] (17.90)	3.88[defg] (14.67)	4.20[b] (17.14)	3.80[c] (14.50)
Pretilachor + HW	1.97[k] (3.38)	5.14[cd] (26.00)	2.25[jk] (4.56)	5.00[cd] (24.67)	3.37[i] (10.86)	2.31[h] (5.33)	3.55[i] (12.10)	3.49[efgh] (12.00)	2.78[c] (7.23)	3.99[c] (17.00)
CW(20)+HW (40)	5.30[d] (27.59)	5.03[cd] (25.33)	4.53[ef] (20.02)	4.53[cde] (20.00)	3.35[i] (10.72)	2.96[gh] (9.33)	3.88[ghi] (14.55)	4.05[cdefg] (16.00)	4.26[b] (17.65)	4.14[bc] (17.67)
CW(20 and 40)	5.34[d] (28.02)	5.36[c] (28.67)	4.48[ef] (19.57)	4.70[cde] (22.00)	4.09[fgh] (16.23)	4.20[cdefg] (17.33)	3.86[ghi] (14.40)	4.63[cde] (21.33)	4.44[b] (19.21)	4.72[b] (22.33)
Cowpea	2.50j[k] (5.75)	4.12[cdefg] (16.67)	2.36[jk] (5.07)	3.03[gh] (8.67)	2.32[jk] (4.88)	2.53[h] (6.00)	2.60[j] (6.26)	3.13[fgh] (9.33)	2.44[d] (5.45)	3.20[d] (10.17)
Main plot mean	4.49[a] (19.66)	6.14[a] (46.44)	4.05[b] (15.90)	4.87[b] (25.89)	3.66[c] (12.90)	3.36[d] (12.33)	4.00[d] (15.50)	4.10[c] (17.11)		

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

Table 37. Effect of treatments on dry weight of grasses at harvest (g m^{-2})

Main plot / Sub plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	8.22*[a] (67.07)	14.15[a] (200.00)	7.42[b] (54.56)	11.67[b] (136.00)	5.40[cd] (28.66)	6.05[def] (36.80)	5.87[c] (33.96)	8.61[c] (75.20)	6.73[a] (44.79)	10.12[a] (112.00)
HW(20 and 40)	3.79[ghi] (13.86)	4.02[ghi] (16.00)	3.06[jkl] (8.86)	4.00[ghi] (16.00)	2.26[n] (4.61)	3.41[hi] (11.20)	2.60[lmn] (6.26)	4.66[efgh] (22.40)	2.93[c] (8.08)	4.20[c] (16.40)
Pretilachor + HW	4.58[ef] (20.48)	3.18[hi] (9.60)	2.50[lmn] (5.75)	2.65[i] (9.60)	2.27[n] (4.65)	3.18[hi] (9.60)	2.32[n] (4.88)	3.11[hi] (9.60)	2.92[c] (8.03)	3.03[d] (9.60)
CW(20)+HW (40)	3.40[hijk] (11.06)	4.85[defgh] (24.00)	3.15[ijkl] (9.42)	3.41[hi] (11.20)	2.92[klmn] (8.03)	4.00[ghi] (16.00)	2.38[mn] (5.16)	4.51[efghi] (20.80)	2.96[c] (8.26)	4.19[c] (18.00)
CW(20 and 40)	4.66[ef] (21.22)	6.72[d] (44.80)	4.96[de] (24.10)	5.49[defg] (30.40)	3.94[gh] (15.02)	4.95[defgh] (24.00)	4.09[fg] (16.23)	5.53[defg] (30.40)	4.42[b] (19.04)	5.67[b] (32.40)
Cowpea	3.47[ghijk] (11.54)	6.17[de] (38.40)	2.99[klm] (8.44)	5.66[dfg] (32.00)	2.66[lmn] (6.58)	4.25[fghi] (17.60)	3.66[ghij] (12.90)	4.95[dfgh] (24.00)	3.20[c] (9.74)	5.26[b] (28.00)
Main plot mean	4.69[a] (21.50)	6.52[a] (55.47)	4.02[b] (15.66)	5.48[b] (39.20)	3.24[c] (10.00)	4.31[c] (19.20)	3.49[c] (11.68)	5.23[b] (30.40)		

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

grass biomass. All sub plot treatments (except pretilachlor spray) with normal seed bed showed significantly higher dry weight of grasses.

The dry weight of grasses at 40 DAS was lower in stale seed bed for 14 days with two hoeings (Table 36). Among main plot treatments, normal seed bed showed maximum dry weight. Among the weed control practices in sub plots, cowpea *in situ* green manuring was the best in lowering the dry weight of grasses, followed by pretilachlor spray. All other sub plot treatments with weeding practice were at par. During 2006, better reduction in grass dry matter accumulation was noticed in normal seed bed with pretilachlor spray though on a par with pretilachlor in stale seed bed for 7 days and cowpea in stale seed bed for 14 days with two hoeings. During 2007 significant reduction in grass weight was obtained with the treatment combination of stale seed bed for 14 days (two hoeings) with pretilachlor or cowpea.

The dry weight of grasses at harvest stage is provided in Table 37. Normal seed bed produced the highest dry weight of grasses during 2006 and 2007. Among stale seed bed treatments, stale seed bed for 14 days with two hoeings lowered the dry matter accumulation. The highest dry weight of weeds among the sub plots was noticed in unweeded plots. Cono weeding twice was effective in reducing weed dry weight during 2006. In this year, all other sub plot treatments were at par. During 2007, pretilachlor spray gave significant reduction. Hand weeding at 20 and 40 DAS was on a par with cono weeding at 20 DAS followed by hand weeding at 40 DAS.

Interaction of main plots with sub plots shows that during 2006, the grass dry weight was lower in plots with stale seed bed for 14 days (two hoeings) followed by hand weeding twice. This treatment combination was on a par with pretilachlor + hand weeding in stale seed bed for 14 days with one or two hoeings. During 2007, combination of stale seed bed for 7 days with pretilachlor and hand weeding gave significantly lower dry weight of grasses.

Table 38. Effect of treatments on dry weight of sedges at 20 DAS (g m^{-2})

Sub plot \ Main plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	1.14*^{abcde} (0.80)	1.01^{b} (0.52)	1.22^{abcd} (0.99)	0.99^{bc} (0.49)	1.26^{abc} (1.09)	0.81^{defg} (0.15)	1.48^{a} (1.69)	0.83^{defg} (0.18)	1.28^{a} (1.14)	0.91^{a} (0.34)
HW(20 and 40)	0.88^{e} (0.27)	1.07^{b} (0.64)	1.25^{abc} (1.06)	1.07^{b} (0.65)	1.25^{abc} (1.06)	0.79^{defg} (0.12)	1.35^{ab} (1.32)	0.79^{defg} (0.12)	1.18^{a} (0.89)	0.93^{a} (0.38)
Pretilachor + HW	1.23^{abcd} (1.01)	0.77^{efg} (0.09)	0.91^{de} (0.33)	0.77^{efg} (0.09)	0.90^{de} (0.31)	0.71^{g} (0)	0.88^{e} (0.27)	0.77^{efg} (0.09)	0.98^{b} (0.46)	0.76^{c} (0.07)
CW(20)+HW (40)	1.00^{cde} (0.50)	1.18^{a} (0.89)	1.05^{bcde} (0.60)	0.90^{cd} (0.31)	1.43^{a} (1.54)	0.81^{defg} (0.15)	1.21^{abcde} (.96)	0.86^{def} (0.25)	1.17^{a} (0.87)	0.94^{a} (0.40)
CW(20 and 40)	1.43^{a} (1.54)	0.88^{cde} (0.28)	1.21^{abcde} (0.96)	0.90^{cd} (0.31)	1.17^{abcde} (0.87)	0.81^{defg} (0.15)	1.26^{abc} (1.09)	0.81^{defg} (0.15)	1.26^{a} (1.09)	0.85^{b} (0.22)
Cowpea	1.20^{abcde} (0.94)	0.71^{g} (0)	0.95^{cde} (0.40)	0.75^{fg} (0.06)	0.88^{e} (0.27)	0.77^{efg} (0.09)	1.08^{bcde} (0.67)	0.75^{fg} (0.06)	1.03^{b} (0.56)	0.75^{c} (0.05)
Main plot mean	1.15^{a} (0.82)	0.94^{a} (0.40)	1.10^{a} (0.71)	0.90^{a} (0.32)	1.15^{a} (0.82)	0.78^{b} (0.11)	1.21^{a} (0.96)	0.80^{b} (0.14)		

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

Table 39. Effect of treatments on dry weight of sedges at 40 DAS (g m^{-2})

Sub plot \ Main plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	2.75^{ab} (7.06)	2.59^{bcd} (6.83)	2.49^{abc} (5.70)	3.68^{a} (13.65)	2.21^{abcde} (4.38)	2.92^{ab} (8.12)	2.52^{abc} (5.85)	2.34^{bcdef} (5.12)	2.49^{a} (5.70)	2.88^{a} (8.43)
HW(20 and 40)	2.90^{a} (7.91)	1.47^{fghi} (1.71)	1.77^{cdef} (2.63)	1.26^{hi} (1.28)	1.07^{fgh} (0.64)	2.78^{bc} (7.25)	1.88^{bcdef} (3.03)	2.25^{bcdefg} (4.69)	1.91^{b} (3.15)	1.94^{c} (3.73)
Pretilachor + HW	0.82^{gh} (0.17)	2.36^{bcdef} (5.12)	1.36^{efgh} (1.35)	2.99^{ab} (8.53)	1.70^{cdefg} (2.39)	1.72^{defgh} (2.56)	1.76^{cdef} (2.60)	2.91^{ab} (8.11)	1.41^{c} (1.49)	2.49^{b} (6.08)
CW(20)+HW (40)	2.52^{abc} (5.85)	1.61^{efgh} (2.13)	2.07^{abcde} (3.78)	1.97^{cdefgh} (3.41)	1.64^{cdefg} (2.19)	1.75^{defgh} (2.56)	2.46^{abc} (5.55)	2.01^{cdefgh} (3.84)	2.17^{ab} (4.21)	1.84^{c} (2.99)
CW(20 and 40)	2.31^{abcd} (4.84)	1.76^{defgh} (2.99)	2.12^{abcde} (3.99)	2.49^{bcde} (5.97)	1.39^{defgh} (1.43)	1.40^{ghi} (1.71)	2.20^{abcde} (4.34)	2.15^{cdefgh} (4.27)	2.00^{b} (3.50)	1.95^{c} (3.73)
Cowpea	0.71^{h} (0)	0.71^{i} (0)	0.71^{h} (0)	0.71^{i} (0)	0.71^{h} (0)	0.71^{i} (0)	0.71^{h} (0)	0.71^{i} (0)	0.71^{d} (0)	0.71^{d} (0)
Main plot mean	2.00^{a} (3.50)	1.75^{a} (3.13)	1.75^{a} (2.56)	2.18^{a} (5.48)	1.45^{a} (1.60)	1.88^{a} (3.70)	1.92^{a} (3.19)	2.06^{a} (4.34)		

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

Table 40. Effect of treatments on dry weight of broad leaf weeds at 20 DAS (g m^{-2})

Sub plot \ Main plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	4.37*^{b} (18.60)	2.96^{a} (8.27)	4.67^{b} (21.31)	2.24^{b} (4.53)	4.40^{b} (18.86)	1.10^{ghi} (0.73)	5.28^{b} (27.38)	1.58^{cdef} (2.00)	4.68^{ab} (21.40)	1.97^{b} (3.88)
HW(20 and 40)	4.16^{b} (16.81)	2.90^{a} (8.00)	5.05^{b} (25.00)	2.39^{b} (5.20)	4.63^{b} (20.94)	1.16^{ghi} (0.87)	5.45^{b} (29.20)	1.60^{cde} (2.07)	4.82^{ab} (22.73)	2.01^{ab} (4.03)
Pretilachor + HW	3.36^{b} (10.79)	1.43^{cdefg} (1.60)	3.41^{b} (11.13)	1.37^{efg} (1.40)	1.33^{c} (1.27)	0.91^{i} (0.33)	3.33^{b} (10.59)	1.26^{efghi} (1.13)	2.86^{c} (7.68)	1.25^{c} (1.12)
CW(20)+HW (40)	5.11^{b} (25.61)	2.99^{a} (8.47)	4.19^{b} (17.06)	2.54^{b} (5.93)	5.13^{b} (25.82)	1.40^{defg} (1.47)	5.44^{b} (29.09)	1.81^{c} (2.80)	4.97^{ab} (24.20)	2.18^{a} (4.67)
CW(20 and 40)	9.53^{ab} (90.32)	3.02^{a} (8.80)	4.41^{b} (18.95)	2.40^{b} (5.33)	4.31^{b} (18.08)	1.32^{efg}h (1.27)	5.22^{b} (26.75)	1.77^{cd} (2.67)	5.87^{a} (33.96)	2.13^{ab} (4.52)
Cowpea	2.50^{b} (5.75)	1.62^{cde} (2.13)	3.13^{b} (9.30)	1.25^{efghi} (1.07)	2.80^{b} (7.34)	0.95^{hi} (0.40)	4.04^{b} (15.82)	1.19^{fghi} (0.93)	3.12^{bc} (9.23)	1.25^{c} (1.13)
Main plot mean	4.84^{a} (22.93)	2.49^{a} (6.21)	4.14^{a} (16.64)	2.03^{b} (3.91)	3.77^{a} (13.71)	1.14^{d} (0.84)	4.79^{a} (22.44)	1.54^{c} (1.93)		

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

Dry weight of sedges

A perusal of data in Table 38 reveals that seed bed manipulation had no significant influence on dry weight of sedges at 20 DAS during 2006. However, significant variation was noticed in 2007 with the lowest dry weight in stale seed bed for 14 days either with one or two hoeings. Among sub plot treatments, pre emergence spraying of pretilachlor or concurrent growing of cowpea reduced the dry matter accumulation by sedges. During 2006, the sedge dry matter production was maximum in normal seed bed with cowpea and in 2007, normal seed bed with cono weeding recorded the highest values.

Dry weight of sedges at 40 DAS showed no significant variation among the main plot treatments during both years of the study. However, sub plot treatments showed significant differences. Complete control for the sedges was obtained by the *in situ* green manuring of cowpea. Dry weight was found to be the highest in unweeded plots. Complete control of sedges was noticed by the concurrent growing of cowpea with all four main plot treatments (Table 39).

Dry weight of broad leaf weeds

Dry matter of broad leaf weeds at 20 DAS showed no significant variation among main plot treatments at 20 DAS during 2006. During 2007, stale seed bed for 14 days with two hoeings produced significantly lower dry matter production of broad leaf weeds than all other main plot treatments (Table 40). Plots which received pre emergence spraying of pretilachlor recorded the lowest dry weight of broad leaf weeds. This sub plot treatment with stale seed bed for 14 days (two hoeings) recorded the lowest dry weight.

At 40 DAS, normal seed bed recorded the highest dry weight of broad leaf weeds followed by stale seed bed for 7 days. Among sub plot treatments, cowpea grown plots showed significantly higher and weedy check significantly lower dry weight of broad leaf

Table 41. Effect of treatments on dry weight of broad leaf weeds at 40 DAS (g m^{-2})

Main plot / Sub plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	6.98*[a] (48.22)	9.15[a] (83.33)	6.34[b] (39.70)	7.14[b] (52.67)	4.43[efg] (19.12)	4.51[efgh] (20.00)	4.75[cde] (22.06)	4.86[cdefgh] (23.33)	5.63[a] (31.20)	6.42[a] (44.83)
HW(20 and 40)	5.08[c] (25.31)	5.09[cdefgh] (26.00)	4.28[efgh] (17.82)	3.78[hi] (14.00)	3.99[ghij] (15.42)	3.89[ghi] (14.67)	3.85[hij] (14.32)	4.37[efghi] (18.67)	4.30[bc] (17.99)	4.28[c] (18.33)
Pretilachor + HW	2.36[k] (5.07)	6.14[bc] (38.00)	4.30[efgh] (17.99)	5.53[cde] (31.33)	3.72[ij] (13.34)	3.11[i] (9.33)	4.09[fghi] (16.23)	4.02[fghi] (16.00)	3.62[d] (12.60)	4.70[bc] (23.67)
CW(20)+HW (40)	5.15[c] (26.02)	5.92[cd] (64.67)	4.50[def] (19.75)	5.33[cdef] (28.00)	3.88[hij] (14.55)	4.06[fghi] (16.00)	4.35[efgh] (18.42)	4.51[efgh] (20.00)	4.47[b] (19.48)	4.96[b] (24.67)
CW(20 and 40)	4.95[cd] (24.00)	5.14[cdefg] (26.00)	3.85[hij] (14.32)	4.78[defgh] (22.67)	3.58[j] (12.32)	4.45[efgh] (19.33)	4.22[fgh] (17.31)	5.00[cdefgh] (24.67)	4.15[c] (16.72)	4.84[bc] (23.17)
Cowpea	0.71[l] (0)	0.71[j] (0)	0.71[l] (0)	0.71[j] (0)	0.71[l] (0)	0.71[j] (0)	0.71[l] (0)	0.71[j] (0)	0.71[e] (0)	0.70[d] (0)
Main plot mean	4.21[a] (17.22)	5.36[a] (34.67)	4.00[ab] (15.50)	4.55[b] (24.78)	3.38[c] (10.92)	3.46[d] (13.22)	3.66[bc] (12.90)	3.91[c] (17.11)		

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

Table 42. Effect of treatments on dry weight of broad leaf weeds at harvest (g m^{-2})

Main plot / Sub plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	6.41*^{a} (40.59)	10.47^{a} (109.33)	5.79^{ab} (33.02)	6.34^{b} (40.00)	4.53^{cd} (20.02)	4.38^{de} (20.00)	5.23^{bc} (26.85)	5.87^{bc} (34.67)	5.49^{a} (29.64)	6.77^{a} (51.00)
HW(20 and 40)	3.36^{efgh} (10.79)	4.67^{cd} (21.33)	3.24^{efghi} (10.00)	3.46^{def} (12.00)	2.26^{ij} (4.61)	4.34^{de} (18.67)	2.49^{hij} (5.70)	4.20^{de} (17.33)	2.84^{c} (7.57)	4.17^{b} (17.33)
Pretilachor + HW	3.35^{efgh} (10.72)	3.51^{def} (12.00)	2.41^{hij} (5.31)	2.92^{ef} (8.00)	2.39^{hij} (5.21)	2.92^{ef} (8.00)	2.31^{ij} (4.84)	3.46^{def} (12.00)	2.61^{c} (6.31)	3.21^{c} (10.00)
CW(20)+HW (40)	3.63^{def} (12.68)	2.92^{ef} (8.00)	2.54^{ghij} (5.95)	4.59^{cd} (21.33)	2.90^{fghij} (7.91)	3.66^{def} (13.33)	2.31^{ij} (4.84)	4.34^{de} (18.67)	2.84^{c} (7.57)	3.88^{b} (15.33)
CW(20 and 40)	3.50^{efg} (11.75)	2.56^{fg} (8.00)	4.22^{de} (17.31)	4.53^{cd} (20.00)	3.93^{de} (14.94)	3.99^{def} (16.00)	4.04^{de} (15.82)	4.53^{cd} (20.00)	3.92^{b} (14.87)	3.90^{b} (16.00)
Cowpea	2.15^{j} (4.12)	2.92^{ef} (8.00)	0.71^{k} (0)	0.71^{h} (0)	0.71^{k} (0)	0.71^{h} (0)	0.71^{k} (0)	1.45^{gh} (2.67)	1.07^{d} (0.64)	1.43^{d} (2.67)
Main plot mean	3.73^{a} (13.41)	5.32^{a} (27.78)	3.15^{b} (9.42)	4.17^{b} (16.89)	2.79^{b} (7.28)	3.63^{b} (12.67)	2.85^{b} (7.62)	4.25^{b} (17.56)		

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

weeds (Table 41). Absence of weeding in normal seed bed plots resulted in maximum assimilation of dry weight by broad leaf weeds. *In situ* green manuring of cowpea in combination with all four seed bed preparation methods gave complete control of broad leaf weeds.

Dry weight of broad leaf weeds did not vary appreciably among various stale seed bed techniques. Only normal seed bed showed significant variation during 2006. However, during 2007, stale seed bed for 14 days with two hoeings showed significant reduction in dry weights. The lowest dry weight was noticed in cowpea grown plots. As expected no weeding resulted in the greatest accumulation of dry weight. Significantly lower biomass was recorded by the unweeded plots of normal seed bed, followed by stale seed bed for 7 days and stale seed bed for 14 days with one hoeing. Concurrent growing of cowpea and its incorporation at 30 DAS in combination with stale seed bed techniques gave significant reduction in dry matter accumulation by broad leaf weeds (Table 42).

4.2.2. Studies on crop

Plant height

Effects of main and sub plot treatments and their interaction on plant height at maximum tillering stage of the crop is presented in Table 43. During 2006, plant height in normal seed bed was on a par with stale seed bed for 14 days (one hoeing). During 2007, except in normal seed bed the plant height exhibited no significant variation. The lowest plant height of 21.95 cm was noticed in normal seed bed.

Concurrent growing of cowpea with rice caused severe reduction in the plant height at maximum tillering stage during both years (19.97cm and 19.48 cm). Combination of cowpea with all four main plot treatments significantly lowered the plant height at maximum tillering during 2006 and 2007.

Table 43. Effect of treatments on plant height at maximum tillering (cm)

Main plot / Sub plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	23.70^{ab}	21.43^{i}	23.90^{ab}	22.39^{h}	24.77^{ab}	23.63^{fg}	24.13^{ab}	23.19^{g}	24.13^{a}	22.66^{d}
HW(20 and 40)	22.53^{bcd}	22.07^{hi}	25.33^{ab}	24.20^{cdef}	25.40^{ab}	23.75^{efg}	25.00^{ab}	24.49^{bcde}	24.57^{ab}	23.63^{c}
Pretilachor + HW	23.33^{abc}	23.91^{defg}	25.17^{ab}	25.49^{a}	24.10^{ab}	24.84^{abc}	24.27^{ab}	24.33^{bcdef}	24.22^{ab}	24.64^{a}
CW(20)+HW (40)	24.70^{ab}	22.07^{hi}	23.43^{ab}	24.35^{bcdef}	25.57^{a}	24.60^{bcd}	24.95^{ab}	24.73^{bc}	24.66^{ab}	23.94^{bc}
CW(20 and 40)	25.13^{ab}	22.40^{h}	25.43^{ab}	24.22^{cdef}	26.01^{a}	24.67^{bcd}	25.47^{ab}	25.06^{ab}	25.51^{a}	24.09^{b}
Cowpea	20.37^{de}	19.80^{j}	20.77^{cde}	19.40^{j}	19.97^{de}	19.56^{j}	18.79^{e}	19.17^{j}	19.97^{b}	19.48^{e}
Main plot mean	23.29^{b}	21.95^{b}	24.01^{a}	23.34^{a}	24.30^{a}	23.51^{a}	23.77^{ab}	23.50^{a}		

Table 44. Effect of treatments on plant height at panicle initiation (cm)

Main plot / Sub plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	51.57^{l}	49.13^{h}	60.87^{k}	55.28^{g}	68.03^{ef}	64.26^{cde}	65.07^{hi}	62.69^{e}	61.38^{c}	57.84^{c}
HW(20 and 40)	66.18^{g}	67.71^{abcd}	68.57^{cdef}	66.96^{ab}	69.30^{abcd}	66.50^{abc}	68.70^{bcdef}	67.13^{ab}	68.19^{a}	66.57^{a}
Pretilachor + HW	65.27^{gh}	65.69^{abcd}	68.47^{def}	68.21^{a}	69.97^{a}	68.01^{ab}	69.73^{ab}	66.57^{abc}	68.36^{a}	67.12^{a}
CW(20)+HW (40)	67.77^{f}	65.32^{bcd}	68.47^{def}	67.49^{ab}	69.40^{abcd}	67.61^{ab}	68.90^{abcde}	66.86^{abc}	68.63^{a}	66.82^{a}
CW(20 and 40)	65.53^{gh}	65.59^{abcd}	68.63^{cdef}	66.19^{abc}	69.60^{abc}	67.47^{ab}	69.27^{abcd}	66.67^{abc}	68.26^{a}	66.48^{a}
Cowpea	63.23^{j}	60.17^{f}	64.20^{i}	62.51^{ef}	65.17^{ghi}	63.62^{de}	65.60^{gh}	62.15^{ef}	64.55^{b}	62.11^{b}
Main plot mean	63.26^{d}	61.94^{d}	66.53^{c}	64.44^{c}	68.58^{a}	66.25^{a}	67.88^{b}	65.35^{b}		

Table 45. Effect of treatments on plant height at harvest (cm)

Main plot / Sub plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	60.55^{m}	58.08^{i}	66.47^{l}	64.09^{h}	82.21^{ij}	77.62^{f}	80.43^{k}	74.64^{g}	72.42^{d}	68.61^{c}
HW(20 and 40)	81.87^{j}	80.48^{de}	85.39^{ef}	82.50^{bcd}	86.50^{bc}	84.30^{ab}	85.57^{def}	83.15^{abc}	84.83^{c}	82.61^{a}
Pretilachor + HW	82.43^{ij}	81.54^{cde}	86.63^{bc}	84.55^{ab}	87.83^{a}	84.96^{a}	86.17^{cde}	83.32^{abc}	85.77^{b}	83.59^{a}
CW(20)+HW (40)	82.33^{ij}	81.43^{cde}	87.13^{ab}	83.42^{abc}	86.34^{bcd}	83.48^{abc}	86.32^{bcd}	83.55^{abc}	85.53^{b}	82.97^{a}
CW(20 and 40)	82.83^{i}	82.61^{abcd}	87.57^{a}	83.70^{abc}	86.57^{bc}	82.47^{bcd}	87.54^{a}	82.72^{abcd}	86.13^{a}	82.88^{a}
Cowpea	85.17^{fg}	79.86^{e}	85.80^{cdef}	81.42^{cde}	84.50^{gh}	82.44^{bcd}	84.37^{h}	81.58^{cde}	84.96^{c}	81.33^{b}
Main plot mean	79.20^{d}	77.33^{d}	83.17^{c}	79.95^{c}	85.66^{a}	82.55^{a}	85.06^{b}	81.50^{a}		

Table 46. Effect of treatments on number of tiller/m^{2} at maximum tillering

Main plot / Sub plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	153^{j}	160^{hi}	159^{ghi}	173^{defg}	180^{bcd}	171^{efg}	167^{e}	184^{abc}	165^{b}	172^{c}
HW(20 and 40)	179^{cd}	181^{abcd}	183^{abc}	186^{a}	188^{a}	184^{ab}	188^{a}	179^{abcde}	184^{a}	183^{a}
Pretilachor + HW	155^{ij}	152^{i}	159^{hi}	160^{hi}	162^{efgh}	175^{cdef}	160^{fghi}	166^{fgh}	160^{c}	163^{d}
CW(20)+HW (40)	176^{d}	173^{defg}	182^{abc}	176^{bcde}	185^{ab}	183^{abc}	184^{abc}	182^{abcd}	182^{a}	179^{b}
CW(20 and 40)	179^{cd}	173^{defg}	183^{abc}	178^{abcde}	185^{ab}	181^{abcd}	186^{ab}	183^{abc}	183^{a}	179^{b}
Cowpea	165^{ef}	160^{hi}	165^{ef}	161^{h}	165^{ef}	176^{bcde}	165^{efg}	165^{gh}	165^{b}	167^{d}
Main plot mean	168^{d}	166^{c}	172^{c}	172^{b}	178^{a}	178^{a}	175^{b}	177^{ab}		

At panicle initiation stage (Table 44) plants were tallest in stale seed bed for 14 days with two hoeings followed by stale seed bed for 14 days with one hoeing. The lowest height was noticed in normal seed bed. Sub plots with cowpea recorded lower values (64.55 cm and 62.11 cm). Combination of pretilachlor with stale seed bed for 14 days with two hoeings produced tallest plants (69.97 cm) during 2006 and pretilachlor in stale seed bed for 7 days showed the highest plant height (68.21 cm) in 2007. At this stage of observation, plant height was significantly lower in normal seed bed with no weeding.

At harvest stage of the crop, significantly lower height was noticed in plants under normal seed bed. Stale seed bed for 14 days with two hoeings was the best treatment with respect to plant height during both years (85.66 cm and 82.55 cm). Spraying of pretilachlor at 3 DAS followed by hand weeding at 40 DAS in stale seed bed plots (14 days with two hoeings) significantly enhanced the plant height. Unweeded plots with normal seed bed gave the lowest height at harvest followed by those of stale seed bed for 7 days (Table 45).

Number of tillers

Observations on number of tillers at maximum tillering stage are presented in Table 46. The tiller count varied significantly among main plot treatments with the highest count in stale seed bed for 14 days with two hoeings. Among the sub plot treatments, pre emergence spraying of pretilachlor significantly reduced the number of tillers during both years of study (159 and 163). During 2006, hand weeding with stale seed bed for 14 days (with one or two hoeings) recorded higher number of tillers. During 2007, the highest tiller count was observed in hand weeded plots of stale seed bed for 7 days.

At panicle initiation stage, the highest number of tillers per unit area was noticed in stale seed bed for 14 days. During 2006, stale seed bed for 14 days with one hoeing or two

Table 47. Effect of treatments on number of tillers/m^2 at panicle initiation

Main plot / Sub plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	169^{i}	169^{k}	176^{i}	196^{j}	285^{ab}	258^{fg}	250^{h}	220^{i}	220^{d}	211^{d}
HW(20 and 40)	284^{abc}	247^{h}	293^{a}	271de	294^{a}	291^{a}	293^{a}	283^{abc}	291^{a}	273^{b}
Pretilachor + HW	269^{cdefg}	263^{ef}	283^{abc}	285^{ab}	287^{ab}	278^{bcd}	282^{abc}	285^{ab}	280^{b}	278^{ab}
CW(20)+HW (40)	265^{efg}	264^{ef}	271^{bcdef}	286^{ab}	277^{bcde}	283^{abc}	283^{abc}	282^{abcd}	274^{b}	279^{a}
CW(20 and 40)	267^{defg}	265^{ef}	274^{bcdef}	273^{cde}	277^{bcde}	278^{bcd}	281^{abcd}	284^{abc}	275^{b}	275^{ab}
Cowpea	255^{gh}	249^{gh}	255^{gh}	286^{ab}	256^{gh}	254^{fgh}	260^{fgh}	245^{h}	256^{c}	258^{c}
Main plot mean	252^{c}	243^{c}	260^{b}	266^{b}	279^{a}	274^{a}	275^{a}	266^{b}		

Table 48. Effect of treatments on number of tillers/m^2 at harvest

Main plot / Sub plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	169^{g}	178^{l}	198^{f}	224^{k}	322^{d}	308^{hi}	311^{e}	273^{j}	250^{c}	246^{b}
HW(20 and 40)	378^{bc}	297^{i}	384^{abc}	321^{defgh}	384^{abc}	341^{ab}	381^{abc}	333^{abcd}	381^{b}	323^{a}
Pretilachor + HW	382^{abc}	316^{fgh}	384^{abc}	335^{abcd}	388^{ab}	328^{bcdef}	391^{a}	335^{abcd}	386^{ab}	329^{a}
CW(20)+HW (40)	388^{ab}	316^{fgh}	385^{abc}	336^{abc}	390^{ab}	333^{abcd}	390^{ab}	332^{abcde}	388^{a}	330^{a}
CW(20 and 40)	389^{ab}	318^{efgh}	389^{ab}	323^{cdefg}	388^{ab}	328^{bcdef}	386^{ab}	334^{abcd}	388^{a}	326^{a}
Cowpea	374^{c}	318^{efgh}	389^{ab}	344^{a}	387^{ab}	336^{abc}	388^{ab}	311^{gh}	385^{ab}	327^{a}
Main plot mean	347^{c}	291^{c}	355^{b}	314^{b}	377^{a}	329^{a}	375^{a}	320^{b}		

hoeings were at par, while in 2007, stale seed bed for 14 days with two hoeings exhibited superiority. Significantly lower number of tillers was noticed in plots under normal seed bed (220 and 243).

No weeding and *in situ* green manuring of cowpea caused reduction in tiller production. The lowest tiller count during both years of study was noticed in unweeded plots followed by cowpea grown plots. Stale seed bed for 14 days (two hoeings) followed by hand weeding at 20 and 40 DAS increased the number of tillers. Unweeded plots of normal seed bed showed the lowest number of tillers followed by unweeded plots of stale seed bed for 7 days and 14 days with one hoeing (Table 47).

During 2006, higher tiller count of 377 and 375/m^2 were observed in stale seed bed for 14 days with two or one hoeings (Table 48). The normal seed bed showed the lowest tiller count of 347. During 2007, stale seed bed for 14 days with two hoeings exhibited significant superiority over other main plots (329). Lower tiller counts of 250 and 246 during 2006 and 2007 were observed in unweeded plots. Combination of pretilachlor + hand weeding with stale seed bed for 14 days with one hoeing significantly increased the tiller production during 2006 (391/m^2). Whereas, during 2007, it was the highest in cowpea grown plots with stale seed bed for 7 days (344).

Crop dry matter production

Dry matter production by the crop at 20 DAS was the least in plots with normal seed bed (1.43g and 1.62g). Growing of cowpea along with rice adversely affected crop dry matter production at 20 DAS. Crop dry matter produced by cowpea grown plots was 1.48g and 1.53g respectively during 2006 and 2007. Whereas it was above 1.54 and 1.63 g in other treatments. During the first year of experiment, pre - emergence spraying of pretilachlor in stale seed bed for 14 days with one hoeing facilitated maximum build up of dry weight by the crop (Table 49).

Table 49. Effect of treatments on crop dry matter production (g plant^{-1}) at 20 DAS

Main plot / Sub plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	1.45^{cd}	1.60^{de}	1.50^{bc}	1.61^{cde}	1.62^{a}	1.67^{abcd}	1.60^{ab}	1.66^{abcd}	1.54^{bc}	1.63^{b}
HW(20 and 40)	1.50^{bc}	1.63^{bcde}	1.62^{a}	1.67^{abcd}	1.65^{a}	1.70^{abcd}	1.65^{a}	1.66^{abcd}	1.61^{a}	1.66^{ab}
Pretilachor + HW	1.36^{de}	1.73^{ab}	1.60^{ab}	1.71^{abc}	1.60^{ab}	1.71^{abc}	1.58^{ab}	1.64^{bcd}	1.54^{c}	1.70^{a}
CW(20)+HW (40)	1.50^{bc}	1.64^{bcd}	1.59^{ab}	1.73^{ab}	1.60^{ab}	1.69^{abcd}	1.64^{a}	1.67^{abcd}	1.58^{abc}	1.68^{a}
CW(20 and 40)	1.47^{c}	1.66^{abcd}	1.61^{a}	1.75^{a}	1.63^{a}	1.66^{abcd}	1.64^{a}	1.66^{abcd}	1.59^{ab}	1.68^{a}
Cowpea	1.30^{e}	1.46^{f}	1.45^{cd}	1.45^{f}	1.58^{ab}	1.53^{ef}	1.59^{ab}	1.66^{abcd}	1.48^{d}	1.53^{c}
Main plot mean	1.43^{b}	16.2^{a}	1.56^{d}	1.65^{a}	1.61^{a}	1.66^{a}	1.62^{a}	1.66^{a}		

Table 50. Effect of treatments on crop dry matter production (g plant^{-1}) at 40 DAS

Main plot / Sub plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	4.27^{h}	5.13^{l}	4.47^{h}	5.58j^{k}	6.00^{ab}	6.07^{bcdefg}	5.79^{bcde}	6.03^{defg}	5.13^{d}	5.70^{d}
HW(20 and 40)	5.63^{cdef}	5.94^{efghi}	5.77^{bcde}	6.09^{bcdef}	6.05^{a}	6.31^{ab}	5.87^{abc}	6.09^{bcdef}	5.83^{a}	6.11^{b}
Pretilachor + HW	5.50^{g}	6.08^{bcdef}	5.72^{cdef}	6.28^{abcd}	6.07^{a}	6.45^{a}	5.80^{bcde}	6.14^{bcde}	5.77^{a}	6.24^{a}
CW(20)+HW (40)	5.26^{g}	5.76^{hij}	5.75^{cde}	5.85^{fghi}	5.84^{abcd}	6.28^{abc}	5.77^{bcde}	6.27^{abcd}	5.66^{b}	6.04^{b}
CW(20 and 40)	5.24^{g}	5.71^{ijk}	5.74^{cde}	5.83^{ghi}	5.79^{bcde}	6.22^{abcd}	5.81^{bcde}	5.96^{efgh}	5.65^{b}	5.93^{c}
Cowpea	5.07^{g}	5.21^{l}	5.57^{ef}	5.52^{k}	5.61^{def}	5.57^{jk}	5.72^{cdef}	6.03^{cdefg}	5.49^{c}	5.58^{e}
Main plot mean	5.16^{d}	5.64^{c}	5.50^{c}	5.86^{b}	5.89^{a}	6.15^{a}	5.79^{b}	6.09^{a}		

Table 51. Effect of treatments on crop dry matter production (g plant^{-1}) at 60 DAS

Main plot / Sub plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	12.73^{l}	11.94^{l}	13.26^{k}	14.14^{k}	15.98^{efgh}	16.13^{j}	15.71^{hi}	16.04^{j}	14.42^{d}	14.56^{d}
HW(20 and 40)	15.40^{ij}	18.53^{bcde}	16.35^{cde}	18.91^{abc}	16.82^{ab}	18.97^{ab}	16.88^{a}	19.09^{ab}	16.36^{b}	18.88^{b}
Pretilachor + HW	16.17^{defg}	19.03^{ab}	16.89^{abc}	19.50^{a}	16.89^{a}	18.62^{bcde}	16.90^{a}	19.01^{ab}	16.66^{a}	19.04^{a}
CW(20)+HW (40)	15.15^{j}	17.81^{fghi}	16.22^{defg}	18.55^{bcde}	16.09^{efg}	18.31^{cdef}	15.92^{fgh}	18.75^{bcd}	15.84^{c}	18.36^{b}
CW(20 and 40)	15.47^{i}j	17.25^{i}	16.24^{def}	18.02^{efgh}	16.03^{efgh}	18.20^{defg}	15.86^{gh}	18.17^{defg}	15.90^{c}	17.91^{c}
Cowpea	16.46^{bcd}	17.38^{i}	17.04^{a}	17.54^{hi}	16.75^{ab}	18.04^{efgh}	16.81^{ab}	17.62^{ghi}	16.77^{a}	17.64^{c}
Main plot mean	15.23^{c}	16.99^{b}	15.97^{b}	17.78^{c}	16.43^{a}	18.04^{a}	16.35^{a}	18.11^{a}		

Table 52. Effect of treatments on crop dry matter production (g plant^{-1}) at harvest

Main plot / Sub plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	22.59^{g}	23.04^{l}	28.29^{f}	25.64^{k}	33.50^{d}	31.55^{i}	32.88^{e}	30.62^{j}	29.32^{d}	27.71^{d}
HW(20 and 40)	32.69^{e}	35.13^{h}	34.66^{c}	36.96^{ef}	35.22^{c}	37.34^{de}	35.06^{c}	38.29^{abc}	34.41^{c}	26.93^{b}
Pretilachor + HW	33.56^{d}	36.20^{fg}	35.23^{c}	38.60^{a}	35.86^{b}	38.49^{ab}	35.90^{b}	37.51^{cde}	35.14^{b}	37.70^{a}
CW(20)+HW (40)	32.71^{e}	36.08^{g}	34.96^{c}	37.51^{cde}	34.88^{c}	38.12^{abcd}	35.15^{c}	37.25^{de}	34.43^{c}	37.24^{b}
CW(20 and 40)	33.05^{de}	35.73^{gh}	35.13^{c}	37.10^{e}	35.09^{c}	37.42^{cde}	34.95^{c}	37.71^{bcde}	34.56^{c}	36.99^{b}
Cowpea	34.86^{c}	35.38^{gh}	36.76a	36.15^{fg}	35.78^{b}	37.20^{e}	36.31^{ab}	37.05^{e}	35.93^{a}	36.45^{c}
Main plot mean	31.58^{c}	33.59^{c}	34.17^{b}	35.33^{b}	35.06^{a}	36.69^{a}	35.04^{a}	36.41^{a}		

The lowest crop dry matter production was observed in unweeded plots of normal seed bed. The cowpea intercropped plots of stale seed bed for 7 days gave the lowest dry weight during 2007 followed by the same sub plot treatment in combination with normal seed bed, which were at par.

Stale seed bed for 14 days favored the maximum accumulation of dry weight at 40 DAS (Table 50). During 2006, stale seed bed for 14 days (two hoeings) was significantly superior to stale seed bed for 14 days with one hoeing (5.79 and 5.89 g). While in 2007, these were at par (6.15 and 6.09g).

Sub plot treatments showed significant influence on crop dry matter production at 40 DAS. Higher values were found in plots with hand weeding and pretilachlor + hand weeding (5.83 and 5.77 g) during 2006. In 2007, pretilachlor sprayed plots exhibited superiority over hand weeded plots. During both years, dry weights were lower in unweeded and cowpea grown plots. Stale seed bed (14 days) with two hoeings either with pretilachlor + hand weeding or hand weeding twice gave significantly higher crop dry matter production during both years of study.

At 60 DAS, stale seed bed for 14 days with two hoeings or one hoeing were statistically on a par. The least values were found in normal seed bed (14.42 and 14.56 g). The plots with *in situ* green manuring of cowpea showed superior value of 16.77 g and pre emergence spraying of pretilachlor gave a dry matter of 16.66 g during 2006. Spraying of pretilachlor followed by hand weeding twice favoured higher dry matter production during 2007.

During 2006, higher dry matter of 17.04 g was noticed in plots with cowpea under stale seed bed for 7 days. This was on a par with stale seed bed for 14 days (two hoeings) along with pretilachlor + hand weeding, stale seed bed for 14 days with one hoeing followed either by hand weeding twice or pretilachlor + hand weeding (Table 51). During

2007, pretilachlor + hand weeding under stale seed bed for 7 days produced the highest dry weight of 19.50g. During both years unweeded plots of normal seed bed recorded lower values of 12.7.g and 11.94g.

Table 52 shows the crop dry matter production at harvest stage. At this stage, stale seed bed plots produced significantly higher dry matter over normal seed bed. The stale seed bed for 14 days with two or one hoeing were at par and superior to stale seed bed for 7 days and normal seed bed.

Among the sub plot treatments, *in situ* green manuring of cowpea at 30 DAS significantly improved the crop dry weight during 2006 (35.93g). On the other hand, during 2007 it was the highest in pretilachlor sprayed plots (37.70g). Lower values of 29.32g and 27.71g were computed from unweeded plots. Stale seed bed for 7 days combined with cowpea gave the highest dry weight of 36.76 g during 2006 and stale seed bed for 7 days with pretilachlor + hand weeding recorded the highest dry weight of 38.60g during 2007.

2.2.4. Chlorophyll content of leaves

Chlorophyll ‘a’ content of the index leaf at maximum tillering stage of the crop as influenced by treatments is presented in Table 53. During 2006, chlorophyll ‘a’ was higher in stale seed bed for 14 days (two hoeings) and in stale seed bed for 7 days which were at par. In 2007, chlorophyll ‘a’ content was the least in normal seed bed. Other seed bed techniques were at par. Among the weed control methods, pretilachlor sprayed plots showed higher chlorophyll ‘a’ content during both years (1.25 mgg^{-1} and 1.30 mgg^{-1}). Plots with cowpea showed the lowest value.

During 2006, the lowest content of chlorophyll ‘a’ was noticed in cowpea grown plots of normal seed bed. It was on a par with cowpea grown plots of stale seed bed for 14 days (two hoeings) and unweeded plots of normal seed bed.

Table 53. Chlorophyll 'a' content of leaves at maximum tillering (on fresh weight basis mg g^{-1})

Main plot / Sub plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	1.10^{fgh}	1.09^{hij}	1.23^{abcd}	1.18^{cdefg}	1.28^{a}	1.12^{fghi}	1.21^{abcde}	1.23^{bcd}	1.20^{dc}	1.15^{c}
HW(20 and 40)	1.22^{abcde}	1.17^{cdefgh}	1.25^{ab}	1.20^{cdef}	1.28^{a}	1.25^{abc}	1.24^{abc}	1.22^{cde}	1.25^{a}	1.21^{b}
Pretilachor + HW	1.23^{abcd}	1.30^{ab}	1.22^{abcde}	1.31^{ab}	1.25^{ab}	1.32^{a}	1.26^{ab}	1.25^{abc}	1.24^{ab}	1.30^{a}
CW(20)+HW(40)	1.27^{a}	1.11^{ghi}	1.28^{a}	1.16^{defgh}	1.24^{abc}	1.21^{cde}	1.15^{defg}	1.19^{cdefg}	1.23^{abc}	1.17^{c}
CW(20 and 40)	1.17^{bcdef}	1.13^{efghi}	1.28^{a}	1.15^{defgh}	1.21^{abcde}	1.19^{cdef}	1.14^{efg}	1.19^{cdef}	1.20^{c}	1.17^{c}
Cowpea	1.06^{h}	1.05^{ij}	1.15^{defg}	1.05^{ij}	1.16^{cdefg}	1.06^{ij}	1.09^{gh}	1.02^{j}	1.11^{d}	1.04^{d}
Main plot mean	1.18^{b}	1.14^{b}	1.24^{a}	1.17^{a}	1.24^{ab}	1.19^{a}	1.18^{b}	1.18^{a}		

Table 54. Chlorophyll 'b' content of leaves at maximum tillering (on fresh weight basis mg g^{-1})

Main plot / Sub plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	0.83^{e}	0.80^{k}	0.92^{bc}	0.81^{jk}	0.87^{cde}	0.87^{de}	0.89^{cd}	0.84^{ghi}	0.88^{c}	0.83^{d}
HW(20 and 40)	0.93^{bc}	0.87^{d}	0.93^{bc}	0.86^{de}	0.90^{bcd}	0.84^{fgh}	0.90^{bcd}	0.82^{ij}	0.91^{b}	0.85^{c}
Pretilachor + HW	0.90^{bcd}	0.89^{c}	0.85^{de}	0.86^{def}	0.92^{bc}	0.86^{de}	0.88^{cde}	0.86^{de}	0.89^{bc}	0.87^{b}
CW(20)+HW (40)	0.90^{bcd}	0.82^{ijk}	0.93^{bc}	0.83^{hij}	0.92^{bc}	0.86^{def}	0.88^{cde}	0.82^{ijk}	0.91^{b}	0.83^{d}
CW(20 and 40)	0.90^{bcd}	0.83^{hij}	0.95^{ab}	0.85^{efg}	0.92^{bc}	0.83^{ghij}	0.88^{cde}	0.83^{hij}	0.91^{b}	0.84^{d}
Cowpea	1.00^{a}	0.97^{b}	0.99^{a}	0.97^{b}	1.00^{a}	0.98^{ab}	1.00^{a}	0.99^{a}	1.00^{a}	0.98^{a}
Main plot mean	0.91^{a}	0.86^{a}	0.93^{a}	0.86^{a}	0.92^{a}	0.87^{a}	0.90^{a}	0.86^{a}		

Table 55. Total chlorophyll content of leaves at maximum tillering (on fresh weight basis mg g^{-1})

Main plot / Sub plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	1.91^{e}	1.91^{h}	2.18^{abcd}	2.01^{efg}	2.16^{abcd}	2.02^{defg}	2.10^{abcd}	2.06^{cdef}	2.09^{c}	2.00^{c}
HW(20 and 40)	2.14^{abcd}	2.04^{cdef}	2.19^{abc}	2.08^{cde}	2.21^{ab}	2.10^{bcd}	2.14^{abcd}	2.04^{cdef}	2.17^{ab}	2.07^{b}
Pretilachor + HW	2.14^{abcd}	2.21^{a}	2.24^{a}	2.18^{ab}	2.17^{abcd}	2.18^{ab}	2.17^{abcd}	2.12^{bc}	2.18^{a}	2.17^{a}
CW(20)+HW (40)	2.16^{abcd}	1.94^{gh}	2.20^{ab}	2.00^{efg}	2.15^{abcd}	2.07^{cde}	2.05^{cd}	2.03^{defg}	2.14^{abc}	2.01^{c}
CW(20 and 40)	2.08^{bcd}	1.98^{fgh}	2.24^{a}	2.00^{efg}	2.13^{abcd}	2.04^{cdef}	2.04^{d}	2.02^{defg}	2.12^{abc}	2.01^{c}
Cowpea	2.05^{cd}	2.04^{cdef}	2.19^{abc}	2.04^{cdef}	2.16^{abcd}	2.04^{cdef}	2.08^{bcd}	2.01^{efg}	2.12^{bc}	2.03^{bc}
Main plot mean	2.08^{b}	2.02^{b}	2.21^{a}	2.05^{ab}	2.17^{a}	2.07^{a}	2.10^{b}	2.05^{ab}		

Table 56. Chlorophyll 'a' content of leaves at panicle initiation (on fresh weight basis mg g^{-1})

Main plot / Sub plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeing		Stale (14 days) + one hoeings		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	1.02^{d}	1.07^{n}	1.10^{c}	1.14^{m}	1.21^{a}	1.24^{ij}	1.13^{bc}	1.21^{k}	1.11^{c}	1.17^{e}
HW(20 and 40)	1.18^{ab}	1.25^{i}	1.21^{a}	1.30^{efg}	1.22^{a}	1.36^{bc}	1.20^{a}	1.28^{h}	1.20^{a}	1.30^{c}
Pretilachor + HW	1.18^{ab}	1.37^{ab}	1.19^{a}	1.38^{a}	1.20^{a}	1.36^{abc}	1.21^{a}	1.32^{de}	1.20^{a}	1.36^{a}
CW(20)+HW (40)	1.12^{bc}	1.31^{def}	1.20^{a}	1.30^{fgh}	1.20^{a}	1.34^{c}	1.20^{a}	1.30^{efgh}	1.18^{ab}	1.31^{b}
CW(20 and 40)	1.10^{c}	1.32^{de}	1.16^{ab}	1.29^{gh}	1.16^{ab}	1.32^{d}	1.20^{a}	1.31^{def}	1.16^{b}	1.31^{b}
Cowpea	1.07^{cd}	1.21^{k}	1.10^{c}	1.26^{i}	1.07^{c}	1.23^{j}	1.07^{c}	1.18^{l}	1.08^{d}	1.22^{d}
Main plot mean	1.11^{c}	1.26^{b}	1.16^{b}	1.28^{b}	1.18^{a}	1.31^{a}	1.17^{a}	1.27^{b}		

During 2007, significantly higher content was observed in stale seed bed for 14 days with two hoeings and pretilachlor spray. It was on a par with pretilachlor in combination with other three stale seed bed treatments. Combination of cowpea with stale seed bed for 14 days (one hoeing) showed the lowest chlorophyll 'a' content.

Chlorophyll 'b' content of index leaves showed no significant variation between main plot treatments during both years (Table 54). Among the sub plot treatments, the highest content of chlorophyll 'b' was noticed in cowpea grown plots (0.98 and 1.00 mg). Higher values for chlorophyll 'b' contents were noticed in cowpea with normal seed bed and stale seed beds. The lowest values were found in plots with no weeding under normal seedbed situation.

Total chlorophyll content was better in stale seed bed for 14 days (two hoeings). During 2006, this treatment was on a par with stale seed bed for 7 days. Plots that received pretilachlor spray had higher total chlorophyll contents of 2.18 mgg^{-1} and 2.07 mgg^{-1} respectively during 2006 and 2007 (Table 55). Pre emergence spraying of pretilachlor showed maximum values of total chlorophyll (2.24 mgg^{-1}) during 2006. This treatment was on a par with cono weeding under stale seed bed for 7 days. The lowest total chlorophyll was noticed in normal seed bed with no weeding. During 2007, pre - emergence spraying of pretilachlor resulted in significantly higher and no weeding had lower values of total chlorophyll (2.21mgg^{-1} and 1.91 mg^{-1}).

Chlorophyll 'a' contents at panicle initiation stage as affected by treatments is given in Table 56. Higher chlorophyll 'a' values of 1.18 mgg^{-1} and 1.31 mgg^{-1} during 2006 and 2007 were noticed in stale seed bed for 14 days with two hoeings followed by stale seed bed for 14 days with one hoeing. Higher values among the sub plot treatments were noticed in pretilachlor sprayed plots. Unweeded plots produced the lowest chlorophyll 'a' content. During 2006, chlorophyll 'a' content was higher in hand weeded plots of stale seed bed (14 days with two hoeings). During 2007, stale seed bed for 7 days with pretilachlor + hand weeding showed highest content of 1.38 mgg^{-1} and was on a par with pretilachlor sprayed plots of normal seed bed and stale seed bed for 14 days with two hoeings. Chlorophyll ‘b’ content at the panicle initiation stage showed no significant variation among main plots. Concurrent growing of cowpea with rice significantly increased the content. Combination of cowpea with all four main plot treatments improved chlorophyll ‘b’ values. Unweeded plots of normal seed bed recorded the lowest chlorophyll ‘b’ values (Table 57).

Stale seed beds either for 7 or 14 days (with one or two hoeings) recorded on a par values for total chlorophyll contents at panicle initiation stage during 2006 (Table 58). On the other hand, during 2007, stale seed bed for 14 days with two hoeings was significantly superior. Normal seed bed gave lower values during both years. Unweeded plots of stale seed bed for 14 days with two hoeings and pretilachlor sprayed plots of stale seed bed for 7 days recorded significantly higher total chlorophyll values during the years 2006 and 2007 respectively.

Leaf area index (LAI)

Leaf area index of rice at 20 DAS as influewnced by treatments is presented in Table 59. During 2006, the normal seed bed recorded the lowest LAI of 2.96. Other main plot treatments were at par. During 2007, stale seed bed for 14 days with two hoeings recorded significantly higher LAI of 2.75 followed by stale seed bed for 14 days with one hoeing (2.66). Plots which received no weed control measures up to 20 DAS showed lower LAI values as compared to plots with weed control measures (pretilachlor and cowpea intercropping) during 2006.

Table 57. Chlorophyll 'b' content of leaves at panicle initiation (on fresh weight basis mg g^{-1})

Main plot / Sub plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	0.83^{e}	0.88^{e}	0.87^{de}	0.92^{cde}	0.94^{abc}	0.98^{abc}	0.87^{de}	0.92^{cde}	0.88b^{c}	0.92^{c}
HW(20 and 40)	0.85^{de}	0.90^{de}	0.86^{de}	0.91^{de}	0.88^{cde}	0.92^{cde}	0.89^{cde}	0.94^{cde}	0.87^{c}	0.91^{c}
Pretilachor + HW	0.89^{cde}	0.93^{cde}	0.91^{bcd}	0.95^{bcd}	0.91^{bcd}	0.96^{bcd}	0.89^{cde}	0.93^{cde}	0.90^{b}	0.94^{b}
CW(20)+HW (40)	0.88^{cde}	0.92^{cde}	0.87^{de}	0.91^{de}	0.88^{cde}	0.93^{cde}	0.90^{cd}	0.94^{cde}	0.88^{bc}	0.93^{b}
CW(20 and 40)	0.90^{bcd}	0.94^{cde}	0.89^{cde}	0.93^{cde}	0.89^{cde}	0.94^{cde}	0.90^{bcd}	0.95^{bcd}	0.90^{bc}	0.94^{b}
Cowpea	0.97^{a}	1.02^{a}	0.96^{ab}	1.00^{ab}	0.98^{a}	1.00^{ab}	0.99^{a}	1.03^{a}	0.97^{a}	1.00^{a}
Main plot mean	0.89^{a}	0.93^{a}	0.89^{a}	0.93^{a}	0.91^{a}	0.96^{a}	0.91^{a}	0.95^{a}		

Table 58. Total chlorophyll content of leaves at panicle initiation (on fresh weight basis mg g^{-1})

Main plot / Sub plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	1.87^{b}	1.95^{i}	1.98^{ab}	2.06^{h}	2.15^{a}	2.22^{def}	2.00^{ab}	2.13^{g}	2.00^{ab}	2.09^{d}
HW(20 and 40)	1.39^{c}	2.15^{g}	2.09^{ab}	2.21^{f}	2.10^{ab}	2.28^{abcd}	2.09^{ab}	2.22^{ef}	1.92^{b}	2.21^{c}
Pretilachor + HW	2.09^{ab}	2.30^{abc}	2.12^{ab}	2.33^{a}	2.11^{ab}	2.32^{ab}	2.11^{ab}	2.25^{cdef}	2.11^{a}	2.30^{a}
CW(20)+HW (40)	2.01^{ab}	2.23^{def}	2.07^{ab}	2.21^{ef}	2.09^{ab}	2.27^{bcde}	2.11^{ab}	2.24^{cdef}	2.07^{a}	2.24^{bc}
CW(20 and 40)	2.01^{ab}	2.26^{bcdef}	2.05^{ab}	2.22^{def}	2.05^{ab}	2.26^{bcdef}	2.12^{ab}	2.26^{bcdef}	2.06^{a}	2.25^{b}
Cowpea	2.03^{ab}	2.23^{def}	2.06^{ab}	2.26^{bcdef}	2.05^{ab}	2.26^{bcdef}	2.06^{ab}	222^{ef}	2.05^{a}	2.24^{bc}
Main plot mean	1.90^{b}	2.19^{b}	2.06^{a}	2.21^{a}	2.09^{a}	2.27^{a}	2.08^{a}	2.22^{a}		

Table 59. Leaf area index of rice at 20 DAS as influenced by treatments

Sub plot \ Main plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	2.93^{a}	2.50^{g}	2.97^{a}	2.55^{fg}	3.05^{a}	2.68^{cde}	3.01^{a}	2.59^{efg}	2.99^{d}	2.58^{c}
HW(20 and 40)	2.95^{a}	2.55^{fg}	3.04^{a}	2.62^{def}	3.06^{a}	2.81^{ab}	3.06^{a}	2.71^{bcd}	3.03^{b}	2.67^{b}
Pretilachor + HW	2.95^{a}	2.60^{efg}	3.01^{a}	2.74^{abc}	3.06^{a}	2.82^{a}	3.01^{a}	2.81^{ab}	3.01^{c}	2.74^{a}
CW(20)+HW (40)	2.99^{a}	2.51^{g}	3.06^{a}	2.78^{abc}	3.07^{a}	2.80^{ab}	3.05^{a}	2.75^{abc}	3.04^{a}	2.71^{ab}
CW(20 and 40)	3.02^{a}	2.53^{fg}	3.06^{a}	2.77^{abc}	3.05^{a}	2.80^{ab}	3.06^{a}	2.77^{abc}	3.05^{a}	2.72^{ab}
Cowpea	2.90^{a}	2.36^{h}	3.01^{a}	2.51^{fg}	3.01^{a}	2.59^{efg}	3.01^{a}	2.59^{efg}	2.98^{e}	2.51^{d}
Main plot mean	2.96^{b}	2.51^{d}	3.02^{a}	2.66^{c}	3.05^{a}	2.75^{a}	3.03^{a}	2.70^{b}		

Table 60. Leaf area index of rice at 40 DAS as influenced by treatments

Sub plot \ Main plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	3.73^{k}	2.79^{i}	4.00^{j}	2.85^{h}	4.31^{h}	3.06^{ef}	4.25^{i}	3.02^{efg}	4.07^{d}	2.93^{d}
HW(20 and 40)	4.45^{bcde}	3.01^{fg}	4.51^{a}	3.07^{e}	4.47^{abc}	3.26^{ab}	4.47^{abc}	3.16^{d}	4.48^{a}	3.12^{c}
Pretilachor + HW	4.45^{bcde}	3.05^{ef}	4.46^{abcd}	3.20^{cd}	4.43^{cdef}	3.28^{a}	4.39^{efg}	3.26^{ab}	4.43^{b}	3.20^{a}
CW(20)+HW (40)	4.45^{bcde}	2.96^{g}	4.50^{ab}	3.23^{abc}	4.39^{fg}	3.25^{abc}	4.47^{abc}	3.20^{bcd}	4.45^{b}	3.16^{b}
CW(20 and 40)	4.45^{abcd}	2.98^{g}	4.44^{bcdef}	3.22^{abc}	4.43^{cdef}	3.25^{abc}	4.43^{cdef}	3.22^{abc}	4.44^{b}	3.17^{b}
Cowpea	4.36^{gh}	2.79^{i}	4.36^{gh}	2.88^{h}	4.40^{defg}	3.04^{ef}	4.43^{cdef}	3.01^{fg}	4.39^{c}	2.93^{d}
Main plot mean	4.32^{b}	2.93^{d}	4.38^{b}	3.07^{c}	4.41^{a}	3.19^{a}	4.41^{a}	3.15^{b}		

Table 61. Leaf area index of rice at 60 DAS as influenced by treatments

Main plot / Sub plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	3.84b[c]	3.09[l]	4.05[abc]	3.31[k]	4.67[ab]	3.54[efg]	4.58[ab]	3.46[h]	4.29[b]	3.35[e]
HW(20 and 40)	4.85[ab]	3.49[gh]	4.94[a]	3.55[ef]	4.97[a]	3.74[ab]	4.93[a]	3.64[d]	4.92[a]	3.61[c]
Pretilachor + HW	4.93[a]	3.53[efg]	4.98[a]	3.68[cd]	4.96[a]	3.76[a]	4.98[a]	3.74[ab]	4.96[a]	3.68[a]
CW(20)+HW (40)	4.87[a]	3.44[h]	3.47[c]	3.71[abc]	4.89[a]	3.73[abc]	4.91[a]	3.69[bcd]	4.54[ab]	3.64[b]
CW(20 and 40)	4.90[a]	3.43[hi]	4.98[a]	3.68[cd]	4.94[a]	3.73[abc]	4.92[a]	3.68[cd]	4.94[a]	3.63[bc]
Cowpea	4.70[ab]	3.34[jk]	4.75[ab]	3.38[ij]	4.73[ab]	3.58[e]	4.68[ab]	3.52[fg]	4.72[ab]	3.46[d]
Main plot mean	4.68[a]	3.39[c]	4.53[a]	3.55[b]	4.86[a]	3.68[a]	4.83[a]	3.62[a]		

During 2007, plots that received pretilachlor produced the highest leaf area index. Concurrent growing of cowpea significantly lowered the leaf area index of rice during both years. Lower LAI was noticed in normal seed bed with cowpea green manuring (2.90 and 2.36 during 2006 and 2007 respectively).

At 40 DAS, higher LAI was observed in stale seed bed for 14 days (with one or two hoeings). Stale seed bed for 7 days and normal seed bed were at par during 2006. Stale seed bed for 14 days with two hoeings recorded the highest LAI of 3.19 during 2007 followed by stale seed bed for 14 days with one hoeing (3.15). During both years, normal seed bed showed the lowest LAI.

Among weed control treatments, LAI was the highest in hand weeded plots (4.48) and pretilachlor sprayed plots (3.20) during 2006 and 2007 respectively. *In situ* green manuring with cowpea and no weeding resulted in reduction in LAI (Table 60).

At 60 DAS during 2006, LAI values showed no significant variation between main plot treatments, however, during 2007, stale seed bed for 14 days with two or one hoeing showed significantly higher values. Pretilachlor + hand weeding treatment showed the maximum leaf area index. This was on a par with hand weeding twice and cono weeding followed by hand weeding during 2006. The highest LAI of 3.68 was noticed in pretilachlor sprayed plots during 2007. Unweeded plots showed the lowest LAI value of 3.35 (Table 61).

considering the interaction effects during 2006 showed that the leaf area index values was the lowest in plots with cono weeding at 20 DAS followed by hand weeding at 40 DAS (3.47) uring 2006. It was on a par with unweeded plots of normal seed bed and stale seed bed for 7 days. During 2007, stale seed bed for 14 days (two hoeings) with pretilachlor + hand weeding and unweeded plots of normal seed bed showed the highest and lowest values for leaf area index.

Grain and straw yield

Grain yield

Grain yield of rice was higher (3207 kg ha^{-1} and 3097 kg ha^{-1} during 2006 and 2007) in plots with stale seed bed for 14 days (two hoeings). During 2006, it was on a par with stale seed bed for 14 days with one hoeing (3152 kg ha^{-1}). The normal seed bed produced the lowest grain yield of 2626 kg ha^{-1} and 2559 kg ha^{-1} respectively during 2006 and 2007 (Table 62).

In situ green manuring with cowpea produced higher grain yield of 3269 kg ha^{-1}during 2006. This treatment was on a par with pre - emergence spraying of pretilachlor followed by hand weeding at 40 DAS (3218 kg ha^{-1}). During 2007, pretilachlor + hand weeding recorded the highest grain yield of 3201 kg ha^{-1}. During both years, grain yield was the lowest in unweeded plots (1777 kg ha^{-1} and 1667 kg ha^{-1}).

Concurrent growing of cowpea in stale seed bed for 7 days produced significantly higher grain yield of 3330 kg ha^{-1} during 2006. It was on a par with hand weeding twice, pretilachlor + hand weeding and cowpea inter cropping all in stale seed bed for 14 days with two hoeings, pretilachlor + hand weeding in stale seed bed for 7 days, pretilachlor + hand weeding or cowpea inter cropping in stale seed bed for 14 days with one hoeing and cowpea inter cropping in normal seed bed.

During 2007, the plots which received pretilachlor spray at 3 DAS followed by hand weeding on 40 DAS under stale seed bed for 14 days with two hoeings or in stale seed bed for 7 days recorded superior grain yields of 3327 kg ha^{-1} and 3277 kg ha^{-1}. During both years, lowest grain yield (378 kg ha^{-1} and 583 kg ha^{-1}) was noticed in plots with no weeding under normal seed bed.

Table 62. Effect of treatments on grain yield of rice (kg ha^{-1})

Sub plot \ Main plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	378^{k}	583^{l}	627^{j}	820^{k}	3089^{efgh}	2728^{i}	3013^{h}	2535^{j}	1777^{c}	1667^{d}
HW(20 and 40)	2840^{i}	2898^{h}	3033^{gh}	2943^{gh}	3287^{ab}	3125^{bcd}	3167^{bcdef}	3020^{efg}	3082^{b}	2997^{c}
Pretilachor + HW	3125^{cdefgh}	3028^{defg}	3243^{abc}	3277^{a}	3263^{ab}	3327^{a}	3242^{abc}	3172^{b}	3218^{a}	3201^{a}
CW(20)+HW (40)	3170^{bcdef}	3025^{efg}	3058^{fgh}	3138^{bc}	3138^{cdefg}	3150^{bc}	3132^{cdefg}	3062^{cdef}	3125^{b}	3094^{b}
CW(20 and 40)	3013^{h}	2808^{i}	3133^{cdefg}	3008^{fg}	3187^{bcde}	3085^{bcdef}	3117^{defgh}	3100^{bcdef}	3113^{b}	3000^{c}
Cowpea	3230^{abcd}	3012^{efg}	3330^{a}	3073^{bcdef}	3277^{ab}	3168^{b}	3240^{abc}	3112^{bcde}	3269^{a}	3091^{b}
Main plot mean	2626^{c}	2559^{d}	2737^{b}	2710^{c}	3207^{a}	3097^{a}	3152^{a}	3000^{b}		

Table 63. Effect of treatments on straw yield of rice (kg ha^{-1})

Sub plot \ Main plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	258^{g}	425^{k}	360^{f}	610^{j}	1417^{bcd}	1892^{ab}	1387^{bcd}	1812^{cd}	856^{d}	1185^{d}
HW(20 and 40)	1350^{cd}	1500^{hi}	1267^{e}	1778^{def}	1417^{bcd}	1885^{abc}	1395^{bcd}	1817^{bcd}	1357^{c}	1745^{ab}
Pretilachor + HW	1383^{bcd}	1575^{g}	1433^{bc}	1802de	1517^{a}	1903^{a}	1413^{bcd}	1830^{abcd}	1437^{a}	1777^{a}
CW(20)+HW (40)	1417^{bcd}	1553^{gh}	1340de	1765^{def}	1433^{bc}	1812^{cd}	1350^{cd}	1823^{bcd}	1385^{bc}	1738^{b}
CW(20 and 40)	1455^{ab}	1592^{g}	1408^{bcd}	1725^{ef}	1433^{bc}	1782^{def}	1416^{bcd}	1798de	1428^{a}	1724^{b}
Cowpea	1347^{cd}	1475^{i}	1403^{bcd}	1715^{f}	1420^{bcd}	1768^{def}	1450^{ab}	1788^{def}	1405^{ab}	1687^{c}
Main plot mean	1202^{c}	1353^{c}	1202^{b}	1566^{b}	1440^{a}	1840^{a}	1402^{a}	1812^{a}		

Straw yield

Straw yield of rice was higher in stale seed bed plots. Stale seed bed for 14 days with one or two hoeings were at par. Sowing of seeds in normal seed bed produced lower straw yield (1202 kg ha^{-1} and 1353 kg ha^{-1} during 2006 and 2007 respectively). The plots that received pretilachlor + hand weeding produced the highest straw yield (1777 kg ha^{-1}) during 2006. It was on a par with hand weeded plots (1745 kg ha^{-1}). Higher straw yield of 1437 kg ha^{-1} and 1428 kg ha^{-1} during 2007 were recorded by pretilachlor + hand weeding and plots with cono weeding twice (Table 63).

Pre - emergence spraying of pretilachlor followed by hand weeding in combination with stale seed bed for 14 days significantly increased the straw yield during both years (1903 kg ha^{-1} and 1517 kg ha^{-1}). Straw yield was the lowest in unweeded plots of normal seed bed.

Yield attributes

Plants grown in stale seed bed for 14 days with one or two hoeings produced higher panicle length of 21.72 cm and 21.42 cm during 2006 and 20.58 cm and 20.54 cm during 2007 (Table 64). During 2006, cowpea grown plots showed maximum panicle length of 21.94 cm. The highest panicle length of 20.98 cm was observed in plot with pretilachlor + hand weeding followed by plots with cowpea (20.37 cm). The lowest panicle length of 19.44 cm was observed in unweeded plots.

During 2006 the combination of stale seed bed for 7 days with cowpea gave higher panicle length. However, during 2007, combination of pretilachlor + hand weeding with stale seed bed for 14 days with one or two hoeings gave the maximum panicle length.

Table 64. Effect of treatments on panicle length (cm)

Main plot / Sub plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	17.47^{h}	17.13^{h}	18.13^{g}	18.10^{g}	20.82^{e}	20.30^{bcd}	21.33^{bcd}	20.04^{bcde}	19.44^{d}	18.89^{e}
HW(20 and 40)	20.84^{de}	19.52^{ef}	20.14^{f}	19.69^{def}	21.53^{abc}	20.59^{b}	21.63^{ab}	20.37^{bc}	21.04^{c}	20.04^{cd}
Pretilachor + HW	21.59^{ab}	20.26^{bcd}	21.67^{ab}	20.51^{b}	20.94^{de}	21.71^{a}	21.93^{a}	21.43^{a}	21.53^{b}	20.98^{a}
CW(20)+HW (40)	21.34^{bcd}	19.70^{def}	20.66^{e}	19.86^{cdef}	21.59^{ab}	20.57^{b}	21.91^{a}	20.41^{bc}	21.38^{b}	20.13^{bc}
CW(20 and 40)	21.08^{cde}	19.57^{ef}	21.60^{ab}	19.32^{f}	21.68^{ab}	20.11^{bcde}	21.73^{ab}	20.38^{bc}	21.52^{b}	19.85^{d}
Cowpea	21.93^{a}	20.20^{bcd}	22.03^{a}	20.47^{bc}	21.98a	20.17^{bcd}	21.81^{ab}	20.64^{b}	21.94^{a}	20.37^{b}
Main plot mean	20.71^{b}	19.40^{b}	20.71^{b}	19.66^{b}	21.42^{a}	20.58^{a}	21.72^{a}	20.54^{a}		

Table 65 Effect of treatments on number of filled grains/panicle

Main plot / Sub plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	54^{l}	50^{m}	66^{k}	63^{l}	74^{j}	77^{j}	81^{i}	72^{k}	69^{e}	66^{c}
HW(20 and 40)	83^{hi}	87^{ghi}	88^{efg}	90^{defg}	97^{ab}	97^{ab}	86^{fgh}	88^{fghi}	89^{c}	90^{b}
Pretilachor + HW	86^{fgh}	88^{fghi}	92^{de}	93^{bcdef}	96^{bc}	100^{a}	90^{def}	95^{abcde}	91^{b}	94^{a}
CW(20)+HW (40)	87^{fgh}	83^{hi}	87^{fgh}	89^{efgh}	88^{efg}	94^{abcde}	88^{efgh}	92^{bcdefg}	87^{cd}	90^{b}
CW(20 and 40)	85^{ghi}	82^{ij}	87^{fgh}	86^{ghi}	88^{efg}	91^{cdefg}	87^{fgh}	92^{bcdefg}	87^{d}	88^{b}
Cowpea	92^{cd}	89^{defgh}	101^{a}	97^{abc}	98^{ab}	98^{ab}	96^{bc}	95^{abcd}	97^{a}	95^{a}
Main plot mean	81^{d}	80^{d}	87^{c}	86^{c}	90^{a}	93^{a}	88^{b}	89^{b}		

Table 66. Effect of treatments on 1000 grain weight (g)

Main plot / Sub plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	26.23^{j}	25.43^{n}	26.57^{j}	26.14^{m}	28.50^{ghi}	28.43^{jk}	28.43^{hi}	27.76^{l}	27.43^{f}	26.94^{d}
HW(20 and 40)	29.60^{bc}	28.23^{k}	29.57^{bc}	28.94^{ghi}	30.10^{a}	29.36^{bcdef}	29.75^{ab}	29.06^{efghi}	29.75^{c}	28.90^{bc}
Pretilachor + HW	29.10^{de}	29.00^{fghi}	29.23^{cd}	29.17^{cdefgh}	29.83^{ab}	29.80^{a}	29.93^{ab}	29.54^{abc}	29.52^{b}	29.38^{a}
CW(20)+HW (40)	28.67^{fghi}	28.55^{jk}	28.63^{fghi}	28.71^{ij}	28.63^{fghi}	29.61^{ab}	29.00^{def}	29.26^{bcdefg}	28.73^{d}	29.03^{b}
CW(20 and 40)	28.30^{i}	28.27^{k}	28.73^{efghi}	28.80^{hij}	28.87^{defgh}	29.07^{efghi}	28.90^{defg}	29.00^{fghi}	28.70^{e}	28.78^{c}
Cowpea	29.73^{ab}	29.09^{efghi}	29.63^{bc}	29.14^{defgh}	29.97^{ab}	29.51^{abcd}	29.63^{bc}	29.45^{abcde}	29.74^{a}	29.30^{a}
Main plot mean	28.61^{b}	28.10^{d}	28.73^{b}	28.48^{c}	29.32^{a}	29.30^{a}	29.27^{a}	29.01^{b}		

Table 67. Effect of treatments on number of productive tillers/m^{2}

Main plot / Sub plot	Normal dry dibbling		Stale (7 days)		Stale (14 days) + two hoeings		Stale (14 days) + one hoeing		Sub plot mean	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
NW	165^{g}	163^{l}	194^{f}	217^{k}	319^{d}	305^{h}	309^{e}	270^{j}	247^{c}	239^{c}
HW(20 and 40)	375^{bc}	293^{i}	381^{abc}	319^{defg}	381^{ab}	338^{ab}	378^{abc}	330^{abcd}	379^{b}	320^{b}
Pretilachor + HW	379^{abc}	314^{fgh}	382^{ab}	332^{abc}	385^{ab}	325^{cdef}	388^{a}	332^{abcd}	383^{ab}	326^{ab}
CW(20)+HW (40)	384^{ab}	314^{fgh}	382^{ab}	334^{abc}	387^{a}	330^{abcd}	387^{a}	328^{abcde}	385^{a}	327^{a}
CW(20 and 40)	386^{ab}	316^{efgh}	385^{ab}	322^{cdef}	386^{ab}	326^{bcdef}	385^{ab}	331^{abcd}	385^{a}	324^{ab}
Cowpea	371^{c}	316^{efgh}	386^{a}	341^{a}	385^{ab}	333^{abc}	382^{ab}	308^{gh}	381^{ab}	324^{ab}
Main plot mean	343^{d}	286^{c}	352^{c}	311^{b}	374^{a}	326^{a}	371^{b}	317^{a}		

Number of filled grains per panicle produced by the crop during 2006 and 2007 are presented in Table 65. Stale seed bed for 14 days with two hoeings recorded higher number of filled grains per panicle during 2006 and 2007 (90 and 93). The normal seed bed recorded less number of filled grains per panicle.

Concurrent growing of cowpea and its incorporation at 30 DAS significantly increased the number of filled grains per panicle. This was on a par with pretilachlor + hand weeding. Significantly lower grain number was noticed in plots with no weeding. During 2006, pretilachlor + hand weeding under stale seed bed for 14 days with two hoeings recorded higher number of filled grains (101). This was on a par with cowpea grown and hand weeded plots of stale seed bed for 14 days (two hoeings). During 2007, pretilachlor + hand weeding was the best treatment and the unweeded plots of normal seed bed produced lowest number.

During 2006, the highest 1000 grain weight was recorded in stale seed bed for 14 days with two hoeings (29.32 g) and it was on a par with stale seed bed for 14 days with one hoeing (29.27 g) during 2006. Among the sub plot treatments, 1000 grain weight of 29.74 g and 29.30 g were noticed in plots with cowpea during 2006 and 2007.

Plots with cono weeding twice at 20 DAS and 40 DAS recorded significantly lower test weight than cono weeding at 20 DAS followed by hand weeding at 40 DAS. The lowest 1000 grain weight was noticed in plots with no weeding. Stale seed bed for 14 days (two hoeings) along with hand weeding twice at 20 and 40 DAS or Rift at 3 DAS followed by hand weeding at 40 DAS produced higher 1000 grain weights of 30.10 g and 29.80 g respectively during 2006 and 2007 (Table 66).

Number of productive tillers

The number of productive tillers per m^2 at harvest stage as inluenced by treatments is given in Table 67. Productive tillers were higher in plots with stale seed bed for 14 days (two hoeings) followed by stale seed bed for 14 days with one hoeing. Normal seed bed produced the lowest number of productive tillers per m^2.

During 2006, the number of productive tillers was higher in plots with cono weeding twice and cono weeding followed by hand weeding. During 2007, plots with cono weeding followed by hand weeding recorded higher number of productive tillers and was on a par with pretilachlor + hand weeding, cono weeding twice and *in situ* green manuring with cowpea. During both years, the unweeded plots of normal seed bed recorded lower number of productive tillers followed by those of stale seed bed for 7 days.

4.2.3. Nutrient uptake by crop

Nutrient uptake at maximum tillering

Uptake of nutrients by the crop at maximum tillering stage was higher in stale seed bed for 14 days (two hoeings). The uptake values were 10.06, 0.098 and 10.21 kg ha^{-1} N, P and K respectively during 2006 and 10.50, 1.03 and 10.66 kg ha^{-1} during 2007. During 2007, it was on a par with stale seed bed for 14 days with one hoeing (Table 68). Lower values of nutrient uptake were noticed in plots with normal seed bed during both years.

Pre - emergence spraying of pretilachlor increased uptake of nutrients. During 2006, it was on a par with hand weeded plots. Significantly lower values were observed in plots with no weeding and concurrent growing of cowpea.

Nutrient uptake at panicle initiation

At panicle initiation stage, stale seed bed for 14 days (with one or two hoeings) recorded significantly higher nutrient uptake. During 2006 and 2007, plants in the normal seed bed showed uptake of 21.32 and 32.78 kg ha^{-1} N, 2.44 and 2.72 kg ha^{-1} P and 23.35 and 26.05 kg ha^{-1} K respectively.

Table 68. Uptake of nutrients by rice at maximum tillering (kg ha^{-1})

	2006			2007		
Main plot treatments	N	P	K	N	P	K
Normal dry dibbling	8.81^{d}	0.86^{d}	8.95^{d}	9.62^{c}	0.94^{c}	9.78^{c}
Stale (7 days)	9.39^{c}	0.92^{c}	9.54^{c}	10.00^{b}	0.98^{b}	10.15^{b}
Stale (14 days) + two hoeings	10.06^{a}	0.98^{a}	10.21^{a}	10.50^{a}	1.03^{a}	10.66^{a}
Stale (14 days) + one hoeing	9.89^{b}	0.97^{b}	10.04^{b}	10.39^{a}	1.02^{a}	10.55^{a}
Sub plot treatments						
NW	8.76^{d}	0.86^{d}	8.90^{d}	9.73^{d}	0.95^{d}	9.89^{d}
HW(20 and 40)	9.95^{a}	0.97^{a}	10.11^{a}	10.42^{b}	1.02^{b}	10.59^{b}
Rifit + HW	9.85^{a}	0.96^{a}	10.00^{a}	10.65^{a}	1.04^{a}	10.81^{a}
CW(20)+HW (40)	9.65^{b}	0.94^{b}	9.80^{b}	10.31^{b}	1.01^{b}	10.47^{b}
CW(20 and 40)	9.64^{b}	0.94^{b}	9.79^{b}	10.12^{c}	0.99^{c}	10.28^{c}
Cowpea	9.37^{c}	0.92^{c}	9.52^{c}	9.53^{e}	0.93^{e}	9.68^{e}

Table 69. Uptake of nutrients by rice at panicle initiation (kg ha^{-1})

Main plot treatments	2006			2007		
	N	P	K	N	P	K
Normal dry dibbling	21.32^{c}	2.44^{c}	23.35^{c}	23.78^{c}	2.72^{c}	26.05^{c}
Stale (7 days)	22.35^{b}	2.55^{b}	24.48^{b}	24.89^{b}	2.84^{b}	27.26^{b}
Stale (14 days) + two hoeings	23.00^{a}	2.63^{a}	25.19^{a}	25.26^{a}	2.89^{a}	27.67^{a}
Stale (14 days) + one hoeing	22.89^{a}	2.62^{a}	25.07^{a}	25.36^{a}	2.90^{a}	27.77^{a}
Sub plot treatments						
NW	20.19^{b}	2.31^{b}	22.12^{b}	20.39^{e}	2.33^{e}	22.33^{e}
HW(20 and 40)	22.91^{a}	2.62^{a}	25.09^{a}	26.42^{a}	3.02^{a}	28.94^{a}
Rifit + HW	23.33^{a}	2.67^{a}	25.54^{a}	26.65^{a}	3.05^{a}	29.19^{a}
CW(20)+HW (40)	22.18^{a}	2.54^{a}	25.29^{a}	25.70^{b}	2.94^{b}	28.14^{b}
CW(20 and 40)	22.26^{a}	2.54^{a}	24.38^{a}	25.08^{c}	2.87^{c}	27.46^{c}
Cowpea	23.47^{a}	2.68^{a}	25.71^{a}	24.70^{d}	2.82^{d}	27.05^{d}

Table 70. Uptake of nutrients by rice at harvest (kg ha^{-1})

Main plot treatments	2006			2007		
	N	P	K	N	P	K
Normal dry dibbling	37.51^{d}	6.89^{d}	59.71^{d}	38.43^{d}	7.04^{d}	61.03^{d}
Stale (7 days)	38.61^{c}	7.09^{c}	61.45^{c}	41.91^{c}	7.70^{c}	66.70^{c}
Stale (14 days) + two hoeings	45.53^{a}	8.36^{a}	72.48^{a}	48.39^{a}	8.89^{a}	77.02^{a}
Stale (14 days) + one hoeing	44.63^{b}	8.20^{b}	71.04^{b}	47.15^{b}	8.66^{b}	75.06^{b}
Sub plot treatments						
NW	25.80^{d}	4.74^{d}	41.06^{d}	27.95^{b}	5.13^{b}	44.48^{b}
HW(20 and 40)	43.50^{c}	7.99^{c}	69.25^{c}	46.47^{a}	8.54^{a}	73.97^{a}
Rifit + HW	45.62^{a}	8.38^{a}	72.61^{a}	48.79^{a}	8.96^{a}	77.66^{a}
CW(20)+HW (40)	44.19^{b}	8.12^{b}	70.35^{b}	47.36^{a}	8.70^{a}	75.38^{a}
CW(20 and 40)	44.50^{b}	8.17^{b}	70.83^{b}	46.30^{ab}	8.51^{ab}	73.70^{ab}
Cowpea	45.81^{a}	8.42^{a}	72.92^{a}	46.82^{ab}	8.60^{ab}	74.54^{ab}

Table 71. Uptake of nutrients by grasses at 20 DAS (kg ha^{-1})

Main plot treatments	2006			2007		
	N	P	K	N	P	K
Normal dry dibbling	2.22*[a] (4.43)	1.30[a] (1.19)	2.34[a] (4.98)	2.35[a] (2.68)	1.35[a] (1.46)	2.47[a] (6.35)
Stale (7 days)	1.33[b] (1.27)	0.91[b] (0.33)	1.39[b] (1.43)	1.32[b] (1.31)	0.91[b] (0.34)	1.37[b] (1.47)
Stale (14 days) + two hoeings	1.01[c] (0.52)	0.80[c] (0.14)	1.04[c] (0.58)	1.01[d] (0.55)	0.80[d] (0.14)	1.04[d] (0.61)
Stale (14 days) + one hoeing	1.21[b] (0.96)	0.87[b] (0.26)	1.26[b] (1.09)	1.20[c] (0.98)	0.86[c] (0.25)	1.24[c] (1.10)
Sub plot treatments						
NW	1.58[a] (2.00)	1.02[a] (0.54)	1.65[a] (2.22)	1.73[a] (2.97)	1.08[a] (0.76)	1.81[a] (3.33)
HW(20 and 40)	1.61[a] (2.09)	1.04[a] (0.58)	1.68[a] (2.32)	1.75[a] (3.06)	1.09[a] (0.79)	1.84[a] (3.42)
Rifit + HW	0.93[c] (0.36)	0.77[c] (0.09)	0.95[c] (0.40)	0.91[b] (0.35)	0.77[b] (0.09)	0.93[b] (0.39)
CW(20)+HW (40)	1.67[a] (2.29)	1.06[a] (0.62)	1.75[a] (2.56)	1.69[a] (2.87)	1.07[a] (0.74)	1.77[a] (3.21)
CW(20 and 40)	1.62[a] (2.12)	1.04[a] (0.58)	1.69[a] (2.36)	1.68[a] (2.92)	1.07[a] (0.75)	1.76[a] (3.27)
Cowpea	1.27[b] (1.11)	0.89[b] (0.29)	1.32[b] (1.24)	1.04[b] (0.61)	0.81[b] (0.15)	1.07[b] (0.68)

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

Table 72. Uptake of nutrients by grasses at 40 DAS (kg ha^{-1})

Main plot treatments	2006			2007		
	N	P	K	N	P	K
Normal dry dibbling	2.03*[a] (3.62)	1.02[a] (0.54)	2.15[a] (4.12)	2.69[a] (8..36)	1.22[a] (1.16)	2.86[a] (9.52)
Stale (7 days)	1.85[b] (2.92)	0.96[b] (0.42)	1.95[b] (3.30)	2.17[b] (4.66)	1.05[b] (0.65)	2.30[b] (5.31)
Stale (14 days) + two hoeings	1.69[c] (2.36)	0.91[c] (0.33)	1.78[c] (2.67)	1.58[d] (2.2)	0.89[d] (0.31)	1.66[d] (2.53)
Stale (14 days) + one hoeing	1.82[b] (2.81)	0.95[b] (0.40)	1.92[b] (3.19)	1.86[c] (3.08)	0.96[c] (0.43)	1.97[c] (3.51)
Sub plot treatments						
NW	2.69[a] (6.74)	1.20[a] (0.94)	2.86[a] (7.68)	3.41[a] (12.78)	1.44[a] (1.78)	3.63[a] (14.56)
HW(20 and 40)	1.90[b] (3.11)	0.97[b] (0.44)	2.00[b] (3.50)	1.74[cd] (2.61)	0.93[cd] (0.36)	1.84[cd] (2.97)
Rifit + HW	1.35[c] (1.32)	0.83[c] (0.19)	1.42[c] (1.52)	1.82[c] (3.06)	0.95[c] (0.43)	1.93[c] (3.49)
CW(20)+HW (40)	1.92[b] (3.19)	0.98[b] (0.46)	2.03[b] (3.62)	1.88[bc] (3.18)	0.96[bc] (0.44)	1.99[bc] (3.62)
CW(20 and 40)	1.99[b] (3.46)	0.99[b] (0.48)	2.11[b] (3.95)	2.10[b] (4.02)	1.03[b] (0.56)	2.23[b] (4.58)
Cowpea	1.22[d] (0.99)	0.80[d] (0.14)	1.27[d] (1.11)	1.51[d] (1.83)	0.87[d] (0.25)	1.59[d] (2.08)

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

Table 73. Uptake of nutrients by grasses at harvest (kg ha^{-1})

Main plot treatments	2006			2007		
	N	P	K	N	P	K
Normal dry dibbling	1.65*[a] (2.22)	0.88[a] (0.27)	1.78[a] (2.67)	2.21[a] (5.66)	1.03[a] (0.67)	2.40[a] (6.82)
Stale (7 days)	1.46[b] (1.63)	0.84[b] (0.21)	1.57[b] (1.96)	1.91[b] (4.00)	0.96[b] (0.47)	2.07[b] (4.82)
Stale (14 days) + two hoeings	1.25[c] (1.06)	0.80[c] (0.14)	1.33[c] (1.27)	1.54[c] (1.96)	0.85[c] (0.23)	1.66[c] (2.36)
Stale (14 days) + one hoeing	1.31[c] (1.22)	0.81[c] (0.16)	1.40[c] (1.46)	1.81[b] (3.10)	0.92[b] (0.37)	1.96[b] (3.74)
Sub plot treatments						
NW	2.26[a] (4.61)	1.02[a] (0.54)	2.45[a] (5.50)	3.31[a] (11.42)	1.33[a] (1.34)	3.62[a] (13.78)
HW(20 and 40)	1.16[c] (0.85)	0.78[c] (0.11)	1.23[c] (1.01)	1.46[c] (1.67)	0.83[c] (.20)	1.56[c] (2.02)
Rifit + HW	1.16[c] (0.85)	0.78[c] (0.11)	1.23[c] (1.01)	1.20[d] (0.98)	0.78[d] (.12)	1.27[d] (1.18)
CW(20)+HW (40)	1.16[c] (0.85)	0.78[c] (0.11)	1.24[c] (1.04)	1.50[c] (1.84)	0.84[c] (0.22)	1.62[c] (2.21)
CW(20 and 40)	1.56[b] (1.93)	0.85[b] (0.22)	1.68[b] (2.32)	1.93[b] (3.31)	0.94[b] (0.39)	2.10[b] (3.98)
Cowpea	1.22[c] (0.99)	0.79[c] (0.12)	1.31[c] (1.22)	1.81[b] (2.86)	0.91[b] (0.34)	1.96[b] (3.44)

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

Table 74. Uptake of nutrients by sedges at 20 DAS (kg ha^{-1})

Main plot treatments	2006			2007		
	N	P	K	N	P	K
Normal dry dibbling	0.81*[a] (0.16)	0.72[a] (0.02)	0.77[a] (0.09)	0.76[a] (0.07)	0.71[a] (0.01)	0.74[a] (0.04)
Stale (7 days)	0.79[a] (0.12)	0.72[a] (0.02)	0.76[a] (0.08)	0.75[b] (0.06)	0.71[b] (0.01)	0.73[b] (0.03)
Stale (14 days) + two hoeings	0.81[a] (0.16)	0.72[a] (0.02)	0.76[a] (0.08)	0.72[c] (0.02)	0.71[c] (0.01)	0.72[c] (0.01)
Stale (14 days) + one hoeing	0.82[a] (0.17)	0.72[a] (0.02)	0.77[a] (0.09)	0.73[c] (0.03)	0.71[c] (0.01)	0.72[c] (0.01)
Sub plot treatments						
NW	0.84[a] (0.21)	0.73[a] (0.03)	0.78[a] (0.11)	0.75[a] (0.06)	0.71[a] (0.01)	0.73[a] (0.04)
HW(20 and 40)	0.82[ab] (0.17)	0.72[ab] (0.02)	0.77[ab] (0.09)	0.75[a] (0.06)	0.71[a] (0.01)	0.73[a] (0.04)
Rifit + HW	0.77[c] (0.09)	0.72[c] (0.02)	0.74[c] (0.05)	0.72[c] (0.02)	0.71[a] (0.01)	0.71[c] (0.01)
CW(20)+HW (40)	0.81[abc] (0.16)	0.72[abc] (0.02)	0.77[abc] (0.09)	0.76[a] (0.07)	0.71[a] (0.01)	0.74[a] (0.04)
CW(20 and 40)	0.84[a] (0.21)	0.73[a] (0.03)	0.79[a] (0.12)	0.73[bc] (0.04)	0.71[a] (0.01)	0.72[bc] (0.02)
Cowpea	0.78[bc] (0.11)	0.72[bc] (0.02)	0.75[bc] (0.06)	0.72[c] (0.01)	0.71[a] (0.01)	0.71[c] (0.01)

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

Table 75. Uptake of nutrients by sedges at 40 DAS (kg ha^{-1})

Main plot treatments	2006			2007		
	N	P	K	N	P	K
Normal dry dibbling	1.05*[a] (0.60)	0.77[a] (0.09)	1.06[a] (0.62)	0.96[a] (0.47)	0.75[a] (0.06)	0.97[a] (0.49)
Stale (7 days)	0.97[a] (0.44)	0.75[ab] (0.06)	0.98[ab] (0.46)	1.10[a] (0.82)	0.78[a] (0.11)	1.11[a] (0.86)
Stale (14 days) + two hoeings	0.88[b] (0.27)	0.74[b] (0.05)	0.89[b] (0.29)	1.00[a] (0.55)	0.76[a] (0.07)	1.01[a] (0.58)
Stale (14 days) + one hoeing	1.01[ab] (0.52)	0.76[ab] (0.08)	1.02[ab] (0.54)	1.05[a] (0.65)	0.76[a] (0.09)	1.06[a] (0.68)
Sub plot treatments						
NW	1.17[a] (0.87)	0.79[a] (0.12)	1.19[a] (0.92)	1.30[a] (1.26)	0.82[a] (0.19)	1.32[a] (1.32)
HW(20 and 40)	1.01[b] (0.52)	0.76[b] (0.08)	1.02[b] (0.54)	1.01[c] (0.56)	0.76[c] (0.08)	1.02[c] (0.58)
Rifit + HW	0.87[c] (0.26)	0.73[c] (0.03)	0.87[c] (0.26)	1.17[b] (0.91)	0.79[b] (0.12)	1.19[b] (0.95)
CW(20)+HW (40)	1.08[ab] (0.67)	0.77[ab] (0.09)	1.09[ab] (0.69)	0.97[c] (0.45)	0.75[c] (0.06)	0.98[c] (0.47)
CW(20 and 40)	1.02[b] (0.54)	0.76[b] (0.08)	1.03[b] (0.56)	1.01[c] (0.56)	0.76[c] (0.08)	1.02[c] (0.58)
Cowpea	0.71[d] (0)	0.71[d] (0)	0.71[d] (0)	0.71[d] (0)	0.71[d] (0)	0.71[d] (0)

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

Table 76. Uptake of nutrients by broad leaf weeds at 20 DAS (kg ha^{-1})

Main plot treatments	2006			2007		
	N	P	K	N	P	K
Normal dry dibbling	2.56*[a] (6.05)	1.09[a] (0.69)	2.21[a] (4.38)	1.42[a] (1.62)	0.81[a] (0.16)	1.26[a] (1.15)
Stale (7 days)	2.22[a] (4.43)	0.98[a] (0.46)	1.92[a] (3.19)	1.21[b] (1.02)	0.78[b] (0.10)	1.10[b] (0.73)
Stale (14 days) + two hoeings	2.03[a] (3.62)	0.94[a] (0.38)	1.77[a] (2.63)	0.85[d] (0.22)	0.72[d] (0.02)	0.81[d] (0.16)
Stale (14 days) + one hoeing	2.52[a] (5.85)	1.05[a] (0.60)	2.17[a] (4.21)	1.00[c] (0.50)	0.74[c] (0.05)	0.92[c] (0.36)
Sub plot treatments						
NW	2.47[abc] (5.60)	1.03[abc] (0.56)	2.12[abc] (3.99)	1.19[b] (1.01)	0.77[b] (0.10)	1.08[b] (0.72)
HW(20 and 40)	2.53[ab] (5.90)	1.05[ab] (0.60)	2.18[ab] (4.25)	1.21[ab] (1.02)	0.76[ab] (0.11)	1.09[ab] (0.75)
Rifit + HW	1.60[c] (2.06)	0.85[c] (0.22)	1.40[c] (1.46)	0.88[c] (0.29)	0.73[c] (0.03)	0.84[c] (0.21)
CW(20)+HW (40)	2.61[ab] (6.31)	1.07[ab] (0.64)	2.24[ab] (4.52)	1.28[a] (1.21)	0.79[a] (0.12)	1.15[a] (0.87)
CW(20 and 40)	3.07[a] (8.92)	1.21[a] (0.96)	2.63[a] (6.42)	1.26[ab] (1.17)	0.79[a] (0.12)	1.13[ab] (0.84)
Cowpea	1.74[bc] (2.53)	0.87[bc] (0.26)	1.52[bc] (1.81)	0.89[c] (0.29)	0.73[c] (0.03)	0.84[c] (0.21)

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

Table 77. Uptake of nutrients by broad leaf weeds at 40 DAS (kg ha^{-1})

Main plot treatments	2006			2007		
	N	P	K	N	P	K
Normal dry dibbling	2.15*[a] (4.12)	1.01[a] (0.52)	1.92[a] (3.19)	2.69[a] (7.97)	1.15[a] (0.90)	2.38[a] (6.07)
Stale (7 days)	2.05[ab] (3.70)	0.98[ab] (0.46)	1.83[ab] (2.85)	2.31[b] (5.70)	1.05[b] (0.64)	2.05[b] (4.34)
Stale (14 days) + two hoeings	1.77[c] (2.63)	0.90[c] (0.31)	1.59[c] (2.03)	1.80[d] (3.04)	0.91[d] (0.35)	1.62[d] (2.31)
Stale (14 days) + one hoeing	1.90[bc] (3.11)	0.94[bc] (0.38)	1.69[bc] (2.36)	2.01[c] (3.94)	0.96[c] (0.45)	1.80[c] (2.99)
Sub plot treatments						
NW	2.77[a] (7.17)	1.15[a] (0.82)	2.44[a] (5.45)	3.14[a] (10.31)	1.26[a] (1.17)	2.77[a] (7.85)
HW(20 and 40)	2.16[bc] (4.17)	0.98[bc] (0.46)	1.91[bc] (3.15)	2.15[c] (4.22)	0.99[c] (0.48)	1.91[c] (3.21)
Rifit + HW	1.85[d] (2.92)	0.92[d] (0.35)	1.65[d] (2.22)	2.34[bc] (5.44)	1.04[bc] (0.62)	2.08[bc] (4.14)
CW(20)+HW (40)	2.23[b] (4.47)	1.01[b] (0.52)	1.98[b] (3.42)	2.46[b] (5.67)	1.07[b] (0.64)	2.18[b] (4.32)
CW(20 and 40)	2.09[c] (3.87)	0.97[c] (0.44)	1.85[c] (2.92)	2.40[bc] (5.33)	1.05[bc] (0.60)	2.13[bc] (4.05)
Cowpea	0.71[e] (0)	0.71[e] (0)	0.71[e] (0)	0.71[d] (0)	0.71[d] (0)	0.71[d] (0)

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

Table 78. Uptake of nutrients by broad leaf weeds at harvest (kg ha^{-1})

Main plot treatments	2006			2007		
	N	P	K	N	P	K
Normal dry dibbling	1.35*^{a} (1.32)	0.77^{a} (0.09)	1.43^{a} (1.54)	1.58^{a} (2.64)	0.81^{a} (0.17)	1.68^{a} (3.11)
Stale (7 days)	1.22^{b} (0.99)	0.75^{b} (0.06)	1.29^{b} (1.16)	1.38^{b} (1.60)	0.78^{b} (0.10)	1.47^{b} (1.89)
Stale (14 days) + two hoeings	1.12^{b} (0.75)	0.74^{b} (0.05)	1.18^{b} (0.89)	1.26^{b} (1.20)	0.76^{b} (0.08)	1.34^{b} (1.42)
Stale (14 days) + one hoeing	1.15^{b} (0.82)	0.75^{b} (0.06)	1.20^{b} (0.94)	1.43^{ab} (1.67)	0.78^{ab} (0.11)	1.52^{ab} (1.97)
Sub plot treatments						
NW	1.82^{a} (2.81)	0.82^{a} (0.17)	1.96^{a} (3.34)	2.20^{a} (4.85)	0.89^{a} (0.31)	2.37^{a} (5.71)
HW(20 and 40)	1.11^{c} (0.73)	0.74^{c} (0.05)	1.17^{c} (0.87)	1.45^{b} (1.65)	0.78^{b} (0.10)	1.55^{b} (1.94)
Rifit + HW	1.05^{c} (0.60)	0.73^{c} (0.03)	1.10^{c} (0.71)	1.19^{c} (0.95)	0.75^{c} (0.06)	1.26^{c} (1.12)
CW(20)+HW (40)	1.11^{c} (0.73)	0.74^{c} (0.05)	1.17^{c} (0.87)	1.38^{b} (1.46)	0.77^{b} (0.09)	1.47^{b} (1.72)
CW(20 and 40)	1.39^{b} (1.43)	0.77^{b} (0.09)	1.47^{b} (1.66)	1.40^{b} (1.52)	0.77^{b} (0.10)	1.49^{b} (1.79)
Cowpea	0.71^{d} (0)	0.71^{d} (0)	0.71^{d} (0)	0.85^{d} (0.25)	0.72^{d} (0.02)	0.86^{d} (0.30)

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

The lowest uptake was noticed in weeded situation during 2006. All other weed control mehtods were at par. However, during 2007, pretilachlor sprayed (3 DAS) and hand weeded (20 DAS) plots were at par.

Nutrient uptake at harvest stage

The uptake of nutrients by rice as affected by treatments at harvest stage is provided in Table 70. At this stage, stale seed bed for 14 days (two hoeings) removed NPK@ 45.53 kg ha^{-1}, 8.36 kg ha^{-1} and 72.48 kg ha^{-1} during 2006 and 48.39 kg ha^{-1}, 8.89 kg ha^{-1} and 77.02 kg ha^{-1} during 2007. This treatment was found to be significantly superior. Significantly lower nutrient uptake was noticed in plots, which did not receive any weed control measure.

4.2.4. Nutrient uptake by weeds

Nutrient uptake by grasses

Higher removal of nutrients by grasses at 20 DAS was noticed in normal seed bed. Stale seed bed for 14 days with two hoeings significantly reduced the uptake of nutrients by grasses (Table 71). At this stage during 2006, except for the treatments, pre - emergence spraying of pretilachlor and cowpea concurrent growing, nutrient removal was almost same. Significantly lower removal of N, P and K was observed in plots with pretilachlor and concurrent growing of cowpea. However, in 2007, these treatments were at par.

Normal seed bed and stale seed bed for 14 days with two hoeings recorded the highest and lowest nutrient uptake values by grasses at 40 DAS (Table 72). Among the sub plot treatments, the unweeded plots and plots with concurrent growing of cowpea showed the highest and lowest values during both years.

Uptake of nutrients by grass weeds at harvest stage is presented in Table 73. At this stage, lower uptake was found in stale seed bed for 14 days plots with two hoeings and in plots with stale seed bed for 14 days with one hoeing. The normal seed bed recorded the maximum uptake. Among the sub plot treatments, unweeded control caused the highest uptake. During 2006, cono weeding twice was significantly inferior, whereas in 2007, cono weeding twice and cowpea incorporation were at par.

Nutrient uptake by sedges

During 2006, the nutrient removal by sedges showed no significant variation among main plots. However, in 2007, the normal seed bed and stale seed bed for 7 days showed significantly higher uptake values (Table 74). Among weed control treatments, unweeded plots and plots with cono weeding twice recorded higher uptake and there were at par during 2006. However, in 2007, plots with no weeding, hand weeding twice and cono weeding followed by hand weeding recorded higher nutrient uptake, which were at par.

Nutrient uptake by sedges was higher in normal seed bed plots during 2006. However, no significant variation could be observed between seed bed treatments during 2007 (Table 75). Maximum uptake of nutrients by sedges was observed during both years in unweeded plots.

Nutrient uptake by broad leaf weeds

Uptake of nutrients by the broad leaf weeds at 20 DAS during 2006 showed no variation between main plots. During 2007, the stale seed bed for 14 days with two hoeings recorded the lowest nutrient uptake and the normal seed bed gave the maximum uptake. The sub plot treatment pretilachlor caused the lowest nutrient uptake during 2006. Pretilachlor sprayed plots and cowpea grown plots showed lower values during 2007 (Table 76).

The stale seed bed influenced the nutrient uptake by broad leaf weeds at 40 DAS significantly. Normal seed bed increased the uptake of nutrients. Stale seed bed for 14 days with two hoeings recorded lower values and it was on a par with stale seed bed for 14 days with one hoeing (Table 77). Concurrent growing of cowpea and its incorporation at 30 DAS caused the least nutrient uptake. No weeding facilitated maximum nutrient removal by broad leaf weeds.

At harvest stage, all stale seed bed plots were statistically on a par with respect to nutrient removal by broad leaf weeds. Normal seed bed produced significantly higher values. The unweeded plots recorded the maximum uptake of nutrients during both years. Cono weeding twice and cowpea incorporation gave lower uptake during 2006. The plots with pretilachlor + hand weeding and cowpea green manuring recorded lower nutrient removal during 2007 (Table 78).

4.2.5. Economics of cultivation

Economics of cultivation as influenced by various treatments is given in Tables 79, 80 and 81.

The highest cost of production was worked for preparing normal seed bed (Rs. 21565/ha). During both years of study, the highest total return was obtained in plots with stale seed bed for 14 days (one hoeing). The lowest B:C ratio of 1.24 and 1.22 were in normal seed bed plots. Among the sub plot treatments, the highest B:C ratio was obtained for pre - emergence spraying of Pretilachlor (Rifit) and for concurrent growing of cowpea.

Table 79. Economics of cultivation per hectare for main plot treatments (Rs./ha)

Seed bed	Total cost	Total income		Total profit		B:C ratio	
		2006	2007	2006	2007	2006	2007
Normal seed bed	21565	26639	26414	4530	3903	1.24	1.22
Stale 7 (one hoeing)	19815	27638	28305	13195	13700	1.39	1.43
Stale 14 (two hoeings)	20315	32463	32473	18840	18190	1.60	1.60
Stale 14 (one hoeing)	19815	31873	31530	19920	18665	1.61	1.59

Table. 80 B:C ratio for sub plot treatments during 2006 (Rs./ha)

Treatments	Normal seed bed	Stale 7 (one hoeing)	Stale 14 (two hoeings)	Stale 14 (one hoeing)
UWC	0.26	0.33	1.78	1.74
HW(20 and 40)	1.34	1.50	1.67	1.61
Rifit + HW	1.85	1.87	1.69	1.86
CW(20)+HW (40)	1.75	1.76	1.63	1.80
CW(20 and 40)	1.74	1.81	1.65	1.80
Cowpea	1.90	1.91	1.69	1.87

Table. 81 B:C ratio for sub plot treatments during 2007 (Rs./ha)

Treatments	Normal seed bed	Stale 7 (one hoeing)	Stale 14 (two hoeings)	Stale 14 (one hoeing)
UWC	0.41	0.46	1.67	1.56
HW(20 and 40)	1.38	1.52	1.66	1.60
Rifit + HW	1.93	1.94	1.77	1.89
CW(20)+HW (40)	1.70	1.86	1.68	1.83
CW(20 and 40)	1.66	1.79	1.65	1.84
Cowpea	1.92	1.82	1.68	1.85

4.3. Stale seed bed techniques suited for wet seeded rice

4.3.1 Studies on weeds

The weeds observed in the experimental field were categorized into grasses, sedges and broad leaf weeds and recorded accordingly. Observations on predominant weeds belonging to these categories were separately recorded. *Echinochloa* spp. was the major grass weed found in the experimental field. Among sedges, *Cyperus* spp. and *Fimbristylis miliacea* were the dominant ones. At 20 DAS *Lindernia crustacea*, *Ludwigia perennis* and *Sphenoclea zeylanica* were the important broad leaf weeds. However, after 20 DAS *Lindernia crustacea* was not a serious problem.

Total population of weeds

Total weed population at 20 DAS during 2005-06 and 2006-07 is given in Table 82.. Among seed bed treatments, stale seed bed for 14 days recorded the lowest weed population followed by stale seed bed for 7 days. Pre - emergence spraying of Sofit gave significant reduction in weed population during 2005-06. All other sub plot treatments were at par since weed control practices were not taken up at this stage. However, during 2006-07, concurrent growing of *Daincha* reduced the weed population. Combination of Sofit with all seed bed treatments gave significant reduction in the number of weeds during both years.

Total number of weeds at 40 DAS is presented in Table 83. At this stage also stale seed bed showed superiority over normal seed bed in reducing the population of weeds. During 2005-06, pre-emergence spraying of Sofit and concurrent growing of daincha gave considerable reduction in weed population. During 2006-07 weed population remained almost same under all weed control methods except in plots with no weeding. Combination of Sofit with stale seed bed either for 14 days or for 7 days lowered the population of weeds

Table 82. Total population of weeds at 20 DAS (Number m^{-2})

Sub plot treatments	Main plot treatments						Sub plot mean	
	Normal seed bed		Stale seed bed (7 days)		Stale seed bed (14 days)			
	05-06	06-07	05-06	06-07	05-06	06-07	05-06	06-07
NW	12.18*[a] (147.85)	8.81[a] (77.12)	7.75[cd] (59.56)	8.53[ab] (72.26)	6.64[d] (43.59)	3.89[de] (14.63)	8.86[a] (78.0)	7.08[a] (49.63)
HW	12.18[a] (147.85)	8.87[a] (78.18)	7.47[cd] (55.30)	7.55[abc] (56.50)	6.65[d] (43.72)	3.80[def] (13.94)	8.77[a] (76.41)	6.74[ab] (44.93)
Sofit	1.18[e] (0.89)	1.45[f] (1.60)	1.65[e] (2.22)	2.65[ef] (6.52)	1.18[e] (0.89)	2.56[ef] (6.05)	1.34[b] (1.30)	2.22[c] (4.43)
CW	12.39[a] (153.01)	8.83[a] (77.47)	7.94[c] (62.54)	6.43[bc] (40.84)	7.66[cd] (58.18)	3.80[def] (13.94)	9.33[a] (86.55)	6.35[ab] (39.82)
Daincha	10.59[b] (111.65)	7.43[abc] (54.70)	8.43[c] (70.56)	5.88[cd] (34.07)	7.59[cd] (57.11)	3.66[def] (12.90)	8.87[a] (78.18)	5.66[b] (31.54)
Main plot mean	9.71[a] (93.78)	7.08[a] (49.63)	6.65[b] (43.72)	6.21[a] (38.06)	5.95[b] (34.90)	3.54[b] (12.03)		

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

Table 83. Total population of weeds at 40 DAS (Number m^{-2})

Sub plot treatments	Main plot treatments						Sub plot mean	
	Normal seed bed		Stale seed bed (7 days)		Stale seed bed (14 days)			
	05-06	06-07	05-06	06-07	05-06	06-07	05-06	06-07
NW	13.84*[a] (191.05)	11.74[a] (137.33)	9.61[b] (91.85)	9.81[b] (95.74)	7.09[c] (49.77)	7.85[c] (61.12)	10.18[a] (103.13)	9.80[a] (95.54)
HW	4.22[efg] (17.31)	3.19[d] (9.68)	5.02[def] (24.70)	3.24[d] (10.00)	5.02[def] (24.70)	4.36[d] (18.51)	4.75[b] (22.06)	3.60[b] (12.46)
Sofit	3.30[fg] (10.39)	3.89[d] (14.63)	3.13[g] (9.30)	3.54[d] (12.03)	3.13[g] (9.30)	4.49[d] (19.66)	3.18[c] (9.61)	3.97[b] (15.26)
CW	6.34[cd] (39.70)	4.37[d] (18.60)	4.73[defg] (21.87)	4.51[d] (19.84)	5.28[de] (27.38)	4.05[d] (15.90)	5.45[b] (29.20)	4.31[b] (18.08)
Daincha	3.80[efg] (13.94)	3.51[d] (11.82)	3.71[efg] (13.26)	4.36[d] (18.51)	3.54[efg] (12.03)	3.30[d] (10.39)	3.68[c] (13.04)	3.72[b] (13.34)
Main plot mean	6.30[a] (39.19)	5.34[a] (28.02)	5.24[b] (26.96)	5.09[a] (25.41)	4.81[b] (22.64)	4.81[a] (22.64)		

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

Table 84. Total population of weeds at harvest (Number m^{-2})

Sub plot treatments	Main plot treatments						Sub plot mean	
	Normal seed bed		Stale seed bed (7 days)		Stale seed bed (14 days)			
	05-06	06-07	05-06	06-07	05-06	06-07	05-06	06-07
NW	11.58* (133.60)	11.36^{a} (128.55)	8.07 (64.62)	7.83^{b} (60.81)	6.02 (35.74)	7.90^{b} (61.91)	8.56^{a} (72.77)	9.03^{a} (81.04)
HW	2.86 (7.68)	5.37^{cde} (28.34)	3.71 (13.26)	5.07^{cde} (25.20)	4.37 (18.60)	4.37^{def} (18.60)	3.65^{b} (12.82)	4.94^{b} (23.90)
Sofit	3.71 (13.26)	5.81^{c} (33.26)	3.03 (8.68)	4.86^{cde} (23.12)	3.13 (9.30)	4.40^{ef} (15.82)	3.29^{b} (10.32)	4.90^{b} (23.51)
CW	3.66 (12.90)	5.33^{cde} (27.91)	4.04 (15.82)	4.67^{cdef} (21.31)	4.37 (18.60)	3.51^{f} (11.82)	4.03^{b} (15.74)	4.50^{b} (19.75)
Daincha	3.33 (10.59)	5.28^{cde} (27.38)	3.89 (14.63)	5.69^{cd} (31.88)	3.80 (13.94)	3.41^{f} (11.13)	3.67^{b} (12.97)	4.80^{b} (22.54)
Main plot mean	5.03a (24.80)	6.63^{a} (43.46)	4.55a (20.20)	5.63^{b} (31.20)	4.34a (18.34)	4.65^{c} (21.12)		

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

Table 85. Population of grasses, sedges and broad leaf weeds at 20 DAS (Number m^{-2})

Main plot treatments	2005-2006			2006-2007		
	Grasses	Sedges	Broad leaf	Grasses	Sedges	Broad leaf
Normal seed bed	2.66*[a] (1.58)	3.89[a] (18.67)	8.37[a] (84.53)	5.53[a] (35.73)	3.42[a] (13.33)	2.96[ab] (9.30)
Stale seed bed (7 days)	0.71[b] (0)	4.00[a] (17.60)	5.25[b] (32.80)	4.12[a] (24.00)	2.15[b] (4.80)	3.74[a] (15.20)
Stale seed bed (14 days)	0.71b (0)	4.18[a] (19.47)	4.30[c] (21.60)	1.08[b] (1.07)	2.12[b] (4.80)	2.64[b] (7.20)
Sub plot treatments						
UWC	1.58*[a] (0.66)	4.89[ab] (24.00)	7.04[a] (54.67)	4.90[a] (35.56)	3.05[a] (10.22)	3.36[a] (11.11)
HW	1.58[a] (0.64)	4.23[b] (17.78)	7.44[a] (60.89)	4.42[a] (25.78)	3.11[a] (9.78)	3.61[a] (14.67)
Sofit	0.86[a] (0.22)	1.18[c] (1.33)	0.71[b] (0)	0.86[b] (0.44)	1.20[b] (1.78)	1.76[b] (3.56)
CW	1.65[a] (0.88)	5.35[a] (28.44)	7.28[a] (58.67)	3.92[a] (22.67)	2.77[a] (8.44)	3.74[a] (14.22)
Daincha	1.11[a] (0.43)	4.46[ab] (21.33)	7.39[a] (57.33)	3.77[a] (16.89)	2.67[a] (8.00)	3.10[a] (9.33)

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

during 2005-06. However, during 2006-07, combination of all weed control methods with all three main plot treatments recorded statically at par values. Plots with no weeding under normal seed bed recorded the highest population.

At harvest stage during 2005-06, weed population showed no significant difference among various seed beds (Table 84) whereas during 2006-07, stale seed bed for 14 days recorded the lowest population followed by stale seed bed for 7 days. At this all weed control methods were at par. Plots with no weeding recorded the highest values. Combination of no weeding with normal seed bed showed the highest weed population during both years followed by those of stale seed bed for 7 days and 14 days. During 2005-06, all other treatment combinations were at par. However, during 2006-07 cono weeding either for incorporation of daincha or for managing weeds gave significant control of weeds.

Total population of grasses, sedges and broad leaf weeds

Total population of grasses, sedges and broad leaf weeds at 20 DAS during 2005-06 and 2006-07 is presented in Table 85. Seed bed manipulation significantly influenced the emergence and establishment of weeds at this stage. Stale seed beds either for 7 days or for 14 days successfully controlled the population of grasses. During 2005-06 the population of sedges remained unaffected by seed bed manipulation. However, during 2006-07, it was the lowest in stale seed bed plots. Population of broad leaf weeds was significantly lower in stale seed bed for 14 days followed by stale seed bed for 7 days.

Among the weed control treatments, pre-emergence spray of Sofit significantly influenced the population of weeds at this stage during both years. Other treatments were at par.

The data on total population of grasses, sedges and broad leaf weeds during 2005-06 at 40 DAS reveals that the population of grasses was influenced greatly by seed bed

Table 86.Population of grasses, sedges and broad leaf weeds at 40 DAS during 2005-2006 (Number m^{-2})

Sub plot treatments	Main plot treatments: Normal seed bed			Stale seed bed (7 days)			Stale seed bed (14 days)			Sub plot mean		
	Grasses	Sedges	Broad leaf	Grasses	Sedges	Broad leaf	Grasses	Sedges	Broad leaf	Grasses	Sedges	Broad leaf
NW	5.73*^{a} (33.33)	7.23^{a} (52.00)	10.20^{a} (106.67)	3.71^{b} (13.33)	5.67^{b} (32.00)	6.86^{b} (46.67)	3.45^{b} (12.00)	4.31^{c} (18.67)	4.11^{c} (20.00)	4.30^{a} (19.56)	5.74^{a} (34.22)	7.06^{a} (57.78)
HW	2.59^{bcd} (6.67)	3.33^{cdef} (10.67)	0.71^{d} (0)	2.92^{bc} (8.00)	4.11^{cd} (17.33)	0.71^{d} (0)	2.86^{bc} (8.00)	3.54^{cd} (13.33)	1.92^{d} (4.00)	2.79^{bc} (7.56)	3.66^{b} (13.78)	1.11^{c} (1.33)
Sofit	2.65^{bcd} (6.87)	1.92^{f} (4.00)	0.71^{d} (0)	1.92^{cde} (4.00)	2.39^{ef} (5.33)	0.71^{d} (0)	1.65^{cde} (2.67)	2.65^{def} (6.67)	0.71^{d} (0)	2.07^{cd} (4.44)	2.32^{c} (5.33)	0.71^{c} (0)
CW	4.02^{b} (16.00)	3.24^{ef} (10.67)	3.68^{c} (13.33)	3.03^{bc} (9.33)	3.50^{cde} (12.00)	1.18^{d} (1.33)	1.92^{cde} (4.00)	3.50^{cde} (12.00)	3.50^{c} (12.00)	3.00^{b} (9.78)	3.42^{b} (11.56)	2.79^{b} (8.89)
Daincha	3.03^{bc} (9.33)	2.18^{ef} (5.33)	0.71^{d} (0)	1.18^{de} (1.33)	3.54^{cde} (12.00)	0.71^{d} (0)	0.71^{e} (0)	3.40^{cdef} (12.00)	1.18^{d} (1.33)	1.64^{d} (3.56)	3.04^{bc} (9.78)	0.86^{c} (0.44)
Main plot mean	3.61^{a} (14.40)	3.58^{a} (16.53)	3.20^{a} (24.00)	2.55^{b} (7.20)	3.84^{a} (15.73)	2.03^{a} (9.60)	2.12^{b} (5.30)	3.48^{a} (12.53)	2.28^{a} (7.47)			

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

Table 87.Population of grasses, sedges and broad leaf weeds at 40 DAS during 2006-2007 (Number m^{-2})

Sub plot treatments	Main plot treatments									Sub plot mean		
	Normal seed bed			Stale seed bed (7 days)			Stale seed bed (14 days)					
	Grasses	Sedges	Broad leaf	Grasses	Sedges	Broad leaf	Grasses	Sedges	Broad leaf	Grasses	Sedges	Broad leaf
NW	9.17*[a] (84.00)	5.81[a] (33.33)	4.40[ab] (20.00)	5.92[b] (34.67)	6.18[a] (41.33)	4.64[a] (21.33)	3.66[c] (13.33)	5.69[a] (32.00)	3.98[abc] (16.00)	6.25[a] (44.00)	5.89[a] (35.56)	4.34[a] (19.11)
HW	1.92[de] (4.00)	1.92[b] (4.00)	1.65[de] (2.67)	1.65[de] (2.67)	2.39[b] (6.67)	1.92[de] (4.00)	1.65[de] (2.67)	3.12[b] (9.33)	2.59[cde] (6.67)	1.74[bc] (3.10)	2.47[b] (6.67)	2.05[b] (4.44)
Sofit	2.39[cd] (5.30)	2.86[b] (8.00)	1.18[e] (1.33)	1.65[de] (2.67)	2.39[b] (5.33)	2.12[de] (5.33)	1.65[de] (2.67)	3.34[b] (10.67)	2.59[cde] (6.67)	1.90[bc] (3.56)	2.86[b] (8.00)	1.96[b] (4.00)
CW	2.65[cd] (6.67)	2.59[b] (6.67)	2.18[de] (5.33)	1.92[de] (4.00)	2.30[b] (6.67)	3.12[abcd] (9.33)	2.39[cd] (5.30)	1.92[b] (4.00)	2.77[bcde] (8.00)	2.32[b] (5.30)	2.67[b] (5.78)	2.69[b] (7.56)
Daincha	1.65[de] (2.67)	2.12[b] (5.33)	2.21[de] (4.00)	0.71[e] (0)	3.06[b] (9.33)	3.06[abcd] (9.50)	1.18[de] (1.30)	2.65[b] (6.67)	1.65[de] (2.67)	1.18[c] (1.30)	2.61[b] (7.11)	2.28[b] (5.35)
Main plot mean	3.55[a] (20.53)	3.06[a] (11.47)	2.31[a] (6.67)	2.37[b] (8.80)	3.26[a] (13.87)	2.97[a] (9.87)	2.11[b] (5.07)	3.34[a] (12.53)	2.72[a] (8.00)			

*√x+0.5 transformed values, Original values in parenthesis

manipulation. At the same time, sedges and broad leaf weeds remained unaffected.

Among weed control methods, *in situ* green manuring of daincha recorded the least number of grasses and broad leaf weeds and it was on a par with pre-emergence spraying of Sofit. Spraying of Sofit was effective in controlling the number of sedges. Among the plots with weed control measures, number of grasses and sedges were found maximum in normal seed bed with cono weeding. However, the number of sedges was the maximum in stale seed bed for 7 days (Table 86). At this stage interaction effect was not significant, since except for herbicide spray and concurrent growing of cowpea, no other sub plot treatments were applied.

During 2006-07, stale seed beds successfully reduced the population build up of grasses and sedges. Grass weeds were found minimum in daincha sown plots followed by Sofit sprayed plots. Number of sedges and broad leaf weeds showed no significant variation among weed control practices. *In situ* green manuring of daincha in stale seed bed plots (7 days) gave complete control of *Echinochloa*. Concurrent growing of Daincha and its incorporation by cono weeding was more effective in controlling weed population build up than giving cono weeding alone (Table 87).

Effects of treatments on total number of grasses, sedges and broad leaf weeds per m^2 at harvest stage in 2005-06 are depicted in Table 88. It points out the superiority of stale seed bed (14 days) in reducing the number of grasses during the entire crop season. Table 89 gives the total weed population at harvest during 2006-07. Grasses were less in stale seed bed for 14 days followed by stale seed bed for 7 days. Sedges and broad leaf weeds were not influenced by seed bed manipulation.

Weed management methods - hand weeding, pre-emergence application of Sofit, cono weeding or concurrent growing of daincha - were at par in controlling the number

Table 88.Population of grasses, sedges and broad leaf weeds at harvest during 2005-2006 (Number m^{-2})

Sub plot treatments	Main plot treatments									Sub plot mean		
	Normal seed bed			Stale seed bed (7 days)			Stale seed bed (14 days)					
	Grasses	Sedges	Broad leaf	Grasses	Sedges	Broad leaf	Grasses	Sedges	Broad leaf	Grasses	Sedges	Broad leaf
NW	8.35*^{a} (69.33)	6.89^{a} (49.33)	3.90^{a} (17.30)	7.13^{b} (50.67)	3.45^{c} (12.00)	1.65^{b} (2.67)	3.12^{c} (9.33)	4.76^{b} (22.67)	2.12^{b} (4.00)	6.20^{a} (43.11)	5.03^{a} (28.00)	2.56^{a} (8.00)
HW	2.65^{c} (6.67)	1.18^{e} (1.33)	0.71^{b} (0)	2.39^{c} (5.33)	2.65^{cd} (6.67)	1.18^{b} (1.13)	2.65^{c} (6.67)	2.92^{cd} (8.00)	2.12^{b} (4.00)	2.56^{b} (6.22)	2.25^{bc} (5.30)	1.34^{b} (1.78)
Sofit	2.56^{c} (8.00)	2.39^{d} (5.00)	1.18^{b} (1.33)	2.65^{c} (6.67)	1.18^{e} (1.30)	1.18^{b} (1.13)	2.39^{c} (5.33)	1.92^{de} (4.00)	0.71^{b} (0)	2.53^{b} (6.60)	1.83^{c} (3.56)	1.02^{b} (0.89)
CW	2.39^{c} (5.33)	2.86^{cd} (8.00)	0.71^{b} (0)	2.65^{c} (6.67)	2.92^{cd} (8.00)	1.18^{b} (1.13)	2.86^{c} (8.00)	2.86^{cd} (8.00)	1.65^{b} (2.67)	2.63^{b} (6.67)	2.88^{b} (8.00)	1.18^{b} (1.33)
Daincha	2.39^{c} (5.33)	2.12^{cde} (4.00)	1.18^{b} (1.33)	2.65^{c} (6.67)	2.65^{cd} (6.67)	1.18^{b} (1.13)	2.86^{c} (8.00)	2.39^{cde} (5.30)	1.18^{b} (1.30)	2.63^{b} (6.67)	2.39^{bc} (5.30)	1.18^{b} (1.33)
Main plot mean	3.66^{a} (18.93)	3.09^{a} (13.60)	1.53^{a} (4.00)	3.49^{a} (15.20)	2.57^{a} (6.93)	1.27^{a} (1.60)	2.78b (7.47)	2.97^{a} (9.60)	1.56^{a} (2.40)			

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

Table 89. Population of grasses, sedges and broad leaf weeds at harvest during 2006-2007 (Number m^{-2})

Sub plot treatments	Main plot treatments									Sub plot mean		
	Normal seed bed			Stale seed bed (7 days)			Stale seed bed (14 days)					
	Grasses	Sedges	Broad leaf	Grasses	Sedges	Broad leaf	Grasses	Sedges	Broad leaf	Grasses	Sedges	Broad leaf
NW	8.96^{*a} (80.00)	5.13^{a} (26.67)	4.76^{ab} (22.67)	5.38^{b} (29.30)	4.31^{abc} (18.67)	3.68^{abc} (13.33)	3.50^{cd} (12.00)	4.91^{ab} (24.00)	5.13^{a} (26.67)	5.95^{a} (40.44)	4.78^{a} (23.11)	4.52^{a} (28.89)
HW	3.24^{cde} (10.67)	3.50^{cd} (12.00)	2.59^{cde} (6.67)	2.39^{defg} (5.30)	3.68^{bcd} (13.33)	2.65^{cde} (6.67)	1.65^{g} (2.70)	3.33^{cde} (10.67)	2.39^{cde} (5.33)	2.43^{b} (6.22)	3.50^{b} (12.00)	2.54^{bc} (6.22)
Sofit	3.68^{c} (13.33)	2.92^{de} (8.00)	3.54^{abcd} (12.00)	2.39^{defg} (5.30)	3.12^{cde} (9.33)	2.77^{cde} (9.33)	1.18^{g} (1.30)	3.50^{cd} (12.00)	1.44^{e} (2.67)	2.42^{b} (6.67)	3.18^{b} (9.78)	2.58^{bc} (8.00)
CW	2.86^{cdef} (8.00)	3.54^{cd} (12.00)	2.86^{cde} (8.00)	2.86^{cdef} (8.00)	3.33^{cde} (10.67)	1.44^{e} (2.670	2.12^{efg} (4.00)	2.12^{e} (5.30)	1.44^{e} (2.67)	2.61^{b} (6.70)	3.00^{b} (9.30)	1.92^{c} (4.44)
Daincha	2.12^{efg} (4.00)	3.45^{cde} (12.00)	3.50^{abcd} (12.00)	2.92^{cde} (8.50)	3.71^{bcd} (13.33)	3.24^{bcd} (10.67)	1.18^{g} (1.30)	2.65^{de} (6.67)	1.92^{de} (4.00)	2.07^{b} (4.44)	3.27^{b} (10.67)	2.86^{b} (8.89)
Main plot mean	4.17^{a} (23.20)	3.71^{a} (14.13)	3.45^{a} (12.27)	3.18^{b} (11.20)	3.63^{a} (13.07)	2.76^{a} (8.53)	1.93^{c} (4.27)	3.30^{a} (11.73)	2.46^{a} (8.27)			

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

of grasses and broad leaf weeds during 2005-06. However, in 2006-07, broad leaf weeds were lower in cono weeded plots. Maximum number of weeds was observed in unweeded plots.

The weed population was significantly lower in unweeded plots of stale seed beds. During 2005-06 significant reduction in the number of sedges was noticed in hand weeded plots of normal seed bed. Stale seed bed for 14 days combined with Sofit spraying or normal seed bed with cono weeding gave complete control of broad leaf weeds.

Grasses were lower in stale seed bed for 14 days with Sofit or daincha during 2006-07. However, stale seed bed for 14 days with cono weeding recorded the lowest number of sedges. Adopting cono weeding or *in situ* green manuring of daincha in stale seed bed plots was found to be superior for controlling broad leaf weeds.

Population of grass and sedge weeds

Population of grasses and sedges at 20 DAS as influenced by treatments during 2005-06 and 2006-07 is presented in Table 90. Seed bed preparation significantly influenced the count at this stage as evidenced by the lowest population of these weeds in stale seed bed plots. Population of *Echinochloa* spp. was the highest in normal seed bed. Among the weed management treatments, pre-emergence spraying of Sofit significantly influenced the population of major weeds at this stage of observation.

During 2006-07 also, stale seed bed for 7 days and for 14 days recorded significantly lower population of *Echinochloa* spp. and *Cyperus* spp. However, the population of *Fimbristylis miliacea* was not affected by seed bed preparation. Among the sub plot treatments, Sofit sprayed plots recorded the lowest counts of *Echinochloa* spp. and *Cyperus* spp. Other treatments were at par. Population of *Fimbristylis miliacea* was not influenced by weed control treatments.

Table 90. Population of grass and sedge weeds at 20 DAS (Number m^{-2})

Main plot treatments	2005-2006			2006-2007		
	Echinochloa	*Cyperus*	*Fimbristylis*	*Echinochloa*	*Cyperus*	*Fimbristylis*
Normal seed bed	2.66*[a] (9.33)	3.89[a] (18.67)	0.71[c] (0)	5.53[a] (35.73)	3.22[a] (11.73)	1.27[a] (1.60)
Stale seed bed (7 days)	0.71[b] (0)	3.44[b] (12.53)	1.96[b] (5.07)	4.12[a] (24.00)	1.76[de] (3.2)	1.27[a] (1.60)
Stale seed bed (14 days)	0.71[b] (0)	2.39[c] (6.13)	3.42[a] (13.33)	1.08[b] (1.07)	1.80[b] (1.60)	1.27[a] (3.2)
Sub plot treatments						
UWC	1.58*[a] (5.33)	3.84[a] (16.89)	2.17[b] (7.11)	4.90[a] (35.56)	2.76[a] (8.89)	1.18[a] (1.30)
HW	1.58[a] (4.00)	3.60[a] (13.33)	1.89[b] (4.44)	4.42[a] (25.78)	2.80[a] (8.00)	1.34[a] (0.78)
Sofit	0.96[a] (0.44)	1.18[b] (1.33)	0.71[c] (0)	0.86[b] (0.44)	1.02[b] (0.89)	1.02[a] (0.89)
CW	1.65[a] (4.44)	4.00[a] (16.89)	2.98[a] (11.56)	3.92[a] (22.67)	2.41[a] (6.67)	1.34[a] (1.780
Daincha	1.11[a] (1.33)	3.57[a] (13.78)	2.40[b] (7.56)	3.77[a] (16.89)	2.30[a] (5.78)	1.49[a] (2.22)

*$\sqrt{x+0.5}$ transformed values, Original values in parenthesi

Table 91. Population of grass and sedge weeds at 40 DAS during 2005-2006 (Number m^{-2})

Sub plot treatments	Main plot treatments									Sub plot mean		
	Normal seed bed			Stale seed bed (7 days)			Stale seed bed (14 days)					
	Echinochloa	*Cyperus*	*Fimbristylis*	*Echinochloa*	*Cyperus*	*Fimbristylis*	*Echinochloa*	*Cyperus*	*Fimbristylis*	*Echinochloa*	*Cyperus*	*Fimbristylis*
NW	5.73*^{a} (33.33)	5.89^{a} (6.70)	4.20^{a} (17.33)	3.71^{b} (13.33)	4.04^{b} (16.00)	4.02^{a} (16.00)	3.45^{b} (12.00)	3.59^{bc} (13.30)	2.39^{abc} (5.33)	4.30^{a} (19.56)	4.51^{a} (21.30)	3.54^{a} (12.89)
HW	2.59^{bcd} (6.67)	2.39^{cde} (5.30)	2.39^{abc} (5.33)	2.92^{bc} (8.00)	2.65^{bcde} (6.67)	2.92^{ab} (10.67)	2.86^{bc} (8.00)	2.30^{cde} (6.67)	2.65^{ab} (5.33)	2.79^{bc} (7.56)	2.45^{bc} (6.20)	2.65^{a} (7.56)
Sofit	2.65^{bcd} (6.67)	1.44^{de} (2.67)	1.18^{bc} (1.33)	1.92^{cde} (4.00)	1.18^{e} (1.30)	2.12^{bc} (4.00)	1.65^{cde} (2.67)	2.65^{bcde} (6.67)	0.71^{c} (0)	2.07^{cd} (4.44)	1.76^{c} (3.56)	1.34^{b} (1.78)
CW	4.02^{b} (16.00)	2.86^{bcd} (8.00)	1.65^{bc} (2.67)	3.03^{bc} (9.33)	3.30^{bc} (10.67)	1.18^{bc} (1.33)	1.92^{cde} (4.00)	2.86^{bcd} (8.00)	1.92^{bc} (4.00)	3.00^{b} (9.78)	3.00^{b} (8.89)	1.58^{b} (2.67)
Daincha	3.03^{bc} (9.33)	2.18^{cde} (5.30)	0.71^{c} (0)	1.18^{de} (1.33)	2.65^{bcde} (6.67)	2.39^{abc} (5.33)	0.71^{e} (0)	2.59^{bcde} (6.67)	1.83^{bc} (5.33)	1.64^{d} (3.56)	2.47^{bc} (6.22)	1.64^{b} (3.56)
Main plot mean	3.61^{a} (14.40)	2.95^{a} (11.20)	2.02^{a} (5.00)	2.55^{b} (7.20)	2.76^{a} (8.27)	2.53^{a} (7.47)	2.12^{b} (5.30)	2.80^{a} (8.30)	1.90^{a} (4.27)			

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

Table 92. Population of grass and sedge weeds at 40 DAS during 2006-2007 (Number m^{-2})

Sub plot treatments	Main plot treatments									Sub plot mean		
	Normal seed bed			Stale seed bed (7 days)			Stale seed bed (14 days)					
	Echino-chloa	*Cyperus*	*Fimbristylis*	*Echinochloa*	*Cyperus*	*Fimbristylis*	*Echinochloa*	*Cyperus*	*Fimbristylis*	*Echinochloa*	*Cyperus*	*Fimbristylis*
NW	9.17*[a] (84.00)	5.33[a] (28.00)	2.39[a] (5.30)	5.92[b] (34.67)	5.67[a] (36.00)	2.39[a] (5.30)	3.66[c] (13.33)	5.33[a] (28.00)	2.12[ab] (4.00)	6.25[a] (44.00)	5.45[a] (30.67)	2.30[a] (4.89)
HW	1.92[de] (4.00)	1.18[b] (1.30)	1.65[abc] (2.67)	1.65[de] (2.67)	1.92[b] (4.00)	1.65[abc] (2.67)	1.65[de] (2.67)	1.65[b] (2.67)	2.65[a] (6.67)	1.74[bc] (3.10)	1.58[b] (2.67)	1.98[ab] (4.00)
Sofit	2.39[de] (5.30)	2.12[b] (4.00)	1.92[ab] (4.00)	1.65[de] (2.67)	1.18[b] (1.30)	2.12[ab] (4.00)	1.65[de] (2.67)	2.65[b] (6.67)	2.12[ab] (4.00)	1.90[bc] (3.56)	1.98[b] (4.00)	2.05[ab] (4.00)
CW	2.65[cd] (6.67)	2.59[b] (6.67)	0.71[c] (0)	1.92[de] (4.00)	1.83[b] (5.30)	1.18[bc] (1.30)	2.39[cd] (5.30)	1.92[b] (4.00)	0.71[c] (0)	2.32[b] (5.30)	2.11[b] (5.30)	0.86[c] (0.44)
Daincha	1.65[de] (2.67)	1.44[b] (2.67)	1.65[abc] (2.70)	0.71[e] (0)	2.65[b] (6.67)	1.65[abc] (2.67)	1.18[de] (1.30)	2.12[b] (4.33)	1.65[abc] (2.67)	1.18[c] (1.30)	2.07[b] (4.44)	1.65[b] (2.67)
Main plot mean	3.55[a] (20.53)	2.53[a] (8.53)	1.66[a] (2.93)	2.37[b] (8.80)	2.65[a] (10.67)	1.80[a] (3.20)	2.11[b] (5.07)	2.73[a] (9.07)	1.85[a] (3.47)			

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

At 40 DAS, during 2005-06 and 2006-07, only the population of *Echinochloa* was influenced by seed bed preparation with the least count in stale seed bed plots. Population of *Cyperus* and *Fimbristylis* remained unaffected (Table 91 and 92). Among weed management treatments, lower population of *Echinochloa* was observed in plots with concurrent growing of daincha during both years. This treatment was on a par with pre -emergence spraying of Sofit. The count of *Cyperus* was the least in Sofit sprayed plots.

Combination of stale seed bed (14 days) with Daincha gave complete control of *Echinochloa* during 2005-06. Adoption of hand weeding or cono weeding after stale seed bed considerably reduced the population of weeds at 40 DAS as compared to normal seed bed. However, during 2006-07, this trend was noticed with concurrent growing of daincha in stale seed bed for 7 days plots. Significantly higher population of grasses and sedges was observed in unweeded plots of normal seed bed than unweeded plots of stale seed beds.

Population of broad leaf weeds

The data presented in Table 93 indicates that at 20 DAS during 2005-06, stale seed bed preparation reduced the number of broad leaf weeds, except that of *Sphenoclea zeylanica*. The population of broad leaf weeds was the highest in normal seed bed. Pre- emergence spraying of Sofit significantly lowered the population of broad leaf weeds. Concurrent growing of daincha with rice was beneficial in reducing the population of *Lindernia crustacea*. The highest population of *Ludwigia perennis* and *Sphenoclea zeylanica* were noticed in normal seed bed with Daincha.

During 2006-07, only the population of *Ludwigia perennis* was affected by the seed bed treatments. Pre - emergence spraying of Sofit significantly decreased the population of broad leaf weeds at this stage. The effect of seed bed manipulation and weed management on population of broad leaf weeds at 40 DAS is presented in Table 94.

Table 93. Population of major broad leaf weeds at 20 DAS (Number m^{-2})

Main plot treatments	2005-2006			2006-2007	
	Ludwigia	*Lindernia*	*Sphenoclea*	*Ludwigia*	*Sphenoclea*
Normal seed bed	5.00*[a] (10.81)	5.04[a] (9.83)	3.52[a] (4.62)	2.39[ab] (6.13)	1.76[a] (3.20)
Stale seed bed (7 days)	3.76[b] (11.71)	0.71[b] (0)	3.76[a] (8.12)	2.74[a] (7.73)	2.59[a] (7.47)
Stale seed bed (14 days)	4.23[b] (15.51)	0.71[b] (0)	0.90[b] (0.38)	2.74[b] (2.93)	2.00[a] (4.27)
Sub plot treatments					
UWC	5.10*[ab] (16.42)	3.12[a] (5.71)	2.37[c] (3.19)	2.52[a] (6.22)	2.30[ab] (4.89)
HW	4.83[b] (16.06)	3.28[a] (5.07)	3.33[b] (5.34)	2.60[a] (7.56)	2.46[ab] (7.11)
Sofit	0.71[c] (0)	0.71[b] (0)	0.71[d] (0)	1.02[b] (0.89)	1.52[c] (2.67)
CW	5.31[ab] (13.70)	2.95[a] (5.60)	3.01[bc] (3.37)	2.61[a] (7.11)	2.57[a] (7.11)
Daincha	5.70[a] (17.21)	0.71[b] (0)	4.23[a] (9.97)	2.47[a] (6.22)	1.74[bc] (3.11)

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

Table 94.Population of broad leaf weeds at 40 DAS during 2005-2006 (Number m^{-2})

Sub plot treatments	Main plot treatments						Sub plot mean	
	Normal seed bed		Stale seed bed (7 days)		Stale seed bed (14 days)			
	Ludwigia	*Sphenoclea*	*Ludwigia*	*Sphenoclea*	*Ludwigia*	*Sphenoclea*	*Ludwigia*	*Sphenoclea*
NW	7.60*[a] (57.33)	5.92[a] (38.67)	3.45[b] (12)	4.64[ab] (21.33)	2.92[bc] (9.33)	2.56[cd] (8.00)	4.66[a] (26.22)	4.38[a] (22.67)
HW	0.70[d] (0)	0.71[e] (0)	0.71[b] (0)	0.71[e] (0)	1.92[c] (4.00)	0.71[e] (0)	1.11[b] (1.33)	0.71[c] (0)
Sofit	0.71[d] (0)	0.71[e] (0)	0.71[b] (0)	0.71[e] (0)	0.71[d] (0)	0.71[e] (0)	0.71[b] (0)	0.71[c] (0)
CW	2.18[c] (5.33)	2.92[c] (8.00)	0.71[b] (0)	0.71[e] (0)	0.71[d] (0)	3.50[bc] (12.00)	1.20[b] (1.78)	2.38[b] (6.67)
Daincha	0.71[d] (0)	0.71[e] (0)	0.71[b] (0)	0.71[e] (0)	0.71[d] (0)	1.18[de] (1.33)	0.71[b] (0)	0.86[c] (0.44)
Main plot mean	2.38[a] (12.53)	2.19[a] (9.33)	1.26[b] (2.40)	1.49[a] (4.27)	1.39[b] (2.67)	1.73[a] (4.27)		

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

Table 95. Population of broad leaf weeds at 40 DAS during 2006-2007 (Number m^{-2})

Sub plot treatments	Main plot treatments						Sub plot mean	
	Normal seed bed		Stale seed bed (7 days)		Stale seed bed (14 days)			
	Ludwigia	*Sphenoclea*	*Ludwigia*	*Sphenoclea*	*Ludwigia*	*Sphenoclea*	*Ludwigia*	*Sphenoclea*
NW	3.54*^{ab} (12.00)	1.92^{abc} (4.00)	3.84^{a} (14.67)	2.65^{ab} (6.67)	3.40^{ab} (12.00)	2.12^{ab} (4.00)	3.58^{a} (12.89)	2.23^{a} (4.89)
HW	1.18^{c} (1.30)	071^{c} (0)	1.92^{bc} (4.00)	0.71^{c} (0)	1.78^{c} (1.30)	1.92^{c} (4.00)	1.42^{b} (2.22)	1.11^{b} (1.33)
Sofit	0.71^{c} (0)	1.18^{bc} (1.33)	1.92^{bc} (4.00)	1.18^{bc} (1.33)	1.65^{c} (4.00)	1.65^{abc} (2.67)	1.42^{b} (2.67)	1.34^{b} (1.78)
CW	1.44^{c} (2.67)	1.44^{abc} (1.65)	0.71^{c} (0)	12.86^{a} (8.00)	1.18^{c} (1.30)	3.89^{ab} (5.33)	1.11^{b} (1.33)	2.23^{a} (5.33)
Daincha	0.71^{c} (0)	1.65^{abc} (2.25)	2.39^{abc} (6.67)	1.65^{abc} (2.67)	1.65^{c} (2.67)	0.71^{c} (0)	1.58^{b} (3.11)	1.34^{b} (1.78)
Main plot mean	2.17^{a} (3.20)	1.38^{b} (2.13)	1.36^{a} (5.87)	1.81^{a} (3.73)	1.81^{a} (4.27)	1.76^{ab} (3.20)		

*√x+0.5 transformed values, Original values in parenthesis

Table 96. Total dry weight of weeds at 20 DAS (g m^{-2})

Sub plot treatments	Main plot treatments						Sub plot mean	
	Normal seed bed		Stale seed bed (7 days)		Stale seed bed (14 days)			
	05-06	06-07	05-06	06-07	05-06	06-07	05-06	06-07
NW	6.62*[a] (43.32)	5.69[a] (31.88)	5.93[c] (34.66)	3.78[b] (13.79)	5.51[d] (29.86)	2.23[c] (9.93)	6.02[a] (35.74)	3.90[a] (14.71)
HW	6.61[a] (43.19)	5.55[a] (30.30)	5.91[c] (34.43)	4.38[b] (18.68)	5.48[d] (29.53)	2.02[cd] (3.58)	6.00[a] (35.50)	3.99[a] (15.42)
Sofit	0.75[f] (0.06)	0.80[e] (0.14)	1.08[e] (0.67)	0.98[e] (0.46)	0.71[f] (0)	1.16[de] (0.85)	0.85[b] (0.22)	0.98[b] (0.46)
CW	6.41[ab] (40.59)	5.64[a] (31.31)	5.92[c] (34.55)	3.72[c] (13.34)	5.60[d] (30.86)	1.66[cde] (2.26)	5.98[a] (35.26)	3.68[a] (13.04)
Daincha	6.28[b] (38.94)	4.71[ab] (21.68)	5.97[c] (35.14)	3.88[cd] (14.48)	5.57[d] (30.52)	2.07[cd] (3.78)	5.94[a] (34.78)	3.55[a] (12.10)
Main plot mean	5.34[a] (28.02)	4.48[a] (19.57)	4.96[b] (24.10)	3.35[b] (10.72)	4.57[c] (20.38)	1.83[c] (2.85)		

Table 97. Total dry weight of weeds at 40 DAS (g m^{-2})

Sub plot treatments	Main plot treatments						Sub plot mean	
	Normal seed bed		Stale seed bed (7 days)		Stale seed bed (14 days)			
	05-06	06-07	05-06	06-07	05-06	06-07	05-06	06-07
NW	8.87*[a] (78.18)	8.87[a] (78.18)	7.76[b] (59.72)	7.72[a] (59.10)	7.81[b] (60.50)	5.97[b] (35.14)	8.15[a] (65.92)	7.52[a] (56.05)
HW	3.78[de] (13.79)	2.44[c] (5.45)	4.34[d] (18.34)	2.45[c] (5.50)	2.91[fg] (7.97)	2.99[c] (8.44)	3.68[c] (13.04)	2.63[b] (6.42)
Sofit	3.65[fgh] (6.52)	3.02[c] (8.62)	1.96[h] (3.34)	2.24[c] (4.52)	2.18[gh] (4.25)	3.13[c] (9.30)	2.26[d] (4.61)	2.80[b] (7.34)
CW	5.42[c] (28.88)	3.54[c] (12.03)	4.46[d] (19.39)	3.31[c] (10.46)	3.26[ef] (10.13)	3.02[c] (8.62)	4.38[b] (18.68)	3.29[b] (10.32)
Daincha	2.92[fg] (8.03)	2.51[c] (5.80)	2.62[fgh] (6.36)	3.38[c] (10.92)	2.59[fgh] (6.21)	2.44[c] (5.45)	2.71[d] (6.84)	2.77[b] (7.17)
Main plot mean	4.73[a] (21.87)	4.08[a] (16.15)	4.23[b] (17.39)	3.82[b] (14.09)	3.75[c] (13.56)	3.51[c] (11.82)		

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

during 2005-06. At this stage the population of *Sphenoclea zeylanica* varied profoundly among seed bed treatments. Stale seed bed technique significantly decreased its population compared to normal seed bed.

All weed management methods successfully decreased the population of broad leaf weeds. The least population of *Sphenoclea* and *Ludwigia* was in Sofit sprayed plots. Concurrent growing of daincha also gave complete control of *Ludwigia* and reduced the population of *Sphenoclea*. Population of major broad leaf weeds was significantly higher in unweeded plots. Under normal seed bed situation cono weeding was found not effective in controlling them. However, combination of stale seed bed with cono weeding gave complete control of these weeds.

The data presented in Table 95 points out that stale seed bed had no effect in reducing the population of broad leaf weeds. The lowest count of *Sphenoclea* was found in normal seed bed. Concurrent growing of daincha with rice was not effective in reducing the population of *Sphenoclea* at this stage.

Total dry matter production of weeds

Total weed dry weight at 20 DAS as influenced by treatments during 2005-06 and 2006-07 is presented in Table 96. Data clearly reveals the superiority of stale seed bed technique in reducing the weed dry weight. Stale seed bed for 14 days was the best main plot treatment followed by stale seed bed for 7 days. Pre - emergence spraying of Sofit reduced the dry weight of weeds at this stage. All other sub plot treatments were at par.

Combination of Soft with stale seed bed for 14 days gave complete control of weeds. It was followed by Sofit in normal seed bed and in stale seed bed for 7 days during 2005-06. However, during 2006-07, Sofit in normal seed bed showed lower weed dry weight followed by Sofit in stale seed bed for 7 days and 14 days.

Table 98. Total dry weight of weeds at harvest (g m^{-2})

Sub plot treatments	Main plot treatments: Normal seed bed		Stale seed bed (7 days)		Stale seed bed (14 days)		Sub plot mean	
	05-06	06-07	05-06	06-07	05-06	06-07	05-06	06-07
NW	7.82*[a] (60.65)	9.88[a] (97.11)	7.55[a] (56.50)	6.54[b] (42.27)	5.07[b] (25.20)	6.53[b] (42.14)	6.81[a] (45.88)	7.65[a] (58.02)
HW	2.03[g] (3.62)	4.55[c] (20.20)	3.69[c] (13.12)	4.41[cd] (18.95)	3.45[cd] (11.40)	3.79[cde] (13.86)	3.05[b] (8.80)	4.25[b] (17.56)
Sofit	3.09[cde] (9.05)	4.66[c] (21.22)	2.70[efg] (6.79)	4.38[cd] (18.68)	2.58[efg] (6.16)	3.31[def] (10.46)	2.79[b] (7.28)	4.12[bc] (16.47)
CW	2.27[fg] (4.65)	4.34[cd] (18.34)	3.68[c] (13.04)	4.16[cd] (16.81)	3.58[cd] (12.32)	2.34[f] (4.98)	3.18[b] (9.61)	3.61[c] (12.53)
Daincha	2.88[def] (7.79)	4.49[c] (19.66)	3.45[cd] (11.40)	4.87[c] (23.22)	3.07[cde] (8.92)	2.88[ef] (7.79)	3.14[b] (9.36)	4.08[bc] (16.15)
Main plot mean	3.62[b] (12.60)	5.58[a] (30.64)	4.21[a] (17.22)	4.87[b] (23.22)	3.55[c] (12.10)	3.77[c] (13.71)		

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

Table 99. Dry weight of grasses, sedges and broad leaf weeds at 20 DAS (g m^{-2})

Main plot treatments	2005-2006			2006-2007		
	Grasses	Sedges	Broad leaf	Grasses	Sedges	Broad leaf
Normal seed bed	2.66*[a] (1.58)	3.89[a] (6.39)	8.37[a] (25.26)	3.87[a] (17.06)	2.99[a] (11.56)	1.58[b] (2.31)
Stale seed bed (7 days)	0.71[b] (0)	3.99[a] (6.47)	5.25[b] (19.85)	2.60[b] (7.76)	0.91[c] (0.40)	2.06[a] (4.33)
Stale seed bed (14 days)	0.71b (0)	4.18[a] (8.26)	4.30[c] (15.89)	0.80[c] (0.18)	1.24[b] (1.24)	1.41[b] (1.67)
Sub plot treatments						
UWC	1.58*[a] (0.66)	4.89[ab] (9.97)	7.04[a] (25.32)	2.99[a] (11.56)	1.68[a] (2.87)	1.68[a] (2.51)
HW	1.58[a] (0.64)	4.23[b] (8.59)	7.44[a] (26.49)	2.93[a] (10.73)	1.66[a] (2.71)	2.03[a] (4.18)
Sofit	0.86[a] (0.22)	1.18[c] (0.27)	0.71[b] (0)	0.72[b] (0.03)	0.75[c] (0.07)	0.93[b] (0.44)
CW	1.65[a] (0.88)	5.35[a] (11.80)	7.28[a] (22.68)	2.73[a] (10.87)	1.37[b] (1.84)	1.97[a] (3.66)
Daincha	1.11[a] (0.43)	4.46[ab] (7.26)	7.39[a] (27.18)	2.75[a] (8.87)	1.37[b] (1.57)	1.81[a] (3.06)

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

Stale seed bed for 14 days continued its superiority in reducing the weed dry weight at 40 DAS (Table 97). Plots with no weeding recorded the highest weed dry weight during both years. During 2005-06, Sofit and concurrent growing of daincha produced lower weed dry matter, whereas, in the subsequent year all weed management treatments were at par. Pre emergence spraying of Sofit in stale seed bed for 7 days gave the lowest weed dry weight during the first year of study. However, during second year except un weeded plots of normal seed bed, stale seed bed for 7 days and stale seed bed for 14 days, all other treatment combinations were at par.

Weed dry weight at harvest stage was lowest in stale seed bed for 14 days during both years. Unweeded plots recorded the highest weed dry weight. Unweeded plots of normal seed bed and stale seed bed for 7 days recorded higher weed dry weight followed by unweeded plots of stale seed bed for 14 days. Hand weeding in normal seed bed gave the lowest weed dry weight during 2005-06 whereas, during 2006-07 cono weeding in stale seed bed for 14 days was the best treatment combination, which lowered the dry matter accumulation by weeds at harvest stage (Table 98).

Seed bed manipulation exerted profound influence on the total dry weights of grass weeds at 20 DAS (Table 99). Complete control of *Echinochloa* was observed in stale seed bed plots. Compared to normal seed bed, stale seed bed had a negative influence on the dry matter accumulation of broad leaf weeds. Dry weight of broad leaf weeds was the lowest in stale seed bed for 14 days followed by stale seed bed for 7 days. Among weed management treatments, Sofit influenced the dry matter production of sedges and broad leaf weeds. Plots with concurrent growing of daincha showed slight decrease in the dry weight of grasses.

During 2006-07, at 20 DAS, least dry weights of grass weeds was observed in stale seed bed (14 days) plots followed by stale seed bed for 7 days. Dry biomass of grasses and sedges showed the maximum in normal seed bed. Significantly lower dry weight of sedges was observed in stale seed bed for 7 days followed by stale seed bed for 14 days.

Table 100. Dry weight of grasses, sedges and broad leaf weeds at 40 DAS during 2005-2006 (g m^{-2})

Sub plot treatments	Main plot treatments									Sub plot mean		
	Normal seed bed			Stale seed bed (7 days)			Stale seed bed (14 days)					
	Grasses	Sedges	Broad leaf	Grasses	Sedges	Broad leaf	Grasses	Sedges	Broad leaf	Grasses	Sedges	Broad leaf
NW	4.07^{*ab} (16.29)	4.95^{a} (24.27)	6.16^{a} (37.71)	3.82^{ab} (14.09)	4.11^{a} (16.47)	5.44^{a} (2.917)	4.83^{a} (23.64)	4.08^{a} (16.81)	4.38^{b} (20.17)	4.24^{a} (18.01)	4.38^{a} (19.18)	5.33^{a} (29.02)
HW	3.27^{bc} (11.01)	1.96^{bcd} (3.36)	0.71^{e} (0)	3.36^{bc} (10.76)	2.82^{b} (7.64)	0.71^{e} (0)	1.67^{de} (2.44)	1.95^{bcd} (3.95)	1.45^{de} (1.88)	2.76^{b} (8.07)	2.24^{b} (4.98)	0.95^{c} (0.63)
Sofit	2.39^{cd} (5.24)	1.25^{d} (1.43)	0.71^{e} (0)	1.61^{de} (2.49)	1.13^{d} (0.89)	0.71^{e} (0)	1.40^{de} (1.73)	1.72^{cd} (2.53)	0.71^{e} (0)	1.80^{c} (3.16)	1.36^{c} (1.62)	0.71^{c} (0)
CW	3.77^{ab} (13.89)	2.08^{bcd} (3.92)	3.37^{c} (11.12)	3.41^{bc} (11.33)	2.86^{b} (8.01)	0.78^{e} (0.12)	1.47^{de} (2.00)	2.01^{bcd} (3.60)	2.18^{d} (4.53)	2.88^{b} (9.08)	2.33^{b} (5.18)	2.11^{b} (5.26)
Daincha	2.45^{cd} (5.61)	1.68^{cd} (2.79)	0.71^{e} (0)	1.02^{e} (0.72)	4.23^{a} (5.81)	0.71^{e} (0)	0.71^{e} (0)	2.44^{bc} (5.56)	1.05^{e} (0.83)	1.39^{c} (2.11)	2.18^{b} (4.72)	0.82^{c} (0.28)
Main plot mean	3.19^{a} (10.41)	2.38^{a} (7.15)	2.33^{a} (9.77)	2.64^{ab} (7.88)	2.68^{a} (7.74)	1.67^{c} (5.86)	2.02^{b} (5.96)	2.44^{a} (6.49)	1.95^{b} (5.48)			

*√x+0.5 transformed values, Original values in parenthesis

Table 101. Dry weight of grasses, sedges and broad leaf weeds at 40 DAS 2006-2007 (g m^{-2})

Sub plot treatments	Main plot treatments									Sub plot mean		
	Normal seed bed			Stale seed bed (7 days)			Stale seed bed (14 days)					
	Grasses	Sedges	Broad leaf	Grasses	Sedges	Broad leaf	Grasses	Sedges	Broad leaf	Grasses	Sedges	Broad leaf
NW	7.09*[a] (50.00)	3.94[a] (15.09)	3.66[ab] (13.20)	4.80[b] (22.53)	4.11[a] (17.89)	4.45[a] (19.35)	3.12[c] (9.85)	3.85[a] (14.33)	3.34[abc] (11.27)	5.00[a] (27.46)	3.97[a] (15.77)	3.82[a] (14.60)
HW	1.88[def] (3.79)	1.16[b] (1.01)	1.41[d] (1.93)	1.39[def] (1.67)	1.55[b] (2.32)	1.74[d] (3.24)	1.29[ef] (1.35)	1.86[b] (2.99)	2.11[cd] (4.20)	1.52[bc] (2.27)	1.52[b] (2.11)	1.75[b] (3.12)
Sofit	2.29[cde] (4.81)	1.84[b] (2.93)	1.05[d] (0.84)	1.34[def] (1.48)	1.15[b] (0.97)	1.72[d] (3.19)	1.26[ef] (1.24)	2.29[b] (4.77)	1.94[cd] (3.64)	1.63[bc] (2.51)	1.76[b] (2.89)	1.57[b] (2.56)
CW	2.49[cd] (5.77)	2.11[b] (4.37)	1.40[d] (2.40)	1.30[ef] (1.72)	1.66[b] (3.37)	2.41[bcd] (5.47)	1.73[def] (2.60)	1.51[b] (2.12)	2.19[cd] (4.80)	1.84[b] (3.36)	1.76[b] (3.29)	2.00[b] (4.22)
Daincha	1.50[def] (2.11)	1.42[b] (2.03)	1.49[d] (1.73)	0.71[f] (0)	2.21[b] (4.59)	2.52[bcd] (6.44)	1.00[f] (0.67)	1.94[b] (3.35)	1.36[d] (1.57)	1.07[c] (0.92)	1.86[b] (3.32)	1.79[b] (3.25)
Main plot mean	3.05[a] (13.30)	2.10[a] (5.09)	1.80[b] (4.02)	1.91[b] (5.48)	2.14[a] (5.83)	2.57[a] (7.54)	1.68[b] (3.14)	2.29[a] (5.51)	2.19[ab] (5.10)			

*√x+0.5 transformed values, Original values in parenthesis

Almost similar trend of dry weight of broad leaf weeds was noticed in stale seed bed for 14 days and in normal seed bed plots. Pre-emergence application of Sofit significantly decreased the dry weight of weeds at 20 DAS. Concurrent growing of daincha with rice increased the dry weight of sedges compared to other weed control treatments.

Total dry weight of grasses, sedges and broad leaf weeds at 40 DAS, during 2005-06 showed the lowest value of grasses in stale seed bed for 14 days followed by stale seed bed for 7 days. Total dry weight of sedges was not influenced by the seed bed preparation. Broad leaf weed dry weight was the lowest in stale seed bed (7 days) plots. Pre emergence spray of Sofit gave significant reduction in the dry weight of grasses and sedges and gave complete control of broad leaf weeds. *In situ* green manuring of daincha significantly reduced the dry weight of grasses and broad leaf weeds. Hand weeding decreased the dry weight of broad leaf weeds.

Significant reduction in the dry weight of grasses was noticed in stale seed bed (14 days) in combination with any of the weed control method. These treatments were not much effective in controlling the dry weight of grasses in normal seed bed (Table 100).

Total dry weight of grasses, sedges and broad leaf weeds at 40 DAS during 2006-07 is given in Table 101. Both stale seed bed plots were almost similar with respect to dry weight of grasses. Among weed control treatments, the lowest dry weight of grasses was observed in daincha grown plot. This treatment was on a par with hand weeding and Sofit. Dry weight of sedges and broad leaf weeds was the highest in unweeded plots. All other sub plots were at par. Stale seed bed for 14 days with or without weeding gave significant reduction in the dry weight of grasses compared to normal seed bed. As compared to normal seed bed, stale seed bed exerted no significant variation in the dry weights of sedges and broad leaf weeds.

Table 102. Dry weight of grasses, sedges and broad leaf weeds at harvest during 2005-2006 (g m^{-2})

Sub plot treatments	Main plot treatments									Sub plot mean		
	Normal seed bed			Stale seed bed (7 days)			Stale seed bed (14 days)					
	Grasses	Sedges	Broad leaf	Grasses	Sedges	Broad leaf	Grasses	Sedges	Broad leaf	Grasses	Sedges	Broad leaf
NW	5.30*^{b} (28.40)	4.65^{a} (21.39)	3.23^{a} (10.88)	6.86^{a} (46.95)	2.93^{bc} (8.36)	1.30^{b} (1.36)	3.51^{c} (11.97)	3.39^{b} (11.04)	1.63^{b} (2.17)	5.23^{a} (29.11)	3.65^{a} (13.60)	2.05^{a} (4.80)
HW	1.97^{de} (3.47)	0.85^{f} (0.27)	0.71^{b} (0)	2.82^{cd} (7.49)	2.32^{cd} (4.93)	1.00^{b} (0.67)	2.45^{cde} (5.52)	2.20^{cd} (4.32)	1.38^{b} (1.56)	2.42^{b} (5.49)	1.79^{bc} (3.17)	1.03^{b} (0.74)
Sofit	1.92^{de} (3.93)	2.22^{cd} (4.68)	0.93^{b} (0.45)	2.46^{cde} (5.57)	1.07^{f} (0.91)	0.93^{b} (0.45)	2.23^{de} (4.68)	1.37^{ef} (1.59)	0.71^{b} (0)	2.20^{b} (4.73)	1.55^{c} (2.39)	0.85^{b} (0.30)
CW	1.36^{e} (1.49)	1.91^{de} (3.17)	0.71^{b} (0)	2.99^{cd} (8.52)	2.10^{de} (3.89)	1.04^{b} (0.79)	2.87^{cd} (7.84)	2.01^{de} (3.57)	1.17^{b} (0.99)	2.40^{b} (5.95)	2.01^{b} (3.55)	0.97^{b} (0.59)
Daincha	2.20^{de} (4.47)	1.82^{de} (2.83)	1.01^{b} (0.71)	2.51^{cd} (5.83)	2.44^{cd} (5.52)	0.78^{b} (0.12)	2.34^{de} (5.24)	1.98^{de} (3.43)	1.00^{b} (0.67)	2.35^{b} (5.18)	2.08^{b} (3.92)	0.93^{b} (0.50)
Main plot mean	2.55^{b} (8.35)	2.29^{a} (6.470	1.32^{a} (2.41)	3.53^{a} (14.87)	2.17^{a} (4.72)	1.01^{a} (0.68)	2.68^{b} (7.05)	2.19^{a} (4.79)	1.18^{a} (1.08)			

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

Table 103. Dry weight of grasses, sedges and broad leaf weeds at harvest during 2006-2007 (g m^{-2})

Sub plot treatments	Main plot treatments									Sub plot mean		
	Normal seed bed			Stale seed bed (7 days)			Stale seed bed (14 days)					
	Grasses	Sedges	Broad leaf	Grasses	Sedges	Broad leaf	Grasses	Sedges	Broad leaf	Grasses	Sedges	Broad leaf
NW	7.79*^{a} (60.13)	4.98^{a} (25.07)	3.50^{ab} (12.13)	4.15^{b} (17.08)	4.23^{abc} (17.67)	2.81^{abc} (7.68)	2.81^{cd} (7.61)	4.44^{ab} (19.52)	3.93^{a} (15.24)	4.92^{a} (28.28)	4.55^{a} (20.75)	3.42^{a} (11.68)
HW	2.65^{cd} (6.96)	3.15^{cde} (9.61)	2.09^{cd} (4.13)	1.91^{cdef} (3.21)	3.51^{bcd} (12.00)	2.07^{cd} (3.84)	1.33^{ef} (1.48)	3.13^{cde} (9.40)	1.86^{cd} (3.04)	1.96^{b} (3.88)	3.26^{b} (10.34)	2.01^{b} (3.67)
Sofit	2.89^{c} (8.00)	2.74^{def} (7.01)	2.60^{bc} (6.28)	2.06^{cdef} (4.05)	3.06^{cde} (8.96)	2.34^{bcd} (6.37)	1.04^{f} (0.79)	2.90^{de} (8.17)	1.25^{d} (1.67)	2.00^{b} (4.28)	2.90^{b} (8.05)	2.07^{b} (4.77)
CW	2.38^{cde} (5.36)	3.02^{cde} (8.63)	2.18^{cd} (4.45)	2.08^{cdef} (4.13)	3.41^{bcde} (11.27)	1.21^{d} (1.47)	1.07^{f} (0.91)	1.65^{f} (2.85)	1.22^{d} (1.49)	1.84^{b} (3.47)	2.70^{b} (7.58)	1.53^{b} (2.47)
Daincha	1.76^{def} (2.60)	3.37^{bcde} (11.20)	2.57^{bc} (6.24)	2.44^{cd} (5.44)	3.52^{bcd} (11.93)	2.48^{bcd} (5.97)	1.18^{f} (0.79)	2.28^{ef} (5.03)	1.53^{cd} (2.28)	1.79^{b} (3.12)	3.06^{b} (9.39)	2.20^{b} (4.83)
Main plot mean	3.49^{a} (16.61)	3.45^{a} (12.30)	2.56^{a} (6.65)	2.63^{b} (6.78)	3.55^{a} (12.37)	2.18^{a} (5.07)	1.49^{c} (2.42)	2.88^{b} (4.00)	1.96^{a} (4.74)			

*$\sqrt{x+0.5}$ transformed values, Original values in parenthes

Table 104. Dry weight of grass and sedge weeds at 20 DAS (g m^{-2})

Main plot treatments	2005-2006			2006-2007		
	Echinochloa	*Cyperus*	*Fimbristylis*	*Echinochloa*	*Cyperus*	*Fimbristylis*
Normal seed bed	2.66*[a] (1.58)	3.89[a] (6.39)	0.71[c] (0)	3.87[a] (17.06)	1.95[a] (3.78)	0.72[a] (0.02)
Stale seed bed (7 days)	0.71[b] (0)	3.44[b] (6.60)	1.96[b] (1.45)	2.60[b] (7.76)	0.90[c] (0.38)	0.72[a] (0.02)
Stale seed bed (14 days)	0.71b (0)	2.39[c] (3.05)	3.42[a] (5.20)	0.80[c] (0.18)	1.24[b] (1.22)	0.72[a] (0.02)
Sub plot treatments						
UWC	1.58*[a] (0.66)	3.84[a] (7.11)	2.17[b] (2.86)	2.99[a] (11.56)	1.68[a] (2.85)	0.72[a] (0.01)
HW	1.58[a] (0.64)	3.60[a] (7.30)	1.86[b] (1.29)	2.93[a] (10.73)	1.66[a] (2.69)	0.72[a] (0.02)
Sofit	0.86[a] (0.22)	1.23[b] (1.02)	0.71[c] (0)	0.72[b] (0.03)	0.74[c] (0.06)	0.72[a] (0.01)
CW	1.65[a] (0.88)	4.00[a] (7.40)	2.98[a] (4.39)	2.73[a] (10.87)	1.36[b] (1.82)	0.72[a] 90.02)
Daincha	1.11[a] (0.43)	3.57[a] (4.70)	2.70[b] (2.56)	2.75[a] (8.87)	1.36[b] 1.55)	0.72[a] (0.02)

*√x+0.5 transformed values, Original values in parenthesis

Total dry weight of grasses, sedges and broad leaf weeds during harvest stage of the crop during 2005-06 is presented in Table 102. At this stage, the dry weight of grasses varied significantly among the seed bed treatments. Stale seed bed for 14 days lowered the dry weight of grasses. Weed management treatments had no significant effect on dry weight of grasses and broad leaf weeds at this stage. However, the dry weight of sedges showed the lowest values in Sofit sprayed plots. Unweeded plots of stale seed bed (14 days) recorded the minimum dry weights of all weeds than the unweeded plots of normal seed bed. Pre-emergence spraying of Sofit in stale seed bed (14 days) significantly lowered the dry weight of sedges than its combination with normal seed bed and this treatment combination gave complete control of broad leaf weeds.

The data in Table 103 reveals that during 2006-07, stale seed bed continued its influence on weeds till harvest stage. The lowest weight of grasses and sedges were noticed in stale seed bed (14 days) plots. The stale seed bed for 7 days gave significant control only for grasses. Except in unweeded control plots, dry weight of grasses, sedges and broad leaf weeds showed no significant variation. Weed control treatments in combination with stale seed bed for 14 days significantly lowered the dry weights of grasses and broad leaf weeds than their combination with normal seed bed or with stale seed bed for 7 days.

Dry weight of grass and sedge weeds

Dry weight of grasses and sedges at 20 DAS showed significant variation due to seed bed manipulation (Table 104). Considerably lower dry matter was observed in stale seed bed. However, dry weight of *Fimbristylis* was the lowest in normal seed bed plots. At this stage, weed control treatments had no significant influence on the dry weight of *Echinochloa*. However, the dry weight of *Cyperus* and *Fimbristylis* were lower in plots received pre - emergence spraying of Sofit.

Table 105. Dry weight of grass and sedge weeds at 40 DAS during 2005-2006 (g m^{-2})

Sub plot treatments	Main plot treatments									Sub plot mean		
	Normal seed bed			Stale seed bed (7 days)			Stale seed bed (14 days)					
	Echinochloa	*Cyperus*	*Fimbristylis*	*Echinochloa*	*Cyperus*	*Fimbristylis*	*Echinochloa*	*Cyperus*	*Fimbristylis*	*Echinochloa*	*Cyperus*	*Fimbristylis*
NW	4.07*^{ab} (16.29)	4.50^{a} (20.13)	2.15^{ab} (4.13)	3.82ab (14.09)	3.52^{b} (11.87)	2.23^{a} (4.60)	4.83^{a} (23.64)	3.64^{ab} (13.52)	1.92^{abc} (3.29)	4.24^{a} (18.01)	3.89^{a} (15.73)	2.10^{a} (4.01)
HW	3.27^{bc} (11.01)	1.88^{cdef} (3.07)	0.89^{def} (0.29)	3.36bc (10.76)	2.32^{cd} (5.09)	1.62^{abcd} (2.55)	1.67^{de} (2.44)	1.40^{def} (1.72)	1.56^{abcde} (2.23)	2.76^{b} (8.07)	1.87^{b} (3.29)	1.36^{b} (1.69)
Sofit	2.39^{cd} (5.24)	1.17^{ef} (1.31)	0.78^{ef} (0.12)	1.61^{de} (2.49)	1.00^{f} (0.67)	0.85^{def} (0.23)	1.40^{de} (1.73)	1.72^{def} (2.53)	0.71^{f} (0)	1.80^{c} (3.16)	1.30^{c} (1.50)	0.78^{c} (0.12)
CW	3.77^{ab} (13.89)	2.05^{cde} (3.77)	0.80^{def} (0.15)	3.41^{bc} (11.33)	2.87^{bc} (7.93)	0.76^{ef} (0.08)	1.47^{de} (2.00)	1.96^{cdef} (3.41)	0.82^{def} (0.19)	2.88^{b} (9.08)	2.29^{b} (5.04)	0.79^{c} (0.14)
Daincha	2.45^{cd} (5.61)	1.68^{def} (2.79)	0.71^{f} (0)	1.02^{e} (0.72)	2.10^{cde} (4.09)	1.43^{bcdef} (1.72)	0.71^{e} (0)	2.14^{cde} (4.32)	1.16^{cdef} (1.24)	1.39^{c} (2.11)	1.97^{b} (3.73)	1.10^{bc} (0.99)
Main plot mean	3.19^{a} (10.41)	2.26^{a} (6.21)	1.07b (0.94)	2.64^{ab} (7.88)	2.36^{a} (5.93)	1.38^{a} (1.84)	2.02^{b} (5.96)	2.17^{a} (5.10)	1.23^{ab} (1.39)			

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

Table 106. Dry weight of grass and sedge weeds at 40 DAS during 2006-2007 (g m^{-2})

Sub plot treatments	Main plot treatments									Sub plot mean		
	Normal seed bed			Stale seed bed (7 days)			Stale seed bed (14 days)					
	Echinochloa	*Cyperus*	*Fimbristylis*	*Echinochloa*	*Cyperus*	*Fimbristylis*	*Echinochloa*	*Cyperus*	*Fimbristylis*	*Echinochloa*	*Cyperus*	*Fimbristylis*
NW	7.09*[a] (50.00)	3.81[a] (14.04)	1.22[abc] (1.05)	4.80[b] (22.53)	3.93[a] (16.65)	1.29[ab] (1.24)	3.12[c] (9.85)	3.77[a] (13.68)	1.07[abc] (0.65)	5.00[a] (27.46)	3.84[a] (14.79)	1.19[a] (0.98)
HW	1.88[def] (3.79)	0.98[b] (0.60)	0.94[abc] (0.41)	1.39[def] (1.67)	1.46[b] (1.97)	0.90[abc] (0.35)	1.29[ef] (1.35)	1.29[b] (1.30)	1.44[a] (1.65)	1.52[bc] (2.27)	1.24[b] (1.30)	1.10[a] (0.80)
Sofit	2.29[cde] (4.81)	1.58[b] (2.00)	1.14[abc] (0.93)	1.34[def] (1.48)	0.97[b] (0.57)	0.94[abc] (0.40)	1.26[ef] (1.24)	1.91[b] (3.23)	1.42[a] (1.55)	1.63[bc] (2.51)	1.48[b] (1.93)	1.17[a] (0.96)
CW	2.49[cd] (5.77)	2.11[b] (4.37)	0.71[c] (0)	1.30[ef] (1.72)	1.51[b] (3.09)	0.86[bc] (0.28)	1.73[def] (2.60)	1.51[b] (1.85)	0.71[c] (0)	1.84[b] (3.36)	1.71[b] (3.20)	0.78[b] (0.09)
Daincha	1.50[def] (2.11)	1.18[b] (1.35)	1.06[abc] (0.68)	0.71[f] (0)	1.98[b] (3.51)	1.20[abc] (1.08)	1.00[f] (0.67)	1.62[b] (2.12)	1.26[abc] (1.23)	1.07[c] (0.92)	1.59[b] (2.32)	1.17[a] (0.97)
Main plot mean	3.05[a] (13.30)	1.93[a] (4.72)	1.01[a] (0.62)	1.91[b] (5.48)	1.97[a] (5.16)	1.04[a] (0.70)	1.68[b] (3.14)	2.02[a] (4.50)	1.18[a] (1.02)			

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

During 2006-07, seed bed manipulation affected the dry weight of weeds with the lowest dry weight of *Echinochloa* and *Cyperus* in plots with stale seed bed for 14 days. Dry weight of *Fimbristylis* was not affected by the different treatments. Among weed management treatments pre-emergence spraying of Sofit significantly reduced the dry weights of *Echinochloa* and *Cyperus*.

The data in Table 105 reveals that the dry weight of *Echinochloa* at 40 DAS was significantly lower in stale seed bed (14 days) plots. Seed bed treatments exhibited influence on dry weight of *Cyperus* at this stage. The lowest dry weight of *Fimbristylis* was observed in normal seed bed.

Weed control methods showed significant variation in dry weights of grasses and sedges. Pre emergence application of Sofit continued its superiority over other sub plots in lowering the dry matter accumulation of *Echinochloa*, *Cyperus* and *Fimbristylis*. *In situ* green manuring of daincha also reduced the dry weight of *Echinochloa*. Cono weeding at 20 DAS was effective in controlling the dry matter accumulation of *Fimbristylis*.

Combination of stale seed bed with green manuring of daincha significantly lowered the dry weight of *Echinochloa*. Sofit in combination with all seed bed treatments gave significant reduction in the dry weights of *Cyperus* and *Fimbristylis*. Reduction in the dry weight of *Fimbristylis* was noticed with daincha in normal seed bed or cono weeding in stale seed bed for 7 days.

Significant reduction in dry weight of *Echinochloa* was observed in stale seed bed plots in contrast to normal seed bed during 2006-07 (Table 106). However, dry weight of *Cyperus* and *Fimbristylis* showed no significant variation among different seed bed treatments. The lowest dry weight of *Echinochloa* was achieved by concurrent growing of daincha. This treatment was on a par with pre - emergence spray of Sofit and hand weeding. Except in unweeded control plots, dry weight of *Cyperus* was not significantly influenced by weed control measures. Cono weeding proved beneficial in reducing the dry weight of *Fimbristylis*.

Among unweeded plots, dry weight of *Echinochloa* was found to be the lowest under stale seed bed for 14 days, followed by stale seed bed for 7 days. Normal seed bed showed the maximum dry matter accumulation under unweeded situation. However, stale seed bed technique was not effective in reducing the dry weight of *Cyperus*.

In situ green manuring of daincha in combination with stale seed bed for 14 days or for 7 days significantly reduced the dry weight of *Echinochloa*. Post emergence weed control methods in combination with stale seed bed technique for 14 days was found to be very effective in managing *Echinochloa* as compared to combination of post emergence weed control measures with normal seed bed.

Dry weight of broad leaf weeds

Dry matter production of major broad leaf weeds at 20 DAS during 2005-06 and 2006-07 are presented in Table 107. Adoption of stale seed bed technique either for 7 days or for 14 days significantly reduced the dry weights of *Lindernia* and *Ludwigia*. The highest reduction in the dry weight of *Sphenoclea* was noticed in plots with stale seed bed for 14 days. Dry matter production of major weeds was higher in normal seed beds. Complete control of broad leaf weeds was obtained with application of Sofit at 3 DAS.

Dry weights of *Ludwigia* and *Sphenoclea* were the lowest at 20 DAS during 2006-07 in plots with stale seed bed for 14 days. At this stage of observation, stale seed bed for 7 days produced the highest dry weight of broad leaf weeds. Concurrent growing of daincha had no effect on the dry weights at 20 DAS.

Table 107. Dry weight of broad leaf weeds at 20 DAS (g m^{-2})

Main plot treatments	2005-2006			2006-2007	
	Ludwigia	*Lindernia*	*Sphenoclea*	*Ludwigia*	*Sphenoclea*
Normal seed bed	5.00*[a] (10.81)	5.04[a] (9.83)	3.52[a] (4.62)	1.40[ab] (1.81)	0.96[b] (0.50)
Stale seed bed (7 days)	3.76[b] (11.71)	0.71[b] (0)	3.76[a] (8.12)	1.61[a] (2.38)	1.48[a] (1.95)
Stale seed bed (14 days)	4.23[b] (15.51)	0.71[b] (0)	0.90[b] (0.38)	1.18[b] (0.97)	1.06[b] (0.71)
Sub plot treatments					
UWC	5.10*[ab] (16.42)	3.12[a] (5.71)	2.37[c] (3.19)	1.34[a] ((1.48)	1.20[ab] (1.03)
HW	4.83[b] (16.06)	3.28[a] (5.07)	3.33[b] (5.34)	1.67[a] (2.57)	1.34[a] (1.60)
Sofit	0.71[c] (0)	0.71[b] (0)	0.71[d] (0)	0.76[b] (0.08)	0.89[b] (0.35)
CW	5.31[ab] (13.70)	2.95[a] (5.60)	3.01[bc] (3.37)	1.52[a] (2.18)	1.32[a] (1.48)
Daincha	5.70[a] (17.21)	0.71[b] (0)	4.23[a] (9.97)	1.58[a] (2.26)	1.08[ab] (0.80)

*√x+0.5 transformed values, Original values in parenthesis

Table 108. Dry weight of broad leaf weeds at 40 DAS during 2005-2006 (g m^{-2})

Sub plot treatments	Main plot treatments						Sub plot mean	
	Normal seed bed		Stale seed bed (7 days)		Stale seed bed (14 days)			
	Ludwigia	*Sphenoclea*	*Ludwigia*	*Sphenoclea*	*Ludwigia*	*Sphenoclea*	*Ludwigia*	*Sphenoclea*
NW	4.28*^{a} (17.83)	4.13^{a} (19.8)	3.42^{b} (11.19)	3.75^{a} (13.59)	3.20^{b} (9.91)	2.54^{b} (7.60)	3.63^{a} (12.97)	3.47^{a} (12.66)
HW	0.71^{e} (0)	0.71^{c} (0)	0.71^{e} (0)	0.71^{c} (0)	1.45^{d} (1.88)	0.71^{c} (0)	0.95^{bc} (0.63)	0.71^{c} (0)
Sofit	0.71^{e} (0)	0.71^{c} (0)	0.71^{e} (0)	0.71^{c} (0)	0.71^{e} (0)	0.71^{c} (0)	0.71^{c} (0)	0.71^{c} (0)
CW	2.18^{c} (5.32)	2.50^{c} (5.80)	0.71^{e} (0)	0.71^{c} (0)	0.71^{e} (0)	2.18^{b} (4.53)	1.20^{b} (1.77)	1.79^{b} (3.44)
Daincha	0.71^{e} (0)	0.71^{c} (0)	0.71^{e} (0)	0.71^{c} (0)	0.71^{e} (0)	1.05^{c} (0.83)	0.71^{c} (0)	0.82^{c} (0.28)
Main plot mean	1.72^{a} (4.63)	1.75^{b} (4.52)	1.25^{b} (2.24)	1.32^{b} (2.72)	1.35^{b} (2.36)	4.44^{a} (2.59)		

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

Table 109. Dry weight of broad leaf weeds at 40 DAS during 2006-2007 (g m^{-2})

Sub plot treatments	Main plot treatments						Sub plot mean	
	Normal seed bed		Stale seed bed (7 days)		Stale seed bed (14 days)			
	Ludwigia	*Sphenoclea*	*Ludwigia*	*Sphenoclea*	*Ludwigia*	*Sphenoclea*	*Ludwigia*	*Sphenoclea*
NW	3.25*[ab] (10.13)	1.47[abc] (2.00)	3.82[a] (14.11)	2.34[a] (5.24)	2.95[ab] (8.97)	1.67[abc] (2.29)	3.34[a] (11.07)	1.83[a] (3.18)
HW	1.24[cd] (1.60)	0.71[c] (0)	1.74[cd] (3.24)	0.71[c] (0)	1.15[cd] (1.23)	1.55[abc] (2.39)	1.38[b] (2.02)	0.99[b] (0.80)
Sofit	0.71[d] (0)	1.05[bc] (0.84)	1.60[cd] (2.55)	0.99[bc] (0.64)	1.41[cd] (2.47)	1.24[abc] (1.17)	1.29[b] (1.67)	1.09[b] (0.88)
CW	0.71[d] (0)	1.40[abc] (2.40)	0.71[d] (0)	2.27[a] (4.96)	1.03[cd] (0.77)	1.96[ab] (3.52)	0.82[b] (0.26)	1.88[a] (3.63)
Daincha	0.71[d] (0)	1.25[abc] (1.20)	2.18[bc] (5.33)	1.22[abc] (1.11)	1.36[cd] (1.57)	0.71[c] (0)	1.42[b] (2.30)	1.06[b] (0.77)
Main plot mean	1.32[a] (2.35)	1.17[a] (1.29)	2.01[a] (5.05)	1.50[a] (2.39)	1.58[a] (3.00)	1.42[a] (1.88)		

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

During 2005-06 at 40 DAS lower dry weight of broad leaf weeds was noticed in stale seed bed for 14 days (Table 108). The highest dry matter of *Ludwigia* was observed in normal seed bed, while that of *Sphenoclea* was in stale seed bed for 14 days. Pre emergence spray of Sofit and concurrent growing of daincha gave complete control of *Ludwigia* at 40 DAS. Successful control of *Sphenoclea* was noticed in hand weeded plots and in plots with Sofit spray.

Among unweeded plots of three main plots, the dry weight of broad leaf weeds was the lowest in stale seed bed for 14 days. Combination of cono weeding with normal seed bed was not effective in lowering the dry weights of broad leaf weeds.

Observations on dry weight of broad leaf weeds at 40 DAS during 2006-07 is presented in Table 109. At this stage of observation, main plot treatments did not show any influence on the dry weight. All sub plot treatments with weeding were at par with respect to dry weight of *Ludwigia*. Dry weight of *Sphenoclea* recorded higher values in unweeded plots and in cono weeded plots.

Combination of normal seed bed with Sofit, cono weeding or concurrent growing of daincha gave complete control of *Ludwigia*. Complete control of *Sphenoclea* was obtained with hand weeding in combination with normal seed bed or stale seed bed for 14 days.

4.3.2 Studies on crop

Plant height

Plant height at various growth stages as influenced by the seed bed preparation and weed control methods are presented in Table 110. Significantly taller plants at all stages of observation was noticed in stale seed bed plots. At 20 DAS of 2005-06, stale seed bed for 14 days was on a par with stale seed bed for 7 days.

Table 110. Plant height (cm) at various growth stages

Main plot treatments	2005-2006			2006-2007		
	20DAS	40DAS	Harvest	20DAS	40DAS	Harvest
Normal seed bed	18.45[b]	63.81[b]	94.71[c]	18.14[b]	63.83[b]	77.15[c]
Stale seed bed (7 days)	18.92[a]	64.77[b]	97.31[b]	18.44[a]	64.68[a]	78.31[b]
Stale seed bed (14 days)	18.95[a]	66.05[a]	99.83[a]	18.34[ab]	65.04[a]	79.75[a]
Sub plot treatments						
UWC	18.73[b]	60.44[d]	87.12[b]	18.20[c]	61.12[c]	71.97[c]
HW	18.79[b]	65.39[c]	99.41[a]	18.46[b]	65.48[a]	79.97[b]
Sofit	20.52[a]	67.57[a]	99.96[a]	19.12[a]	65.96[a]	80.73[a]
CW	18.82[b]	66.47[b]	99.96[a]	18.44[b]	65.33[a]	79.81[b]
Daincha	17.00[c]	64.53[c]	99.96[a]	17.31[d]	64.70[b]	79.52[b]

Table 111. Tiller count/m^2 at various growth stages during 2005-‘06

Sub plot treatments	Main plot treatments											
	Normal seed bed			Stale seed bed (7 days)			Stale seed bed (14 days)			Sub plot mean		
	20DAS	40DAS	Harvest	20DAS	40DAS	Harvest	20DAS	40DAS	Harvest	20DAS	40DAS	Harvest
NW	171^{h}	170^{h}	166^{h}	186^{fg}	233^{g}	206^{g}	197de	275^{f}	334^{f}	185^{d}	226^{d}	235^{d}
HW	202^{d}	306^{cde}	455^{ab}	211^{c}	316^{bcd}	459^{a}	213^{bc}	321^{b}	461^{a}	209^{b}	314^{b}	458^{a}
Sofit	212^{bc}	307^{cde}	461^{a}	218^{ab}	340^{a}	458^{ab}	219^{a}	340^{a}	458^{ab}	216^{a}	329^{a}	459^{a}
CW	198de	306^{cde}	427^{d}	214^{abc}	324^{b}	448^{bc}	208^{c}	319^{bc}	444^{c}	206^{b}	317^{b}	440^{b}
Daincha	186^{g}	294^{e}	406^{e}	194^{e}	304de	413^{e}	192^{ef}	294^{e}	411^{e}	190^{c}	298^{c}	410^{c}
Main plot mean	194^{b}	277^{b}	383^{c}	205^{a}	304^{a}	399^{b}	207^{a}	310^{a}	422^{a}			

Table 112. Tiller count/m^2 at various growth stages during 2006-‘07

Sub plot treatments	Main plot treatments											
	Normal seed bed			Stale seed bed (7 days)			Stale seed bed (14 days)			Sub plot mean		
	20DAS	40DAS	Harvest	20DAS	40DAS	Harvest	20DAS	40DAS	Harvest	20DAS	40DAS	Harvest
NW	160^{g}	170^{j}	158^{i}	174^{f}	190^{i}	203^{h}	179^{ef}	210^{h}	301^{g}	171^{d}	190^{e}	221^{d}
HW	194^{cd}	313de	413^{cde}	203^{b}	329^{bc}	422^{abc}	207^{ab}	335^{ab}	429^{ab}	202^{b}	326^{b}	421^{a}
Sofit	202^{bc}	329^{bc}	416^{bcd}	207^{ab}	335^{ab}	434^{a}	212^{a}	343^{a}	434^{a}	207^{a}	336^{a}	428^{a}
CW	192^{d}	321^{cd}	400^{ef}	201^{bcd}	307^{ef}	418^{bcd}	204^{ab}	317^{cde}	420^{a}	199^{b}	315^{c}	412^{b}
Daincha	181^{ef}	294^{g}	387^{f}	184^{e}	300^{fg}	406de	194^{cd}	292^{g}	402^{e}	186^{c}	295^{d}	398^{c}
Main plot mean	186^{c}	285^{b}	356^{c}	194^{b}	292^{ab}	377^{b}	199^{a}	299^{a}	397^{a}			

Normal seed bed recorded the lowest plant height at all stages of observation.

Among the weed control treatments, Sofit sprayed plots exhibited significantly higher plant height at all stages of observation during both years. At harvest stage Sofit was on a par with hand weeding, cono weeding and concurrent growing of daincha. However, concurrent growing of daincha significantly reduced the plant height at initial growth stages.

Number of tillers

Tiller count/m^2 at 20, 40 and harvest stages showed significant variation among main plot treatments. Stale seed bed plots showed higher values at all stages of observation (Tables 111 and 112). Among weed control treatments, pre- emergence spray of Sofit significantly promoted the tiller count. During 20 and 40 DAS of 2005-06, plots with concurrent growing of daincha and hand weeded plots were at par. Number of tillers were the lowest in unweeded plots at all stages.

At 20 DAS, significantly higher tiller production was observed in stale seed bed plots (14 days) sprayed with Sofit. Reduction in the number of tillers in unweeded plots of stale seed bed for 14 days was less compared to that in unweeded plots of normal seed bed. Concurrent growing of daincha reduced the tiller production and thus combination of all seed bed treatments with daincha showed inferior values of tiller count.

Dry matter production

Data presented in Table 113 shows the effect of treatments on crop dry matter production. During both years of study, stale seed bed for 14 days accumulated maximum amount of dry matter. Stale seed bed for 7 days was the next best treatment.

Among weed management treatments, pre-emergence spraying of Sofit was the best in terms of accumulation of dry matter. Although, concurrent growing of daincha reduced the dry matter accumulation during early growth stages of the crop, later it picked up and gave comparable values at harvest. At all stages of observations unweeded plots of normal seed bed gave significantly lower dry matter.

Table 113. Crop dry matter production at various growth stages (g plant^{-1})

Main plot treatments	2005-2006				2006-2007			
	20DAS	40DAS	60DAS	Harvest	20DAS	40DAS	60DAS	Harvest
Normal seed bed	3.13[c]	7.46[c]	24.74[c]	38.93[c]	3.30[b]	6.23[c]	26.40[c]	39.57[c]
Stale seed bed (7 days)	3.31[b]	7.90[b]	27.29[b]	40.41[b]	3.40[a]	6.43[b]	28.28[b]	40.49[b]
Stale seed bed (14 days)	3.38[a]	8.10[a]	28.45[a]	40.87[a]	3.40[a]	7.08[a]	28.92[a]	41.25[a]
Sub plot treatments								
UWC	3.00[d]	6.94[d]	22.20[d]	37.61[c]	3.10[c]	5.94[d]	22.68[d]	32.99[c]
HW	3.34[b]	8.02[b]	27.33[c]	40.66[b]	3.49[b]	6.76[b]	29.30[b]	41.66[b]
Sofit	3.61[a]	8.18[a]	28.91[a]	41.22[a]	3.61[b]	7.04[a]	29.92[a]	43.43[a]
CW	3.36[b]	8.14[a]	27.90[b]	40.42[b]	3.48[b]	6.79[b]	29.08[b]	41.98[b]
Daincha	3.07[c]	7.81[c]	27.78[bc]	40.43[b]	3.14[b]	6.37[c]	28.36[c]	42.12[b]

Chlorophyll content of leaves

Chlorophyll content at maximum tillering stage during 2005-06 is presented in Table 114. Chlorophyll ‘a’, ‘b’ and total chlorophyll showed maximum values in stale seed bed for 7 days. Chlorophyll ‘a’ values in normal seed bed and in stale seed bed for 14 days were at par. However, total chlorophyll was the lowest in normal plots. Total chlorophyll and chlorophyll ‘a’ contents were highest in plots where weeds were controlled with Sofit. The content of chlorophyll ’b’ was the highest in unweeded plots.

Significantly higher values for total chlorophyll was noticed in combination of all sub plot treatments with stale seed bed plots than with normal seed bed. Concurrent growing of daincha decreased the concentration of chlorophyll ‘a’ and total chlorophyll and increased the content of chlorophyll 'b’.

Stale seed bed for 14 days produced higher contents of total chlorophyll, chlorophyll ‘a’, and chlorophyll ‘b’ during 2006-07. This was followed by stale seed bed for 7 days. Sofit sprayed plots recorded the highest values for all chlorophyll parameters. Hand weeding and cono weeding were at par. *In situ* green manuring of daincha decreased the chlorophyll content. The highest content of chlorophyll ‘a’ was noticed in stale seed bed for 14 days combined with Sofit spraying. Higher chlorophyll ‘b’ contents were observed in the combination of Sofit with stale seed bed for 7 or 14 days. The same treatments also produced higher total chlorophyll content.

At panicle initiation stage during 2005-06, stale seed bed for 14 days produced the highest chlorophyll ‘a’, ‘b’ and total chlorophyll contents. Stale seed bed for 7 days was the next best treatment. The lower values for chlorophyll contents were noticed in unweeded plots. Among the various combinations, Sofit with stale seed bed significantly increased chlorophyll ‘a’ content (Table 115). Chlorophyll contents of unweeded control plots significantly improved under stale seed bed.

Table 114. Chlorophyll content at maximum tillering stage (on fresh weight basis mg g^{-1})

Main plot treatments	2005-2006			2006-2007		
	Chl 'a'	Chl 'b'	Total	Chl 'a'	Chl 'b'	Total
Normal seed bed	1.29^{b}	0.94^{b}	2.23^{c}	2.49^{b}	1.62^{b}	3.00^{c}
Stale seed bed (7 days)	1.59^{a}	1.22^{a}	2.81^{a}	2.73^{a}	1.71^{a}	3.20^{b}
Stale seed bed (14 days)	1.62^{a}	0.94^{b}	2.56^{b}	2.75^{a}	1.73^{a}	3.27^{a}
Sub plot treatments						
UWC	1.18^{e}	1.10^{a}	2.27^{e}	2.22^{d}	1.59^{d}	2.95^{c}
HW	1.67^{b}	0.92^{c}	2.59^{b}	2.73^{b}	1.69^{b}	3.15^{b}
Sofit	1.85^{a}	1.06^{ab}	2.90^{a}	3.00^{a}	1.78^{a}	3.35^{a}
CW	1.51^{c}	1.01^{b}	2.52^{c}	2.79^{b}	1.71^{b}	3.22^{b}
Daincha	1.29^{d}	1.08^{ab}	2.37^{d}	2.54^{c}	1.65^{c}	3.12^{b}
Interaction						
Normal X UWC	1.04^{j}	0.76^{g}	1.80^{k}	2.29^{gh}	1.50^{e}	2.85^{d}
Normal X HW	1.32^{gh}	0.85^{fg}	2.17^{i}	2.51^{ef}	1.66^{c}	2.92^{d}
Normal X Sofit	1.52^{e}	1.27^{b}	2.79^{c}	2.73^{cd}	1.72^{b}	3.29^{ab}
Normal X CW	1.38^{fg}	0.92^{ef}	2.29^{h}	2.53^{e}	1.66^{c}	3.02^{cd}
Normal X Daincha	1.18^{i}	0.88^{efg}	2.07^{j}	2.36^{fg}	1.56^{d}	2.93^{d}
Stale (7 days) X UWC	1.19^{i}	1.48^{a}	2.67^{de}	2.16^{h}	1.60^{d}	2.99^{cd}
Stale (7 days) X HW	1.82^{c}	1.08^{cd}	2.90^{b}	2.85^{c}	1.69^{bc}	3.20^{ab}
Stale (7 days) X Sofit	1.93^{b}	1.11^{c}	3.04^{a}	3.03^{b}	1.81^{a}	3.40^{a}
Stale (7 days) X CW	1.72^{d}	1.15^{c}	2.87^{bc}	3.05^{b}	1.73^{b}	3.26^{ab}
Stale (7 days) X Daincha	1.28^{h}	1.31^{b}	2.58^{e}	2.57^{de}	1.70^{bc}	3.16^{bc}
Stale (14 days) X UWC	1.30^{gh}	1.05^{cd}	3.25^{gh}	2.19^{gh}	1.68^{bc}	3.01^{cd}
Stale (14 days) X HW	1.86^{bc}	0.83^{fg}	2.69^{d}	2.82^{c}	1.72^{b}	3.32^{ab}
Stale (14 days) X Sofit	2.09^{a}	0.80^{fg}	2.88^{bc}	3.23^{a}	1.80^{a}	3.37^{a}
Stale (14 days) X CW	1.43^{f}	0.98^{cd}	2.41^{fg}	2.79^{c}	1.73^{b}	3.39^{a}
Stale (14days) X Daincha	1.42^{f}	1.06^{cd}	2.47^{f}	2.70^{cd}	1.70^{bc}	3.27^{ab}

Table 115. Chlorophyll content at panicle initiation stage (on fresh weight basis mg g^{-1})

Main plot treatments	2005-2006			2006-2007		
	Chl 'a'	Chl 'b'	Total	Chl 'a'	Chl 'b'	Total
Normal seed bed	1.45^{b}	1.20^{c}	2.65^{c}	1.62^{b}	1.38^{b}	3.00^{c}
Stale seed bed (7 days)	1.49^{b}	1.36^{b}	2.85^{b}	1.71^{a}	1.49^{a}	3.20^{a}
Stale seed bed (14 days)	1.57^{a}	1.44^{a}	3.01^{a}	1.73^{a}	1.54^{a}	3.27^{a}
Sub plot treatments						
UWC	1.25^{d}	0.94^{e}	2.19^{d}	1.59^{d}	1.35^{c}	2.95^{c}
HW	1.58^{b}	1.34^{d}	2.92^{c}	1.69^{b}	1.46^{b}	3.15^{b}
Sofit	1.65^{a}	1.53^{a}	3.18^{a}	1.78^{a}	1.57^{a}	3.35^{a}
CW	1.53^{c}	1.42^{c}	2.95^{bc}	1.71^{b}	1.51^{ab}	3.22^{b}
Daincha	1.50^{c}	1.46^{b}	2.96^{b}	1.65^{c}	1.46^{b}	3.12^{b}
Interaction						
Normal X UWC	1.11^{h}	0.63^{e}	1.74^{i}	1.50^{e}	1.33^{ef}	2.85^{d}
Normal X HW	1.57^{bc}	1.21^{c}	2.78^{f}	1.66^{c}	1.26^{f}	2.92^{d}
Normal X Sofit	1.62^{ab}	1.50^{a}	3.11^{bc}	1.72^{b}	1.57^{ab}	3.29^{ab}
Normal X CW	1.49^{de}	1.33^{b}	2.82^{f}	1.66^{c}	1.35^{ef}	3.02^{cd}
Normal X Daincha	1.46^{ef}	1.34^{b}	2.80^{f}	1.56^{d}	1.37^{def}	2.93^{d}
Stale (7 days) X UWC	1.24^{g}	1.02^{d}	2.25^{h}	1.60^{d}	1.39^{cdef}	2.99^{cd}
Stale (7 days) X HW	1.55^{cd}	1.33^{b}	2.88^{e}	1.69^{bc}	1.51^{abcd}	3.20^{ab}
Stale (7 days) X Sofit	1.66^{a}	1.54^{a}	3.20^{a}	1.81^{a}	1.58^{ab}	3.40^{a}
Stale (7 days) X CW	1.50^{de}	1.38^{b}	2.88^{e}	1.73^{b}	1.53^{abc}	3.26^{ab}
Stale (7 days) X Daincha	1.50^{de}	1.56^{a}	3.06^{cd}	1.71^{bc}	1.44^{bcde}	3.16^{bc}
Stale (14 days) X UWC	1.42^{f}	1.16^{c}	2.58^{b}	1.68^{bc}	1.32^{ef}	3.01^{cd}
Stale (14 days) X HW	1.63^{ab}	1.48^{a}	3.10^{bc}	1.72^{b}	1.60^{ab}	3.32^{ab}
Stale (14 days) X Sofit	1.67a	1.56^{a}	3.22^{a}	1.80^{a}	1.56^{ab}	3.37^{a}
Stale (14 days) X CW	1.60b	1.54^{a}	3.15^{b}	1.73^{b}	1.65^{a}	3.39^{a}
Stale (14days) X Daincha	1.54cd	1.48^{a}	3.02^{d}	1.70^{bc}	1.58^{ab}	3.27^{ab}

Table 116. Leaf area index of rice at different growth stages

Main plot treatments	2005-2006			2006-2007		
	20DAS	40DAS	60DAS	20DAS	40DAS	60DAS
Normal seed bed	1.72^{b}	2.96^{c}	3.13^{b}	1.84^{b}	2.95^{c}	3.19^{a}
Stale seed bed (7 days)	1.78^{a}	3.02^{b}	3.21^{a}	1.86^{a}	3.02^{b}	3.21^{a}
Stale seed bed (14 days)	1.79^{a}	3.12^{a}	3.25^{a}	1.86^{a}	3.04^{a}	3.20^{a}
Sub plot treatments						
UWC	1.86^{c}	2.75^{d}	3.05^{c}	1.84^{a}	2.65^{d}	3.00^{b}
HW	1.88^{b}	3.12^{b}	3.24^{a}	1.86^{a}	3.11^{b}	3.29^{a}
Sofit	1.90^{a}	3.13^{a}	3.26^{a}	1.89^{a}	3.13^{a}	3.31^{a}
CW	1.89^{b}	3.12^{b}	3.27^{a}	1.87^{a}	3.11^{b}	3.28^{a}
Daincha	1.31^{d}	3.05^{c}	3.18^{b}	1.82^{a}	3.03^{c}	3.12^{a}
Interaction						
Normal X UWC	1.83^{f}	2.57^{i}	2.93^{h}	1.83^{a}	2.62^{k}	2.98^{c}
Normal X HW	1.86^{e}	3.08^{de}	3.22^{cde}	1.85^{a}	3.03^{g}	3.27^{a}
Normal X Sofit	1.88^{cd}	3.08^{d}	3.23^{cde}	1.88^{a}	3.07^{e}	3.30^{a}
Normal X CW	1.88^{de}	3.06^{ef}	3.19^{ef}	1.86^{a}	3.05^{ef}	3.25^{a}
Normal X Daincha	1.15^{h}	3.01^{g}	3.08^{g}	1.81^{a}	3.00^{h}	3.14^{b}
Stale (7 days) X UWC	1.86^{e}	2.62^{h}	3.06^{g}	1.85^{a}	2.65^{j}	3.00^{c}
Stale (7 days) X HW	1.89^{bcd}	3.14^{bc}	3.23^{cde}	1.86^{a}	3.14^{cd}	3.32^{a}
Stale (7 days) X Sofit	1.91^{ab}	3.15^{ab}	3.26^{bcd}	1.87^{a}	3.15^{bc}	3.32^{a}
Stale (7 days) X CW	1.89^{cd}	3.13^{c}	3.32^{a}	1.87^{a}	3.12^{d}	3.28^{a}
Stale (7 days) X Daincha	1.38^{g}	3.06^{f}	3.20^{def}	1.83^{a}	3.03^{g}	3.11^{b}
Stale (14 days) X UWC	1.88^{de}	3.06^{f}	3.15^{f}	1.85^{a}	2.67^{i}	3.01^{c}
Stale (14 days) X HW	1.89^{bcd}	3.15^{abc}	3.28^{abc}	1.86^{a}	3.16^{ab}	3.28^{a}
Stale (14 days) X Sofit	1.91^{a}	3.16^{a}	3.29^{ab}	1.89^{a}	3.17^{a}	3.31^{a}
Stale (14 days) X CW	1.90^{bc}	3.15^{ab}	3.28^{abc}	1.88^{a}	3.15^{bc}	3.29^{a}
Stale (14days) X Daincha	1.39^{g}	3.09^{d}	3.26^{bcd}	1.83^{a}	3.05^{f}	3.12^{b}

Chlorophyll contents of leaves at panicle initiation stage during 2006-07, was higher in stale seed bed plots. Sofit sprayed plots recorded the highest chlorophyll ‘a’, ‘b’ and total chlorophyll contents. Unweeded plots of normal seed bed produced the lowest chlorophyll content. In the combination treatments, chlorophyll ‘a’, ‘b’ and total chlorophyll were higher in Sofit combined with stale seed bed.

Leaf area index (LAI)

Leaf area index at all stages of observation during 2005-06 was higher in stale seed bed plots. Crops in normal seed bed showed lower LAI. Among weed control treatments, at 20 DAS, the lowest value of 1.31 was noticed in daincha grown plots. At 40 and 60 DAS too, daincha showed inferior values (Table 116). At 20 DAS during 2006-07 also, LAI values were better in stale seed bed plots. At 40 DAS, LAI of stale seed bed for 7 days was inferior to stale seed bed for 14 days. At 60 DAS, LAI of all main plot treatments were at par.

The different weed control methods were at par with respect to LAI at 20 DAS of 2006-07. At 40 DAS Sofit proved superiority. The lowest LAI at harvest stage was noticed in unweeded plots.

Grain yield

Grain yield of wet seeded rice as influenced by seed bed preparation and weed control practices are presented in Table 117. During both years, higher grain yield of 7213 kg ha^{-1} and 7157 kg ha^{-1} was produced by stale seed bed for 14 days, followed by stale seed bed for 7 days (6860 kg ha^{-1} and 7052 kg ha^{-1}).

Among the weed control treatments during 2005-06, hand weeded plots recorded the maximum grain yield of 8383 kg ha^{-1} and this was on a par with Sofit spraying (8100 kg ha^{-1}). However, in 2006-07, Sofit recorded the highest grain yield of 8212 kg ha^{-1}.

Hand weeded plots showed the next best grain yield (8093 kg ha^{-1}). During both years of experiment, concurrent growing and incorporation of daincha by cono weeding recorded grain yield on a par with plots with cono weeding alone. The lowest grain yield was obtained in normal seed bed and in unweeded plots. Stale seed bed (14 days) with hand weeding or stale seed bed (7 days) with Sofit were at par in grain yields.

During 2006-07, combination of pre-emergence spray of Sofit with stale seed bed for 14 days gave the highest grain yield. Stale seed bed followed by hand weeding was on a par with stale seed bed for 7 days followed by Sofit

Straw yield

The data in Table 118 indicates that straw yield of rice was significantly influenced by the seed bed preparation. Stale seed bed plots showed superior values of straw yield than in normal seed bed. During 2005-06, except in cono weeded and unweeded plots, straw yield showed no significant difference among the other treatments. Combination of all weed control methods with stale seed bed for 14 days gave significantly higher straw yield. However, in 2006-07, Sofit produced significantly higher straw yield (4511 kg ha^{-1}) and it was on a par with hand weed plots (4411 kg ha^{-1}).

Combination of stale seed bed (7 days) with Sofit produced higher straw yield of 4617 kg ha^{-1}, though it was on a par with stale seed bed for 14 days with Sofit spray and normal seed bed with hand weeding.

Table 117. Grain yield of rice (kg ha^{-1})

Sub plot treatments	2005-2006 Main plot treatments: Normal seed bed	Stale seed bed (7 days)	Stale seed bed (14 days)	Sub plot mean	2006-2007 Main plot treatments: Normal seed bed	Stale seed bed (7 days)	Stale seed bed (14 days)	Sub plot mean
NW	3183^{i}	4150^{h}	5217^{g}	4183^{c}	2065^{j}	3328^{i}	3580^{h}	2991^{d}
HW	7767^{c}	7767^{b}	8383^{a}	8069^{a}	7963^{cde}	8075^{c}	8241^{b}	8093^{b}
Sofit	7633^{c}	8308^{ab}	8100^{ab}	8014^{a}	7988^{cd}	8225^{b}	8422^{a}	8212^{a}
CW	6408^{f}	6725^{e}	7150^{d}	6761^{b}	7625^{g}	7839^{def}	7740^{fg}	7735^{c}
Daincha	6342^{f}	7058^{e}	7217^{d}	6872^{b}	7843^{def}	7792^{f}	7803^{ef}	7813^{c}
Main plot mean	6266^{c}	6860^{b}	7213^{a}		6697^{c}	7052^{b}	7157^{a}	

Table 118. Straw yield of rice (kg ha^{-1})

Sub plot treatments	2005-2006 Main plot treatments: Normal seed bed	Stale seed bed (7 days)	Stale seed bed (14 days)	Sub plot mean	2006-2007 Main plot treatments: Normal seed bed	Stale seed bed (7 days)	Stale seed bed (14 days)	Sub plot mean
NW	2792^{i}	3517^{h}	3983^{g}	3430^{c}	1566^{e}	2813^{d}	3080^{d}	2486^{d}
HW	4925^{cd}	5752de	5783^{a}	5153^{a}	4483^{a}	4333^{ab}	4417^{ab}	4411^{ab}
Sofit	4448^{ef}	5333^{b}	5817^{a}	5199^{a}	4378^{ab}	4617^{a}	4537^{a}	4511^{a}
CW	3925^{g}	4867^{cd}	5933^{a}	4908^{b}	4033^{bc}	4282^{ab}	4367^{ab}	4227^{bc}
Daincha	4233^{fg}	5200^{bc}	5900^{a}	5111^{a}	3777^{c}	4253^{ab}	4217^{ab}	4082^{c}
Main plot mean	4064^{c}	4933^{b}	5483^{a}		3648^{b}	4060^{a}	4123^{a}	

Table 119. Yield attributes of rice during 2005-2006

Sub plot treatments	Main plot treatments									Sub plot mean		
	Normal seed bed			Stale seed bed (7 days)			Stale seed bed (14 days)					
	Panicle length (cm)	Filled grains (No.)	1000 grain weight (g)	Panicle length (cm)	Filled grains (No.)	1000 grain weight (g)	Panicle length (cm)	Filled grains (No.)	1000 grain weight (g)	Panicle length (cm)	Filled grains (No.)	1000 grain weight (g)
NW	18.30^{h}	63^{g}	24.80^{e}	18.77^{g}	76^{f}	26.70^{d}	20.27^{f}	84^{e}	27.00^{d}	19.11^{c}	74^{c}	26.17^{c}
HW	22.77^{cd}	92^{cd}	28.10^{c}	22.90^{bcd}	95^{abcd}	28.43^{abc}	23.27^{ab}	100^{ab}	28.70^{ab}	22.98^{a}	96^{a}	28.41^{ab}
Sofit	23.07^{bc}	94^{abcd}	28.77^{a}	23.53^{a}	97^{abc}	28.50^{abc}	22.57^{de}	101^{a}	28.73^{a}	23.06^{a}	97^{a}	28.67^{a}
CW	22.23^{e}	93^{cd}	28.43^{abc}	22.80^{cd}	93^{cd}	28.23^{abc}	22.80^{cd}	98^{abc}	28.13^{bc}	22.61^{b}	95^{ab}	28.27^{b}
Daincha	22.57^{de}	92^{cd}	28.00^{c}	22.77^{cd}	89^{de}	28.50^{abc}	22.63^{cde}	93^{bcd}	28.20^{abc}	22.66^{b}	91^{b}	28.23^{b}
Main plot mean	21.79^{b}	87^{b}	27.62^{b}	22.15^{a}	90^{b}	28.07^{a}	22.31^{a}	95^{a}	28.15^{a}			

Table 120. Yield attributes of rice during 2006-2007

Sub plot treatments	Main plot treatments									Sub plot mean		
	Normal seed bed			Stale seed bed (7 days)			Stale seed bed (14 days)					
	Panicle length (cm)	Filled grains (No.)	1000 grain weight (g)	Panicle length (cm)	Filled grains (No.)	1000 grain weight (g)	Panicle length (cm)	Filled grains (No.)	1000 grain weight (g)	Panicle length (cm)	Filled grains (No.)	1000 grain weight (g)
NW	19.07^{f}	75^{e}	22.20^{e}	19.60^{e}	85^{d}	22.57^{e}	19.73^{e}	87^{d}	22.47^{e}	19.47^{d}	82^{c}	22.41^{b}
HW	23.50^{bc}	96^{c}	23.17^{d}	23.90^{b}	100^{bc}	23.60^{abcd}	24.00^{b}	105^{ab}	23.97^{a}	23.80^{b}	100^{b}	23.58^{a}
Sofit	24.00^{b}	108^{a}	23.33^{cd}	24.00^{b}	101^{bc}	23.77^{abc}	24.77^{a}	106^{ab}	24.00^{a}	24.26^{a}	105^{a}	23.70^{a}
CW	23.27^{cd}	98^{c}	23.07^{d}	23.97^{b}	98^{c}	23.77^{abc}	23.90^{b}	100^{bc}	23.90^{ab}	23.71^{bc}	99^{b}	23.58^{a}
Daincha	22.97^{d}	96^{c}	23.17^{d}	23.57^{bc}	97^{c}	23.37^{bcd}	23.97^{b}	98^{c}	23.83^{abc}	23.50^{c}	97^{b}	23.46^{a}
Main plot mean	22.56^{b}	95^{b}	22.99^{c}	23.01^{a}	96^{b}	23.41^{b}	23.27^{a}	99^{a}	23.63^{a}			

Yield attributes

The yield attributes of rice, namely, panicle length, number of filled grains per panicle and 1000 grain weight-recorded superior values in stale seed bed (14 days) followed by stale seed bed for 7 days (Table 119). Among the weed control treatments, hand weeded plots and Sofit sprayed plots were at par in panicle length and number of filled grains. At the same time, 1000 grain weight was significantly higher in Sofit plots followed by hand weeded plots.

Rice panicle recorded the maximum length of 23.53 cm in stale seed bed (7 days) in combination with Sofit. The highest number of filled grains and better 1000 grain weight values were found in stale seed bed for 14 days combined with Sofit. The yield attributes were significantly improved by the adoption of stale seed bed technique for 14 days as evidenced by the higher panicle length, number of filled grains and 1000 grain weight in unweeded plots of stale seed bed for 14 days.

During 2006-07 also, stale seed bed for 14 days recorded the highest values for yield parameters. Pre - emergence spraying of Sofit favored yield attributes. Panicle length, number of filled grains and 1000 grain weight were lower in unweeded plots. Combination of Sofit with stale seed bed for 14 days produced the highest length of panicle and 1000 grain weight. However, the number of filled grains per panicle was the highest in normal seed bed with Sofit (Table 120).

Number of productive tillers

The data on number of productive tillers per m^2 during 2005-06 and 2006-07 is presented in Table 121. During both years, stale seed bed for 14 days recorded significantly higher numbers of productive tillers. In 2005-06, stale seed bed for 7 days recorde the second

Table 121. Number of productive tillers/m^2

Sub plot treatments	2005-2006				2006-2007			
	Main plot treatments				Main plot treatments			
	Normal seed bed	Stale seed bed (7 days)	Stale seed bed (14 days)	Sub plot mean	Normal seed bed	Stale seed bed (7 days)	Stale seed bed (14 days)	Sub plot mean
NW	161^{h}	193^{g}	314^{f}	223^{d}	153^{d}	189^{d}	298^{c}	214c
HW	451^{abc}	454^{abc}	458^{a}	454^{a}	407^{b}	417^{b}	626^{a}	483a
Sofit	459^{a}	456^{ab}	454^{abc}	456^{a}	412^{b}	430^{b}	395^{b}	412b
CW	424^{d}	444^{bc}	441^{c}	436^{b}	392^{b}	415^{b}	416^{b}	408b
Daincha	404^{e}	409^{e}	408^{e}	407^{c}	384^{b}	403^{b}	397^{b}	394b
Main plot mean	380^{c}	391^{b}	415^{a}		350^{b}	371^{b}	426^{a}	

highest number followed by normal seed bed. However, during 2006-07, stale seed bed treatments were at par.

During 2005-06, among the weed control treatments, Sofit sprayed plots and hand weeded plots were better. In 2006-07, Sofit was inferior to hand weeded plots. The lowest numbers of productive tillers were noticed in unweeded plots. Combination of stale seed bed with hand weeding enhanced the number of productive tillers.

4.3.3 Nutrient uptake by crop

Nutrient uptake at maximum tillering

In 2005-06, seed bed treatments did not significantly influence the uptake of major nutrients (Table 122). However, in 2006-07, stale seed bed for 14 days showed significantly higher uptake of 12 kg ha^{-1} N, 2.6 kg ha^{-1} P and 10 kg ha^{-1} K.

Pre - emergence spraying of Sofit favored the uptake of nutrients. This treatment was on a par with cono weeeded plots during 2005-06 and with hand weeded plots during 2006-07. The lowest uptake was noticed in unweeded plots.

Nutrient uptake at panicle initiation

At panicle initiation stage, stale seed bed for 14 days showed higher uptake of nutrients. It was on a par with stale seed bed for 7 days. The lowest uptake of 42 kg ha^{-1} N, 11 kg ha^{-1} P and 33 kg ha^{-1} K was noticed in normal seed bed plots. Sofit sprayed plots showed the highest values for N, P and K. Plots with cono weeding for incorporation of Daincha and cono weeding alone were at par. Significantly lower uptake was noticed in unweeded plots (Table. 123).

Table 122. Uptake of nutrients by rice at maximum tillering (kg ha^{-1})

Main plot treatments	2005-2006			2006-2007		
	N	P	K	N	P	K
Normal seed bed	11.74[a]	2.09[a]	9.75[a]	10.38[b]	2.33[b]	8.80[b]
Stale seed bed (7 days)	12.43[a]	2.21[a]	10.32[a]	10.72[b]	2.40[b]	9.09[b]
Stale seed bed (14 days)	12.75[a]	2.27[a]	10.59[a]	11.80[a]	2.64[a]	10.01[a]
Sub plot treatments						
Unweeded control	10.93[d]	1.94[d]	9.07[d]	9.91[d]	2.22[d]	8.40[d]
Hand weeding	12.62[b]	2.25[b]	10.48[b]	11.26[b]	2.52[b]	9.55[b]
Sofit	12.87[a]	2.29[a]	10.69[a]	11.74[a]	2.63[a]	9.96[a]
Cono weeding	12.81[a]	2.28[a]	10.64[a]	11.31[b]	2.53[b]	9.60[b]
Daincha	12.29[c]	2.19[c]	10.20[c]	10.61[c]	2.38[c]	9.00[c]

Table 123. Uptake of nutrients by rice at panicle initiation (kg ha^{-1})

Main plot treatments	2005-2006			2006-2007		
	N	P	K	N	P	K
Normal seed bed	41.89[b]	11.05[b]	33.15[b]	43.47[c]	8.45[c]	37.84[c]
Stale seed bed (7 days)	46.21[a]	12.19[a]	36.56[a]	46.57[b]	9.05[b]	40.54[b]
Stale seed bed (14 days)	48.17[a]	12.71[a]	38.12[a]	47.62[a]	9.26[a]	41.45[a]
Sub plot treatments						
Unweeded control	37.59[d]	9.92[d]	29.75[d]	37.34[d]	7.26[d]	32.50[d]
Hand weeding	46.28[c]	12.21[c]	36.63[c]	48.25[b]	9.38[b]	42.00[b]
Sofit	48.96[a]	12.91[a]	38.74[a]	49.27[a]	9.58[a]	42.89[a]
Cono weeding	47.25[b]	12.46[b]	37.39[b]	47.88[b]	9.31[b]	41.68[b]
Daincha	47.04[b]	12.41[b]	37.22[b]	46.69[c]	9.07[c]	40.64[c]

Table 124. Uptake of nutrients by rice at harvest (kg ha^{-1})

Main plot treatments	2005-2006			2006-2007		
	N	P	K	N	P	K
Normal seed bed	91.99[a]	26.74[a]	105.90[a]	77.59[b]	21.73[b]	103.45[b]
Stale seed bed (7 days)	96.57[a]	28.07[a]	111.16[a]	83.34[a]	23.34[a]	111.12[a]
Stale seed bed (14 days)	109.19[a]	31.74[a]	125.70[a]	84.61[a]	23.69[a]	112.81[a]
Sub plot treatments						
Unweeded control	65.48[d]	19.04[d]	75.38[d]	41.09[d]	11.51[d]	4.78[d]
Hand weeding	113.72[a]	33.06[a]	130.81[a]	93.79[b]	26.26[b]	125.04[b]
Sofit	113.64[a]	33.03[a]	130.81[a]	95.42[a]	26.72[a]	127.22[a]
Cono weeding	100.36[c]	29.17[c]	115.53[c]	89.71[c]	25.12[c]	119.62[c]
Daincha	103.06[b]	29.96[b]	118.64[b]	89.21[c]	24.98[c]	118.95[c]

Observations on the uptake of nutrients at panicle initiation stage of 2006-07 indicates the superiority of stale seed bed (14 days) in accelerating the nutrient uptake by the crop. Spraying of Sofit recorded the highest uptake followed by hand weeding and cono weeding.

Nutrient uptake at harvest stage

At the harvest stage of the crop, main plot treatment showed no significant variation. However, sub plot treatments showed significant variation in uptake values. Hand weeding and spraying of Sofit showed almost similar uptake values. At harvest stage also, unweeded plots showed the lowest uptake (Table 124).

4.3.4 Nutrient uptake by weeds

Nutrient uptake by grasses

Uptake of nutrients by grasses at 20 DAS is presented in Table 125. Among the seed bed treatments, normal seed bed showed significantly higher uptake values during both years. Stale seed bed for 14 days and stale seed bed for 7 days were at par. During 2005-06, weed control treatments showed no significant variation. However, during 2006-07, Sofit sprayed plots showed lower uptake. All other treatments were at par.

At 40 DAS of 2005-06, grassy weeds exhibited the lowest uptake values in stale seed bed (14 days) plots. Unweeded plots showed the highest uptake followed by cono weeded plots. Growing of daincha along with rice led to the lowest uptake of nutrients. During 2006-07 also, the lowest values of nutrient uptake was in stale seed bed for 14 days. Concurrent growing of daincha showed the lowest uptake of 0.17, 0.05 and 0.16 $kgha^{-1}$ N, P and K respectively (Table 126).

Table 125. Uptake of nutrients by grasses at 20 DAS (kg ha^{-1})

Main plot treatments	2005-2006			2006-2007		
	N	P	K	N	P	K
Normal seed bed	0.87*[a] (0.26)	0.75[a] (0.06)	0.83[a] (0.19)	1.81[a] (2.78)	1.09[a] (0.69)	1.60[a] (2.06)
Stale seed bed (7 days)	0.71[b] (0)	0.71[b] (0)	0.71[b] (0)	1.32[b] (1.24)	0.90[b] (0.31)	1.19[b] (0.92)
Stale seed bed (14 days)	0.71[b] (0)	0.71[b] (0)	0.71[b] (0)	0.73[c] (0.03)	0.71[a] (0)	0.73[c] (0.03)
Sub plot treatments						
Unweeded control	0.78*[a] (0.11)	0.73[a] (0.03)	0.76[a] (0.08)	1.49[a] (1.72)	0.97[a] (0.44)	1.33[a] (1.27)
Hand weeding	0.79[a] (0.12)	0.73[a] (0.03)	0.76[a] (0.08)	1.46[a] (1.63)	0.96[a] (0.42)	1.31[a] (1.22)
Sofit	0.71[a] (0)	0.71[a] (0)	0.71[a] (0)	0.71[b] (0)	0.71[b] (0)	0.71[b] (0)
Cono weeding	0.80[a] (0.14)	0.73[a] (0.03)	0.78[a] (0.11)	1.40[a] (1.46)	0.94[a] (0.38)	1.26[a] (1.09)
Daincha	0.75[a] (0.06)	0.72[a] (0.02)	0.74[a] (0.05)	1.37[a] (1.38)	0.92[a] (0.35)	1.24[a] (1.04)

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

Table 126. Uptake of nutrients by grasses at 40 DAS (kg ha^{-1})

Main plot treatments	2005-2006			2006-2007		
	N	P	K	N	P	K
Normal seed bed	1.64*[a] (2.19)	1.00[a] (0.5)	1.52*[a] (1.81)	1.62[a] (2.12)	1.01[a] (0.52)	1.51[a] (1.78)
Stale seed bed (7 days)	1.43[ab] (1.54)	0.93[b] (1.54)	1.34[b] (1.30)	1.16[b] (0.85)	0.85[b] (0.22)	1.10[b] (0.71)
Stale seed bed (14 days)	1.20[b] (0.94)	0.86[b] (0.94)	1.13[b] (0.78)	1.04[b] (0.58)	0.80[b] (0.14)	0.99[b] (0.48)
Sub plot treatments						
Unweeded control	2.10*[a] (3.91)	1.17[a] (3.91)	1.93[a] (3.22)	2.46[a] (5.55)	1.32[a] (1.24)	2.26[a] (4.61)
Hand weeding	1.47[b] (1.66)	0.94[b] (1.66)	1.36[b] (1.35)	0.98[bc] (0.46)	0.78[bc] (0.11)	0.94[bc] (0.38)
Sofit	1.08[c] (0.67)	0.81[c] (0.67)	1.02[c] (0.54)	1.01[bc] (0.52)	0.79[bc] (0.12)	0.96[bc] (0.42)
Cono weeding	1.53[b] (1.84)	0.96[b] (1.81)	1.42[b] (1.52)	1.09[b] (0.69)	0.81[b] (0.16)	1.04[b] (0.58)
Daincha	0.94[c] (0.38)	0.77[c] (0.38)	0.91[c] (0.33)	0.82[c] (0.17)	0.74[c] (0.05)	0.81[c] (0.16)

*√x+0.5 transformed values, Original values in parenthesis

Table 127. Uptake of nutrients by grasses at harvest (kg ha^{-1})

Main plot treatments	2005-2006			2006-2007		
	N	P	K	N	P	K
Normal seed bed	1.08*^{b} (0.67)	0.72^{b} (0.02))	1.07^{b} (0.64)	1.33^{a} (1.27)	0.73^{a} (0.03)	1.31^{a} (1.22)
Stale seed bed (7 days)	1.32^{a} (1.24)	0.73^{a} (0.03)	1.30^{a} (1.19)	1.06^{b} (0.62)	0.72^{b} (0.02)	1.04^{b} (0.58)
Stale seed bed (14 days)	1.08^{b} (0.67)	0.72^{b} (0.0.2)	1.07^{b} (0.64)	0.85^{c} (0.22)	0.71^{c} (0)	0.84^{c} (0.21)
Sub plot treatments						
Unweeded control	1.79*^{a} (2.70)	0.75^{a} (0.06)	1.76^{a} (2.60)	1.71^{a} (2.42)	0.75^{a} (0.06)	1.68^{a} (2.32)
Hand weeding	1.02^{b} (0.54)	0.72^{b} (0.02)	1.01^{b} (0.52)	0.93^{b} (0.36)	0.71^{b} (0)	0.92^{b} (0.35)
Sofit	0.98^{b} (0.46)	0.71^{b} (0)	0.97^{b} (0.44)	0.95^{b} (0.40)	0.71^{b} (0)	0.94^{b} (0.38)
Cono weeding	1.03^{b} (0.56)	0.72^{b} (0.02)	1.02^{b} (0.54)	0.91^{b} 90.33)	0.71^{b} (0)	0.90^{b} (0.31)
Daincha	1.00^{b} (0.50)	0.71^{b} (0)	0.99^{b} (0.48)	0.89^{b} (0.29)	0.71^{b} (0)	0.89^{b} (0.29)

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

Table 128. Uptake of nutrients by sedges at 20 DAS (kg ha^{-1})

Main plot treatments	2005-2006			2006-2007		
	N	P	K	N	P	K
Normal seed bed	1.11*[a] (0.73)	0.88[a] (0.27)	1.08[a] (0.67)	0.98[a] (0.46)	0.82[a] (0.17)	0.96[a] (0.42)
Stale seed bed (7 days)	1.20[a] (0.94)	0.92[a] (0.35)	1.16[a] (0.85)	0.74[c] (0.05)	0.72[b] (0.02)	0.74[b] (0.05)
Stale seed bed (14 days)	1.22[a] (0.99)	0.93[a] (0.36)	1.18[a] (0.89)	0.81[b] (0.16)	0.75[b] (0.06)	0.80[b] (0.14)
Sub plot treatments						
Unweeded control	1.32*[ab] (1.24)	0.97[ab] (0.44)	1.27[ab] (1.11)	0.91[a] (0.33)	0.79[a] (0.12)	0.90[a] (0.31)
Hand weeding	1.25[bc] (1.06)	0.94[dc] (0.38)	1.21[dc] (0.96)	0.90[a] (0.31)	0.79[a] (0.12)	0.89[a] (0.02)
Sofit	0.73[d] (0.03)	0.72[d] (0.02)	0.73[d] (0.03)	0.72[c] (0.02)	0.71[c] (0)	0.72[c] (0.19)
Cono weeding	1.39[a] (1.43)	1.01[a] (0.52)	1.34[a] (1.30)	0.84[b] (0.21)	0.76[b] (0.08)	0.83[b] (0.17)
Daincha	1.17[c] (0.87)	0.90[c] (0.87)	1.13[c] (0.78)	0.83[b] (0.19)	0.75[b] (0.06)	0.82[b] (0.06)

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

Table 129. Uptake of nutrients by sedges at 40 DAS (kg ha^{-1})

Main plot treatments	2005-2006			2006-2007		
	N	P	K	N	P	K
Normal seed bed	1.18^{*a} (0.89)	0.96^{a} (0.42)	1.08^{a} (0.89)	1.09^{a} (0.69)	0.90^{a} (0.69)	1.00^{a} (0.50)
Stale seed bed (7 days)	1.27^{a} (1.11)	1.00^{a} (0.50)	1.14^{a} (0.80)	1.11^{a} (0.73)	0.92^{a} (0.73)	1.02^{a} (0.54)
Stale seed bed (14 days)	1.18^{a} (0.89)	0.95^{a} (0.40)	1.07^{a} (0.64)	1.13^{a} (0.78)	0.92^{a} (0.78)	1.03^{a} (0.56)
Sub plot treatments						
Unweeded control	1.85^{*a} (2.92)	1.33^{a} (1.27)	1.61^{a} (2.09).	1.70^{a} (2.42)	1.24^{a} (2.42)	1.49^{a} (1.72)
Hand weeding	1.11^{b} (0.73)	0.91^{b} (0.33)	1.02^{b} (0.54)	0.90^{b} (0.31)	0.80^{b} (0.31)	0.85^{b} (0.22)
Sofit	0.86^{c} (0.24)	0.78^{c} (0.11)	0.82^{c} (0.17)	0.96^{b} (0.42)	0.83^{b} (0.42)	0.90^{b} (0.31)
Cono weeding	1.13^{b} (0.78)	0.92^{b} (0.35)	1.03^{b} (0.56)	0.98^{b} (0.46)	0.84^{b} (0.46)	0.91^{b} (0.33)
Daincha	1.10^{b} (0.71)	0.90^{b} (0.31)	1.00^{b} (0.50)	1.00^{b} (0.50)	0.85^{b} (0.50)	0.92^{b} (0.35)

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

Table 130. Uptake of nutrients by sedges at harvest (kg ha^{-1})

Main plot treatments	2005-2006			2006-2007		
	N	P	K	N	P	K
Normal seed bed	0.98*[a] (0.46)	0.74[a] (0.05)	0.94[a] (0.38)	1.22[a] (0.99)	0.77[a] (0.09)	1.14[a] (0.80)
Stale seed bed (7 days)	0.94[a] (0.38)	0.74[a] (0.05)	0.90[a] (0.31)	1.23[a] (1.01)	0.77[a] (0.09)	1.15[a] (0.82)
Stale seed bed (14 days)	0.94[a] (0.38)	0.73[a] (0.03)	0.90[a] (0.31)	1.10[b] (0.71)	0.76[b] (0.08)	1.03[b] (0.56)
Sub plot treatments						
Unweeded control	1.26*[a] (1.09)	0.78[a] (0.11)	1.18[a] (0.89)	1.49[a] (1.72)	0.82[a] (0.17)	1.37[a] (1.38)
Hand weeding	0.87[b] (0.26)	0.73[b] (0.03)	0.84[b] (0.21)	1.17[b] (0.87)	0.76[b] (0.08)	1.09[b] (0.69)
Sofit	0.83[b] (0.19)	0.72[b] (0.02)	0.81[b] (0.16)	1.08[b] (0.67)	0.75[b] (0.06)	1.02[b] (0.54)
Cono weeding	0.89[b] (0.29)	0.73[b] (0.03)	0.86[b] (0.24)	1.05[b] (0.60)	0.75[b] (0.06)	1.00[b] (0.50)
Daincha	0.91[b] (0.33)	0.73[b] (0.03)	0.87[b] (0.26)	1.12[b] (0.75)	0.76[b] (0.08)	1.06[b] (0.62)

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

Table 131. Uptake of nutrients by broad leaf weeds at 20 DAS (kg ha^{-1})

Main plot treatments	2005-2006			2006-2007		
	N	P	K	N	P	K
Normal seed bed	2.33*[a] (4.93)	1.25[a] (1.06)	2.01[a] (3.54)	0.99[b] (0.48)	0.78[b] (0.11)	0.92[b] (0.35)
Stale seed bed (7 days)	2.09[b] (3.87)	1.16[b] (0.85)	1.81[b] (2.78)	1.17[a] (0.87)	0.83[a] (0.19)	1.06[a] (0.62)
Stale seed bed (14 days)	1.91[c] (3.15)	1.09[c] (0.69)	1.82[c] (2.26)	0.92[b] (0.35)	0.76[b] (0.08)	0.87[b] (0.26)
Sub plot treatments						
Unweeded control	2.45*[a] (5.50)	1.28[a] (1.14)	2.10[a] (3.91)	1.01[a] (0.52)	0.78[a] (0.11)	0.94[a] (0.38)
Hand weeding	2.51[a] (5.80)	1.30[a] (1.19)	2.15[a] (4.12)	1.16[a] (0.85)	0.83[a] (0.19)	1.05[a] (0.60)
Sofit	0.71[c] (0)	0.71[c] (0)	0.71[c] (0)	0.77[b] (0.11)	0.72[b] (0.02)	0.75[b] (0.06)
Cono weeding	2.33[b] (4.93)	1.23[b] (1.01)	1.99[b] (3.46)	1.12[b] (0.75)	0.81[b] (0.16)	1.02[b] (0.54)
Daincha	2.53[a] (5.90)	1.31[a] (1.22)	2.17[a] (4.21)	1.07[a] (0.64)	0.80[a] (0.14)	0.98[a] (0.46)

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

Table 132. Uptake of nutrients by broad leaf weeds at 40 DAS (kg ha^{-1})

Main plot treatments	2005-2006			2006-2007		
	N	P	K	N	P	K
Normal seed bed	1.32*[a] (1.24)	0.99[a] (0.48)	1.25[a] (1.06)	1.07[b] (0.64)	0.86[b] (0.24)	1.03[b] (0.56)
Stale seed bed (7 days)	1.08[b] (0.67)	0.88[b] (0.27)	1.04[b] (0.58)	1.34[a] (1.30)	0.97[a] (0.44)	1.27[a] (1.11)
Stale seed bed (14 days)	1.14[ab] (0.80)	0.89[ab] (0.29)	1.09[ab] (0.69)	1.19[ab] (0.92)	0.90[ab] (0.31)	1.13[ab] (0.78)
Sub plot treatments						
Unweeded control	2.47*[a] (5.60)	1.53[a] (1.84)	2.29[a] (4.74)	1.83[a] (2.85)	1.20[a] (0.94)	1.70[a] (2.39)
Hand weeding	0.78[c] (0.10)	0.74[c] (0.05)	0.77[c] (0.09)	1.03[b] (0.56)	0.83[b] (0.19)	0.99[b] (0.50)
Sofit	0.71[c] (0)	0.71[c] (0)	0.71[c] (0)	0.97[b] (0.44)	0.81[b] (0.16)	0.94[b] (0.38)
Cono weeding	1.18[b] (0.89)	0.90[b] (0.31)	1.12[b] (0.75)	1.12[b] (0.75)	0.87[b] (0.26)	1.07[b] (0.64)
Daincha	0.74[c] (0.05)	0.72[c] (0.02)	0.74[c] (0.05)	1.04[b] (0.58)	0.84[b] (0.21)	1.00[b] (0.50)

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

Table 133. Uptake of nutrients by broad leaf weeds at harvest (kg ha^{-1})

Main plot treatments	2005-2006			2006-2007		
	N	P	K	N	P	K
Normal seed bed	0.83*[a] (0.19)	0.74[a] (0.05)	0.81[a] (0.16)	1.07*[a] (0.64)	0.80[a] (0.14)	1.02[a] 0.54)
Stale seed bed (7 days)	0.75[b] (0.06)	0.72[b] (0.02)	0.75[b] (0.06)	0.99[a] (0.48)	0.78[a] (0.11)	0.95[a] (0.40)
Stale seed bed (14 days)	0.78[b] (0.11)	0.73[b] (0.03)	0.77[b] (0.09)	0.96[a] (0.42)	0.77[a] (0.09)	0.92[a] (0.35)
Sub plot treatments						
Unweeded control	0.96*[a] (0.42)	0.77[a] (0.09)	0.93[a] (0.36)	1.28[a] (1.14)	0.86[a] (0.24)	1.21[a] .(0.96)
Hand weeding	0.76[b] (0.08)	0.72[b] (0.02)	0.75[b] (0.36)	0.93[b] (0.36)	0.76[b] (0.08)	0.90[b] (0.31)
Sofit	0.73[b] (0.03)	0.71[b] (0)	0.73[b] (0.03)	0.97[b] (0.44)	0.78[b] (0.11)	0.93[b] (0.36)
Cono weeding	0.75[b] (0.06)	0.72[b] (0.02)	0.74[b] (0.05)	0.85[b] (0.22)	0.74[b] (0.05)	0.83[b] (0.19)
Daincha	0.74[b] (0.05)	0.72[b] (0.02)	0.74[b] (0.05)	0.98[b] (0.46)	0.78[b] (0.11)	0.94[b] (0.38)

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

Significantly higher uptake of nutrients by grasses at harvest stage of 2005-06 was observed in stale seed bed for 7 days. The other two main plots were at par. Among the weed control treatments, unweeded plots showed the highest uptake values. During 2006-07 also, stale seed bed (7days) and no weeding favoured the maximum uptake by grasses (Table 127).

Nutrient uptake by sedges

Nutrient removal by sedges at 20 DAS is presented in Table 128. At this stage of observation, seed bed treatments showed no significant variation in uptake values. However, during 2006-07, stale seed bed for 7 days favoured the lowest nutrient removal. Significant reduction in the removal of nutrients by sedges during both years was achieved by the pre emergence spraying of Sofit.

At 40 DAS, all the main plot treatments behaved similarly in terms of uptake and the differences were not significant. Maximum removal of nutrients by sedges at 40 DAS was in unweeded plots (Table 129).

The data on nutrient uptake by sedges at harvest stage of the crop is presented in Table 130. The main plot treatments showed no significant effect on nutrient removal by sedges at harvest stage during 2005-06. While, during 2006-07 stale seed bed for 7 days and normal seed bed showed almost similar nutrient removal. During both years, unweeded plots showed the maximum nutrient uptake.

Nutrient uptake by broad leaf weeds

At 20 DAS of 2005-06, normal seed bed preparation demonstrated the highest uptake of nutrients by broad leaf weeds, that is, 4.93, 1.25 and 2.0 kg ha^{-1} N, P and K (Table 131).

During 2006-07 also, normal seed bed showed the highest nutrient removal followed by stale seed bed for 7 days. Sofit spraying significantly reduced the nutrient uptake by broad leaf weeds.

Observations on the uptake of nutrients by broad leaf weeds at 40 DAS are depicted in Table 132. At this stage, higher removal of nutrients was observed in normal seed bed followed by stale seed bed for 14 days. Stale seed bed for 14 days was on a par with stale seed bed for 7 days. During 2006-07, stale seed bed for 7 days showed significant superiority in nutrient uptake. Unweeded plots showed the highest uptake values during both years.

At harvest stage of the crop during 2005-06, normal seed bed and unweeded plots showed significantly higher nutrient uptake values. All other treatments showed no significant variation with respect to removal of major plant nutrients (Table 133). During 2006-07, main plot treatments did not show significant differences in uptake of nutrients. Among the sub plots, unweeded plots registered the lowest values. Other treatments were at par.

Table 134. Economics of cultivation per hectare for main plot treatments (Rs./ha)

Seed bed	**Total cost**	**Total income**		**Total benefit**		**B:C ratio**	
		05-06	06-07	05-06	06-07	05-06	06-07
Normal seed bed	21765	66554	69393	44789	47628	3.06	3.19
Stale seed bed (7 days)	20663	74073	73618	53408	52953	3.58	3.56
Stale seed bed (14 days)	20663	78625	74721	57960	54056	3.80	3.62

Table.135 B:C ratio of the various treatments (Rs./ha)

Treatments	Normal seed bed		Stale 7		Stale 14	
	05-06	06-07	05-06	06-07	05-06	06-07
Unweeded control	1.98	1.25	2.51	2.01	3.09	2.17
Hand weeding	3.78	3.81	4.08	4.04	4.35	4.12
Sofit	3.99	4.14	4.32	4.19	4.28	4.27
Cono weeding	3.33	3.88	3.52	3.93	3.83	3.90
Daincha	3.65	4.32	4.05	4.27	4.21	4.27

4.3.5. Economics of cultivation

Economic analysis of the treatments reveals the superiority of stale seed bed techniques. Although the total cost of cultivation was the highest in normal seed bed, the net profit and B:C ratio were higher in stale seed bed plots (Table 134). Among the treatment combinations, hand weeding or pre - emergence spraying of pretilachlor + safener and concurrent growing of daincha gave higher benefit cost ratio (more than 4) under stale seed bed situation (Table 135).

4.4. Crop weed competition in transplanted rice: Influence of plant stand

4.4.1. Studies on weeds

Observations on total number of weeds and their dry weights were recorded. In addition, population and dry weight of major species of weeds were also observed. *Echinochloa* spp., *Ludwigia perennis* and *Sphenoclea zeylanica* were the major species of weeds observed in the experimental field.

Weed population

The data on weed population at 20 days after planting (before the weed management treatments, except in SRI managed plots) during 2005-06 are presented in Table136. Main plot treatments significantly reduced the total weed count at this stage of observation, with lower values in weeded plots.

Among the different spacings, the highest population of *Echinochloa* was noticed in 30 cm X 30 cm spacing under POP management. The lowest count was in 10 cm X 10 cm under POP management. Even after cono weeding, SRI managed plots had higher values for *Echinochloa* count. Population of *Ludwigia* and *Sphenoclea* were the highest in modified SRI. Total weed count was also higher in plots with wider spacing. The weed population was found to decline significantly with reduction in plant spacing.

During 2006-07, the lowest population of *Echinochloa*/m^2 was noticed in modified SRI, which was on a par with 10 cm X 10 cm (Table 137), whereas the count of broad leaf weeds was the highest in modified SRI. The treatment 10 cm X 10 cm recorded significantly lower population of weeds.

Data on weed count at 40 days after planting during 2005-06 are presented in Table 138. Weeded plots recorded lower weed population as compared to unweeded plots. Among the sub plot treatments, the lowest count of weeds was in 10cm x 10cm under POP

Table 136. Effect of treatments on weed count at 20 DAT during 2005-06 (Number m^{-2})

Sub plot treatments	*Echinochloa* spp.			*Ludwigia perennis*			*Sphenoclea zeylanica*			Total weed count		
	Main plot treatments			Main plot treatments			Main plot treatments			Main plot treatments		
	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean
10 cm X 10 cm (POP)	4.22*[d] (17.33)	3.89[d] (14.67)	4.05[d] (16.00)	2.86[c] (8.00)	2.86[c] (8.00)	2.86[cd] (8.00)	2.39[cd] (5.33)	1.65[de] (2.67)	2.01[c] (4.00)	5.55[c] (30.67)	5.07[c] (25.33)	5.31[c] (28.00)
20 cm X10 cm (POP)	4.65[d] (21.33)	5.75[c] (33.33)	5.20[bc] (27.33)	3.30[bc] (10.67)	3.33[bc] (10.67)	3.32[bc] (10.67)	2.65[bcd] (6.67)	3.13[bc] (9.33)	2.89[b] (8.00)	6.22[bc] (38.67)	7.28[b] (53.33)	6.75[b] (46.00)
30 cmX30 cm (POP)	7.12[b] (50.67)	8.59[a] (73.33)	7.85[a] (62.00)	4.36[b] (18.67)	3.13[c] (9.33)	3.74[b] (14.00)	3.46[bc] (12.00)	2.39[cd] (5.33)	2.92[b] (8.67)	8.99[a] (81.33)	9.39[a] (88.00)	9.19[a] (84.67)
30 cmX30 cm (SRI)	2.92[e] (8.00)	8.50[a] (72.00)	5.71[b] (40.00)	1.18[d] (1.33)	3.13[c] (9.33)	2.15[d] (5.33)	0.71[e] (0)	2.92[bc] (8.00)	1.82[c] 94.00)	3.13[d] (9.33)	9.47[a] (89.00)	6.30[b] (49.33)
30 cmX30 cm (Modified SRI)	0.71[f] (0)	8.74[a] (76.00)	4.72[c] (38.00)	8.09[a] (65.33)	3.51[bc] (12.00)	5.80[a] (38.67)	5.18[a] (28.00)	3.68[b] (13.33)	4.43[a] (20.67)	9.68[a] (93.33)	10.08[a] (101.33)	9.88[a] (97.33)
Main plot mean	3.92 (19.47)	7.09 (53.87)		3.96 (20.80)	3.19 (9.87)		2.88 (10.400	2.75 (7.73)		6.71 (50.67)	8.26 (71.47)	

* $\sqrt{X+0.5}$ transformed values, Original values with in parenthesis

Table 137. Effect of treatments on weed count at 20 DAT during 2006-2007 (Number m^{-2})

Sub plot treatments	*Echinochloa* spp.			*Ludwigia perennis*			*Sphenoclea zeylanica*			Total weed count		
	Main plot treatments			Main plot treatments			Main plot treatments			Main plot treatments		
	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean
10 cm X 10 cm (POP)	4.65*^{c} (21.33)	5.06^{c} (25.330	4.86^{cd} (23.33)	4.04^{b} (16.00)	4.04^{b} (16.00)	4.04^{b} (16.00)	2.12^{cd} (4.00)	2.65^{bc} (6.67)	2.39^{c} (5.33)	6.25^{c} (38.67)	6.46^{c} (41.33)	6.36^{b} (40.00)
20 cm X10 cm (POP)	5.42^{c} (29.33)	6.56^{b} (42.67)	5.99^{b} (36.00)	3.66^{b} (13.33)	4.37^{b} (18.67)	4.01^{b} (16.00)	2.65^{bc} (6.67)	3.84^{ab} (14.670	3.25^{ab} (10.67)	6.54^{c} (43.00)	7.86^{b} (61.00)	7.20^{b} (52.00)
30 cmX30 cm (POP)	6.81^{b} (46.67)	8.89^{a} (78.67)	7.85^{a} (62.67)	3.84^{b} (14.67)	3.84^{b} (14.67)	3.84^{b} (14.67)	2.92^{bc} (8.00)	3.40^{ab} (12.00)	3.16^{abc} (10.00)	7.79^{b} (61.33)	9.68^{a} (93.00)	8.73^{a} (77.33)
30 cmX30 cm (SRI)	2.86^{d} (8.00)	8.26^{a} (68.00)	5.56^{c} (38.00)	1.92^{c} (4.00)	4.13^{b} (17.33)	3.03^{b} (10.67)	1.45^{d} (2.67)	3.51^{ab} (12.00)	2.48^{bc} (7.33)	3.40^{d} (12.00)	9.26^{a} (85.00)	6.33^{b} (48.67)
30 cmX30 cm (Modified SRI)	0.71^{e} (0)	8.02^{a} (64.00)	4.37^{d} (32.00)	7.83^{a} (61.33)	4.18^{b} (17.33)	6.01^{a} (39.33)	4.34^{a} (18.67)	2.92^{bc} (8.00)	3.63^{a} (13.33)	7.83^{b} (61.33)	9.03^{ab} (81.00)	8.43^{a} (71.33)
Main plot mean	4.09 (21.07)	7.36 955.73)		4.26 (21.87)	4.11 (16.800		2.70 (8.00)	3.26 (10.67)		6.36 (43.20)	8.46 (72.53)	

* √X+0.5 transformed values, Original values with in parenthesis

Table 138. Effect of treatments on weed count at 40 DAT during 2005-06 (Number m^{-2})

Sub plot treatments	*Echinochloa* spp.			*Ludwigia perennis*			Total weed count		
	Main plot treatments			Main plot treatments			Main plot treatments		
	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean
10 cm X 10 cm (POP)	0.71^{*f} (0)	2.65^{e} (6.67)	1.68^{c} (3.33)	0.71^{d} (0)	1.65^{cd} (2.67)	1.18^{d} (1.33)	0.71^{f} (0)	3.13^{e} (9.33)	1.92^{c} (4.67)
20 cm X10 cm (POP)	0.71^{f} (0)	3.89^{d} (14.67)	2.30^{c} (7.00)	0.71^{d} (0)	2.39^{bc} (5.33)	1.55^{cd} (2.67)	0.71^{f} (0)	4.51^{d} (20.00)	2.61^{c} (10.00)
30 cmX30 cm (POP)	3.33^{de} (10.67)	9.15^{b} (84.00)	6.24^{b} (47.00)	1.18^{d} (1.33)	3.98^{a} (16.00)	2.58^{ab} (8.67)	3.51^{de} (12.00)	9.97^{b} (100.00)	6.74^{b} (56.00)
30 cmX30 cm (SRI)	6.56^{c} (42.67)	11.44^{a} (132.00)	9.00^{a} (87.00)	2.18^{bc} (5.00)	3.51^{a} (12.00)	2.85^{a} (9.00)	6.95^{c} (56.00)	11.96^{a} (144.00)	9.45^{a} (96.00)
30 cmX30 cm (Modified SRI)	0.71^{f} (0)	10.84^{a} (117.00)	5.77^{b} (132.00)	0.71^{d} (0)	3.13^{ab} (9.33)	1.92^{bc} (4.67)	0.71^{f} (0)	11.26^{a} (126.67)	5.99^{b} (63.33)
Main plot mean	2.41 (10.67)	7.60 (70.93)		1.10 (1.33)	2.93 (9.07)		2.52 (9.33)	8.97 (80.00)	

* $\sqrt{X+0.5}$ transformed values, Original values with in parenthesis

Table 139. Effect of treatments on weed count at 40 DAT during 2006-2007 (Number m^{-2})

Sub plot treatments	*Echinochloa* spp.			*Ludwigia perennis*			*Sphenoclea zeylanica*			Total weed count		
	Main plot treatments			Main plot treatments			Main plot treatments			Main plot treatments		
	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean
10 cm X 10 cm (POP)	0.71*[f] ((0)	5.06[d] (25.33)	2.87[d] (12.67)	1.65[c] (2.67)	2.92[b] (8.50)	2.29[c] (5.33)	0.71[f] (0)	1.65[e] (2.67)	1.18[c] (1.33)	1.65[f] (2.67)	5.80[d] (33.33)	3.73[d] (18.00)
20 cm X10 cm (POP)	0.71[f] (0)	8.19[c] (66.67)	4.45[c] (33.33)	2.12[bc] (4.00)	2.86[b] (8.00)	2.49[bc] (6.00)	2.12[de] (4.00)	2.92[bc] (8.00)	2.52[b] (6.00)	2.12[f] (4.00)	8.66[c] (75.00)	5.39[c] (39.00)
30 cmX30 cm (POP)	4.51[d] (20.00)	11.10[a] (123.00)	7.81[a] (71.33)	2.92[b] (8.00)	4.51[a] (20.00)	3.72[a] (14.00)	3.89[a] (14.67)	3.51[ab] (12.00)	3.70[a] (13.00)	5.33[d] (28.00)	11.96[ab] (143.00)	8.65[a] (85.33)
30 cmX30 cm (SRI)	1.18[f] (1.33)	11.56[a] (133.00)	637[b] (67.00)	2.12[bc] (4.00)	4.61[a] (21.33)	3.36[a] (12.67)	2.39[cd] (5.33)	2.12[de] (4.00)	2.25[b] (4.67)	2.39[f] (5.33)	12.43[a] (155)	7.41[b] (80.00)
30 cmX30 cm (Modified SRI)	2.86[e] (8.00)	10.28[b] (105.00)	6.57[b] (56.67)	2.12[bc] (4.00)	4.26[a] (18.67)	3.19[ab] (11.33)	2.12[de] (5.33)	2.92[bc] (8.00)	2.52[b] (6.00)	3.51[e] (12.00)	11.16[b] (124)	7.33[b] (68.00)
Main plot mean	2.00 (5.87)	9.24 (90.67)		2.19 (4.53)	3.83 (90.67)		2.25 (5.60)	2.62 (6.93)		3.00 (10.40)	10.00 (105.87)	

* $\sqrt{X+0.5}$ transformed values, Original values with in parenthesis

management. With respect to total weed count, 30cm x 30cm (POP) and 30cm X 30cm (modified SRI) were at par. Population of *Echinochloa* also followed the same trend. Plots with 10 cm x 10 cm spacing recorded the lowest count of *Ludwigia*.

Data on weed count taken at 40 days after planting during 2006-07 (Table139), indicates that 10 cm x 10 cm spacing under POP management produced significantly lower population of weeds. The treatment 30 cm X 30 cm under POP management recorded significantly higher population of weeds, but 30 cm X 30 cm under SRI management and under modified SRI were at par with respect to weed count at 40 DAT. At this stage of observation number of *Echinochloa*, *Ludwigia* and *Sphenoclea* followed similar trends. Combinations of 10 cm X 10 cm or 20 cm X 20 cm under POP management with hand weeding gave complete control of *Echinochloa*. The number of *Echinochloa* was the highest in 30 cm X 30 cm under SRI management without conoweeding and it was on a par with 30 cm X 30 cm under POP management without hand weeding. Significant reduction in the population of broad leaf weeds was observed in closer spacing.

Number of weeds at harvest during 2005-06 is presented in Table 140. Under all the spacing and management practices, weeded plots recorded significantly lower weed population. Among weeded plots, the maximum count of weeds was noticed in 30 cm x 30 cm under POP management and in SRI management. Number of *Echinochloa* and *Ludwigia* were significantly lower in 10 cm x 10 cm. Interaction effect between main and sub plots were also significant with respect to weed count at harvest. The treatment, 10 cm X 10 cm spacing under POP management with hand weeding recorded the least weed count.

During 2006-07, total weed count was significantly lower in 10 cm x 10 cm (Table141), followed by 20 cm X 10 cm and 30 cm x 30 cm under modified SRI. At harvest, weed count in 10 cm X 10 cm with or without weeding were statically at par. Among weeded plots, 30 cm X 30 cm under SRI management recorded the highest

Table 140. Effect of treatments on weed count at harvest during 2005-06 (Number m^{-2})

Sub plot treatments	*Echinochloa* spp.			*Ludwigia perennis*			Total weed count		
	Main plot treatments			Main plot treatments			Main plot treatments		
	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean
10 cm X 10 cm (POP)	2.12^{*d} (4.00)	2.92^{d} (8.00)	2.52^{d} (6.00)	0.71^{d} (0)	1.92^{bcd} (4.00)	1.31^{b} (2.00)	2.12^{f} (4.00)	3.51^{d} (12.00)	2.81^{e} (8.00)
20 cm X10 cm (POP)	2.65^{d} (6.67)	5.20^{c} (26.67)	3.93^{c} (16.67)	1.65^{bcd} (3.00)	2.92^{ab} (8.00)	2.89^{b} (5.33)	3.13^{de} (9.33)	5.92^{c} (34.67)	4.52^{d} (22.00)
30 cmX30 cm (POP)	5.28^{c} (28.00)	8.43^{b} (70.67)	6.85^{b} (49.33)	3.03^{ab} (9.00)	4.04^{a} (16.00)	3.54^{a} (12.67)	6.09^{c} (37.00)	9.32^{b} (86.67)	7.71^{b} (62.00)
30 cmX30 cm (SRI)	5.45^{c} (29.33)	11.10^{a} (123.00)	8.28^{a} (76.00)	1.92^{bcd} (4.00)	1.65^{bcd} (4.00)	1.79^{b} (4.00)	5.78^{c} (33.00)	11.27^{a} (127.00)	8.53^{a} (80.00)
30 cmX30 cm (Modified SRI)	2.12^{d} (4.00)	10.66^{a} (113.00)	6.39^{b} (59.00)	1.18^{cd} (1.33)	2.39^{bc} (6.67)	1.79^{b} (4.00)	2.39^{ef} (5.33)	10.98^{a} (120.00)	6.68^{c} (63.00)
Main plot mean	3.53 (14.40)	7.66 (68.27)		1.70 (3.47)	2.59 (7.73)		3.90 (17.87)	8.20 (76.00)	

* $\sqrt{X+0.5}$ transformed values, Original values with in parenthesis

Table 141. Effect of treatments on weed count at harvest during 2006-2007 (Number m^{-2})

Sub plot treatments	*Echinochloa* spp.			*Ludwigia perennis*			*Sphenoclea zeylanica*			Total weed count		
	Main plot treatments			Main plot treatments			Main plot treatments			Main plot treatments		
	Weeded	Un weeded	Sub plot mean	Weeded	Un weede d	Sub plot mean	Weeded	Un weede d	Sub plot mean	Weeded	Un weeded	Sub plot mean
10 cm X 10 cm (POP)	2.12*^{f} (4.00)	3.51^{e} (12.00)	2.81^{d} (8.00)	2.92^{b} (8.00)	2.65^{b} (6.67)	2.79^{b} (7.30)	1.65^{ab} (2.67)	2.12^{a} (4.00)	1.89^{a} (3.33)	3.71^{c} (13.33)	4.34^{c} (18.67)	4.03^{e} (16.00)
20 cm X10 cm (POP)	3.71^{e} (13.33)	5.33^{d} (28.00)	4.52^{c} (20.67)	2.39^{b} (5.33)	3.13^{b} (9.33)	2.76^{b} (7.33)	0.71^{c} (0)	2.12^{a} (4.00)	1.42^{ab} (2.00)	4.36^{c} (18.67)	6.15^{b} (37.00)	5.25^{d} (28.00)
30 cmX30 cm (POP)	5.06^{d} (25.00)	10.12^{b} (102.67)	7.59^{b} (64.00)	4.18^{a} (17.00)	4.36^{a} (18.67)	4.27^{a} (18.00)	2.12^{a} (4.00)	0.71^{c} (0)	1.42^{ab} (2.00)	6.54^{b} (42.67)	11.00^{a} (121.00)	8.77^{b} (82.00)
30 cmX30 cm (SRI)	6.66^{c} (44.00)	11.74^{a} (137.00)	9.20^{a} (91.00)	2.92^{b} (8.00)	2.65^{b} (6.67)	2.79^{b} (7.30)	1.18^{bc} (1.33)	1.65^{ab} (2.67)	1.42^{ab} (2.00)	7.24^{b} (52.00)	12.02^{a} (144.00)	9.63^{a} (98.00)
30 cmX30 cm (Modified SRI)	3.13^{ef} (9.00)	11.18^{ab} (125.33)	7.16^{b} (67.00)	2.65^{b} (6.67)	2.92^{b} (8.00)	2.79^{b} (7.30)	1.18^{bc} (1.33)	0.71^{c} (0)	0.95^{b} (0.67)	4.06^{c} (16.00)	11.54^{a} (133.00)	7.80^{c} (75.00)
Main plot mean	4.14 (19.20)	8.38 (81.07)		3.01 (9.07)	3.14 (9.87)		1.37 (1.87)	1.46 (2.13)		5.18 (28.53)	9.01 (90.93)	

* $\sqrt{X+0.5}$ transformed values, Original values with in parenthesis

Table 142. Effect of treatments on weed dry matter production at 20 DAT during 2005-06 (g m^{-2})

Sub plot treatments	*Echinochloa* spp.			*Ludwigia perennis*			*Sphenoclea zeylanica*			Total weed dry weight		
	Main plot treatments			Main plot treatments			Main plot treatments			Main plot treatments		
	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean
10 cm X 10 cm (POP)	3.79^{*ef} (13.84)	3.59^{f} (12.12)	3.67^{c} (12.98)	2.76^{bc} (7.33)	2.40^{c} (5.33)	2.58^{b} (6.33)	1.95^{ab} (3.54)	1.37^{bc} (1.60)	1.66^{b} (2.57)	3.87^{f} (14.47)	4.24^{ef} (17.45)	4.06^{c} (15.96)
20 cm X10 cm (POP)	4.09^{e} (16.33)	3.59^{f} (12.36)	3.84^{c} (14.35)	2.60^{c} (6.43)	1.61^{d} (2.11)	2.11^{c} (4.27)	2.00^{ab} (3.64)	1.27^{bc} (1.13)	1.64^{b} (2.39)	4.79^{e} (22.76)	4.74^{e} (22.02)	4.33^{c} (18.61)
30 cmX30 cm (POP)	5.71^{c} (32.08)	5.13^{d} (25.83)	5.42^{a} (28.95)	2.67^{c} (6.69)	1.63^{d} (2.17)	2.15^{bc} (4.43)	1.61^{b} (2.16)	1.28^{bc} (1.20)	1.45^{b} 91.68)	6.27^{c} (38.77)	5.34^{d} (28.00)	5.80^{b} (33.39)
30 cmX30 cm (SRI)	1.57^{g} (1.97)	7.10^{b} (49.89)	4.34^{b} (25.93)	0.79^{e} (0.13)	2.49^{c} (5.83)	1.64^{d} (2.98)	0.71^{c} (0)	2.06^{ab} (3.76)	1.39^{b} 91.88)	1.61^{g} (2.11)	7.50^{b} (55.72)	4.56^{c} (28.91)
30 cmX30 cm (Modified SRI)	0.71^{h} (0)	8.30^{a} (68.69)	4.51^{b} (34.35)	5.45^{a} (29.20)	3.38^{b} (11.20)	4.42^{a} (20.20)	2.46^{a} (5.60)	2.68^{a} (7.04)	2.57^{a} (6.32)	5.45^{d} (29.20)	8.96^{a} (79.89)	7.21^{a} (54.55)
Main plot mean	3.17 (12.85)	5.53 (33.78)		2.86 (9.96)	2.30 (5.33)		1.74 (2.99)	1.73 (2.95)		4.69 (21.46)	6.40 (40.62)	

* $\sqrt{X+0.5}$ transformed values, Original values with in parenthesis

Table 143. Effect of treatments on weed dry matter production at 20 DAT during 2006-2007 (g m^{-2})

Sub plot treatments	*Echinochloa spp.*			*Ludwigia perennis*			*Sphenoclea zeylanica*			Total weed dry weight		
	Main plot treatments			Main plot treatments			Main plot treatments			Main plot treatments		
	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean
10 cm X 10 cm (POP)	3.52^{*e} (11.86)	4.25^{d} (17.73)	3.89^{c} (14.80)	2.07^{b} (3.84)	2.07^{b} (3.84)	2.07^{b} (3.84)	1.74^{de} (2.52)	2.15^{cde} (4.20)	1.94^{c} (3.36)	4.13^{ef} (16.55)	4.69^{de} (19.06)	4.41^{d} (19.06)
20 cm X10 cm (POP)	4.55^{d} (20.53)	5.51^{c} (29.87)	5.03^{b} (25.20)	1.90^{b} (3.20)	2.23^{b} (4.48)	2.06^{b} (3.84)	2.15^{cde} (4.20)	3.07^{ab} (9.24)	2.61^{ab} (6.72)	4.89^{d} (23.73)	5.90^{c} (29.04)	5.40^{bc} (29.04)
30 cmX30 cm (POP)	6.08^{bc} (36.53)	7.45^{a} (55.07)	6.76^{a} (45.80)	1.98^{b} (3.52)	1.98^{b} (3.52)	1.98^{b} (3.52)	2.35^{bcd} (5.04)	2.73^{abc} (7.56)	2.54^{abc} (6.30)	6.36^{bc} (40.05)	7.68^{a} (49.32)	7.02^{a} (49.32)
30 cmX30 cm (SRI)	2.42^{f} (5.60)	6.92^{a} (47.60)	4.67^{b} (26.60)	1.16^{c} (0.96)	2.12^{b} (4.16)	1.64^{b} (2.56)	1.26^{e} (1.68)	2.81^{abc} (7.56)	2.04^{bc} (4.62)	2.95^{g} (6.56)	7.22^{a} (29.16)	4.91^{cd} (29.16)
30 cmX30 cm (Modified SRI)	0.71^{g} (0)	6.72^{ab} (44.80)	3.72^{c} (22.40)	3.89^{a} (14.72)	2.14^{b} (4.16)	3.01^{a} (9.44)	3.47^{a} (11.76)	2.35^{bcd} (5.04)	2.91^{a} (8.40)	3.89^{f} (14.72)	7.03^{ab} (31.84)	5.46^{b} (31.84)
Main plot mean	3.46 (14.91)	6.17 (39.01)		2.20 (5.25)	2.11 (4.03)		2.19 (5.04)	2.62 (6.72)		4.37 (20.32)	6.51 (43.05)	

* √X+0.5 transformed values, Original values with in parenthesis

population of weeds. The number of *Echinochloa* was the lowest in 10 cm X 10 cm with hand weeding. The count of *Ludwigia* did not differ significantly among main plots. Population of *Ludwigia* was the highest in 30 cm X 30 cm under POP management. In all other treatments number of *Ludwigia* were at par.

Dry matter production of weeds

The dry matter production of weeds at 20 days after planting during 2005-06 is presented in Table 142. Total weed dry weight was significantly lower in weeded main plots. Among the sub plot treatments, modified SRI recorded the highest total weed dry weight of 54.55 gm^{-2} followed by 30 cm X 30 cm under POP management. All other treatments were at par. Interaction effect was also significant. The weed dry matter production was the lowest in 10 cm x 10 cm with hand weeding followed by 10cm x 10cm without hand weeding, which were at par.

The dry weight of *Echinochloa* differed significantly among main plots. Weeded plots recorded the lowest dry weight. The treatment 30 cm x 30 cm under POP management produced maximum dry weight of *Echinochloa*. It was followed by 30 cm x 30 cm SRI and modified SRI plots, which were at par. The dry weight was lower in 10 cm x 10 cm and 20 cm X 10 cm under POP management.

Main plot treatments did not show any significant effect on the dry weight of broad leaf weeds. SRI plots with 30 cm x 30 cm plant spacing recorded the lowest dry matter of *Ludwigia*, where as the dry weight of *Sphenoclea* was the lowest in 30cm X 30 cm under modified SRI. All other sub plot treatments were at par.

A perusal of the data presented in Table 143 shows that total weed dry weight was the greatest in unweeded plots. Among different spacings, statistically higher weed dry weight at 20 days after planting during 2006-07 was in 30 cm x 30 cm under POP management. The treatment 10 cm X 10 cm under POP management recorded the lowest weed dry weight. Combination of 30 cm x 30 cm, modified SRI with weeding produced significantly lower total weed dry weight and it was on a par with 10 cm X 10 cm with hand weeding.

Dry weight of *Echinochloa* was significantly lower in weeded plots. SRI plots with cono weeding produced the lowest dry weight of *Echinochloa*, whereas, it was the highest in SRI without cono weeding and was on a par with 30 cm X 30 cm under POP management. At 20 DAT, the main plot effect was not significant with respect to dry weight of broad leaf weeds. Modified SRI recorded significantly higher dry weight of *Ludwigia*. The least dry weight was in SRI with conoweeding. Other sub plot treatments were at par. Similar trend was observed in the case of dry weight of *Sphenoclea* also.

Dry matter production of weeds at 40 days after planting is depicted in Table 144. Dry weight of all the weeds was significantly influenced by main plot treatments. Weeded plots recorded significantly lower dry weight of weeds. The weed dry weight in 10 cm X 10 cm POP managed plots was the lowest among sub plots, followed by 20 cm X 10 cm. The highest weed dry matter of 1320 gm^{-2} was noticed in SRI plots. Interaction effect was also significant. Among the weeded plots, 30 cm X 30 cm SRI with conoweeding recorded the highest value for total weed dry matter. All other treatments were at par. Among unweeded plots, the lowest weed dry weight was in 10 cm X 10 cm.

Dry weight of *Echinochloa* remained higher even after conoweeding in SRI plots. The treatment 10 cm X 10 cm without weeding was significantly inferior to SRI with conoweeding with respect to total dry matter and dry weight of *Echinochloa* at 40 DAT during 2005-06. Treatments 10 cm X 10 cm, 20 cm X 10 cm and modified SRI, with weeding did not have any *Echinochloa* plants and so dry weight could not be recorded. *Ludwigia* was also absent in 10 cm X 10 cm and 20 cm X 10 cm plots without weeding.

Table 144. Effect of treatments on weed dry matter production at 40 DAT during 2005-06 (g m^{-2})

Sub plot treatments	*Echinochloa spp.*			*Ludwigia perennis*			Total weed dry weight		
	Main plot treatments			Main plot treatments			Main plot treatments		
	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean
10 cm X 10 cm (POP)	0.71*^{g} (0)	8.17^{f} (66.40)	4.44^{e} (33.20)	0.71^{d} (0)	1.92^{cd} (4.00)	1.31^{b} (35.2)	0.71^{g} (0)	8.41^{f} (70.40)	4.56^{e} (35.20)
20 cm X10 cm (POP)	0.71^{g} (0)	13.98^{e} (198.67)	7.34^{d} (99.33)	0.71^{d} (0)	2.32^{bc} (204)	1.52^{b} (5.07)	0.71^{g} (0)	14.15^{e} (203.73)	7.43^{d} (101.87)
30 cmX30 cm (POP)	2.77^{g} (7.20)	30.06^{c} (904.00)	16.42^{c} (455)	0.85^{d} (0.27)	3.61^{ab} (917)	2.23^{ab} (12.80)	2.82^{g} (7.47)	30.27^{c} (916.80)	16.55^{c} (462.13)
30 cmX30 cm (SRI)	24.93^{d} (621.33)	44.37^{b} (2000)	34.65^{a} (1311)	2.56^{bc} (8.00)	3.31^{abc} (2011)	2.94^{a} (10.53)	25.08^{d} (629.33)	44.49^{b} (2011.07)	34.79^{a} (1320.)
30 cmX30 cm (Modified SRI)	0.71^{g} (0)	49.16^{a} (2417)	24.94^{b} (1209)	0.71^{d} (0)	4.62^{a} (2439)	2.66^{a} (21.07)	0.71^{g} (0)	49.37^{a} (2438.40)	25.04^{b} (1219)
Main plot mean	5.97 (1265.71)	29.15 (1117)		1.11 (1.65)	3.16 (10.69)		6.01 (127.36)	29.34 (1128)	

* $\sqrt{X+0.5}$ transformed values, Original values with in parenthesis

Table 145. Effect of treatments on weed dry matter production at 40 DAT during 2006-2007 (g m^{-2})

Sub plot treatments	*Echinochloa* spp.			Total weed weight		
	Main plot treatments			Main plot treatments		
	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean
10 cm X 10 cm (POP)	0.71*^{g} ((0)	4.17^{e} (17.25)	2.44^{d} (8.63)	1.83^{d} (2.84)	4.83^{cd} (23.17)	3.67^{c} (13.01)
20 cm X10 cm (POP)	0.71^{g} (0)	7.62^{c} (57.67)	4.17^{c} (28.830	1.71^{d} (2.42)	8.00^{abc} (63.63)	4.86^{b} (33.03)
30 cmX30 cm (POP)	5.03^{d} (24.93)	12.30^{a} (150.88)	8.67^{a} (87.91)	5.55^{cd} (30.47)	12.82^{a} (164.08)	9.19^{a} (97.27)
30 cmX30 cm (SRI)	1.32^{g} (2.00)	12.79^{a} (163.33)	7.06^{b} (82.67)	2.05^{d} (4.13)	13.32^{a} (177.40)	7.69^{ab} (90.77)
30 cmX30 cm (Modified SRI)	3.29^{f} (10.81)	11.41^{b} (129.79)	7.35^{b} (70.30)	3.67^{cd} (13.39)	11.97^{ab} (142.85)	7.82^{ab} (78.12)
Main plot mean	2.21 (7.550	9.66 (103.78)		3.34 (10.65)	10.19 (114.23)	

* √X+0.5 transformed values, Original values with in parenthesis

Table 146. Effect of treatments on weed dry matter production at harvest during 2005-06 (g m^{-2})

Sub plot treatments	*Echinochloa* spp.			*Ludwigia perennis*			Total weed weight		
	Main plot treatments			Main plot treatments			Main plot treatments		
	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean
10 cm X 10 cm (POP)	2.65^{*fg} (6.67)	3.27^{f} (10.27)	2.96^{e} (8.47)	0.71^{d} (0)	1.38^{cd} (1.73)	1.04^{b} (0.87)	2.65^{g} (6.67)	3.52^{f} (12.00)	3.09^{e} (9.33)
20 cm X10 cm (POP)	4.42^{e} (19.07)	4.61^{e} (20.80)	4.52^{d} (19.93)	1.44^{cd} (1.87)	2.57^{bc} (6.53)	2.01^{b} (4.20)	4.63^{e} (20.93)	5.27^{e} (27.33)	4.95^{d} (24.13)
30 cmX30 cm (POP)	7.71^{d} (59.20)	15.37^{c} (235.64)	11.54^{c} (147.42)	3.12^{ab} (9.47)	4.11^{a} (16.63)	3.62^{a} (13.05)	8.31^{d} (68.67)	15.90^{c} (252.27)	12.10^{c} (160.47)
30 cmX30 cm (SRI)	8.44^{d} (70.93)	23.16^{b} (536.40)	15.80^{a} (303.67)	1.85^{bcd} (3.73)	1.45^{cd} (2.67)	1.65^{b} (3.20)	8.66^{d} (74.67)	23.22^{b} (539.07)	15.95^{a} (306.87)
30 cmX30 cm (Modified SRI)	2.18^{g} (4.27)	24.06^{a} (578.67)	13.12^{b} (291.47)	1.11^{cd} (1.07)	2.60^{bc} (8.27)	1.89^{b} (4.67)	2.40^{g} (5.33)	24.23^{a} (586.93)	13.32^{b} (296.13)
Main plot mean	5.08 (32.03)	14.10 (276.36)		1.64 (3.23)	2.42 (7.17)		5.40 (35.25)	4.43 (283.52)	

* $\sqrt{X+0.5}$ transformed values, Original values with in parenthesis

Table 147. Effect of treatments on weed dry matter production at harvest during 2006-2007 (g m^{-2})

Sub plot treatments	*Echinochloa* spp.			*Ludwigia perennis*			*Sphenoclea zeylanica*			Total weed dry weight		
	Main plot treatments			Main plot treatments			Main plot treatments			Main plot treatments		
	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean
10 cm X 10 cm (POP)	4.98*^{f} (24.27)	8.29^{e} (68.61)	6.63^{d} (46.44)	5.01^{bc} (24.62)	4.17^{c} (16.89)	4.59^{b} (20.76)	2.14^{ab} (5.12)	2.86^{a} (7.68)	2.50^{a} (6.40)	7.20^{f} (51.45)	9.26^{e} (85.51)	8.23^{e} (68.48)
20 cm X10 cm (POP)	9.07^{e} (81.80)	13.25^{d} (175.53)	11.16^{c} (128.67)	4.46^{bc} (19.61)	4.90^{bc} (23.64)	4.68^{b} (21.63)	0.71^{c} (0)	2.86^{a} (7.68)	1.79^{ab} (3.84)	10.09^{e} (101.41)	14.12^{d} (199.71)	12.11^{d} (150.29)
30 cmX30 cm (POP)	13.44^{d} (180.47)	25.56^{b} (657.07)	19.50^{b} (418.77)	8.19^{a} (67.95)	8.54^{a} (73.17)	8.37^{a} (70.56)	2.86^{a} (7.68)	0.71^{c} (0)	1.79^{ab} (3.84)	15.76^{d} (248.41)	26.95^{b} (730.24)	21.35^{b} (489.33)
30 cmX30 cm (SRI)	16.99^{c} (288.27)	29.65^{a} (878.93)	23.32^{a} (583.60)	5.25^{bc} (27.43)	5.10^{bc} (26.13)	5.18^{b} (26.78)	1.43^{bc} (2.56)	2.14^{ab} (5.12)	1.79^{ab} (3.84)	17.77^{c} (315.69)	30.08^{a} (905.07)	23.93^{a} (610.38)
30 cmX30 cm (Modified SRI)	7.20^{e} (51.68)	29.29^{a} (858.99)	18.24^{b} (455.33)	5.10^{bc} (26.13)	5.64^{b} (31.36)	5.37^{b} (28.75)	1.43^{bc} (2.56)	0.71^{c} (0)	1.07^{b} (1.28)	8.84^{ef} (77.81)	29.82^{a} (890.35)	19.33^{c} (484.08)
Main plot mean	10.34 (125.30)	21.21 (527.83)		5.60 (33.15)	5.67 (34.24)		1.71 (3.58)	1.86 (4.10)		11.93 (158.96)	22.05 (562.07)	

* $\sqrt{X+0.5}$ transformed values, Original values with in parenthesis

Total weed dry matter and *Echinochloa* dry matter production during 2006-07 exhibited significant differences between main plot treatments. Weeded plots recorded significantly lower weed dry weight. The plots receiving 30 cm X 30 cm under POP management had the highest weed dry weight, followed by 20 cm X 10 cm. It was on a par with all other sub plot treatments. Significantly lower dry weight of *Echinochloa* was noticed in 10 cm X 10 cm and 20 cm X 10 cm with weeding. Among unweeded plots, 10 cm X 10 cm plots recorded the lowest dry weight of *Echinochloa*. The maximum dry weight of *Sphenoclea* was in 30 cm X 30 cm POP (Table 145). The highest dry weight of *Sphenochlea* was noticed in 30 cm X 30 cm POP with or without weeding.

At harvest, the highest dry weight of weeds was in SRI managed plots followed by modified SRI. Combination of 10 cm X 10 cm POP with hand weeding or 30 cm X 30 cm under SRI with cono weeding were successful in reducing the weed dry matter at harvest stage (Table 146). Dry weight of *Echinochloa* was the lowest in modified SRI. This was on a par with 10 cm X 10 cm with weeding. The treatment 10 cm X 10 cm with weeding was on a par with 10 cm X 10 cm without weeding with respect to dry weight of *Echinochloa*. Modified SRI without weeding recorded significantly higher dry weight of *Echinochloa* (578.67 g m^2). Dry matter of *Ludwigia* at harvest was significantly higher in 30 cm X 30 cm POP with or without weeding.

Data on weed dry weight at harvest during 2006-07 is depicted in Table 147. The results show that main plot treatments influenced the dry weight of *Echinochloa* and total weed dry weight. Among the sub plot treatments, significantly lower values for total weed dry matter was noticed in 10 cm X 10 cm, followed by 20 cm X 10 cm. The treatment 30 cm X 30 cm under SRI management recorded the highest value for total weed dry matter. Interaction showed that combination of 10 cm X 10 cm with weeding reduced the weed weight at harvest stage. The treatments, 20 cm X 10 cm with weeding and 10 cm X 10 cm without weeding were at par.

Among the sub plot treatments, dry weight of *Echinochloa* was the lowest in 10 cm X 10 cm. Interaction between main and sub plots were also significant resulting in lowest dry weight of *Echinochloa* in 10 cm X 10 cm POP with weeding, followed by 10 cm X 10 cm without weeding and 20 cm X 10 cm with weeding. With respect to broad leaf weeds, 30 cm X 30 cm POP plots recorded the highest dry weight. The highest dry weight of *Ludwigia* was in 30 cm X 30 cm, while for *Sphenoclea* the highest was in 10 cm X 10 cm.

4.4.2. Studies on crop

Plant height

The height of rice plants at various stages of observation is presented in Tables 148 and 149. Main plot treatments did not have any significant effect on plant height at maximum tillering stage, where as it had significant influence at panicle initiation and harvest stages. In general, a decline in plant height was observed in unweeded plots.

At maximum tillering stage, SRI and modified SRI plots recorded significantly higher plant height during 2005-06. However, during 2006-07 plant height was the highest in 10cm X 10cm spacing. During both years, the treatment combination of 30 cm X 30 cm under SRI management with cono weeding demonstrated higher values for plant height at maximum tillering stage. Observations on sub plot effects on plant height during both years showed that 10 cm X 10 cm spacing had significantly higher plant height followed by 20 cm X 10 cm. Interaction effect between main and sub plots showed that 10cm X 10cm without weeding and 30 cm X 30 cm SRI with cono weeding were at par during 2005-06. However, during 2006-07 10cm X 10cm without weeding was superior to 30 cm X 30 cm SRI with cono weeding.

Table 148. Plant height (cm) at various stages of observation during 2005-06

Sub plot treatments	Maximum tillering			Panicle initiation			Harvest		
	Main plot treatments								
	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean
10 cm X 10 cm (POP)	41.92^{c}	42.80^{b}	42.36^{b}	76.87^{b}	78.17^{a}	77.52^{a}	91.77^{a}	90.63^{b}	91.20^{a}
20 cm X10 cm (POP)	41.40^{cd}	41.73^{c}	41.57^{c}	75.14^{de}	76.05^{c}	75.59^{b}	89.40^{c}	82.40^{e}	85.90^{b}
30 cmX30 cm (POP)	40.87^{de}	38.80^{f}	39.83^{d}	74.77^{e}	67.64^{g}	71.21^{d}	88.57^{c}	80.50^{f}	84.53^{c}
30 cmX30 cm (SRI)	45.20^{a}	40.43^{e}	42.82^{a}	77.86^{a}	64.15^{h}	71.01^{d}	91.70^{a}	80.37^{f}	86.03^{b}
30 cmX30 cm (Modified SRI)	45.60^{a}	40.40^{e}	43.00^{a}	75.35^{d}	70.55^{f}	72.95^{c}	86.70^{d}	80.30^{f}	83.50^{d}
Main plot mean	43.00	40.83		76.00	71.31		89.63	82.84	

Table 149. Plant height (cm) at various stages of observation during 2006-2007

Sub plot treatments	Maximum tillering			Panicle initiation			Harvest		
	Main plot treatments								
	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean
10 cm X 10 cm(POP)	46.00^{ab}	45.97^{ab}	45.98^{a}	83.80^{b}	84.89^{a}	84.34^{a}	96.16^{a}	96.48^{a}	96.32^{a}
20 cm X10 cm(POP)	42.90^{d}	43.23^{d}	43.07^{d}	82.06^{c}	78.39^{e}	80.23^{b}	90.40^{d}	86.39^{f}	88.40^{b}
30 cm X 30 cm(POP)	44.87^{c}	45.40^{abc}	45.13^{b}	80.87^{d}	76.15^{f}	78.51^{c}	88.97^{e}	80.58^{h}	84.77^{d}
30 cm X 30 cm(SRI)	46.13^{a}	41.63^{e}	43.88^{c}	83.64^{b}	73.78^{g}	78.71^{c}	93.83^{b}	81.75^{g}	87.79^{b}
30 cm X 30 cm (Modified SRI)	45.23^{bc}	42.57^{d}	43.90^{c}	82.04^{c}	72.94^{h}	77.49^{d}	91.64^{c}	82.22^{g}	86.93^{c}
Main plot mean	45.03	43.76		82.48	77.23		92.20	85.49	

Table 150. Tiller count per hill at various growth stages during 2005-06

Sub plot treatments	Maximum tillering			Panicle initiation			Harvest		
	Main plot treatments								
	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean
10 cm X 10 cm (POP)	5.45^{f}	5.20^{f}	5.32^{d}	5.43^{f}	5.13^{f}	5.28^{e}	5.33^{e}	5.53^{e}	5.43^{e}
20 cm X10 cm (POP)	9.24^{d}	7.45^{e}	8.35^{c}	7.87^{e}	7.10^{ef}	7.48^{d}	7.80^{e}	7.87^{e}	7.83^{d}
30 cmX30 cm (POP)	13.72^{ab}	10.79^{cd}	12.25^{b}	21.30^{b}	21.57^{b}	21.43^{b}	19.13^{b}	18.10^{bc}	18.62^{b}
30 cmX30 cm (SRI)	13.20^{b}	10.88^{cd}	12.04^{b}	17.83^{c}	13.00^{d}	15.42^{c}	18.10^{bc}	14.17^{d}	16.13^{c}
30 cmX30 cm (Modified SRI)	15.32^{a}	12.27^{bc}	13.80^{a}	33.87^{a}	13.60^{d}	23.73^{a}	33.87^{a}	14.80^{cd}	24.33^{a}
Main plot mean	11.39	9.32		17.26	12.08		16.85	12.09	

Table 151. Tiller count per hill at various growth stages during 2006-2007

Sub plot treatments	Maximum tillering			Panicle initiation			Harvest		
	Main plot treatments								
	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean
10 cm X 10 cm (POP)	4.93^{g}	4.97^{g}	4.95^{e}	4.93^{i}	5.00^{i}	4.97^{e}	5.00^{g}	4.86^{g}	4.93^{e}
20 cm X10 cm (POP)	8.90^{e}	7.03^{f}	7.97^{d}	9.07^{g}	7.17^{h}	8.12^{d}	8.97^{f}	8.47^{f}	8.72^{d}
30 cmX30 cm(POP)	13.66^{c}	12.07^{d}	12.86^{c}	21.42^{c}	19.95^{d}	20.69^{b}	21.90^{c}	14.06^{d}	17.98^{c}
30 cmX30 cm (SRI)	15.44^{b}	13.63^{c}	14.54^{b}	22.45^{b}	14.25^{e}	18.35^{c}	23.87^{b}	14.73^{d}	19.30^{b}
30 cmX30 cm (Modified SRI)	17.59^{a}	12.44^{d}	15.01^{a}	30.71^{a}	13.23^{f}	21.97^{a}	33.53^{a}	12.66^{e}	23.10^{a}
Main plot mean	12.10	10.03		17.72	11.92		18.66	10.96	

Table 152. Tiller count per m² at various growth stages during 2005-06

Sub plot treatments	Maximum tillering			Panicle initiation			Harvest		
	Main plot treatments								
	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean
10 cm X 10 cm (POP)	545[a]	520[a]	533[a]	543[a]	513[a]	528[a]	533[a]	553[a]	543[a]
20 cm X10 cm (POP)	462[b]	373[c]	417[b]	393[b]	355[b]	374[b]	390[b]	353[b]	392[b]
30 cmX30 cm (POP)	152[de]	120[e]	136[c]	237[c]	240[c]	238[c]	213[c]	201[cd]	207[d]
30 cmX30 cm (SRI)	147[de]	121[e]	134[c]	198[c]	144[d]	171[d]	201[cd]	157[d]	179[d]
30 cmX30 cm (Modified SRI)	170[d]	136[e]	153[c]	376[b]	151[d]	264[c]	376[b]	164[d]	270[c]
Main plot mean	295	254		350	281		343	294	

Table 153. Tiller count per m² at various growth stages during 2006-2007

Sub plot treatments	Maximum tillering			Panicle initiation			Harvest		
	Main plot treatments								
	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean
10 cm X 10 cm (POP)	493[a]	497[a]	495[a]	493[a]	500[a]	497[a]	500[a]	486[a]	493[a]
20 cm X10 cm (POP)	445[b]	352[c]	398[b]	453[b]	358[c]	406[b]	448[b]	423[c]	436[b]
30 cmX30 cm (POP)	152[f]	134[g]	143[d]	238[f]	222[g]	230[d]	243[f]	156[gh]	200[e]
30 cmX30 cm (SRI)	172[e]	151[f]	162[c]	249[e]	158[h]	204[e]	265[e]	164[g]	214[d]
30 cmX30 cm (Modified SRI)	195[d]	138[fg]	167[c]	341[d]	147[i]	244[c]	373[d]	141[h]	257[c]
Main plot mean	291	254		355	277		366	274	

At harvest stage, 10 cm X 10 cm exhibited superiority over other sub plots in plant height during both the years. During 2005-06, 10 cm X 10 cm with weeding was on a par with 30 cm X 30 cm SRI with conoweeding and in 2006-07, 10 cm X 10 cm with or without weeding were at par.

Number of tillers

Data on number of tillers per hill at various growth stages are presented in Tables 150 and 151. During 2005-06, main plot treatments influenced the tiller count at all stages of observation. Weeded plots produced more number of tillers/hill. In both the years, among sub plots, 30 cm X 30 cm modified SRI with weeding showed significantly higher tiller count/hill and the lowest was in 10 cm X 10 cm.

Interaction between the main and sub plot treatments also significantly influenced the tiller count/hill at all stages of observation during both years. The treatment combination, 30 cm X 30 cm modified SRI with weeding produced the highest number of tillers per hill. At maximum tillering stage, during 2005-06, modified SRI was on a par with 30 cm X 30 cm POP with hand weeding. Differences in tiller count between weeded and unweeded plots increased with increase in plant spacing. However, at all stages of observation, tiller count in 10 cm X 10 cm with or without weeding were almost same.

The data in Tables 152 and 153 show that in all the three stages of observation and in both the years, weeded plots recorded significantly higher values for tiller count per m^2. Among the sub plot treatments, closer plant spacing (10 cm X 10 cm) with or without weeding produced more number of tillers/m^2. These two treatments remained on a par. The second highest value for tiller count/m^2 was noticed in 20 cm X 10 cm with weeding. The lowest tiller count/m^2 were noticed in wider plant spacing. At maximum tillering stage, during 2005-06, 30 cm X 30 cm under modified SRI without weeding, 30cm X 30cm under POP without weeding and 30 cm X 30 cm under SRI without weeding were at par. During panicle initiation and harvest stages, 30 cm X 30 cm without weeding and 30 cm X 30 cm under SRI without cono weeding were at par.

Table 154. Crop dry weight at various growth stages during 2005-06 (g plant^{-1})

Sub plot treatments	20DAT			40DAT			60DAT			Harvest		
	Main plot treatments											
	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean
10 cm X 10 cm(POP)	3.41^{g}	3.39^{g}	3.41^{d}	9.74^{g}	9.52^{g}	9.63^{e}	14.88^{h}	14.02^{h}	14.45^{e}	26.25^{g}	23.97^{h}	25.11^{e}
20 cm X10 cm(POP)	3.63^{f}	3.61^{f}	3.62^{c}	10.37^{f}	9.80^{g}	10.09^{d}	19.46^{g}	19.06^{g}	19.26^{d}	30.41^{f}	26.70^{g}	28.55^{d}
30 cmX30 cm(POP)	4.08^{e}	4.57^{d}	4.32^{b}	25.18^{d}	22.65^{e}	23.92^{c}	70.47^{c}	24.30^{f}	47.38^{c}	90.55^{c}	49.93^{d}	70.24^{c}
30 cmX30 cm(SRI)	5.05^{a}	4.89^{b}	4.97^{a}	30.79^{b}	25.20^{d}	28.00^{b}	75.37^{b}	28.17^{e}	51.77^{b}	98.20^{b}	47.93^{e}	73.07^{b}
30 cmX30 cm (Modified SRI)	5.07^{a}	4.78^{c}	4.93^{a}	32.63^{a}	26.03^{c}	29.33^{a}	77.33^{a}	29.29^{d}	53.31^{a}	99.78^{a}	48.47^{e}	74.12^{a}
Main plot mean	4.25	4.25		21.74	18.64		51.50	22.97		69.04	39.40	

Table 155. Crop dry weight at various growth stages during 2006-2007 (g plant^{-1})

Sub plot treatments	20DAT			40DAT			60DAT			Harvest		
	Main plot treatments											
	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean
10 cm X 10 cm(POP)	3.17^{f}	3.33^{ef}	3.25^{d}	8.36^{gh}	8.23^{gh}	8.29^{c}	15.21^{g}	14.87^{g}	15.04^{e}	25.64^{g}	24.26^{h}	24.95^{e}
20 cm X10 cm(POP)	3.54^{e}	3.53^{e}	3.54^{c}	8.86^{f}	8.18^{h}	8.52^{c}	19.66^{e}	17.45^{f}	18.55^{d}	28.79^{e}	27.22^{f}	28.01^{d}
30 cmX30 cm(POP)	4.10^{d}	4.73^{c}	4.42^{b}	14.62^{c}	8.58^{fg}	11.60^{b}	74.85^{a}	21.60^{d}	48.22^{c}	89.49^{b}	49.35^{c}	69.42^{c}
30 cmX30 cm(SRI)	5.12^{b}	5.17^{b}	5.14^{a}	17.60^{b}	12.31^{d}	14.96^{a}	75.73^{a}	27.36^{b}	51.55^{a}	96.47^{a}	45.47^{d}	70.97^{b}
30 cmX30 cm (Modified SRI)	5.43^{a}	5.00^{b}	5.23^{a}	18.20^{a}	11.53^{e}	14.87^{a}	75.27^{a}	23.38^{c}	49.32^{b}	97.45^{a}	48.40^{c}	72.93^{a}
Main plot mean	4.27	4.35		13.53	9.76		52.14	20.93		67.57	38.94	

During 2006-07, among the weeded plots, 10 cm X 10 cm was superior to other sub plots in tiller count/m^2 at all the three stages of observation. The lowest value of 134 at maximum tillering was produced by 30 cm X 30 cm POP without weeding, and it was on a par with 30 cm x 30 cm modified SRI without weeding. At panicle initiation and harvest stages modified SRI without weeding recorded significantly lower tiller count.

Crop dry matter production

At 20 days after planting, main plot treatments had no significant influence on crop dry matter production (Tables 154 and 155). However, at 40 DAT, 60 DAT and at harvest stages, main plots influenced significantly. Observations on dry matter at 20 DAT during 2005-06 revealed that SRI and modified SRI, which were at par, had significantly higher values and they were at par, followed by 30 cm X 30 cm POP treatment. The treatments 10 cm X 10 cm spacing produced the lowest dry weight of plants.

During 2005-06 and 2006-07, the minimum dry weight was noticed in 10 cm X 10 cm. At 40 DAT, 60 DAT and harvest stages of 2005-06, modified SRI produced significantly higher crop dry weight. Combination of 30 cm X 30 cm under modified SRI with chemical weeding gave the highest crop dry weight. It was closely followed by 30 cm X 30 cm SRI with cono weeding.

During 2006-07, main plot and sub plot treatments exhibited similar trend as that in 2005-06. At 20 days after transplanting, modified SRI with weeding recorded higher dry matter prodcution, and the lowest was in 10 cm X 10 cm with weeding. At 40 days after planting, modified SRI with weeding produced more crop dry matter followed by 30 cm X 30 cm with conoweeding. The weeded combination of 30 cm X 3 0cm under different management practices produced statistically on a par values for plant dry weight at 60 DAT. The lowest values for dry weight of plants at this stage was in 10 cm x 10 cm with or without weeding. During harvest stage also, modified SRI with weeding and SRI with cono weeding proved superior.

Chlorophyll content

Chlorophyll content of index leaf at maximum tillering stage during 2005-06 are presented in Table 156. Chlorophyll ‘a’ content was maximum in weeded plots. However, chlorophyll ‘b’ and total chlorophyll contents were higher in unweeded plots.

Among sub plots, significantly higher values of chlorophyll ‘a’, ‘b’ and total chlorophyll were noticed in SRI and in modified SRI. Modified SRI with weeding showed significantly superior value of chlorophyll ‘a’ (2.17 mg g^{-1} fresh weight). However chlorophyll ‘b’ and total chlorophyll were statistically similar in SRI and modified SRI with or without weeding.

At panicle initiation (Table 157) showed that main plot treatments influenced chlorophyll ‘a’ content only. The content of chlorophyll ‘a’ was higher in 30 cm X 30 cm POP followed by 20 cm X 10 cm POP. Combination of 30 cm X 30 cm SRI without conoweeding showed higher value for chlorophyll ‘a’ at this stage of observation. This treatment was on a par with 30 cm X 30 cm POP without weeding. Chlorophyll ‘b’ content recorded superior values in 20 cm X 10 cm and 30 cm X 30 cm POP. However, it was the lowest in 30 cm X 30 cm modified SRI. Significant interactions were noticed in 20 cm X 10 cm POP with weeding and 30 cm X 30 cm SRI without weeding. Total chlorophyll content was the highest in 30 cm x 30 cm POP and was on a par with 20 cm x 10 cm POP. The treatment combination of 30 cm x 30 cm SRI without weeding recorded significantly higher total chlorophyll content.

Table 156. Chlorophyll content at maximum tillering stage during 2005-06 (on fresh weight basis mg g^{-1})

Sub plot treatments	Chlorophyll 'a'			Chlorophyll 'b'			Total Chlorophyll		
	Main plot treatments			Main plot treatments			Main plot treatments		
	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean
10 cm X 10 cm(POP)	1.94^{c}	1.80^{d}	1.87^{b}	0.89^{cde}	0.86^{cde}	0.88^{c}	2.84^{d}	2.66^{e}	2.75^{c}
20 cm X10 cm(POP)	1.72^{e}	1.68^{e}	1.70^{c}	0.83^{de}	0.79^{e}	0.81^{c}	2.55^{ef}	2.47^{f}	2.51^{d}
30 cmX30 cm(POP)	1.94^{c}	1.81^{d}	1.88^{b}	0.95^{cd}	1.24^{b}	1.10^{b}	2.89^{cd}	3.06^{bc}	2.97^{b}
30 cmX30 cm(SRI)	2.08^{b}	1.90^{c}	1.99^{a}	0.96^{cd}	1.64^{a}	1.30^{a}	3.04^{bc}	3.55^{a}	3.29^{a}
30 cmX30 cm (Modified SRI)	2.17^{a}	1.89^{c}	2.03^{a}	1.00^{c}	1.63^{a}	1.32^{a}	3.17^{b}	3.53^{a}	3.35^{a}
Main plot mean	1.97	1.82		0.93	1.23		2.90		

Table 157. Chlorophyll content at panicle initiation stage during 2005-06 (on fresh weight basis mg g^{-1})

Sub plot treatments	Chlorophyll 'a'			Chlorophyll 'b'			Total Chlorophyll		
	Main plot treatments			Main plot treatments			Main plot treatments		
	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean
10 cm X 10 cm(POP)	1.51^{d}	1.56^{d}	1.53^{c}	1.19^{c}	1.24^{bc}	1.22^{bc}	2.70^{d}	2.76^{d}	2.73^{c}
20 cm X10 cm(POP)	1.73^{bc}	1.55^{d}	1.64^{b}	1.48^{a}	1.22^{bc}	1.35^{a}	3.10^{bc}	2.77^{d}	2.94^{ab}
30 cmX30 cm(POP)	1.80^{ab}	1.65^{c}	1.72^{a}	1.35^{b}	1.30^{bc}	1.32^{a}	3.14^{b}	2.95^{c}	3.04^{a}
30 cmX30 cm(SRI)	1.34^{e}	1.82^{a}	1.58^{c}	1.07^{d}	1.50^{a}	1.28^{ab}	2.40^{e}	3.33^{a}	2.87^{b}
30 cmX30 cm (Modified SRI)	1.73^{bc}	1.18^{f}	1.46^{d}	1.29^{bc}	1.04^{d}	1.16^{c}	3.02^{bc}	2.22^{f}	2.60^{d}
Main plot mean	1.62	1.55		1.28	1.26		2.87	2.81	

Table 158. Chlorophyll content at maximum tillering stage during 2006-2007 (on fresh weight basis mg g^{-1})

Sub plot treatments	Chlorophyll 'a'			Chlorophyll 'b'			Total Chlorophyll		
	Main plot treatments			Main plot treatments			Main plot treatments		
	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean
10 cm X 10 cm(POP)	2.10^{bc}	2.17^{b}	2.14^{a}	0.85^{e}	0.87^{e}	0.86^{c}	2.95^{c}	3.04^{bc}	3.00^{b}
20 cm X10 cm(POP)	1.72^{e}	1.69^{e}	1.71^{c}	0.98^{bcd}	0.94^{d}	0.96^{b}	2.70^{d}	2.63^{d}	2.66^{c}
30 cmX30 cm(POP)	2.01^{cd}	1.93^{d}	1.97^{b}	0.95^{cd}	1.05^{a}	1.00^{a}	2.96^{c}	2.98^{c}	2.97^{b}
30 cmX30 cm(SRI)	2.13^{bc}	2.10^{bc}	2.12^{a}	1.01^{abc}	1.05^{a}	1.03^{a}	3.14^{b}	3.15^{b}	3.14^{a}
30 cmX30 cm (Modified SRI)	2.29^{a}	2.06^{bc}	2.17^{a}	1.02^{ab}	1.04^{a}	1.03^{a}	3.31^{a}	3.10^{b}	3.20^{a}
Main plot mean	2.05	1.99		0.96	0.99		3.01	2.98	

Table 159. Chlorophyll content at panicle initiation stage during 2006-2007 (on fresh weight basis mg g^{-1})

Sub plot treatments	Chlorophyll 'a'			Chlorophyll 'b'			Total Chlorophyll		
	Main plot treatments			Main plot treatments			Main plot treatments		
	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean
10 cm X 10 cm(POP)	2.03^{bcd}	2.07^{abcd}	2.05^{ab}	0.85^{f}	0.85^{f}	0.85^{e}	2.88^{ef}	2.92^{def}	2.90^{d}
20 cm X10 cm(POP)	2.24^{a}	1.92^{d}	2.08^{ab}	0.91^{e}	0.93^{de}	0.92^{d}	3.15^{abc}	2.85^{f}	3.00^{cd}
30 cmX30 cm(POP)	2.20^{ab}	2.09^{abd}	2.15^{a}	0.98^{cd}	0.99^{c}	0.99^{c}	3.18^{ab}	3.08^{abcd}	3.13^{a}
30 cmX30 cm(SRI)	1.93^{d}	2.16^{abc}	2.04^{ab}	1.09^{a}	1.05^{ab}	1.07^{a}	3.01^{cde}	3.21^{a}	3.11^{ab}
30 cmX 30cm (Modified SRI)	1.99^{cd}	2.00^{cd}	2.00^{b}	1.02^{bc}	1.03^{abc}	1.03^{b}	3.01^{cde}	3.03^{bcde}	3.02^{bc}
Main plot mean	2.08	2.05		0.97	0.97		3.05	3.02	

During 2006-07, there were no significant differences in chlorophyll ‘a’, chlorophyll ‘b’ and total chlorophyll contents (Tables 158 and 159). Among sub plot treatments, chlorophyll ‘a’ content was higher in modified SRI, 10 cm X 10 cm POP and 30 cm X 30 cm SRI, which were at par. Significantly lower content was recorded in 20 cm X 10 cm. Combination of modified SRI with weeding produced the highest chlorophyll ‘a’ content of 2.29 mg g^{-1} fresh weight of leaves. SRI, modified SRI and 30 cm X 30 cm POP recorded higher chlorophyll ‘b’ content at maximum tillering stage. These treatments were at par. The lowest chlorophyll ‘a’ content was observed in 10cm x 10cm with or without weeding. Total chlorophyll content was also significantly superior in SRI and in modified SRI. The lowest total chlorophyll content of 2.63 mg g^{-1} was observed in 20 cm x 10 cm without weeding and it was on a par with 20 cm X 10 cm with weeding.

Observations on chlorophyll content during 2006-07 revealed that the contents of total chlorophyll and chlorophyll ‘a’ were significantly higher in 30 cm X 30 cm POP plots, whereas chlorophyll ‘b’ was the highest in 30 cm X 30 cm SRI with weeding. Interaction between main and sub plots showed that chlorophyll ‘a’ content was higher in 20 cm X 10 cm POP with weeding and chlorophyll ‘b’ was higher in 30 cm X 30 cm SRI. Total chlorophyll content was higher in 30 cm X 30 cm SRI and it was on a par with 30 cm X 30 cm POP with weeding, 20 cm X 10 cm POP with weeding and 30 cm X 30 cm POP without weeding.

Leaf area index (LAI)

The data on leaf area index (LAI) of crop at 20, 40 and 60 days after planting during 2005-06 are presented in Table 160. Main plot treatments did not influence the LAI at any stages of observation. However, sub plots and their interaction with main plots were significant. The highest LAI was recorded by 10 cm X 10 cm at all stages of observation. The LAI values were lower in plots with wider spacing (30 cm X 30 cm). At 20, 40 and 60 days after planting, 10 cm X 10 cm POP with weeding recorded superior values for leaf area index. Compared to other treatment combinations, 10 cm X 10 cm POP without weeding was the next best treatment combination followed by 20 cm X 10 cm with weeding.

During 2006-07 also, LAI was not influenced by main plot treatments (Table 161). Among sub plots, 10 cm X 10 cm spacing recorded significantly higher LAI values at all stages of observation. It was followed by 20 cm X 10 cm. Interaction data reveal that at 20 DAT, 10 cm X 10 cm POP with or without weeding were at par. However, at 40 and 60 DAT, 10 cm X 10 cm with weeding showed superiority over 10 cm X 10 cm without weeding.

Relative growth rate (RGR)

Relative growth rate (RGR) of rice at 20 days after planting in 2005-06 was unaffected by the treatments or their combinations. At 40 days after planting, main plot treatments were not significant. Among sub plots, all the treatments with wider plant spacing (POP, SRI and modified SRI) recorded on a par values. The treatment 10 cm X 10 cm and 20 cm X 10 cm were at par and were inferior to wider plant spacing (Table 162).

At 60 days after planting, main plot treatments had significant effect on RGR values, with higher growth rates in weeded plots. At this stage, sub plot treatments exhibited no effect on RGR. Combination of 30 cm X 30 cm POP, 30 cm X 30 cm SRI and 30 cm X 30 cm modified SRI - all with weeding favoured RGR significantly.

The data presented in Table 163 reveal that except at 20 days after planting, main plots influenced RGR values. Significantly higher RGR values were noticed in weeded plots at 40 and 60 DAT.

Table 160. Leaf area index at various growth stages during 2005-06

Sub plot treatments	20 DAT			40DAT			60DAT		
	Main plot treatments			Main plot treatments			Main plot treatments		
	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean
10 cm X 10 cm (POP)	3.48^{a}	3.45^{b}	3.47^{a}	3.91^{a}	3.85^{b}	3.88^{a}	4.27^{a}	4.17^{b}	4.22^{a}
20 cm X10 cm (POP)	2.68^{c}	2.65^{d}	2.66^{b}	3.02^{c}	3.00^{d}	3.01^{b}	3.47^{c}	3.42^{c}	3.45^{b}
30 cmX30 cm (POP)	2.04^{g}	2.03^{g}	2.04^{d}	2.37^{f}	2.29^{g}	2.33^{d}	2.56^{de}	2.52^{e}	2.54^{c}
30 cmX30 cm (SRI)	2.12^{e}	2.08^{f}	2.10^{c}	2.47^{e}	2.31^{g}	2.39^{c}	2.62^{d}	2.57^{de}	2.59^{c}
30 cmX30 cm (Modified SRI)	2.13^{e}	2.08^{f}	2.11^{c}	2.46^{e}	2.30^{g}	2.38^{c}	2.59^{de}	2.54^{de}	2.57^{c}
Main plot mean	2.49	2.46		2.85	2.75		3.10	3.04	

Table 161. Leaf area index at various growth stages during 2006-2007

Sub plot treatments	20 DAT			40DAT			60DAT		
	Main plot treatments			Main plot treatments			Main plot treatments		
	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean
10 cm X 10 cm (POP)	3.42^{a}	3.39^{a}	3.40^{a}	3.97^{a}	3.91^{b}	3.94^{a}	4.27^{a}	4.19^{b}	4.23^{a}
20 cm X10 cm (POP)	2.68^{b}	2.61^{c}	2.64^{b}	3.26^{c}	3.24^{c}	3.25^{b}	3.81^{c}	3.74^{d}	3.78^{b}
30 cmX30 cm (POP)	2.04^{fg}	2.00^{g}	2.02^{d}	2.49^{de}	2.44^{e}	2.46^{c}	2.56^{f}	2.50^{g}	2.53^{d}
30 cmX30 cm (SRI)	2.15^{d}	2.09^{f}	2.12^{c}	2.50^{d}	2.43^{e}	2.46^{c}	2.64^{e}	2.53^{fg}	2.58^{c}
30 cmX30 cm (Modified SRI)	2.19^{d}	2.10^{ef}	2.15^{c}	2.47^{de}	2.34^{f}	2.41^{d}	2.65^{e}	2.50^{g}	2.57^{c}
Main plot mean	2.50	2.44		2.94	2.87		3.19	3.10	

Table 162. Relative growth rate at various growth stages during 2005-06 (g g^{-1} day^{-1})

Sub plot treatments	20 DAT			40DAT			60DAT		
	Main plot treatments			Main plot treatments			Main plot treatments		
	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean
10 cm X 10 cm (POP)	0.062^{a}	0.061^{a}	0.061^{a}	0.052^{b}	0.052^{b}	0.052^{b}	0.021^{b}	0.019^{b}	0.020^{a}
20 cm X10 cm (POP)	0.064^{a}	0.064^{a}	0.064^{a}	0.052^{b}	0.050^{b}	0.051^{b}	0.031^{b}	0.033^{b}	0.032^{a}
30 cmX30 cm (POP)	0.070^{a}	0.076^{a}	0.073^{a}	0.091^{a}	0.080^{a}	0.086^{a}	0.051^{a}	0.004^{b}	0.027^{a}
30 cmX30 cm (SRI)	0.081^{a}	0.079^{a}	0.080^{a}	0.090^{a}	0.082^{a}	0.086^{a}	0.045^{a}	0.006^{b}	0.025^{a}
30 cmX30 cm (Modified SRI)	0.081^{a}	0.078^{a}	0.080^{a}	0.093^{a}	0.085^{a}	0.089^{a}	0.043^{a}	0.006^{b}	0.025^{a}
Main plot mean	0.072	0.072		0.076	0.070		0.038	0.014	

Table 163. Relative growth rate at various growth stages during 2006-2007 (g g^{-1} day^{-1})

Sub plot treatments	20 DAT			40DAT			60DAT		
	Main plot treatments			Main plot treatments			Main plot treatments		
	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean
10 cm X 10 cm (POP)	0.058^{d}	0.060^{cd}	0.059^{c}	0.048^{abcd}	0.045^{abcd}	0.047^{a}	0.030^{b}	0.030^{b}	0.030^{b}
20 cm X10 cm (POP)	0.063^{bcd}	0.063^{bcd}	0.063^{bc}	0.046^{abcd}	0.042^{cd}	0.044^{a}	0.040^{b}	0.038^{b}	0.039^{b}
30 cmX30 cm (POP)	0.071^{abcd}	0.078^{abc}	0.074^{ab}	0.064^{a}	0.030^{d}	0.047^{a}	0.082^{a}	0.046^{b}	0.064^{a}
30 cmX30 cm (SRI)	0.082^{ab}	0.082^{ab}	0.082^{a}	0.062^{ab}	0.043^{bcd}	0.053^{a}	0.073^{a}	0.040^{b}	0.056^{a}
30 cmX30 cm (Modified SRI)	0.085^{a}	0.080^{ab}	0.083^{a}	0.060^{abc}	0.043^{cd}	0.051^{a}	0.071^{a}	0.035^{b}	0.053^{a}
Main plot mean	0.072	0.073		0.056	0.040		0.059	0.038	

At 20 DAT, among sub plots, 30 cm X 30 cm SRI and 30 cm X 30 cm modified SRI produced significantly higher values. The lowest RGR at this stage was observed in 10 cm X 10 cm with weeding. At 40 DAT, sub plots did not differ significantly. The treatments 30 cm X 30 cm spacing under POP management without weeding produced superior value and the lowest RGR was in 30 cm X 30 cm POP without weeding. Relative growth rate was superior in 30 cm X 30 cm spacing under all the three management practices at 60 days after planting. The spacings, 10 cm X 10 cm and 20 cm X 10 cm were at par. Wider plant spacing (30 cm X 30 cm) under POP, SRI and modified SRI management with weeding produced higher RGR values at this stage of observation. All other treatment combinations were inferior to them.

Grain yield

The effect of treatments on grain yield of rice is presented in Table 164. Main plot treatments significantly influenced the grain yield. Weeded plots (7445 kg ha^{-1}) expressed significant superiority over unweeded plots (4633 kg ha^{-1}). During 2005-06, among sub plots, higher grain yield was noticed in 10 cm x 10 cm (8608 kg ha^{-1}) which was on a par with 20 cm X 10 cm (8263 kg ha^{-1}). Grain yield was significantly lower in SRI (3700 kg ha^{-1}).

The effect interaction between spacing and weed control on grain yield was significant. Combination of 10 cm X 10 cm POP with weeding recorded the highest yield of 8858 kg ha^{-1}, although it was on a par with 20 cm X 10 cm with weeding (8458 kg ha^{-1}) and 10 cm X 10 cm without weeding (8358 kg ha^{-1}). The lowest grain yield of 2058 kg ha^{-1} was noticed when seedlings were planted at 30 cm X 30 cm under modified SRI without weeding and it was on a par with 30 cm x 30 cm SRI without conoweeding (2150 kg ha^{-1}) and 30 cm X 30 cm POP (2533 kg ha^{-1}). During 2006-07 also, the main plot treatments were significant. Weeded plots produced significantly higher grain yield of 6734 kg ha^{-1}. In the unweeded plots average grain yield was 3335 kg ha^{-1}.

Table 164. Grain yield of rice (kg ha^{-1})

Sub plot treatments	2005-'06			2006-'07		
	Main plot treatments			Main plot treatments		
	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean
10 cm X 10 cm (POP)	8858^{a}	8358^{ab}	8608^{a}	7825^{a}	7567^{a}	7696^{a}
20 cm X10 cm (POP)	8458^{ab}	8067^{b}	8263^{a}	6692^{b}	5900^{c}	6683^{b}
30 cmX30 cm (POP)	7492^{c}	2533^{e}	5013^{b}	6492^{b}	1008^{e}	3750^{c}
30 cmX30 cm (SRI)	5250^{d}	2150^{e}	3700^{c}	5167^{d}	1300^{e}	3234^{d}
30 cmX30 cm (Modified SRI)	7167^{c}	2058^{e}	4612^{d}	6517^{b}	900^{f}	3708^{d}
Main plot mean	7445	4633		6539	3335	

Table 165. Straw yield of rice (kg ha^{-1})

Sub plot treatments	2005-'06			2006-'07		
	Main plot treatments			Main plot treatments		
	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean
10 cm X 10 cm (POP)	4037^{ab}	4025^{ab}	4031^{a}	5217^{a}	5050^{a}	5133^{a}
20 cm X10 cm (POP)	4398^{a}	3262^{bc}	3830^{a}	4850^{a}	3683^{c}	4267^{b}
30 cmX30 cm (POP)	3243^{bc}	3092^{cd}	3168^{b}	4983^{a}	1917^{e}	2950^{d}
30 cmX30 cm (SRI)	2765^{cd}	2263^{d}	2514^{c}	4133^{b}	1683^{e}	3908^{c}
30 cmX30 cm (Modified SRI)	2788^{cd}	2475^{cd}	2632^{bc}	4233^{b}	1033^{e}	2633^{d}
Main plot mean	3446	3023		4683	2673	

Among sub plot treatments, 10 cm X 10 cm spacing produced significantly higher grain yield of 7696 kg ha^{-1}, followed by 20 cm X 10 cm (6683 kg ha^{-1}). Significantly lower grain yield was observed in modified SRI (3234 kg ha^{-1}).

Combination of 10 cm X 10 cm spacing with weeding recorded the highest grain yield of 7825 kg ha^{-1}, although this treatment was on a par with 10 cm X 10 cm spacing without weeding (7567 kg ha^{-1}) and 20 cm X 10 cm with weeding (7467 kg ha^{-1}). Grain yield under 30 cm X 30 cm POP and 30 cm X 30 cm modified SRI were at par. Among weeded plots, SRI recorded significantly lower grain yield (5167 kg ha^{-1}).

Straw yield

Straw yield of rice as influenced by spacing and management are presented in Table 165. During 2005-06 and 2006-07 main plots, sub plots and their combinations significantly influenced the straw yield. During both the years, straw yield was the highest in weeded plots.

In 2005-06, among sub plot treatments, 10 cm X 10 cm was superior and was on a par with 20 cm X 10 cm. Combination of 20 cm X 10 cm with weeding produced the highest grain yield of 4398 kgha^{-1}. It was on a par with 10 cm X 10 cm with or without weeding. During 2006-07, the highest straw yield of 5155 kgha^{-1} was observed in 10 cm X 10 cm and it was followed by 20 cm X 10 cm. Combination of 10 cm X 10 cm with weeding and 20 cm X 10 cm with weeding were superior.

Yield attributes

The yield attributes of rice *viz*; panicle length, number of filled grain per panicle, 1000 grain weight and panicle weight-during 2005-06 is given in Table 166. Among the main plot treatments, weeded plots recorded significantly higher

Table 166. Yield attributes of rice during 2005-06

Sub plot treatments	Panicle length(cm)			Filled grains/panicle(No.)			1000 grain weight (g)			Panicle weight(g)		
	Main plot treatments			Main plot treatments			Main plot treatments			Main plot treatments		
	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean
10 cm X 10cm (POP)	22.20^{a}	21.70^{a}	21.95^{a}	109^{ab}	98^{b}	103^{a}	29.07^{a}	28.33^{ab}	28.70^{a}	2.98^{bcd}	2.99^{bcd}	2.99^{b}
20 cm X10 cm (POP)	20.46^{abc}	21.03^{ab}	20.75^{a}	100^{b}	92^{bc}	96^{ab}	28.13^{bc}	28.40^{ab}	28.27^{a}	3.36^{b}	3.29^{bc}	3.33^{ab}
30 cmX30 cm (POP)	20.03^{abc}	18.47^{c}	19.25^{b}	126^{a}	90^{bc}	108^{a}	26.70^{de}	26.43^{e}	26.57^{b}	4.08^{a}	2.76^{cd}	3.42^{a}
30 cmX30 cm (SRI)	18.97^{bc}	18.65^{c}	18.81^{b}	103^{ab}	58^{d}	81^{b}	27.83^{bc}	26.27^{e}	27.05^{b}	3.29^{bc}	2.67^{d}	2.98^{b}
30 cmX30 cm (Modified SRI)	19.05^{bc}	19.22^{bc}	19.13^{b}	97^{b}	72^{cd}	85^{b}	26.37^{e}	27.37^{cd}	26.87^{b}	2.67^{d}	2.53^{d}	2.60^{c}
Main plot mean	20.14	19.81		107	82		27.62	27.36		3.28	2.85	

Table 167. Yield attributes of rice during 2006-2007

Sub plot treatments	Panicle length(cm)			Filled grains/panicle(No.)			1000 grain weight (g)			Panicle weight(g)		
	Main plot treatments			Main plot treatments			Main plot treatments			Main plot treatments		
	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean
10 cm X 10 cm (POP)	20.47^{ab}	20.30^{ab}	20.39^{a}	112^{a}	102^{b}	107^{a}	28.37a	28.04^{abc}	28.20a	3.07^{bc}	2.98^{bc}	3.03^{ab}
20 cm X10 cm (POP)	20.81^{a}	20.14^{b}	20.48^{a}	105^{b}	91^{c}	98^{b}	28.19ab	27.43^{bcd}	27.81a	3.06^{bc}	2.94^{cd}	3.00^{b}
30 cmX30 cm (POP)	19.24^{c}	18.32^{d}	18.78b	112^{a}	84^{d}	98^{b}	27.56bcd	27.00^{de}	27.28b	3.69^{a}	2.70^{de}	3.19^{a}
30 cmX30 cm (SRI)	19.00^{c}	18.77^{cd}	19.89b	104^{b}	83^{d}	94^{c}	26.92de	25.61^{f}	26.27c	3.25^{b}	2.60^{e}	2.93^{bc}
30 cmX30 cm (Modified SRI)	19.07^{c}	19.25^{c}	19.16b	95^{c}	77^{e}	86^{d}	27.40cd	26.54^{e}	26.97b	2.91^{cd}	2.61^{e}	2.76^{c}
Main plot mean	19.72	19.36		106	87		27.69	26.93		3.20	2.77	

Table 168. Number of productive tillers during 2005-06

Sub plot treatments	Productive tillers/hill			Productive tillers/m^2		
	Main plot treatments			Main plot treatments		
	Weeded	Unweeded	Sub plot means	Weeded	Unweeded	Sub plot means
10 cm X 10 cm (POP)	5.33^{d}	5.48^{d}	5.41^{d}	533^{a}	548^{a}	541^{a}
20 cm X10 cm (POP)	7.67^{d}	7.87^{d}	7.77^{d}	383^{b}	353^{b}	388^{b}
30 cmX30 cm (POP)	19.13^{b}	18.06^{b}	18.60^{b}	213^{c}	301^{cd}	207^{d}
30 cmX30 cm (SRI)	18.10^{b}	13.40^{c}	15.75^{c}	201^{cd}	149de	175^{d}
30 cmX30 cm (Modified SRI)	33.80^{a}	12.47^{c}	23.12^{a}	375^{b}	139^{e}	257^{c}
Main plot mean	16.81	11.46		341	286	

Table 169. Number of productive tillers during 2006-2007

Sub plot treatments	Productive tillers/hill			Productive tillers/m^2		
	Main plot treatments			Main plot treatments		
	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean
10 cm X 10 cm (POP)	4.88^{g}	4.60^{g}	4.72^{e}	488^{a}	460^{b}	474^{a}
20 cm X10 cm (POP)	8.90^{f}	8.30^{f}	8.60^{d}	445^{b}	415^{c}	430^{b}
30 cmX30 cm (POP)	19.95^{c}	12.63^{de}	16.29^{c}	222^{f}	140^{g}	181^{e}
30 cmX30 cm (SRI)	21.84^{b}	13.38^{d}	17.61^{b}	243^{e}	149^{g}	196^{d}
30 cmX30 cm (Modified SRI)	31.08^{a}	11.65^{e}	21.37^{a}	345^{d}	130^{g}	237^{c}
Main plot mean	17.33	10.11		349	259	

number of filled grains and panicle weight. In the case of panicle length and 1000 grain weight there was not much differences.

Among sub plot treatments, 10 cm X 10 cm spacing produced the largest panicles of 21.95 cm, but was on a par with 20 cm x 10 cm (20.75cm). Other sub plots were at par. Interaction effect was also significant. Significantly higher values were recorded by 10 cm X 10 cm with weeding (22.20cm) and 10 cm X 10 cm without weeding (21.70cm).

Number of filled grain per panicle was the highest in 30 cm X 30 cm POP (108) and was on a par with 10 cm x 10 cm (103). Among combinations, 30 cm X 30 cm with weeding was significantly higher and was on a par with 10cm x 10 with weeding and 30 cm X 30 cm SRI with cono weeding. The lowest number of filled grains was in 30 cm X 30 cm SRI without cono weeding (58).

Thousand grain weight was the highest in 10 cm X 10 cm (28.70 g) and was on a par with 20 cm x 10 cm (28.27g). The treatment 10cm X 10cm with weeding was the best combination with respect to 1000 grain weight. It was on a par with 10 cm X 10 cm without weeding and 20 cm X 10 cm with weeding.

Panicle weight was higher in 30 cm x 30 cm POP and it was on a par with 20 cm X 10 cm. The lowest panicle weight was noticed in modified SRI. The treatment combination 30 cm x 30 cm POP with weeding recorded significantly better panicle weight of 4.08g. It was followed by 20 cm x 10 cm with weeding (3.36g).

During 2006-07, only number of filled grains and panicle weight were significantly influenced by main plot treatments (Table 167). Among sub plot treatments, 10 cm X 10 cm and 20 cm X 10 cm were at par with regard to panicle length. These two treatments were significantly superior to other sub plots. The combination 20 cm X 10 cm with weeding recorded the highest panicle length of 20.81 cm followed by 10 cm X 10 cm with or without weeding. The lowest panicle length was observed in 30 cm X 30 cm POP with weeding (19.24) and it was on a par with 30 cm X 30 cm modified SRI with or without weeding. The treatment 10 cm X 10 cm POP recorded significantly higher value for filled grains (107). The lowest number of filled grains were in 30 cm X 30 cm SRI (98). The combination 10 cm X 10 cm under POP management with weeding and 30 cm X 30 cm POP with weeding produced significantly higher number of filled grains per panicle.

During 2006-07, 1000 grain weight was the highest in 10 cm X 10 cm (28.20 g) and 20 cm X 10 cm (27.81 g), which were at par. Among the sub plots, test weight value of 28.37 g was observed in 10 cm X 10 cm with weeding and it was on a par with 20 cm x 10 cm with weeding and 10 cm X 10 cm without weeding. Panicle weight recorded the highest value in 30 cm X 30 cm POP and was on a par with 10 cm X 10 cm POP. Among combination treatments, 30 cm X 30 cm POP was significantly superior and produced a panicle weight of 3.69 g. It was on a par with 10 cm X 10 cm with or without weeding and 20 cm X 10 cm with weeding.

Number of productive tillers

Table 168 depicts the data on number of productive tillers per hill and unit area during 2005-06. Main plot treatments significantly influenced the productive tillers per hill and unit area. The highest number of 23.12 tillers per hill was noticed in 30 cm X 30 cm modified SRI, followed by 30 cm X 30 cm POP. The sub plot treatment 10 cm X 10 cm and 20 cm X 10 cm were significantly inferior and on a par. Among combination plots 30 cm X 30 cm modified SRI recorded significantly higher value of 33.80. However, number of productive tillers per unit area exhibited a reverse trend. It was the highest in 10 cm X 10 cm followed by 20 cm X 10 cm. The treatments, 30 cm X 30 cm POP and 30 cm X 30 cm SRI produced the lowest number of productive tillers per unit area. The treatment 10 cm X 10 cm with or without weeding was significantly superior to all other treatment combinations.

During 2006-07, significantly superior values for productive tillers per hill and unit area were observed in weeded plots (Table 169). The highest number of productive tillers per hill was in 30 cm X 30 cm modified SRI (21.37) followed by 30 cm X 30 cm SRI (17.61). The spacing 10 cm X 10 cm recorded significantly inferior productive tiller count of 4.72. Interaction between main and sub plots were significant and recorded superior value in 30 cm X 30 cm modified SRI with weeding. The treatment 10 cm X 10 cm with or without weeding produced significantly lower values of productive tillers per hill.

Number of productive tillers per unit area was the highest in 10 cm x 10 cm spacing and was the lowest in 30 cm X 30 cm POP. Among combination plots, 10 cm X 10 cm with weeding was significantly superior in number of productive tillers per m^2. This was followed by 10 cm X 10 cm without weeding and 20 cm X 10 cm with weeding, which were at par.

4.4.3. Nutrient uptake by crop

Maximum tillering stage

Uptake of major nutrients at maximum tillering stage during 2005-06 and 2006-07 is presented in Table 170 and 171. During both years, maximum uptake of N, P and K were in weeded plots. Among sub plot treatments, 10 cm X 10 cm and 20 cm X 10 cm under POP management showed the highest uptake. Interaction effect was also significant. The treatment 10 cm X 10 cm with weeding recorded the highest uptake followed by 20 cm X 10 cm POP. The lowest uptake of nutrients was in SRI with or without weeding.

During 2006-07, the spacing 10 cm X 10 cm showed significantly superior values for uptake. The minimum uptake was noticed in 30 cm X 30 cm POP. Combination of 10 cm X 10 cm with or with out weeding recorded better uptake of nutrients at maximum tillering

Table 170. Nutrient uptake (kg ha^{-1}) by rice at maximum tillering stage

Sub plot treatments	N			P			K		
	Main plot treatments			Main plot treatments			Main plot treatments		
	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean
10 cm X 10 cm (POP)	24.48^{a}	21.43^{c}	22.96^{a}	5.66^{a}	4.95^{c}	5.31^{a}	21.54^{a}	18.86^{c}	20.20^{a}
20 cm X10 cm (POP)	23.09^{b}	19.52^{d}	21.31^{a}	5.34^{b}	4.51^{d}	4.93^{a}	20.32^{b}	17.18d	18.75^{a}
30 cmX30 cm (POP)	18.89^{d}	15.90^{e}	17.40^{c}	4.37^{d}	3.93^{e}	4.15^{c}	16.62^{d}	14.95^{e}	15.79^{c}
30 cmX30 cm (SRI)	11.67^{f}	11.03^{f}	11.35^{d}	2.70^{f}	2.55^{f}	2.63^{d}	10.27^{f}	9.70^{f}	9.99^{d}
30 cmX30 cm (Modified SRI)	21.91^{c}	16.99^{d}	19.45^{b}	5.06^{c}	4.07^{d}	4.57^{b}	19.28^{c}	16.63^{d}	17.96^{c}
Main plot mean	20.01	16.97		4.63	4.00		17.61	15.47	

Table 171. Nutrient uptake (kg ha^{-1}) by rice at maximum tillering stage during 2006 - 2007

Sub plot treatments	N			P			K		
	Main plot treatments			Main plot treatments			Main plot treatments		
	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean	Weeded	Un weeded	Sub plot mean
10 cm X 10 cm (POP)	18.23^{a}	17.91^{a}	18.07^{a}	5.19^{a}	5.10^{a}	5.15^{a}	17.15^{a}	16.84^{a}	17.00^{a}
20 cm X10 cm (POP)	13.22^{b}	8.91^{e}	11.07^{b}	3.76^{b}	2.53^{e}	3.15^{b}	12.43^{b}	8.38^{e}	10.41^{b}
30 cmX30 cm (POP)	10.62^{c}	6.24^{g}	8.43^{d}	3.02^{c}	1.77^{g}	2.40^{d}	10.03^{c}	5.87^{g}	8.95^{d}
30 cmX30 cm (SRI)	9.66^{d}	8.94^{e}	9.30^{c}	2.75^{d}	2.55^{e}	2.65^{c}	9.08^{d}	8.41^{e}	8.75^{c}
30 cmX30 cm (Modified SRI)	12.79^{c}	8.38^{f}	10.59^{b}	3.64^{c}	2.39^{f}	3.02^{b}	9.99^{c}	7.88^{f}	8.94^{d}
Main plot mean	12.91	10.08		3.67	2.87		12.14	9.48	

Table 172. Nutrient uptake (kg ha^{-1}) by rice at panicle initiation stage during 2005 – 2006

Sub plot treatments	N			P			K		
	Main plot treatments			Main plot treatments			Main plot treatments		
	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean
10 cm X 10 cm (POP)	57.49^{a}	31.27^{e}	44.38^{a}	16.78^{a}	9.12^{e}	12.95^{a}	64.44^{a}	55.06^{e}	59.75^{a}
20 cm X10 cm (POP)	56.02^{b}	21.26^{f}	38.64^{b}	16.33^{b}	6.19^{f}	11.26^{b}	62.81^{b}	39.12^{f}	50.97^{b}
30 cmX30 cm (POP)	32.38^{c}	20.94^{g}	26.66^{c}	9.67^{c}	6.10^{g}	7.89^{c}	38.72^{c}	16.46^{g}	27.59^{c}
30 cmX30 cm (SRI)	21.69^{f}	18.06^{h}	19.88^{d}	6.32^{f}	5.26^{h}	5.79^{d}	34.32^{f}	10.23^{h}	22.28^{d}
30 cmX30 cm (Modified SRI)	33.18^{d}	18.77^{h}	25.98^{c}	10.27^{d}	5.34^{h}	7.81^{c}	37.20^{d}	11.45^{h}	24.33^{c}
Main plot mean	40.15	22.06		11.87	6.40		47.50	26.46	

Table 173. Nutrient uptake (kg ha^{-1}) by rice at panicle initiation stage during 2006-2007

Sub plot treatments	N			P			K		
	Main plot treatments			Main plot treatments			Main plot treatments		
	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean
10 cm X 10 cm (POP)	52.00^{a}	48.64^{b}	50.32^{a}	12.12^{a}	11.74^{b}	11.93^{a}	66.39^{a}	59.12^{b}	62.76^{a}
20 cm X10 cm (POP)	51.68^{a}	27.97^{d}	39.83^{b}	12.04^{a}	9.19^{d}	10.62^{b}	65.99^{a}	32.94^{d}	49.47^{b}
30 cmX30 cm (POP)	31.40^{c}	19.66^{e}	25.53^{c}	10.98^{c}	4.16^{e}	7.57^{c}	40.00^{c}	23.93^{e}	31.97^{c}
30 cmX30 cm (SRI)	20.25^{e}	18.79^{f}	19.52^{e}	4.18^{e}	3.38^{f}	3.78^{e}	25.85^{e}	15.21^{f}	20.53^{e}
30 cmX30 cm (Modified SRI)	31.33^{d}	16.05^{g}	23.69^{d}	7.30^{d}	2.74^{g}	5.02^{d}	35.62^{d}	10.49^{g}	23.06^{d}
Main plot mean	37.33	26.22		9.32	6.24		46.77	28.34	

Table 174. Nutrient uptake (kg ha^{-1}) by rice at harvest during 2005-06

Sub plot treatments	N			P			K		
	Main plot treatments			Main plot treatments			Main plot treatments		
	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean
10 cm X 10 cm (POP)	32.59[a]	30.49[b]	31.54[a]	8.32[a]	5.99[b]	7.16[a]	39.91[a]	28.76[b]	34.34[a]
20 cm X10 cm (POP)	32.08[a]	16.31[c]	24.20[b]	8.18[a]	4.16[c]	6.17[b]	39.28[a]	19.97[c]	29.63[b]
30 cmX30 cm (POP)	29.58[a]	15.66[c]	22.62[c]	7.55[a]	4.00[c]	5.78[c]	36.22[a]	19.17[c]	27.70[c]
30 cmX30 cm (SRI)	14.90[c]	13.08[c]	13.99[d]	3.80[c]	3.34[c]	3.57[d]	18.24[c]	16.02[c]	17.13[d]
30 cmX30 cm (Modified SRI)	25.73[b]	15.83[c]	20.78[c]	6.57[b]	4.04[c]	5.31[c]	31.50[b]	19.39[c]	25.45[c]
Main plot mean	26.98	18.27		6.88	4.31		33.03	20.66	

Table 175. Nutrient uptake (kg ha^{-1}) by rice at harvest during 2006-2007

Sub plot treatments	N			P			K		
	Main plot treatments			Main plot treatments			Main plot treatments		
	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean	Weeded	Unweeded	Sub plot mean
10 cm X 10 cm (POP)	32.16[a]	28.02[b]	30.09[a]	10.40[a]	7.76[d]	9.08[a]	32.48[a]	26.26[c]	29.37[a]
20 cm X10 cm (POP)	31.83[a]	15.97[e]	23.90[b]	10.29[a]	5.26[e]	7.78[b]	32.16[a]	16.45[e]	24.31[b]
30 cmX30 cm (POP)	29.53[b]	16.29[e]	22.91[b]	8.20[c]	5.16[e]	6.68[b]	25.64[c]	15.16[f]	20.40[b]
30 cmX30 cm (SRI)	14.25[g]	13.48[h]	13.87[c]	4.60[g]	4.36[h]	4.48[c]	14.40[g]	13.61[h]	14.01[c]
30 cmX30 cm (Modified SRI)	25.38[c]	15.00[f]	20.19[b]	9.55[b]	4.85[f]	7.20[b]	29.83[b]	16.13[e]	22.98[b]
Main plot mean	26.63	17.75		8.61	5.48		26.90	17.52	

stage. Almost trend was observed in 10 cm X 10 cm without weeding. Nutrient uptake at this stage was significantly lower in wider spacings. Lower uptake was observed in 30 cm X 30 cm POP without weeding followed by 30 cm X 30 cm modified SRI and SRI.

Panicle initiation stage

At panicle initiation stage, nutrient uptake was significantly influenced by main plot and sub plot treatments and their combinations (Table 172 and 173). Significantly higher uptake of nutrients was noticed in 10 cm X 10 cm plots. The lowest uptake was seen in SRI managed plots. Combination of 10 cm x 10 cm spacing with weeding showed the highest uptake. It was followed by 30 cm x 30 cm SRI with cono weeding. The uptake values was lower in 30 cm X 30 cm SRI and modified SRI without weeding.

During 2006-07, the uptake of nutrients was the highest in 10 cm X 10 cm under POP management whereas, it was the lowest in SRI managed plots. Among interaction treatments, 10 cm X 10 cm and 20 cm X 10 cm spacing with weeding under POP management recorded significantly higher uptake values.

Harvest stage

At harvest, 10 cm X 10 cm spacing recorded the highest nutrient uptake. Interaction effect was significant. Higher uptake was observed in plots receiving closer plant spacing with weeding and wider plant spacing without weeding recorded lower uptake values at this stage of observation during 2005-06 (Table 174).

During 2006-07 also nutrient uptake at harvesting stage was superior in 10 cm x 10 cm. Plots with wider plant spacing under modified SRI and SRI without weeding recorded lower uptake values. Lower uptake was noticed in 20 cm x 10 cm without weeding (Table 175).

Table 176. Uptake of major nutrients (kg ha^{-1}) by grasses at 20 DAT

Main plot treatments	2005-2006			2006-2007		
	N	P	K	N	P	K
Weeded	1.54* (1.87)	1.10 (0.71)	1.59 (2.30)	1.59 (2.03)	1.06 (0.62)	1.53 (1.84)
Unweeded	2.44 (5.45)	1.57 (1.96)	2.54 (5.95)	2.59 (6.21)	1.50 (1.75)	2.46 (5.55)
Sub plot treatments						
10 cm X 10 cm(POP)	1.68^{d} (2.32)	1.15c (0.82)	1.74^{d} (2.53)	1.71^{c} (2.42)	1.09^{c} (0.69)	1.63^{c} (2.16)
20 cm X10 cm(POP)	1.75^{d} (2.56)	1.19c (0.92)	1.81^{d} (2.78)	2.14^{b} (4.08)	1.29^{b} (1.16)	2.04^{b} (3.66)
30 cm X 30 cm(POP)	2.39^{a} (5.21)	1.53a (1.84)	2.48^{a} (5.65)	2.82^{a} (7.45)	1.61^{a} (2.09)	2.67^{a} (6.63)
30 cm X30 cm(SRI)	2.00^{c} (3.50)	1.36b (1.35)	2.07^{c} (3.78)	2.03^{b} (3.62)	1.25^{b} (1.06)	1.94^{b} (3.26)
30 cm X 30 cm(Modified SRI)	2.15^{b} (4.12)	1.46a (1.63)	2.22^{b} (4.43)	1.76^{c} (2.60)	1.16^{c} (0.85)	1.68^{c} (2.32)
Interaction						
10 cm X 10 cm(POP) + Weeding	1.73^{e} (2.49)	1.18^{e} (0.89)	1.79^{ef} (2.70)	1.57^{f} (1.96)	1.02^{f} (0.54)	1.50^{f} (1.75)
20 cm X10 cm(POP) + weeding	1.85^{e} (2.92)	1.24^{e} (1.04)	1.92^{e} (3.19)	1.96^{e} (3.34)	1.20^{e} (0.94)	1.86^{e} (2.96)
30 cmX30 cm(POP) + weeding	2.50^{c} (5.75)	1.60^{c} (2.06)	2.60^{c} (6.26)	2.55^{cd} (6.00)	1.48^{cd} (1.69)	2.42^{cd} (5.36)
30 cmX30 cm(SRI) + weeding	0.93^{f} (0.36)	0.79^{f} (0.12)	0.94^{g} (0.38)	1.18^{g} (0.89)	0.87^{g} (0.26)	1.14^{g} (0.80)
30 cmX30 cm(Modified SRI) + weeding	0.71^{g} (0)	0.71^{f} (0)	0.71^{h} (0)	0.71^{h} (0)	0.71^{h} (0)	0.71^{h} (0)
10 cm X 10 cm(POP) + No weeding	1.64^{e} (2.19)	1.13^{e} (0.78)	1.69^{f} (2.36)	1.85^{e} (2.92)	1.15^{e} (0.82)	1.76^{e} (2.60)
20 cm X10 cm(POP) + No weeding	1.65^{e} (2.22)	1.14^{e} (0.80)	1.71^{ef} (2.42)	2.33^{d} (4.93)	1.37^{d} (1.38)	2.21^{d} (4.38)
30 cmX30 cm(POP) + No weeding	2.27^{d} (4.65)	1.47^{d} (1.66)	2.36^{d} (5.07)	3.09^{a} (9.05)	1.74^{a} (2.53)	2.93^{a} (8.08)
30 cm X 30 cm(SRI) + No weeding	3.08^{b} (8.99)	1.92^{b} (3.19)	3.21^{b} (9.80)	2.89^{ab} (7.85)	1.64^{ab} (2.19)	2.73^{ab} (6.95)
30 cm X 30 cm(Modified SRI) + No weeding	3.58^{a} (12.32)	2.21^{a} (4.38)	3.73^{a} (13.41)	2.81^{bc} (7.40)	1.60^{bc} (2.06)	2.66^{bc} (6.58)

* $\sqrt{X+0.5}$ transformed values, Original values with in parenthesis

Table 177. Uptake of major nutrients (kg ha^{-1}) by grasses at 40 DAT

Main plot treatments	2005-2006 N	2005-2006 P	2005-2006 K	2006-2007 N	2006-2007 P	2006-2007 K
Weeded	3.26* (10.13)	1.80 (2.74)	3.12 (9.23)	1.19 (0.92)	0.89 (0.29)	1.15 (0.82)
Unweeded	14.77 (217.65)	6.95 (47.80)	14.03 (196.34)	3.99 (15.42)	2.20 (4.34)	3.77 (13.71)
Sub plot treatments						
10 cm X 10 cm(POP)	2.45[e] (5.50)	1.38[e] (1.40)	2.34[e] (4.98)	1.26[d] (1.09)	0.92[d] (0.35)	1.22[d] (0.99)
20 cm X10 cm(POP)	3.91[d] (14.79)	2.05[d] (3.70)	3.73[d] (13.41)	1.94[c] (3.26)	1.24[c] (1.04)	1.85[c] (2.92)
30 cmX30 cm(POP)	8.38[c] (69.72)	4.09[c] (16.23)	7.97[c] (63.02)	3.59[a] (12.39)	2.00[a] (3.50)	3.40[a] (11.06)
30 cmX30 cm(SRI)	17.54[b] (307.15)	8.23[a] (67.23)	16.67[a] (277.39)	3.06[b] (8.86)	1.80[b] (2.74)	2.91[b] (7.97)
30 cmX30 cm (Modified SRI)	12.80[a] (163.34)	6.18[b] (37.69)	12.17[b] (147.61)	3.09[b] (9.05)	1.77[b] (2.63)	2.93[b] (8.08)
Interaction						
10 cm X 10 cm(POP) + Weeding	0.71[g] (0)	0.71[g] (0)	0.71[g] (0)	0.71[g] (0)	0.71[g] (0)	0.71[g] (0)
20 cm X10 cm(POP) + weeding	0.71[g] (0)	0.71[g] (0)	0.71[g] (0)	0.71[g] (0)	0.71[g] (0)	0.71[g] (0)
30 cm X 30 cm(POP) + weeding	1.53[g] (1.84)	0.95[g] (0.40)	1.47[g] (1.66)	2.14[d] (4.08)	1.28[d] (1.14)	2.04[d] (3.66)
30 cm X 30 cm(SRI) + weeding	12.63[d] (159.02)	5.94[d] (34.78)	12.00[d] (143.50)	0.88[g] (0.27)	0.77[g] (0.09)	0.87[g] (0.26)
30 cm X 30 cm(Modified SRI) + weeding	0.71[g] (0)	0.71[g] (0)	0.71[g] (0)	1.49[f] (1.72)	1.00[f] (0.50)	1.43[f] (1.54)
10 cm X 10 cm (POP) + No weeding	4.18[f] (16.97)	2.05[f] (3.70)	3.98[f] (15.34)	1.82[e] (2.81)	1.13[e] (0.78)	1.73[e] (2.49)
20 cm X10 cm (POP) + No weeding	7.10[e] (49.91)	3.38[e] (10.92)	6.74[e] (44.93)	3.16[c] (9.49)	1.77[c] (2.63)	2.99[c] (8.44)
30 cm X 30cm (POP) + No weeding	15.22[c] (231.15)	7.15[c] (50.62)	14.46[c] (208.59)	5.04[a] (24.90)	2.72[a] (6.90)	4.76[a] (22.16)
30 cm X 30 cm (SRI) + No weeding	22.46[b] (503.95)	10.52[b] (110.17)	21.34[b] (454.59)	5.24[a] (26.96)	2.83[a] (7.51)	4.95[a] (24.00)
30 cm X 30 cm (Modified SRI) + No weeding	24.88[a] (618.51)	11.65[a] (135.22)	23.63[a] (557.88)	4.68[b] (21.40)	2.54[b] (5.95)	4.43[b] (19.12)

* $\sqrt{X+0.5}$ transformed values, Original values with in parenthesis

Table 178. Uptake of major nutrients (kg ha^{-1}) by grasses at harvest

Main plot treatments	2005-2006			2006-2007		
	N	P	K	N	P	K
Weeded	1.94* (3.26)	1.11 (0.73)	2.44 (5.45)	3.71 (13.26)	1.83 (2.85)	4.79 (22.44)
Unweeded	5.04 (24.90)	2.44 (5.45)	6.52 (42.01)	7.51 (55.90)	3.51 (11.82)	9.75 (94.56)
Sub plot treatments						
10 cm X 10 cm(POP)	1.24^{e} (1.04)	0.85^{e} (0.22)	1.50^{e} (1.75)	2.43^{d} (5.40)	1.29^{d} (1.16)	3.11^{d} (9.17)
20 cm X10 cm (POP)	1.72^{d} (2.46)	1.01^{d} (0.52)	2.16^{d} (4.17)	4.00^{c} (15.50)	1.93^{c} (3.22)	5.16^{c} (26.13)
30 cm X 30 cm (POP)	4.12^{c} (16.47)	2.00^{c} (3.50)	5.33^{c} (27.91)	6.90^{b} (47.11)	3.23^{b} (9.93)	8.96^{b} (79.78)
30cmX30cm(SRI)	5.61^{a} (30.97)	2.67^{a} (6.63)	7.28^{a} (52.50)	8.24^{a} (67.40)	3.83^{a} (14.17)	10.71^{a} (114.20)
30 cm X 30 cm (Modified SRI)	4.76^{b} (22.16)	2.36^{b} (5.07)	6.11^{b} (36.83)	6.48^{b} (41.49)	3.07^{b} (8.92)	8.40^{b} (70.06)
Interaction						
10 cm X 10 cm (POP) + Weeding	1.15^{fg} (0.82)	0.82^{f} (0.17)	1.37^{fg} (1.38)	1.87^{f} (3.00)	1.06^{f} (0.62)	2.36^{f} (5.07)
20 cm X 10 cm (POP) + weeding	1.69^{e} (2.36)	1.00^{e} (0.50)	2.12^{e} (3.99)	3.26^{e} (10.13)	1.62^{e} (2.12)	4.20^{e} (17.14)
30 cm X 30 cm (POP) + weeding	2.79^{d} (7.28)	1.43^{d} (1.54)	3.59^{d} (12.39)	4.78^{d} (22.35)	2.28^{d} (4.70)	6.19^{d} (37.82)
30 cm X 30 cm (SRI) + weeding	3.04^{d} (8.74)	1.53^{d} (1.84)	3.92^{d} (14.87)	6.02^{c} (35.74)	2.83^{c} (7.51)	7.81^{c} (60.50)
30 cm X 30 cm (Modified SRI) + weeding	1.02^{g} (0.54)	0.78^{g} (0.11)	1.18^{g} (0.89)	2.62^{e} (6.36)	1.36^{e} (1.35)	3.36^{e} (10.79)
10 cm X 10 cm (POP) + No weeding	1.33^{f} (1.27)	0.88^{f} (0.27)	1.67^{f} (2.29)	3.00^{e} (8.50)	1.51^{e} (1.78)	3.85^{e} (14.32)
20 cm X10 cm (POP) + No weeding	1.75^{e} (2.56)	1.02^{e} (0.54)	2.21^{e} (4.38)	4.71^{d} (21.68)	2.25^{d} (4.56)	6.11^{d} (36.83)
30 cm X 30 cm (POP) + No weeding	5.45^{c} (29.20)	2.57^{c} (6.10)	7.07^{c} (49.48)	9.02^{b} (80.86)	4.18^{b} (16.97)	11.73^{b} (137.09)
30 cm X 30 cm (SRI) + No weeding	8.18^{b} (66.41)	3.80^{b} (13.94)	10.63^{b} (112.50)	10.46^{a} (108.91)	4.83^{a} (22.83)	13.60^{a} (184.46)
30 cm X 30 cm (Modified SRI) + No weeding	8.50^{a} (71.75)	3.94^{a} (15.02)	11.04^{a} (121.38)	10.34^{a} (106.42)	4.78^{a} (22.35)	13.44^{a} (180.13)

* $\sqrt{X+0.5}$ transformed values, Original values with in parenthesis

Table 179. Uptake of major nutrients (kg ha^{-1}) by broad leaved weeds at 20 DAT

Main plot treatments	2005-2006 N	2005-2006 P	2005-2006 K	2006-2007 N	2006-2007 P	2006-2007 K
Weeded	1.18* (0.89)	0.96 (0.42)	1.16 (0.85)	1.19 (0.92)	0.88 (0.27)	1.02 (0.54)
Unweeded	1.01 (0.52)	0.86 (0.24)	1.00 (0.50)	1.12 (0.75)	0.85 (0.22)	0.97 (0.44)
Sub plot treatments						
10 cm X 10 cm (POP)	1.09^{b} (0.69)	0.90^{b} (0.31)	1.07^{b} (0.64)	1.14^{b} (0.80)	0.85^{b} (0.22)	0.99^{b} (0.48)
20 cm X10 cm (POP)	0.96^{c} (0.42)	0.83^{c} (0.19)	0.95^{c} (0.40)	1.11^{b} (0.73)	0.84^{b} (0.21)	0.96^{b} (0.42)
30 cm X 30 cm (POP)	0.97^{bc} (0.44)	0.84^{bc} (0.21)	0.96^{c} (0.42)	1.08^{b} (0.67)	0.83^{b} (0.19)	0.94^{b} (0.38)
30 cm X 30 cm (SRI)	0.88^{c} (0.27)	0.80^{c} (0.14)	0.87^{c} (0.26)	0.98^{b} (0.46)	0.80^{b} (0.14)	0.88^{b} (0.27)
30 cm X 30 cm (Modified SRI)	1.58^{a} (2.00)	1.18^{a} (0.89)	1.54^{a} (1.87)	1.47^{a} (1.66)	0.99^{a} (0.48)	1.22^{a} (0.99)
Interaction						
10 cm X 10 cm (POP) + Weeding	1.15^{bc} (0.82)	0.93^{bc} (0.36)	1.13^{bc} (0.78)	1.18^{b} (0.89)	0.87^{b} (0.26)	1.01^{b} (0.52)
20 cm X10 cm (POP) + weeding	1.07^{c} (0.64)	0.89^{c} (0.29)	1.06^{c} (0.62)	1.05^{b} (0.60)	0.82^{b} (0.17)	0.93^{b} (0.36)
30 cm X 30 cm (POP) + weeding	1.09^{c} (0.69)	0.90^{c} (0.31)	1.07^{c} (0.64)	1.08^{b} (0.67)	0.83^{b} (0.19)	0.94^{b} (0.38)
30 cm X 30 cm (SRI) + weeding	0.72^{d} (0.02)	0.71^{d} (0)	0.72^{d} (.02)	0.82^{c} (0.17)	0.74^{c} (0.05)	0.78^{c} (0.11)
30cmX30cm(Modified SRI) + weeding	1.87^{a} (3.00)	1.36^{a} (1.35)	1.83^{a} (2.85)	1.81^{a} (2.78)	1.14^{a} (0.80)	1.46^{a} (1.63)
10 cm X 10 cm (POP) + No weeding	1.03^{c} (0.56)	0.86^{c} (0.24)	1.01^{c} (0.52)	1.11^{b} (0.73)	0.84^{b} (0.21)	0.96^{b} (0.42)
20 cm X10 cm (POP) + No weeding	0.84^{d} (0.21)	0.77^{d} (0.09)	0.84^{d} (0.21)	1.16^{b} (0.85)	0.86^{b} (0.24)	1.00^{b} (0.50)
30 cm X 30 cm (POP) + No weeding	0.85^{d} (0.22)	0.77^{d} (0.09)	0.84^{d} (0.21)	1.08^{b} (0.67)	0.83^{b} (0.19)	0.94^{b} (0.38)
30 cm X 30 cm (SRI) + No weeding	1.04^{c} (0.58)	0.88^{c} (0.27)	1.03^{c} (0.56)	1.13^{b} (0.78)	0.85^{b} (0.22)	0.98^{b} (0.46)
30 cm X 30 cm (Modified SRI) + No weeding	1.28^{b} (1.14)	1.00^{b} (0.50)	1.26^{b} (1.09)	1.13^{b} (0.78)	0.85^{b} (0.22)	0.98^{b} (0.46)

* $\sqrt{X+0.5}$ transformed values, Original values with in parenthesis

Table 180. Uptake of major nutrients (kg ha^{-1}) by broad leaved weeds at 40 DAT

Uptake of major elements by broad leaved weeds (kg ha^{-1}) at 40 DAT			
	2005-2006		
Main plot treatments	N	P	K
Weeded	0.79* (0.12)	0.75* (0.06)	0.79 (0.12)
Unweeded	1.2 (0.94)	0.98 (0.46)	1.21 (0.96)
Sub plot treatments			
10 cm X 10 cm(POP)	0.82^{b} (0.17)	0.77^{b} (0.09)	0.82^{b} (0.17)
20 cm X10 cm(POP)	0.86^{b} (0.24)	0.78^{b} (0.11)	0.85^{b} (0.22)
30 cm X30 cm(POP)	1.03^{ab} (0.56)	0.88^{ab} (0.27)	1.02^{ab} (0.54)
30 cm X30 cm(SRI)	1.18^{a} (0.89)	0.96^{a} (0.42)	1.16^{a} (0.85)
30 cm X 30 cm (Modified SRI)	1.17^{a} (0.87)	0.96^{a} (0.42)	1.15^{a} (0.82)
Interaction			
10 cm X 10 cm (POP) + Weeding	0.71^{d} (0)	0.71^{d} (0)	0.71^{d} (0)
20 cm X 10 cm (POP) + weeding	0.71^{d} (0)	0.71^{d} (0)	0.71^{d} (0)
30 cm X 30 cm (POP) + weeding	0.73^{d} (0.03)	0.72^{d} (0.02)	0.73^{d} (0.03)
30 cm X 30 cm (SRI) + weeding	1.11^{bc} (0.73)	0.92^{bc} (0.35)	1.09^{bc} (0.69)
30 cm X 30 cm (Modified SRI) + weeding	0.71^{d} (0)	0.71^{d} (0)	0.71^{d} (0)
10 cm X 10 cm (POP) + No weeding	0.94^{cd} (0.38)	0.82^{cd} (0.17)	0.93^{cd} (0.36)
20cm X10xcm(POP) + No weeding	1.00^{cd} (0.50)	0.85^{cd} (0.22)	0.99^{cd} (0.48)
30 cm X 30 cm (POP) + No weeding	1.34^{ab} (1.30)	1.04^{ab} (0.58)	1.31^{ab} (1.22)
30 cm X 30 cm (SRI) + No weeding	1.26^{bc} (1.09)	0.99^{bc} (0.48)	1.23^{bc} (1.01)
30 cm X 30 cm (Modified SRI) + No weeding	1.63^{a} (2.16)	1.21^{a} (0.96)	1.60^{a} (2.06)

* $\sqrt{X+0.5}$ transformed values, Original values with in parenthesis

Table 181. Uptake of major nutrients (kg ha^{-1}) by broad leaved weeds at harvest

Uptake of major elements by broad leaved weeds (kg ha^{-1}) at harvest			
	2005-2006		
Main plot treatments	N	P	K
Weeded	0.85* (0.22)	0.76 (0.08)	0.84 (0.21)
Unweeded	0.99 (0.48)	0.81 (0.16)	0.97 (0.44)
Sub plot treatments			
10 cm X 10 cm (POP)	0.75^{b} (0.06)	0.72^{b} (0.02)	0.75^{b} (0.06)
20 cm X10 cm (POP)	0.89^{b} (0.29)	0.77^{b} (0.09)	0.88^{b} (0.27)
30 cmX30 cm (POP)	1.20^{a} (0.44)	0.89^{a} (0.29)	1.17^{a} (0.87)
30 cm X 30 cm (SRI)	0.85^{b} (0.22)	0.76^{b} (0.08)	0.84^{b} (0.21)
30 cm X 30 cm (Modified SRI)	0.89^{b} (0.29)	0.77^{b} (0.09)	0.88^{b} (0.27)
Interaction			
10 cm X 10 cm (POP) + Weeding	0.71^{e} (0)	0.71^{e} (0)	0.71^{e} (0)
20 cm X10 cm (POP) + weeding	0.80^{cde} (0.14)	0.74^{cde} (0.05)	0.79^{cde} (0.12)
30 cm X 30cm (POP) + weeding	1.09^{ab} (0.69)	0.84^{ab} (0.21)	1.07^{ab} (0.64)
30c m X 30 cm (SRI) + weeding	0.87^{bcde} (0.26)	0.76^{bcde} (0.08)	0.86^{bcde} (0.24)
30 cm X 30 cm (Modified SRI) + weeding	0.76^{de} (0.08)	0.73^{de} (0.03)	0.76^{de} (0.08)
10 cm X 10 cm (POP) + No weeding	0.79^{cde} (0.12)	0.74^{cde} (0.05)	0.78^{cde} (0.11)
20 cm X 10 cm (POP) + No weeding	0.99^{bcd} (0.05)	0.80^{bcd} (0.14)	0.96^{bcd} (0.42)
30 cm X 30cm (POP) + No weeding	1.31^{a} (1.22)	0.93^{a} (0.36)	1.27^{a} (1.11)
30cmX30cm(SRI) + No weeding	0.82^{cde} (0.17)	0.75^{cde} (0.06)	0.81^{cde} (0.16)
30 cm X 30cm (Modified SRI) + No weeding	1.02^{bc} (0.54)	0.82^{bc} (0.17)	1.00^{bc} (0.50)

* $\sqrt{X+0.5}$ transformed values, Original values with in parenthesis

4.4.4. Nutrient uptake by weeds

Uptake by grass weeds

The data presented in Table 176 indicates that wider plant spacing significantly increased the uptake of major elements by grasses at 20 DAT. Nitrogen and potassium uptake were higher in 30 cm x 30 cm POP followed by 30 cm X 30 cm modified SRI. However, the uptake of phosphorus was maximum in 30 cm x 30 cm POP, and it was on a par with 30 cm X 30 cm modified SRI. At this stage of observation combination of 30 cm X 30 cm modified SRI with weeding showed the lowest uptake of N and K. Uptake of P at 20 DAT by grasses was lower and on a par in SRI and modified SRI with weeding. Uptake of N, P and K were maximum in modified SRI without weeding.

During 2006-07, significantly higher uptake was noticed in plots without weeding. Lower uptake of nutrients was observed in 30 cm X 30 cm modified SRI and in 10 cm X 10 cm POP. These two treatments were at par. Highest uptake values were noticed in 30 cm X 30 cm POP. Among the various combination plots, 30 cm X 30 cm modified SRI and 30 cm X 30 cm POP recorded significantly lower and higher uptake respectively.

Nutrient uptake by grasses at 40 DAT during 2005-06 is presented in Table177. Sub plot treatments significantly influenced the uptake of nutrients, with maximum uptake in SRI. This was followed by modified SRI. Between the interaction plots, modified SRI with weeding showed higher uptake, followed by SRI with cono weeding. Significantly lower uptake was noticed in 10 cm X 10 cm, 20 cm X 10 cm, 30 cm X 30 cm modified SRI, all with weeding.

At 40 DAT during 2006-07, significantly higher uptake of nutrients were observed in 10 cm X 10 cm followed by 20 cm X 10 cm. Uptake by grasses was lower in 10 cm X 10 cm or 20 cm X 10 cm with weeding. These two treatments were at par with SRI with cono weeding. Higher values were observed in wider plant spacing without weeding.

Grasses showed significant difference in nutrient uptake at harvest stage during 2005-06 and 2006-07 due to treatments and their combinations. The highest and lowest uptake values were observed in SRI and 10 cm X 10 cm respectively. Modified SRI without weeding had the highest uptake of nutrients followed by SRI without weeding (Table 178).

Nutrient uptake by broad leaf weeds

Uptake of nitrogen, phosphorus and potassium by broad leaf weeds at 20 DAT during 2005-06 and 2006-07 are presented in Tables 179. Close plant spacing 10 cm X 10 cm and 20 cm X 10 cm under POP management recorded lower nutrient uptake during 2005-06. Among wider plant spacing, modified SRI showed minimum uptake. Significant differences were observed between weeded and unweeded plots with higher uptake in unweeded plots. Modified SRI with and without weeding recorded the lowest and highest uptake values respectively.

The data on uptake of nutrients during 2006-07 revealed that among sub plots, modified SRI showed the highest uptake. All other plots were at par. Among combination plots, modified SRI with weeding recorded maximum uptake and the least was in SRI with conoweeding.

The data in Table 180 showed that reduction in plant spacing is effective in reducing the nutrient uptake by broad leaf weeds. The lower uptake of major elements are observed in plots with 10 cm X 10 cm or 20 cm X 10 cm spacing. At 40 DAT weeded plots exhibited lower uptake. Modified SRI with weeding recorded higher nutrient uptake. During 2006-07, at 40 DAT, nutrient uptake by broad leaf weeds did not change significantly.

Table 182. Economics of treatments under weeded condition (Rs./ha)

Treatments	Total cost of cultivation (Rs.)	Total income (Rs.)		Total profit (Rs.)		B:C ratio	
		05-06	06-07	05-06	06-07	05-06	06-07
10 cm X 10 cm (POP)	28800	89815	83468	61015	54668	3.12	2.90
20 cm X10 cm (POP)	27865	87117	72353	59252	44488	3.13	2.60
30 cm X30 cm (POP)	29715	75536	70886	45821	41171	2.54	2.39
30 cm X 30 cm (SRI)	35660	54163	56836	18503	21176	1.52	1.59
30 cm X30cm (Modified SRI)	26165	71473	69236	45308	43071	2.73	2.65

Table 183. Economics of treatments under unweeded condition (Rs./ha)

Treatments	Total cost of cultivation (Rs.)	Total income (Rs.)		Total profit (Rs.)		B:C ratio	
		05-06	06-07	05-06	06-07	05-06	06-07
10 cm X 10 cm (POP)	27300	85285	80728	57985	53428	3.12	2.96
20 cm X10 cm (POP)	24865	80758	62308	55893	37443	3.25	2.51
30 cm X 30cm (POP)	22215	30527	13865	8312	-8351	1.37	0.62
30 cm X 30 cm (SRI)	33260	25008	15908	-8253	-17353	0.75	0.48
30 cm X 30 cm (Modified SRI)	23565	24710	10683	1145	-12883	1.05	0.45

Significant differences in the uptake values of nutrients was observed in SRI plots followed by modified SRI. Lower uptake was observed in modified SRI with weeding. However, modified SRI without weeding caused the greatest uptake.

The data in Table 181 revealed that among sub plot treatments only 30 cm X 30 cm POP increased the uptake. Other treatments were at par. The spacing, 30 cm X 30 cm under POP management with or without weeding resulted in higher uptake of nutrients at 40 DAT during 2006-07. Other treatment combinations were at par.

4.4.5. Economics of cultivation

Among weeded plots, management as per SRI recorded the highest cost of production and the lowest benefit cost ratio. Unweeded plots under wider row spacing (30cm X 30cm) gave negative returns during both years. Closer plant spacing (10 cm X 10cm) even under unweeded situation gave considerably superior yield and thus better benefit cost ratio (Tables 182 and 183).

Discussion

5. DISCUSSION

5.1. Survey and documentation of weed management practices followed by rice farmers

The survey conducted in four major rice growing tracts of Kerala viz, Palakkad, *Kole*, *Kuttanad* and *Pokkali*, concentrated mainly to elicit information on the farmers practices on the methods of crop establishment, pre-planting weed control methods, post planting weed control methods and major herbicides used by them. The survey revealed some interesting results.

Among the various crop establishment methods, dry seeding was in practice only at Palakkad district, that too during first crop season (Fig.4). In *Kole*, *Kuttanad* and *Pokkali* wet seeding was the major method of crop establishment. The crop establishment method had significant influence on the weed population as indicated by the pattern of labour use in Palakkad district during the first and second crop seasons (Table 7). Increased weed population in dry seeded crop compared to wet seeding or transplanting was reported by Balasubramaniyam and Palaniappan (2001). During the second crop season, wet seeding was the major method in all four locations (Fig.5). In wet seeding and transplanting, relatively less number of labourers were required for weeding, indicating less incidence of weeds.

Summer plouging was the major weed control method practiced by the farmers of Palakkad, *Kole* and *Kuttanad* (Fig.6). Stale seed bed (flooding) was a common method of weed control in *Kuttanad,* while none of the farmers of Palakkad practice this method. Availability of enough water at the time of land preparation and the serious problem of grass weeds such as *Echinochloa* spp. and wild rice may be the reason for the popularity of

Fig. 4. Method of crop establishment in Palakkad district during first crop season

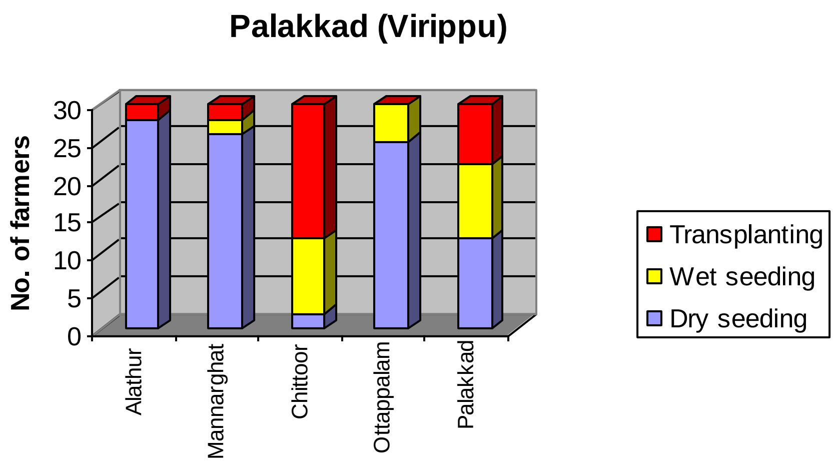
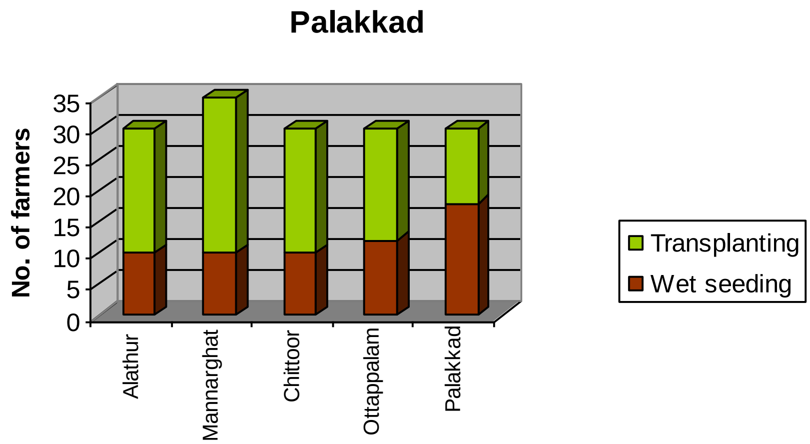
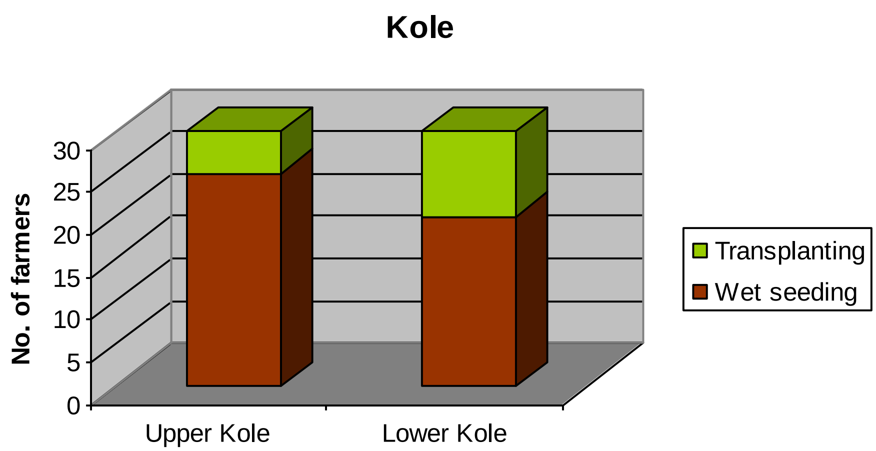


Fig. 5. Method of crop establishment during second crop season





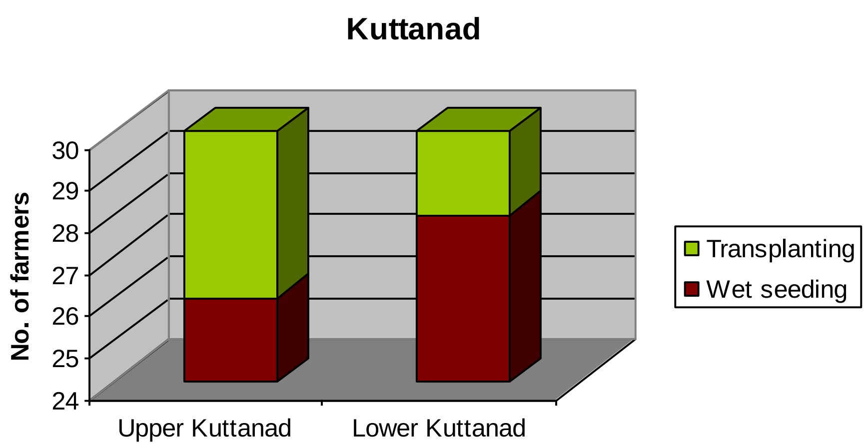


Fig. 6. Major pre planting weed control methods

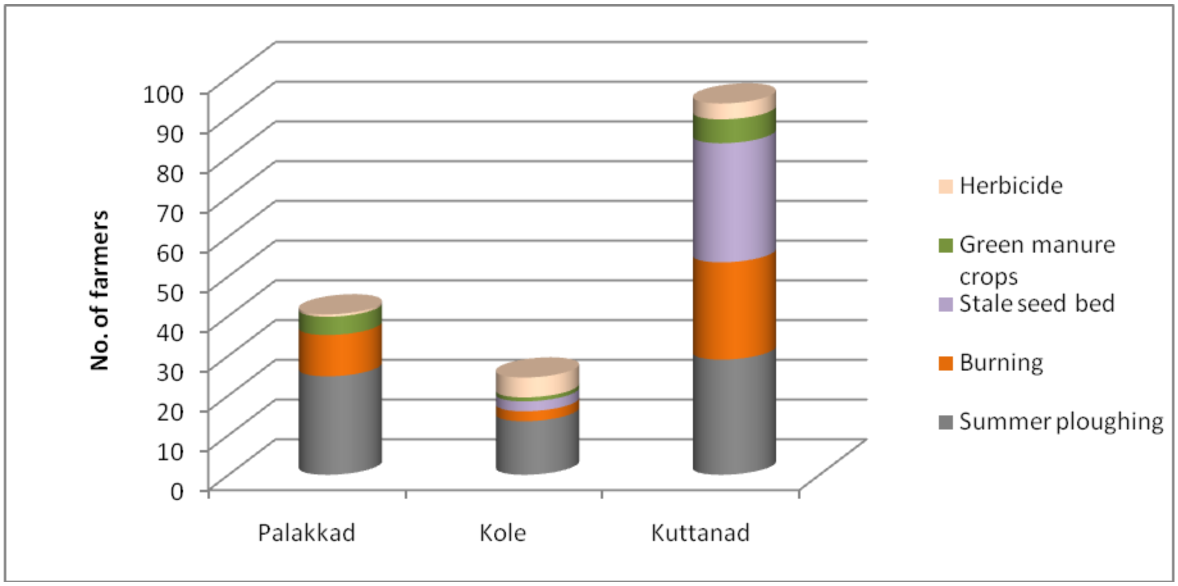
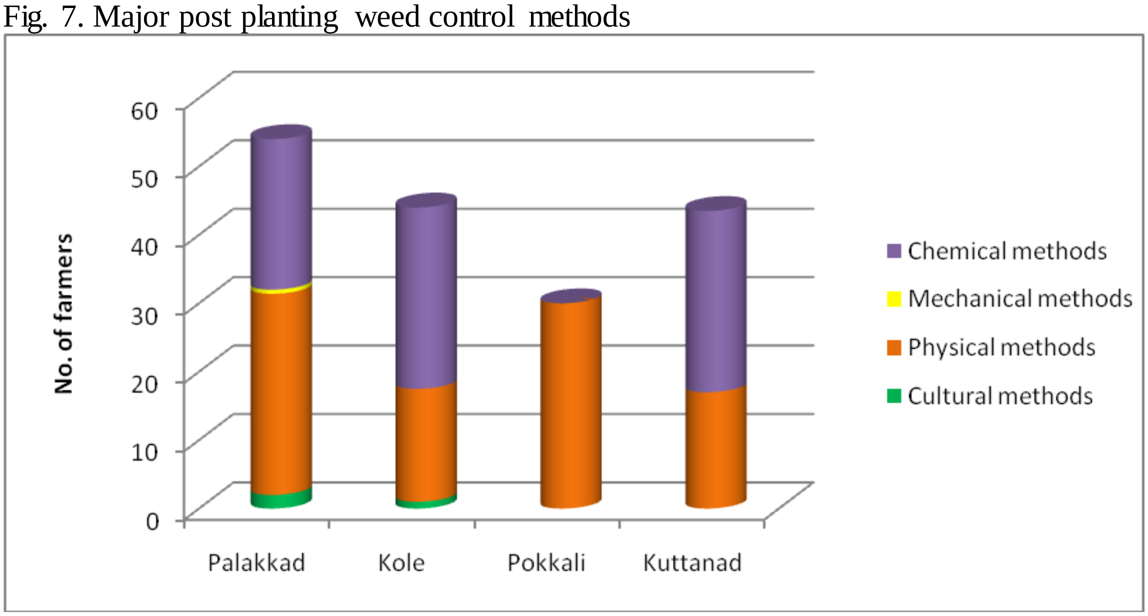


Fig. 7. Major post planting weed control methods



stale seed bed techniques in *Kuttanad*. Effectiveness of stale seed bed in controlling weeds in rice fields have been reported by many workers (Almamum *et al.* ,1986; Mukhopadhyay, 1987 and Moorthy, 1992; Renu (1999).

Survey on common post planting weed control methods revealed the superiority of chemical and physical methods (Fig.7). Mechanical methods were not much popular in rice growing areas, except at Chittoor. In *Pokkali* lands, the only method of weed control was hand pulling. None of the farmers of *Pokkali* region apply herbicides for the control of weeds since the system of rice cultivation was organic by default because of ensuing prawn cultivation immediately after harvest of the crop.

The major herbicide used by the farmers of Palakkad, *Kole* and *Kuttanad* was Fernoxone (2,4-D). Pre-emergence herbicides Rifit (Pretilachlor) and Butachlor (Butachlor) were used by farmers of Palakkad. Popularity of Rifit in this region was mainly because of the dry- seeding practice. Herbicide use pattern of *Kole* and *Kuttanad* region was almost similar as these two regions are similar in physio chemical characteristics and cropping patterns.

5.2. Stale seed bed techniques suited for dry seeded rice

5.2.1. Studies on weeds

Population and dry weight of weeds

Grasses and broad leaf weeds dominated the weed flora of the experiment field. Sedges were very few. A critical analysis of the relative proportion of grasses and broad leaf weeds to the total weed population indicate that at all stages, the proportion of grasses was higher than that of broad leaf weeds. At the harvest stage, sedges were not observed, probably due to the short life span of sedges (Suja and Abraham (1991) and Trivedi *et al.* (1986).

Seed bed preparation significantly influenced the germination and establishment of weeds. The population and dry weight of weeds were the lowest in stale seed bed for 14 days (Fig.8 and Plate 3). The stale seed bed technique consisted of loosening the soil in order to achieve an almost optimal environment around buried seeds for germination, thereby forcing the weed seeds in soil seed bank to germinate. Repeated destruction of weed flushes caused substantial decrease in the weed seed reserves in the soil plough layer as indicated by the lowest population of weeds in the stale seed bed for 14 days with two hoeings. The stale seed bed for 14 days with one hoeing was the next best treatment, which lowered the population and dry matter accumulation by weeds.

The stale seed bed for 7 days with one hoeing was inferior to other stale seed beds mainly because of short period between land preparation and seeding, which may not be adequate to force the germination of all dormant weed seeds in the plough layer. However, this treatment was significantly superior to normal seed bed, since, part of the early germinated weeds was destroyed prior to seeding the crop.

Plate 3. Influence of seed bed preparation on weed intensity

Fig 8. Effect of seed bed preparation on total weed population and dry weight at various stages of observation

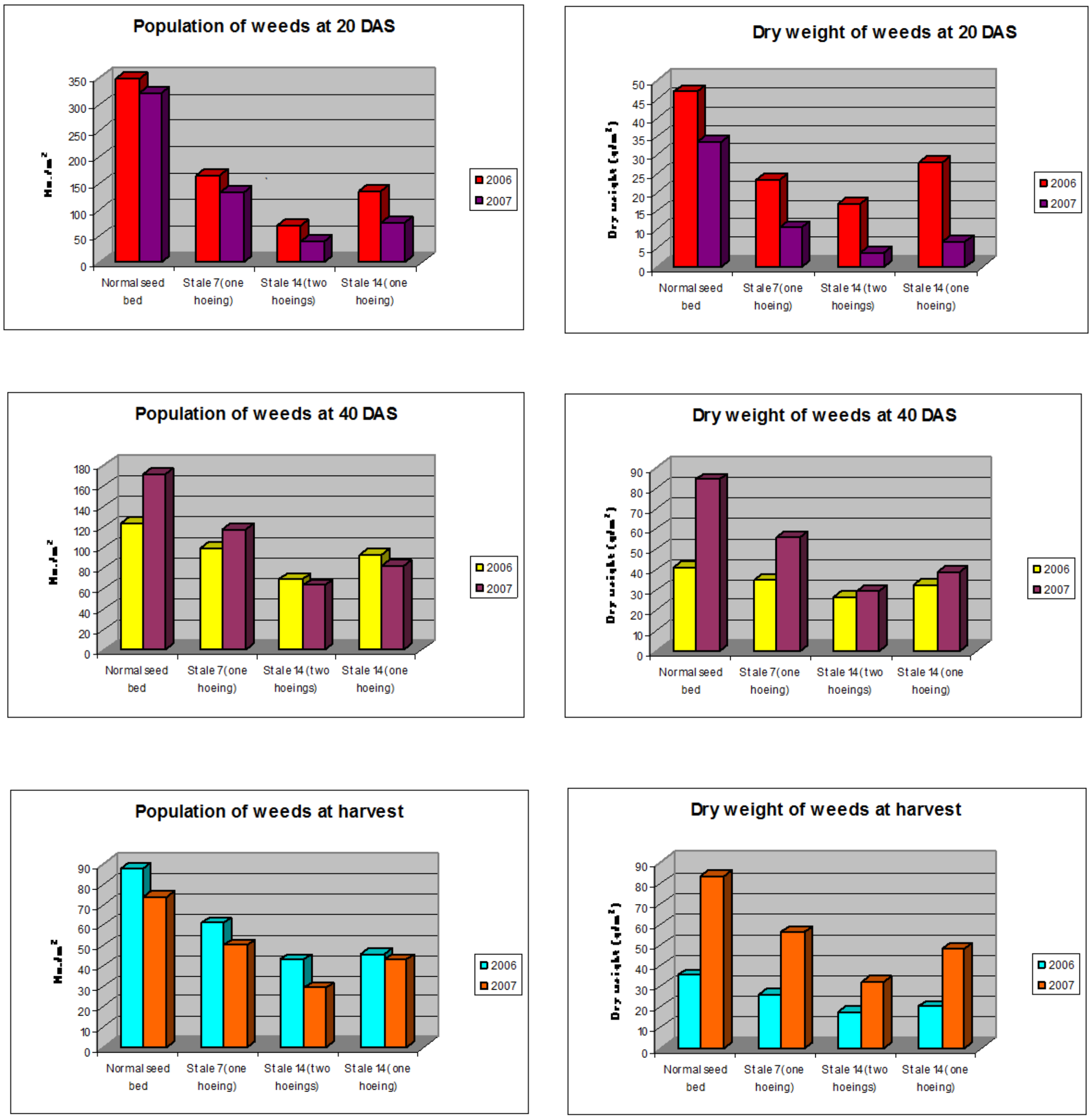
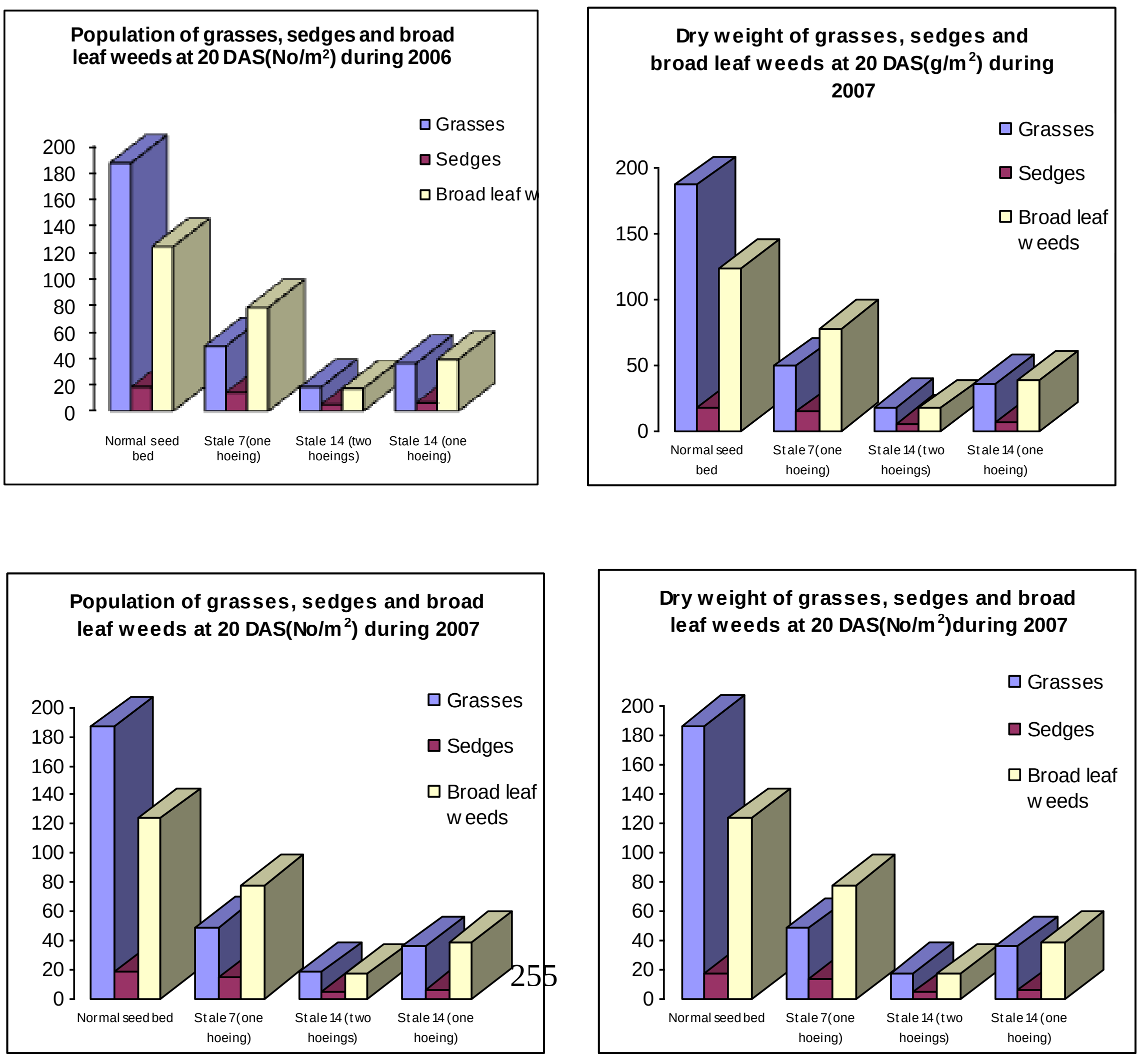


Fig 9. Effect of seed bed preparation on population and dry weight of grasses, sedges and broad leaf weeds



Considerable reduction in the weed seed bank in the shallow layer (0-10 cm) by the adoption of stale seed bed technique was reported by Benvenuti and Macchia (2006). It was reported that more than 60 per cent of the current season weed seeds are deposited in the top 5 cm layer of soil (AICRP -WC, 2006). Influence of stale seed bed technique in decreasing the soil seed reserve was reported by Rasmussen (2004). According to Mukhopadhyay (1987), Moorthy (1992) and Renu (1999) stale seed bed is very effective in preventing the successive flushes of weeds.

The stale seed bed technique adopted for forcing the germination of weed seeds showed differential influence on different groups of weeds (Tables 5, 8 and 10 and Fig.9). Grass weeds gave the highest germination per centage immediately after seed bed preparation, and hence better control of grasses followed by broad leaf weeds. However, seed bed manipulation was not effective on sedges. The low dormancy and longevity characteristics of grass seeds were reported by Williams (1982) and Perez *et al.* (1998). Stale seed bed is suggested as an effective method for the control of red rice (Smith, 1981) and *Sacciolepis* (Renu, 1999), two problem grass weeds of rice.

Among the sub plot treatments, pre-emergence spraying of Rifit and concurrent growing of cowpea gave significant reduction in the population and dry weight of weeds. Spraying of Rifit in plots with stale seed bed for 14 days with two hoeings successfully managed the weed problem in dry sown rice. Germinated weed seedlings from seeds which remained dormant in the plough layer were controlled by the pre emergence spraying of herbicide. Hence the combination gave significant reduction in the population and dry weight of weeds. Accordng to Lonsbary *et al.* (2003), stale seed bed in combination with herbicides is a superior integrated weed management tool compared to conventional weed management methods. Cowpea grown plots showed a reduction in the population of weeds mainly because of the canopy closure by cowpea (Plate 4). Smothering effect of

Plate 4. Concurrent growing of cowpea with rice and its chemical killing

cowpea in rice culture and subsequent reduction in the weed problem in semi dry rice culture were reported earlier by Musthafa (1995).

Observations on crop

Crop growth characters

Stale seed bed for 14 days with two hoeings showed an increase in plant height, number of tillers and crop dry matter production at all stages of observation compared to normal seed bed. Weeds in general will compete with crop for growth factors such as space, light, nutrients and water and there by adversely influence the growth and development of crop. It is presumed that the initial weed free condition in stale seed bed plots reduced the competition and enabled the crop to perform well. Positive effect of stale seed bed in increasing the growth parameters of rice have been reported by Saikia and Pathak (1993) and Renu (1999).

Although, concurrent growing of cowpea reduced the crop growth parameters in the early stages of observation, after its incorporation in the soil these attributes improved substantially. The initial reduction in the crop growth parameters is a clear indication of competition stress. As Abayomi *et al*. (2001) noted, in a rice + cowpea intercropping system, the cowpea will dominate due to its trifoliate leaves with better ability to capture light than rice with its narrow upright leaves. This dominance causes subsequent pull down in the vegetative growth characters of rice. Reduction in crop growth parameters due to competitive stress is a general phenomenon. Several workers, for example, Noda *et al*. (1968), Jayasree (1987) and Palaikudy (1989) have reported similar results. Increase in the tiller production rate from 40 to 60 DAS in semi dry rice culture after *in situ* green manuring of cowpea was reported by Musthaffa (1995).

At maximum tillering stage of the crop, significant reduction in the number of tillers was noticed in plots with pre-emergence spraying of Rifit, mainly due to the phytotoxic effect of the chemical (Table 27). However, in the later stages, there was steady increase in the number of tillers owing to the absence of any inter or intra plant competition. Due to severe weed competition, unweeded plots of normal seed bed gave the lowest values of crop growth parameters. Although the differences between weeded and unweeded plots in the early stages of crop were less, differences became evident by 40 DAS.

Chlorophyll content of leaves

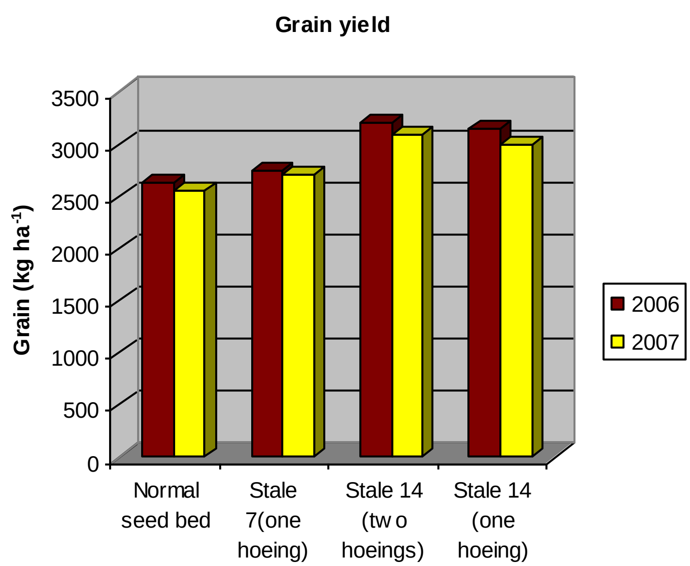
A general increase in the content of leaf chlorophyll was observed in main plot treatment with stale seed bed. However, chlorophyll 'b' content showed no significant variation. The lowest values were noticed in normal seed bed (Tables 34, 35,36,37,38 and 39).

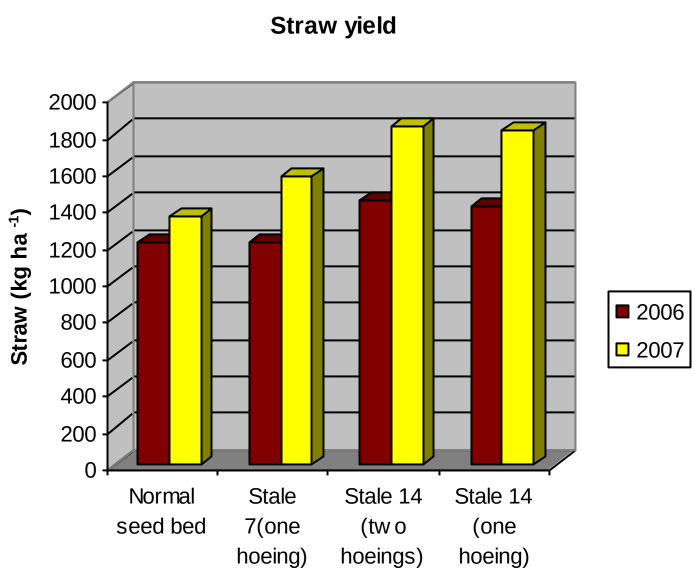
Among sub plot treatments, chlorophyll contents were higher in Rifit sprayed plots. Cowpea grown plots and unweeded plots showed general decline in the contents of chlorophyll 'a' and total chlorophyll, while, it increased the content of chlorophyll 'b'. Chlorophyll 'a' is the photosynthetic unit and the chlorophyll 'b' acts as the light trapping unit (Conn and Stumpf, 1976). Lower values of chlorophyll 'a' indicates the shading and consequent reduction of photosynthesis, which in turn contributed to reduced tiller production and dry matter accumulation in these plots. Decrease in chlorophyll 'a' content and changes in chlorophyll a:b ratio in plants under shade was reported by Johnston and Onwueme (1998).

Leaf area index (LAI)

Higher leaf area index were noticed in plots with stale seed bed for 14 days with one or two hoeings. Increase in the LAI due to stale seed bed technique in wheat was reported by Yadav *et al.* (1995). Because of severe reduction in the plant population and crop dry matter production, the LAI in unweeded plots were inferior. Owing to significant reduction

Fig10. Effect of seed bed preparation on grain and straw yield of rice (kg ha^{-1})





in the population and dry weight of weeds, Rifit sprayed plots showed maximum LAI. However, it was on a par with hand weeded plots (Tables 40, 41 and 42). Combination of these two treatments with stale seed bed for 14 days gave better LAI. Rana and Angiras (1999) reported that Pretilachlor 0.8kg ha^{-1} followed by hand weeding at 25 and 50 DAS increased the leaf area index of direct sown broadcast rice.

Yield and yield attributes

Stale seed bed technique provided a partially weed free environment at early crop growth stages and allowed the crop to yield better than normal seed bed. The better crop growth parameters observed in these plots is a clear indication of lack of competitive stress. There is every reason to believe that the lowest grain yield in unweeded plots of normal seed bed is due to the competition between the crop and weeds. Compared to unweeded plots of normal seed bed, those of stale seed bed for 14 days with two hoeings exhibited an yield increase of 2711 kg ha^{-1} and 2145 kg ha^{-1} during 2006 and 2007 respectively (Table 43 and Fig. 10). The yield difference between normal seed bed and stale seed beds decreased with reduction in the stale seed bed period mainly because of the short time available to achieve optimum environment essential for the germination of buried weed seeds. The difference in grain yield between normal seed bed and stale seed bed for 7 days was only 249 kg ha^{-1} and 237 kg ha^{-1} during 2006 and 2007 respectively. Lonsbary *et al.* (2003) suggested that optimal timing for stale seed bed preparation as 20 to 30 days before planting so as to get good control of weeds.

Among the sub plot treatments, pre emergence spraying of Rifit followed by hand weeding at 40 DAS gave superior grain yield. Initial weed free conditions during germination stage gave the crop a better start and contributed to superior grain yield. Saikia and Pathak (1993) reported the efficacy of repeated hand weeding following a pre emergence herbicide in reducing weed competition and improving the yield of upland rice.

Although, initial growth was poor in cowpea intercropped plots, after its incorporation at 30 DAS, a gradual increase in the crop growth parameters and better final grain yield were noticed. The improvement in grain yield in these plots might be due to increased efficiency of nutrients use resulted from the incorporation of organic matter. Increase in nutrient use efficiency due to *in situ* green manuring of cowpea with rice was reported by Oroka and Omoregie (2007).

Plots with no weeding gave the lowest grain and straw yields mainly due to the shading effect of weeds. In a rice crop, shading by the tall weeds can reduce the light penetration and availability of sun light to rice leaf especially in later crop growth stages and adversely affect the production of assimilates. Yield reduction in rice due to weed competition has been reported by Vaishya et al (1992), Mandal (1990) and AICRP-WC (1992).

Nutrient uptake by crop and weeds

Nutrient uptake by the crop at various growth stages showed that the uptake was higher in plots with less competition (Tables 49,50 and 51). Increase in nutrient uptake by the crop with lesser weed competition was reported by several workers such as Biswas and Sattar (1991) and Varughese (1996).

The pattern of N, P and K removal by weeds was more or less the same as that of dry matter production by weeds. This could be expected as there was not much variation in the respective nutrient contents of the weeds at a particular stage. The demand for nutrients by grasses was in the order of $K \geq N > P$. However, those for broad leaf weeds and sedges were $N > K > P$. Removal of nutrients by weeds was lower in plots with proper weeding. The yield advantage noticed in these plots clearly indicates the absence of competition for nutrients. Similar increase in yield due to less competition for nutrients have been reported by workers such as Sreedevi (1979), Nanjappa and Krishnamoorthy (1980), Reddy *et al*., 1980, Kumar and Singh (1984) and Jayasree (1987).

5.3. Stale seed bed techniques suited for wet seeded rice

5.3.1. Studies on weeds

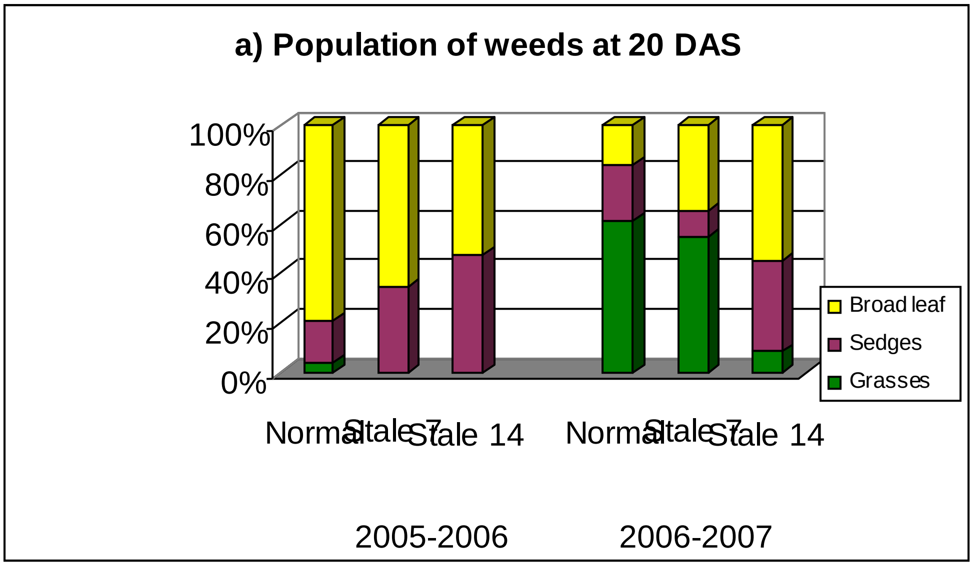
Population and dry weight of weeds

Seed bed preparation significantly influenced the population build up and dry matter accumulation by grasses, sedges and broad leaf weeds. The stale seed bed either for 7 or 14 days gave complete control of grasses during first year and significantly lower values during second year. The main plot treatments gave successful control of broad leaf weeds too. However, at 20 DAS, before giving any sub plot treatments (except Sofit spray and concurrent growing of daincha), no significant differences between normal seed bed and stale seed bed were noticed with respect to number and dry weight of sedges (Fig. 11).

The differential response of grasses, sedges and broad leaf weeds to forced germination could be explained by their relative seed dormancy and longevity characteristics. Perez *et al.* (1998) observed 69 per cent germination of *Echinochloa crusgalli* by shallow ploughing and watering, since they are deposited in the 'transitory seed bank' (Thompson and Grime, 1979) on account of the fairly low dormancy and longevity characters. As Benvenuti *et al.* (2001) noted when seeds are forced to germinate by seed bed preparation, seed germination occurs exclusively from the very first centimeter of the shallowest layer of the seed bank. Ferrero *et al.* (1999) observed that the seeds of plants belonging to plant family Poaceae were deposited in the top 0-10 cm layer of the soil. Based on experiments in wheat, Yaduraju and Mani (1987) observed that stale seed bed preparation had little effect on broad leaf weeds, where as it completely controlled wild oats up to six weeks after sowing.

Among the sub plot treatments, pre emergence spraying of Sofit and concurrent growing of daincha gave significant reduction in the population and dry weight of weeds (Fig. 12). Sofit spray exhibited the greatest influence on the broad leaf weeds. Better control of rice weeds by the pre-emergence spraying of Pretilachlor + safener @ 0.4 kg ai

Fig 11. Population and dry weight of grasses, sedges and broad leaf weeds as influenced by seed bed preparation



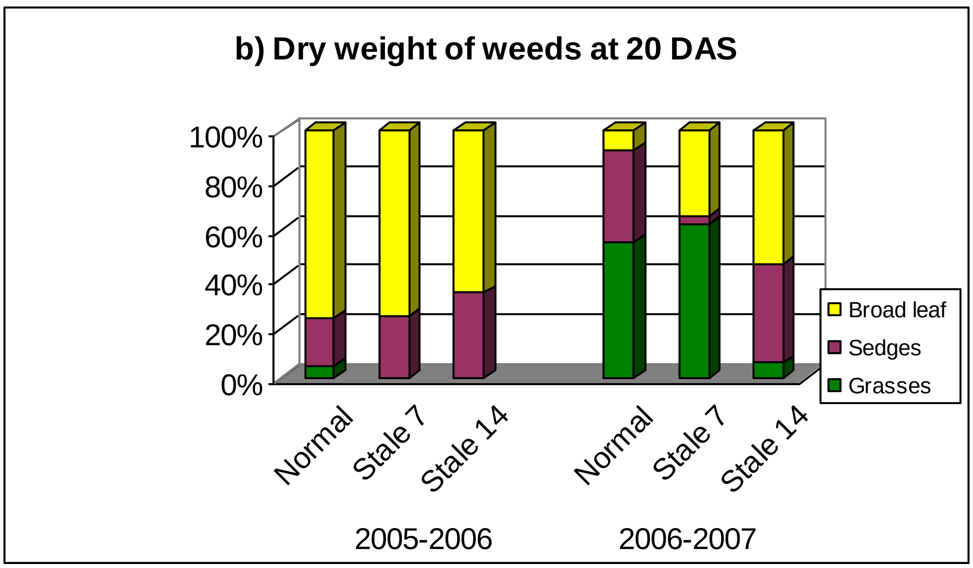
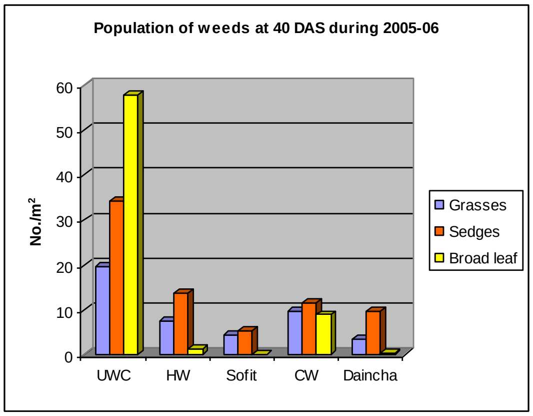
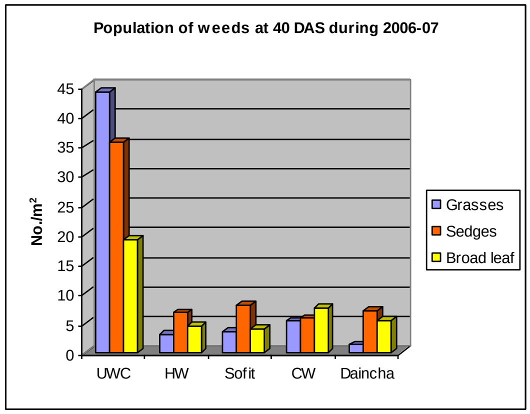
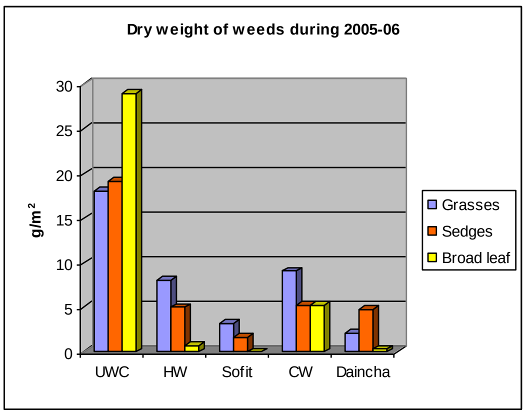


Fig 12. Effect of weed control methods on population and dry weight of weeds at 40 DAS







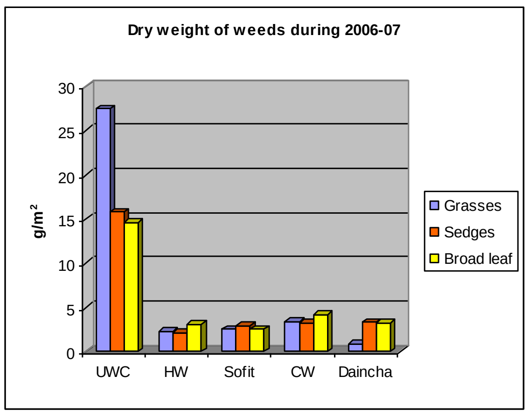
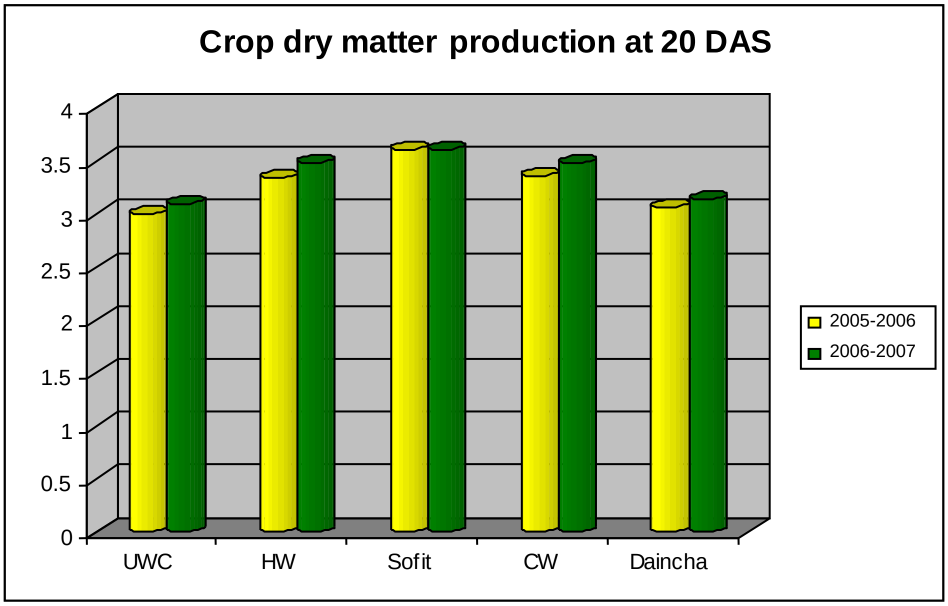
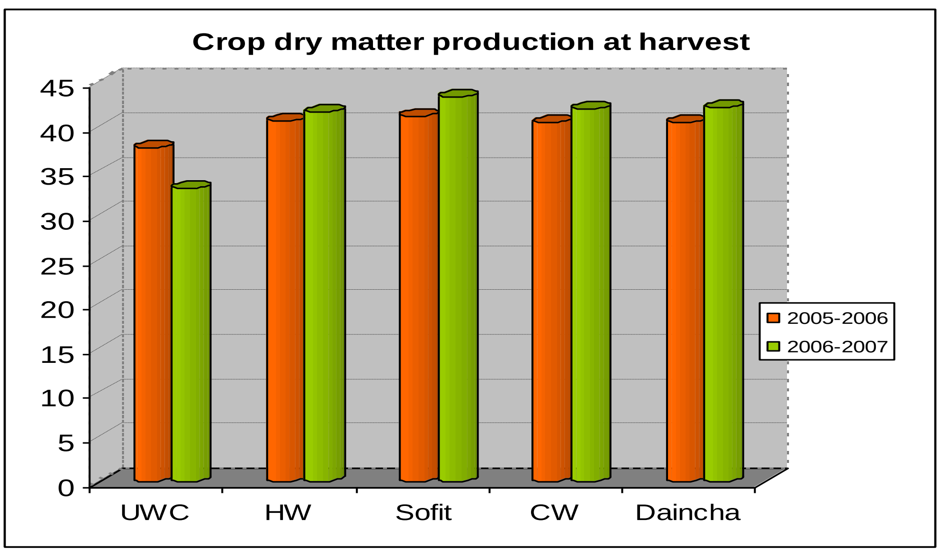


Fig 13. Effect of weed control methods on crop dry matter production at 20 DAS and at harvest





ha^{-1} in puddled rice was reported by Mohankumar (1995). The weed control effect of sesbania in rice - sesbania *in situ* green manuring system was reported by Weerakoon *et al.* (1992).

Weed problem was the highest in unweeded plots of normal seed bed. Combination of stale seed bed for 14 days with pre-emergence spraying of Sofit gave very good control of grasses, sedges and broad leaf weeds. As reported by Lonsbary *et al.* (2003) stale seed bed in combination with herbicide is an effective integrated weed management strategy. Stale seed bed technique is effective in wheat also as reported by Kumar *et al.* (2002) and Yadav *et al.* (1995).

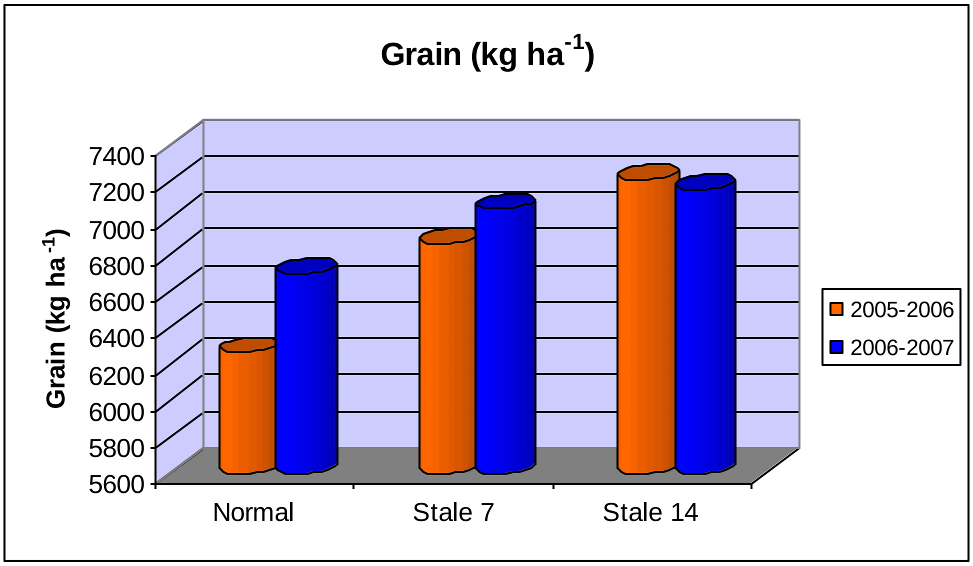
5.3.2 Observations on crop

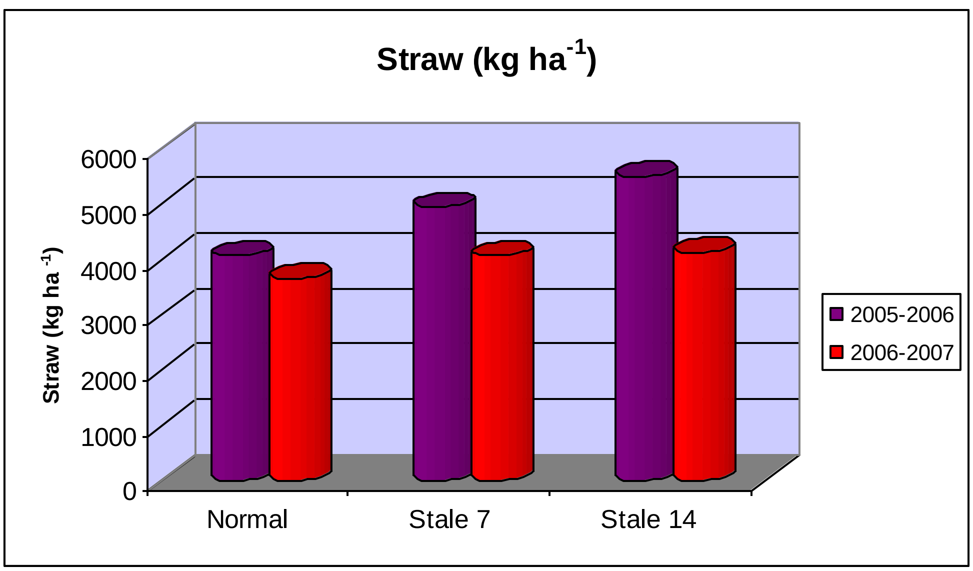
Crop growth characters

Superior values for plant height, number of tillers and crop dry matter were noticed in stale seed bed plots. Yadav *et al.* (1995) reported that the crop under stale seed bed had higher values of yield attributing characters owing to reduced weed growth and competition. Better crop growth under stale seed bed compared to other weed control methods due to less weed competition was also reported by Saikia and Pathak (1993).

The plots with Sofit spray exhibited higher values for crop growth parameters. Concurrent growing of daincha though inhibited the growth during early stages, later they picked up and gave comparable values (Fig. 13). Unweeded plots exhibited poor growth mainly because of competition between crop and weeds. Competition between crop and weeds is a complex phenomenon. Its nature and extent are highly influenced by morphology and physiology of the crop as well as weed plants. Generally, grass weeds are equipped with C_4 mechanism with high photosynthetic efficiency, which renders them to be comparatively better performers in mixed vegetation than crop plants. Hence, the reduction in crop growth in unweeded plots could be ascribed to the outcome of competition.

Fig 14. Grain and straw yields of rice as influenced by seed bed preparation





Reduction in the growth parameters due to crop weed competition was reported by many workers, for example, Chang and De Datta (1974), Sridhar *et al*. (1976), Ravindran *et al*. (1978) and Lakshmi (1983).

Chlorophyll content of leaves

At maximum tillering stage higher contents of chlorophyll ‘a’, ‘b’ and total chlorophyll were noticed in plots with stale seed bed for 7 days. However, at panicle initiation stage, stale seed bed for 14 days gave superior values. Increase in chlorophyll values in these plots could be attributed to the increased light infiltration due to reduced weed competition.

Reduction in the content of chlorophyll ‘a’ and total chlorophyll in plots with concurrent growing of daincha and unweeded plots indicates the adverse effect of competition on photosynthesis as explained in the experiment on stale seed bed for semi dry rice.

Leaf area index (LAI)

At all stages of observation, higher values for LAI was noticed in plots with stale seed bed. Normal seed bed showed lower LAI. As in the case of other growth parameters, no weeding and concurrent growing of daincha recorded lower values for LAI, where as pre emergence spraying of Sofit increased it. The increase in LAI under stale seed bed could be attributed to the elimination of crop weed competition in the early crop growth stages. Reduced leaf area development of rice due to severe weed competition was reported by Venkateswarlu (1977) and Iruthyaraj and Morachan (1980).

Yield and yield attributes

Stale seed bed preparation has brought an increase in the grain and straw yields of wet seeded rice than normal seed bed (Tables 98 and 99 and Fig. 14). An increase in the stale seed bed period contributed to increase in the yields as evident by higher grain yield in plots with stale seed bed for 14 days. The main factor which contributed to increased grain production was the absence of competition for growth factors. As Ampong – Nyarko and De Datta (1991) suggested, competition and yield reduction occurs when one of the limiting resources fall short of the combined requirements of crop and associated weeds.

Among the sub plot treatments, Sofit spray facilitated weed free environment during the germination and vegetative growth period of the crop. Hand weeding controlled the weeds at the critical period of crop weed competition. Thus, these two treatments gave better grain yield and straw yields. Mohankumar (1995) observed rice grain yields in plots with pre - emergence spraying of Pretilachlor + safener to be as statistically on a par with hand weeding twice under puddled condition.

In situ green manuring of daincha by cono weeding and cono weeding for incorporation of weeds gave almost similar grain yields, and it was inferior to Sofit sprayed and hand weeded plots (Table 98). Ishikawa (1988) reported that accumulation of organic acids in significant amounts at the time of decomposition of green manures can restrict the root elongation as well as nutrient uptake and reduce shoot weight and finally the grain yield. Diekmann *et al.* (1992) reported that the release of phenolic substances during decomposition was likely to retard the growth of main crop. Therefore, reduction in grain yields of wet seeded rice in a highly acid soil due to the incorporation of green manures or weeds by cono weeding might be because of its adverse influence on soil acidity.

Yield of rice has been described as the sum of volume of the container and the contents by Murata (1970) and the yield attributes, except 1000 grain weight constitute the volume. The yield attributes like, panicle length, number of filled grains, 1000 grain weight and the number of productive tillers were improved by the adoption of stale seed bed technique for 14 days. Thus, the yield increase in these plots is mainly due to a steady

Fig 15. Uptake of major nutrients by rice in the weeded and unweeded plots at panicle initiation stage

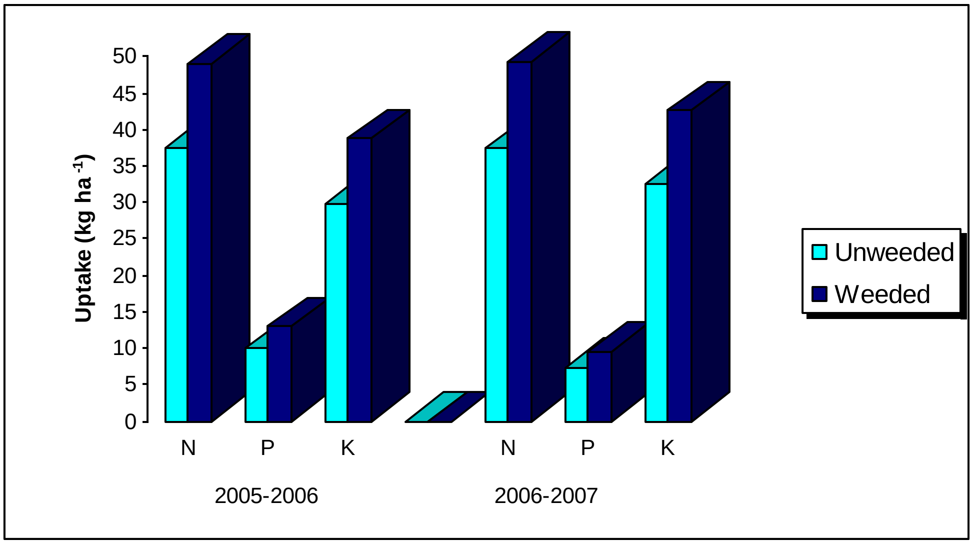
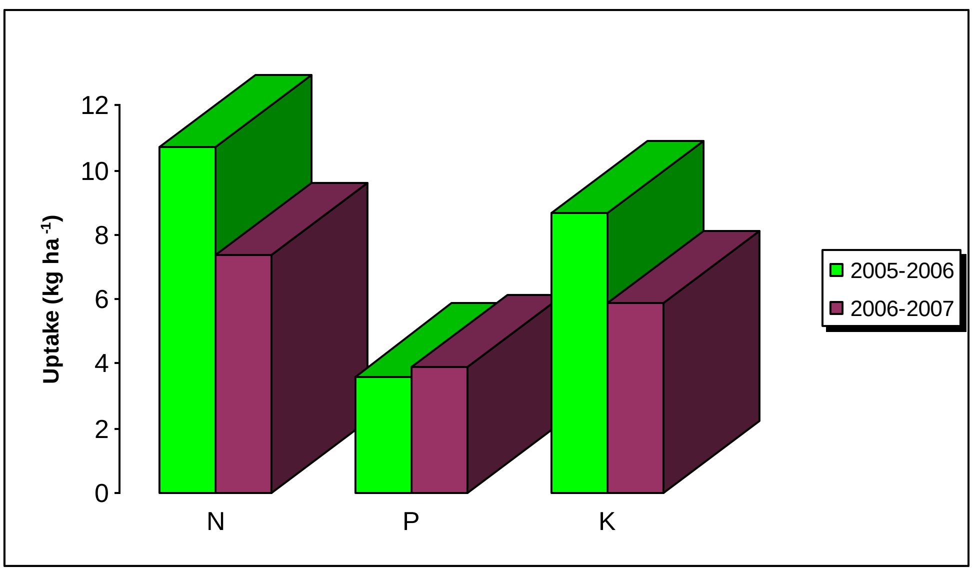


Fig 16. Uptake of major nutrients by weeds at 40 DAS



improvement in the yield attributes. This explanation is applicable to the yield improvement in the Sofit sprayed and hand weeded plots also.

Unweeded plots recorded lower yield attributing parameters mainly because of severe crop weed competition. Reduction in these parameters due to crop weed competition was reported by many workers Noda *et al*. 1968, Ravindran *et al*., 1978, Suja and Abraham, 1991 and Maheswari, 1987.

Nutrient uptake by crop and weeds

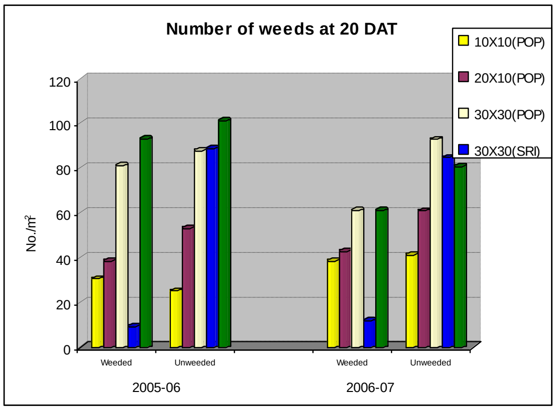
Nutrient content of plants at any time is a function of availability and is a factor for growth; whereas, nutrient uptake is a function of growth, absorption and accumulation. Nutrient uptake study has shown that though nutrient contents were unaffected, uptake of all major nutrients was significantly affected (Tables 101, 102 and 103). A comparative perusal of the dry matter production and nutrient uptake will show that dry matter production and nutrient removal have followed more or less similar pattern. In general, nutrient uptake by the crop increased with decrease in weed competition at all stages of observation (Fig. 15). Significant increase in the uptake of major nutrients by rice under weed free condition was reported by Kumar *et al*. (2007).

Weeds remove proportionately larger quantities of N, P and K. The weeds also followed an uptake trend as described for crop. In general weeds remove major nutrients in the order of N>K>P under wet land puddled field situation (Fig. 16). Seed bed manipulation and weed control practices exhibited greater influence on the uptake of nutrients. The stale seed bed plots significantly lowered the weed biomass and thus reduced the nutrient removal.

Plate 5. Influence of plant spacing on weed growth

Plate 6. Weed escape after cono weeding in SRI

Fig. 17. Number and dry weight of weeds per m^2 at 20 DAT



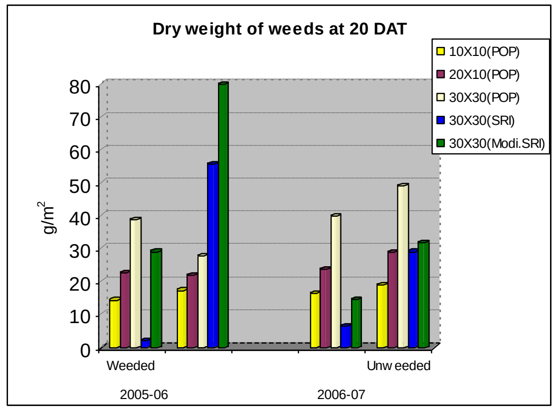
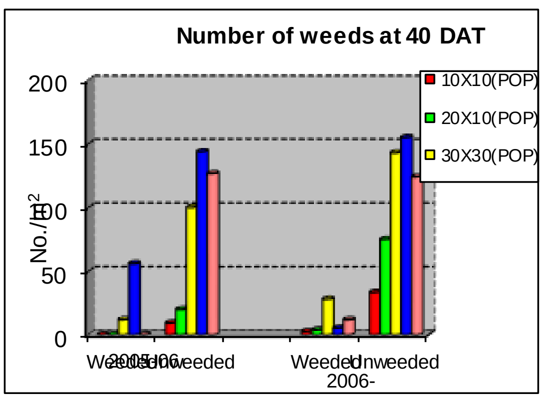


Fig. 18. Number and dry weight of weeds per m^2 at 40 DAT



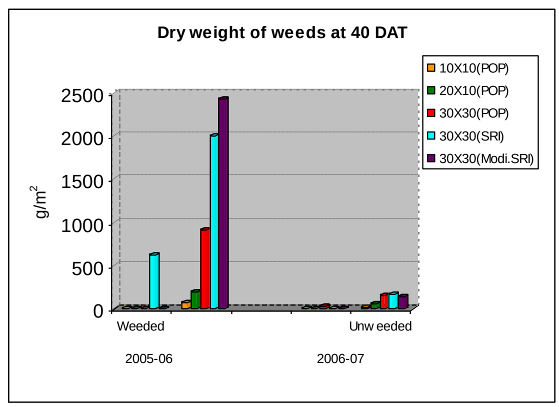
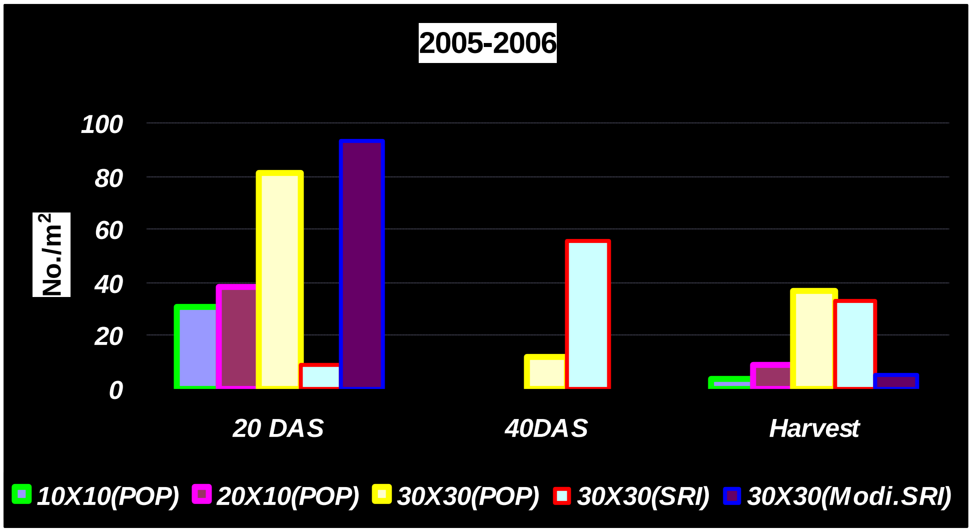
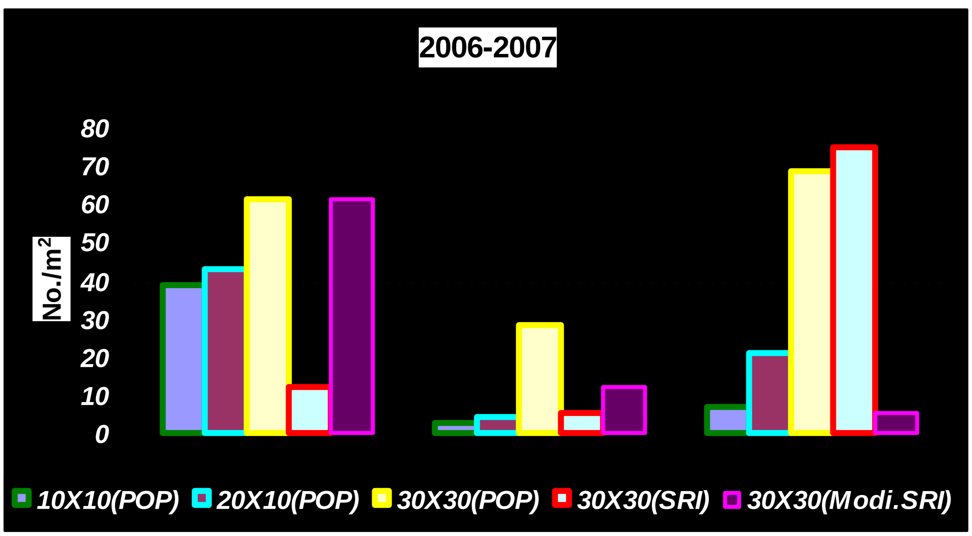


Fig. 19. Population of weeds as influenced by plant spacing and management practices





5.4 . Crop weed competition in transplanted rice: Influence of plant stand

5.4.1. Studies on weeds

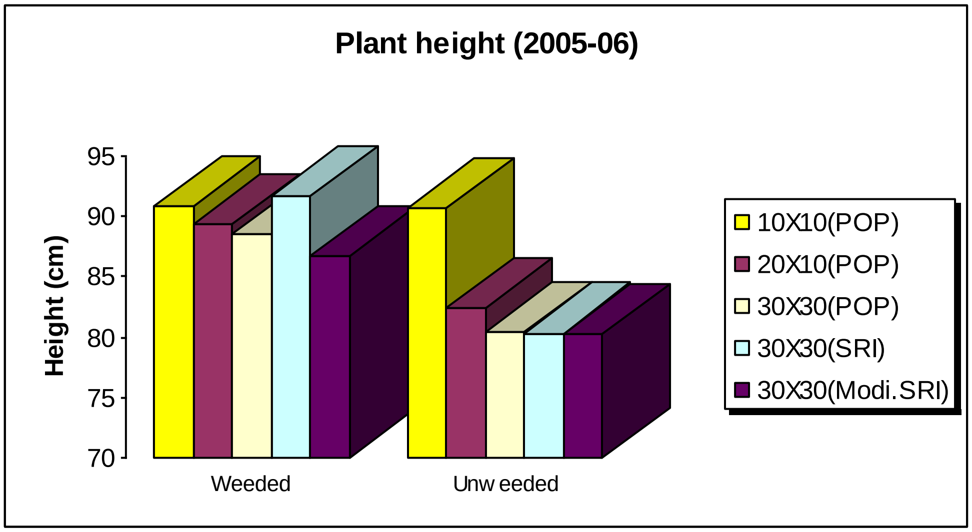
Population and dry weight of weeds

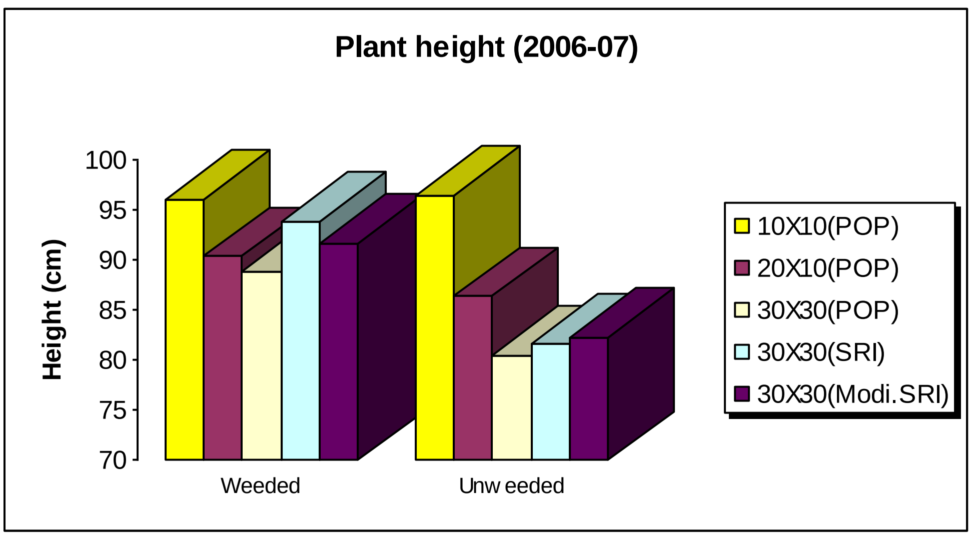
Canopy modification by plant spacing significantly helped the crop to maintain a dominant position over weeds as indicated by lower weed problems in closer spacing. At all stages of observation wider plant spacing gave higher values for weed number and dry weight (Fig.17 and 18).

Among the weeded plots, maximum number and dry weight of weeds was observed in 30 cm X 30 cm spacing. Plots with wider plant spacing recorded significantly higher number of weeds even after hand weeding whereas, number and dry weight of weeds remained lower in closer plant spacing even without weeding (Plate 5). Bhan (1968) reported the superiority of narrow (15 cm) spacing over wide (30 cm and 45 cm) spacing in minimizing weed competition in rice. Rao (2000) suggested narrow row spacing and closer plant spacing as an important weed management technique since it enhances crop competitiveness by suppressing or smothering weeds. Reduced weed growth in narrow row spacing is due to low light regime created at ground level by thick crop canopy (Shenk, 1982).

Better control of weeds was obtained under POP management and modified SRI with hand weeding or chemical weeding. Although, conoweeding under SRI management reduced weed growth during initial stages of crop growth, in the later stages the weed problem was more (Fig.19). Cono weeding at 10 days interval from 10 DAT to panicle initiation stage was not effective in controlling the weeds that grow very close to the plants (Plate 6). According to De Datta, (1981) and Moody (1991) push type rotary weeders are difficult to use because they must be moved back and forth and do not work well if soil is

Fig. 20. Plant height (cm) at harvest as influenced by weeding and plant spacing





too dry, if weeds are too big, or if flood water is too deep. It is practical only in row seeded rice and does not remove weeds within or close to the rice hills, which can still cause marked reduction in yield.

Water serves as an effective means of weed control as many weeds cannot germinate under flooded condition (Bhagat *et al*., 1996). A move from permanent flooding to intermittent irrigation and less canopy closure by crop under wider spacing favoured the population build up of weeds under SRI management. According to Latif *et al*. (2005), SRI requires 25 to 35 per cent more labour for weeding compared to best management recommendations and farmers practices.

5.4.2 Observations on crop

Crop growth characters

Main and sub plot treatments showed significant influence on the plant height (Fig.20). In general, a decline in plant height was observed in unweeded plots. Decrease in plant height due to competitive stress in unweeded plots is common as reported by many workers such as Suja and Abraham (1991) and Shukla *et al*. (1995). Although, plants with wider spacing recorded higher plant height at maximum tillering stage, at harvest stage, 10 cm X 10 cm spacing showed increased height over other sub plot treatments. Increased plant height at closer spacing was reported by Shukla *et al*. (1995).

Plants show extreme plasticity, responding remarkably in size and form to environmental conditions. One of the most potent of these external forces is the presence of competing neighbors, which may reduce a plant to diminutive size. The initial increase and later decrease in height in plants under wider spacing could be explained by the phenomenon of intra plant competition as explained by Donald (1963). The tiller production per hill was higher in 30 cm X 30 cm SRI management (Plate 7). This might have led to intra plant competition within the hill and contributed to lesser plant height

Plate 7. Effect of plant spacing on tiller production per hill

Fig.21. Number of tillers per hill as influenced by plant spacing and management

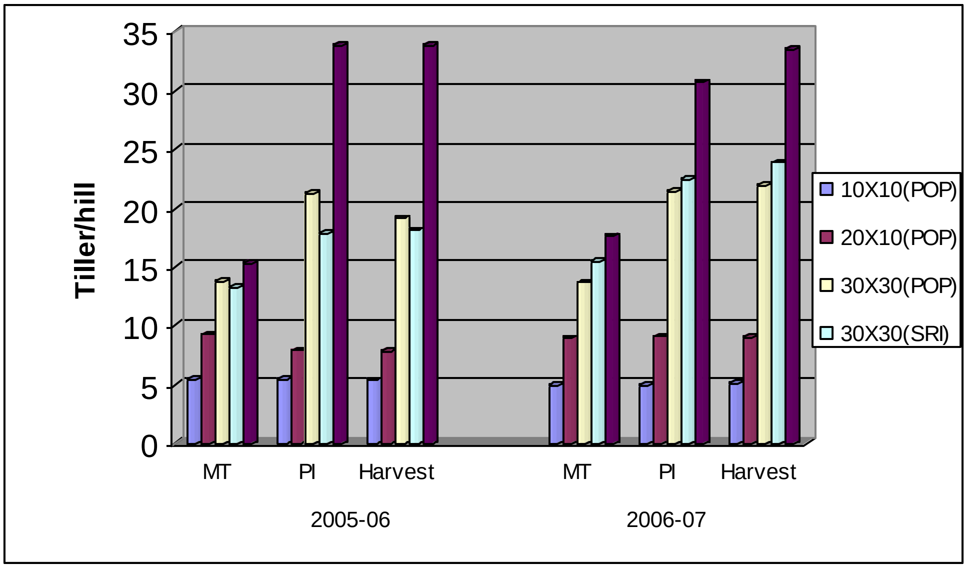
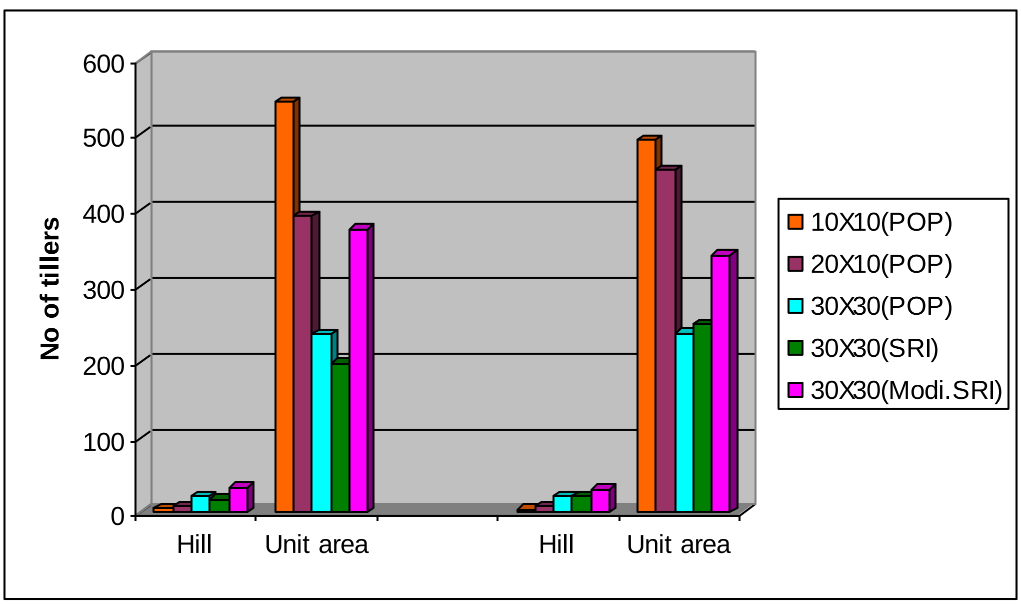


Fig 22. Effect of plant spacing on number of tillers per hill and per unit area



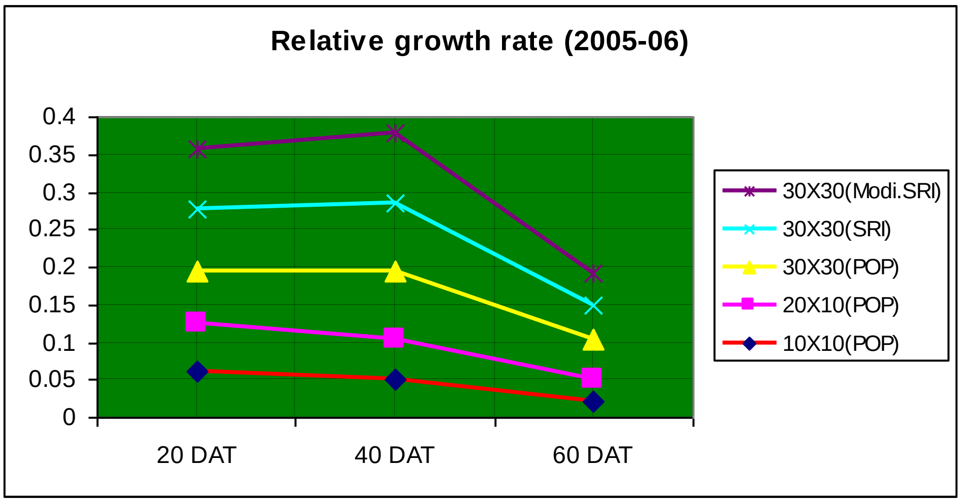
during later stages of crop growth. Reduction in plant height under SRI management compared to conventional irrigated crop was reported by Doberman (2003).

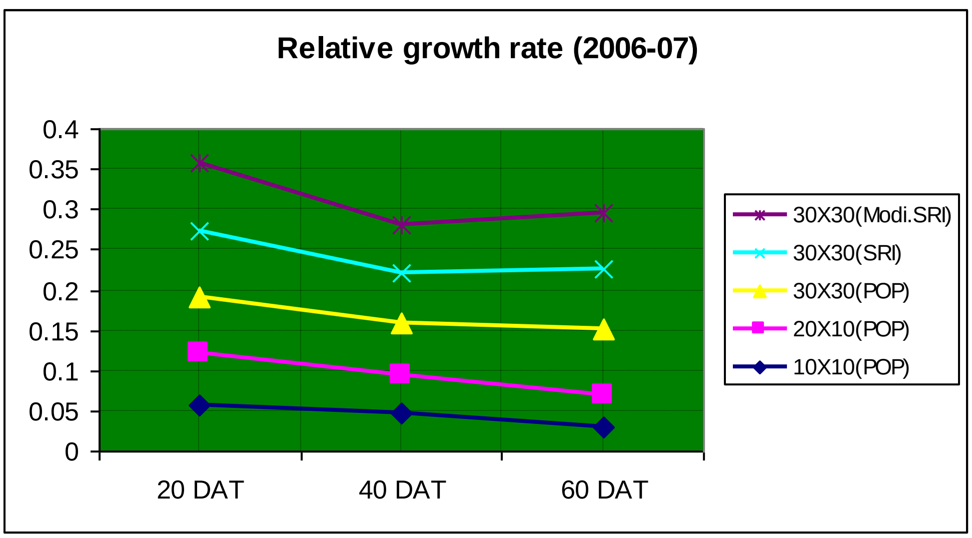
During both years of study, main plot treatments significantly influenced the tiller production with the least tiller count in unweeded plots. Observations on number of tillers per hill and per unit area showed that even though wider plant spacing favored the development of more number of tillers per hill, it did not translate to increased number per unit area. Number of plants per unit area decides the final grain and straw yields in rice. Tiller count per hill in widely spaced plants was almost 3.5 times higher than plants under closer spacing. However, tiller count per unit area showed just the reverse trend. In rice increase in number of tillers per unit area under closer plant spacing (15 cm X 15 cm) compared to wider plant spacing (20 cm X 20 cm) was reported by Singh *et al* (2003).

After maximum tillering stage, plants under POP management with closer spacing showed a general decline in number of tillers (Fig. 21 and 22). However, with the same management, plants under wider spacing (30 cm X 30 cm) showed continued tiller production up to harvest stage. Plants receiving SRI and modified SRI management also showed similar tends. Excessive tillering after maximum tillering stage is a clear indication of wastage of photosynthates and shift in source - sink balance. Photosynthates accumulated in the vegetative source have to be translocated to the reproductive sink for better yield expression. Yoshida (1972) reported that contribution of pre anthesis reserves to grain yield is important in rice, contributing up to 40 per cent of the final grain weight. Excessive tillering in plants with wider spacing caused a shift in this balance and instead of utilizing the photosynthates for filling the grains; it was utilized for continued tillering ultimately resulting in the development of greater source with less efficiency.

Plants at wider spacing under all the three management systems of POP, SRI and modified SRI recorded higher crop dry matter per plant. Lower values for dry weight of plants was recorded in 10 cm X 10 cm spacing with or without weeding. Increased dry

Fig. 23. Relative growth rate of rice under different plant spacing and management methods





weight noticed in widely spaced plots was due to increased tiller production. Nissanka and Bandara (2004) reported that dry weight of stems, leaves, roots and the total plant weightper hill were greater throughout the growing season in the SRI treatment. However, dry matter distribution and total dry weight per unit area basis was less compared to conventional methods due to density differences.

Chlorophyll content of leaves

Chlorophyll 'a', the actual photosynthetic pigment, was higher in weeded plots. While, chlorophyll 'b' was higher in unweeded plots. Increase in the content of chlorophyll 'b' in response to shading was reported by Johnston and Onwueme (1998). Plants under wider row spacing recorded higher chlorophyll 'a', 'b' and total chlorophyll contents. This might be due to increased light interception facilitated by wider plant spacing.

Leaf area index (LAI) and Relative growth rate (RGR)

Closer plant spacing favoured the development of better LAI during all stages of observation. This was due to increase in the number of leaves per unit area in plots with closer spacing. In rice higher LAI under closer plant spacing was reported by many workers for example, Rathi *et al*. (1984) and Verma *et al*. (1988).

RGR was higher in plots with wider spacing. Maximum values foe RGR was noticed at 20 DAT after which, it gradually declined with advancement in growth till maturity (Fig. 23). However, during 2005-2006 under wider plant spacing RGR increased up to 40 DAT. This was due to continued tiller production after maximum tillering stage in these plots. Shrivasthava and Saxena (1982) and Shukla *et al*. (1995) reported that in rice, relative growth rate was maximum up to 30 DAT, possibly due to higher rates of photosynthesis and absorption of minerals.

Yield and yield attributes

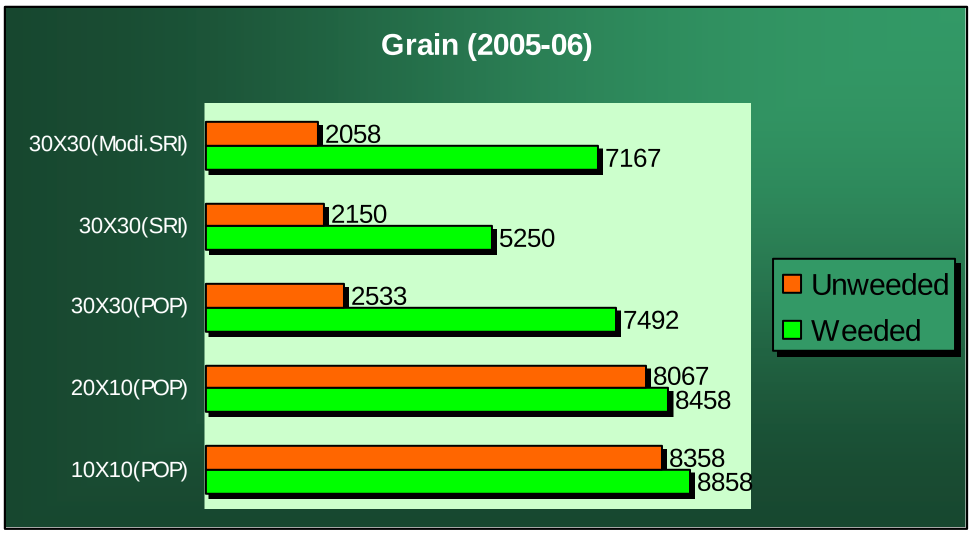
Weeded plots had significant superiority over un weeded plots (Fig. 24) for grain and straw yields. Reduction in yield of rice due to crop weed competition was reported earlier by several workers such as Gosh and Singh (1996), Balasubramanian and Krishnarajan (2001) and Saha *et al*. (2005).

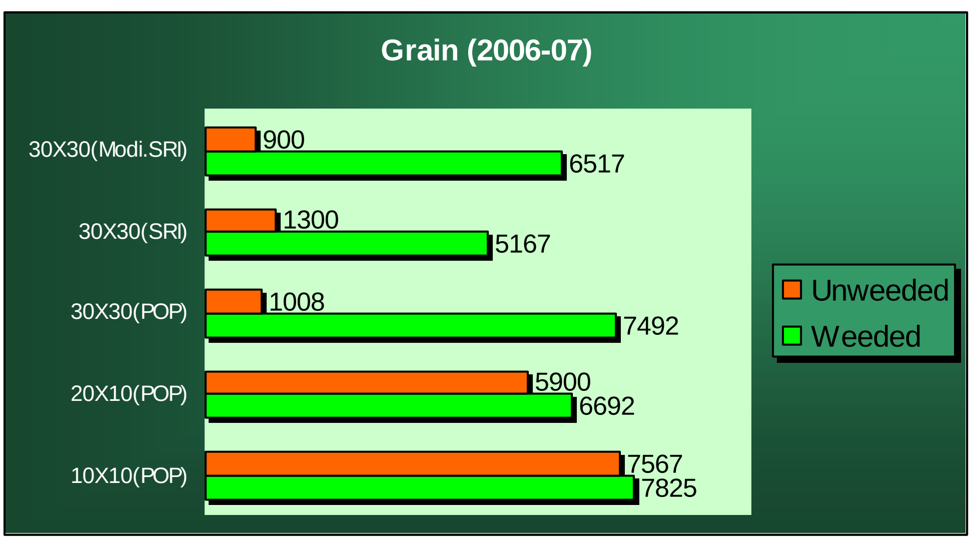
During both years of study, the grain yield was superior in closer plant spacing. Wider plant spacing caused reduction in grain yield. The yield advantage in closer plant spacing was mainly due to higher number of panicles per unit area. Increased grain yield under closer plant spacing was reported by Gupta and Sharma (1991), Reddy and Reddy (1991) and Singh *et al*. (2003).

Plots with closer plant spacing (10 cm X 10 cm) under POP management recorded 1366 kg ha^{-1}more than wider plant spacing (30 cm X 30cm) under same management method and 3608 kg ha^{-1} more grain than SRI management during first year of study and the difference in the second year were 1333 kg and 2658 kg ha^{-1} respectively. The reduction in grain yield in unweeded plots under closer plant spacing (10 cm x 10 cm) was negligible when compared to weeded plants. This points out the possibility of maintaining the field without much economic loss from weeds by transplanting 20 day old seedlings with two seedlings per hill. This is both economical and ecofriendly as the need for hand weeding or herbicides is eliminated.

Yield advantage often claimed in System of Rice Intensification (SRI) method was not observed in the present study. Total grain and straw yields were lower in SRI plots. The main factor that contributed to lower yield was the reduced number of tillers per unit area. In addition, continued tiller production even after panicle initiation stage might have affected the assimilate partitioning to the developing grains. Wang *et al*. (2003) gave explanation for reduced yield in SRI. According to him under SRI management rice yield was limited by low tiller number and restricted dry matter translocation percentage from vegetative organs to grains. Yield reduction in SRI compared to best management practices

Fig 24. Grain yield of rice under different systems of crop production





and conventional methods was reported by many workers such as Moser and Barret (2003), Sheehy *et al*. (2004), Barret *et al*. (2004), Latif *et al*. (2005), Mc Donald *et al*. (2006) and Joseph *et al*. (2006).

Modifying the SRI practice with chemical fertilizers and herbicidal weed control significantly improved the yield than original SRI. Considering the practical difficulties in the adoption of SRI, Zheng *et al*. (2004) and TNAU (2007) suggested modified SRI, where the crop management practices are almost similar to the package of practices recommendations by the Kerala Agricultural University (KAU, 2007).

The yield attributes, panicle length, number of filled grains and 1000 grain weight, were higher in 10 cm X 10 cm POP. Increase in plant spacing and no weeding reduced these parameters. However, panicle weight was superior in 30 cm X 30 cm SRI. Donald (1963) suggested that greater seed weight and number of seeds per inflorescence at intermediate densities are due to the variations in the time of incidence of inter plant and intra plant competition. At the widest spacing of 30 cm x 30 cm, competition is absent in early stage of crop growth and flower primordia are laid down by each plant in large numbers. As growth proceeds, intra plant competition becomes progressively operative and thereby reduce the efficiency of seed production.

The loss in efficiency at the wider spacing was reflected in reduced number of filled grain per inflorescence and reduced grain weight as compared to somewhat denser plant stands. Higher panicle weight, fewer number of filled grains and low 1000 grain weight in wider spacing are clear indications of intra plant competition. Efficient utilization of growth resources coupled with less intra plant competition among closely spaced plants may be ascribed as the reasons for the higher values of yield contributing factors. The present experiment indicates that SRI system does not hold much promise in regions where farmers follow recommended package of practices.

Summary

6. SUMMARY

Competition from weeds and consequent yield reduction are major problems in rice cultivation, which warrants proper weed management either by the use of herbicides or by adopting manual weeding. In Kerala, manual weeding has become very costly due to high wages and shortage of labour. Herbicides have come to stay as a farmer friendly practice. However, chances are that the over dependence and over use of herbicides may create undesirable environmental problems. Therefore, a study was conducted to develop and refine non chemical techniques of weed management integrating stale seed bed techniques and manipulation of plant population. Documentation of existing weed control practices of major rice growing areas of Kerala was also an objective of the study.

The study was undertaken as three separate experiments

Expt. 1. Survey and documentation of weed management practices followed by rice farmers

Palakkad, *Kole*, Pokkali and Kuttanad regions were selected for the study since they are the major rice farming areas of Kerala. The survey was conducted during the first crop season of 2006-07.

Summer plouging was the major weed control method practiced by the farmers of Palakkad, *Kole* and *Kuttanad* .Stale seed bed (flooding) was a common method of weed control in *Kuttanad*. The survey revealed the superiority of chemical and physical methods of post emergence weed control. Mechanical methods were not much popular in rice growing areas. In *Pokkali* lands, the only method of weed control is hand pulling. The major herbicide used by the farmers of Palakkad, *Kole* and *Kuttanad* was Fernoxone (2, 4-D). None of the farmers surveyed were using herbicides for weed control in *Pokkali* lands.

Expt. II. Stale seed bed techniques suited for dry seeded and wet seeded rice

a) Dry seeded rice

The experiment on stale seed bed techniques for dry seeded rice was conducted at ARS, Mannuthy during the first crop season of 2006 and 2007. The trial was laid out in split plot design with four main plots, six sub plots and three replications.

Seed bed preparation significantly influenced the germination and establishment of weeds. Population and dry weight of weeds were the lowest in stale seed bed for 14 days. Stale seed bed for 14 days with one hoeing was the next best treatment which lowered the population and dry matter accumulation by weeds. Stale seed bed technique adopted for forcing the germination of weed seeds showed differential influence on different groups of weeds. Grass weeds gave the highest germination percentage immediately after seed bed preparation, and hence better control of grasses was achieved followed by broad leaf weeds. However, seed bed manipulation was not effective on sedges.

Among the sub plot treatments, pre emergence spraying of Rifit (Pretilachlor) and concurrent growing of cowpea gave significant reduction in the population and dry weight of weeds. Spraying of Rifit (Pretilachlor) in plots with stale seed bed for 14 days with two hoeings successfully managed the weed problem in dry seeded rice.

Stale seed bed technique provided a partially weed free environment at early crop growth stages and allowed the crop to yield better than normal seed bed. Compared to unweeded plots of normal seed bed, those of stale seed bed for 14 days with two hoeings exhibited a yield increase of 2711 kg ha^{-1} and 2145 kg ha^{-1} during 2006 and 2007 respectively. Stale seed bed for 14 days gave the highest B:C ratio during both years of study.

b) Wet seeded rice

The experiment on stale seed bed techniques suited for wet seeded rice was conducted in the field of Mr. Kesavaraj, Kulappully house, Purathur, in Alappad *Kole* lands of Thrissur district during the Mundakan season of 2005 and 2006. The trail was laid out in split plot with three main plots, five sub plots and three replocations.

Stale seed bed either for 7 or 14 days gave complete control of grasses during the first year and significantly lower values during second year. Under wet seeded condition, stale seed bed gave successful control of broad leaf weeds too. Among the sub plot treatments, pre emergence spraying of Sofit (Pretilachlor + safener) and concurrent growing of daincha gave significant reduction in the population and dry weight of weeds. Sofit (Pretilachlor + safener) spray exhibited the greatest influence on broad leaf weeds.

Higher plant height, number of tillers and crop dry matter were noticed in stale seed bed plots. Stale seed bed preparation has brought an increase in the grain and straw yields of wet seeded rice than normal seed bed. An increase in stale seed bed period contributed to corresponding increase in the yields as evident by higher grain yield in plots with stale seed bed for 14 days.

In situ green manuring of daincha by cono weeding and cono weeding for incorporation of weeds gave almost similar grain yields, and it was inferior to Sofit (Pretilachlor + safener) sprayed and hand weeded plots. Unweeded plots recorded lower yield attributing parameters mainly because of severe crop weed competition. In the main plot treatment stale seed bed for 14 days, hand weeding, pre–emergence spraying of Sofit and concurrent growing of daincha gave benefit cost ratios above 4.0 in both years.

Expt. III. Crop weed competition in transplanted rice: Influence of plant stand

Canopy modification by plant spacing significantly helped the crop to maintain a dominant position over weeds as indicated by lower weed problems in closer spacing. At all stages of observation, wider plant spacing gave higher weed count and dry weight. Cono weeding at 10 days interval from 10 DAT to panicle initiation stage was not effective in controlling the weeds that grow very close to the plants.

Observations on number of tillers per hill and per unit area showed that even though wider plant spacing favored the development of more number of tillers per hill, it did not translate to increased number per unit area. Tiller count per hill in widely spaced plants was almost 3.5 times higher than plants under closer spacing. However, tiller count per unit area showed just the reverse trend.

During both years of study, grain yield was superior in closer plant spacing. Wider plant spacing caused reduction in grain yield. Plots with closer plant spacing (10 cm X 10 cm) under management as recommended by Kerala Agricultural University, recorded 1366 kg ha^{-1}more than wider plant spacing (30 cm X 30cm) under same management method and 3608 kg ha^{-1} more grain than SRI management during first year of study and the difference in second year were 1333 kg and 2658 kg ha^{-1} respectively. The reduction in grain yield in unweeded plots under closer plant spacing (10 cm x 10 cm) was negligible when compared to weeded plants. Total grain and straw yields were lower in SRI plots. Modifying the SRI practice with chemical fertilizers and herbicidal weed control significantly improved the yield than original SRI.

The highest cost of production and the lowest benefit cost ratio was worked out from weeded plots under SRI management. Closer plant spacing (10 cm X 10 cm) even without weeding gave considerably superior yield, and thus better benefit cost ratio.

From the study, it could be concluded that stale seed bed technique is an efficient tool for the management of weeds both under semi dry and wet seeded condition. The ecofriendly treatments of hand weeding and concurrent growing of green manure crops under stale seed bed situations gave almost similar control of weeds with that of pretilachlor.

In *Kole* lands, reduction in grain yield in unweeded plots under closer plant spacing (10 cm x 10 cm) was negligible when compared to weeded plants. This points out the possibility of maintaining the field without much economic loss from weeds by transplanting 20 day old seedlings with two seedlings per hill at a spacing of 10 cm X 10 cm. This is both economical and ecofriendly as the need for hand weeding or herbicides is eliminated. The present experiment also indicates that SRI system does not hold much promise in regions where farmers follow recommended package of practices.

References

REFERENCES

Abayomi, Y.A., Fadayomi, O., Babatola, J.O. and Tian, G. 2001. Evaluation of selected legume cover crops for biomass production, dry season survival and fertility improvement in a moist savanna location in Nigeria. *Afr. Crop Sci. J.* 9:615-627

Ahmed, N.U. 1981. Weed control in dry seeded bunded rice and its residual effect on weed growth of the subsequent transplanted rice. *IRRI Newsl.*6:13

AICRP-WC. 1992. *Annual Progress Report, 1990-91*. All India coordinated research programme on weed control, Thrissur centre, Kerala agricultural university.

AICRP-WC. 2006. *Annual Progress report, 2006-07*. All India coordinated research programme on weed control, Thrissur centre, Kerala agricultural university.

Akobundu, I.O. 1987. *Weed Science in the Tropics: Principles and Practices*. Wiely, Chicester, 522p.

Akobundu, I.O. and Fagade, S.O. 1978. Weed problems of African rice lands. In: Buddenhagen, I.W. and Persley, G.J. (eds.), *Rice in Africa*. Academic Press, London. pp.181-192

Ali, A.M. and Sankaran, S. 1984. Effect of time of application and residual effect of herbicides on direct seeded flooded rice and rainfed bunded rice. *IRRI Newsl.* 9:21

Allard, J.L. and Zoschke, A. 1990. A solution to the major weed problems in wet sown rice: Experiments with pretilachlor + fenclorim in SE Asia. In: *Proceedings of the Seminar on Pest Management in Rice*, 4-7 June, 1990. Chemical Industry, London pp.378-388

Almamum, A., Jerajak, J.A. and Kjadir. 1986. Crop production in Iraque with emphasis on weeds and their control. *Bangladesh J. agric. Sci*. 13(2):19-29

Ampong – Nyarko, K. and De Datta, S.K. 1991. *A Hand Book of Weed Control in Rice*. IRRI, Philippines, 113p.

Arai, M. 1967. Competition between rice plants and weeds. In: *Proceedings of 1st Asian Pacific Weed Control Interchange*, Japan pp. 37-41

Azmi, M. and Baki, B.B. 2002. Impact of direct seeding rice culture on wed species diversity in the Malasian rice ecosystem. In: Omar, R., Rahman, A., Lihan, T. and Adam, J.H. (eds.), *Proceedings of the Regional Symposium on Environmental and Natural Resources,* 10-11th April, 2002, Kuala Lumpur, Malaysia, Vol. I, pp-61-67

Baki, B.B. and Khir, Md. 1983. Weeds in major rice growing areas in Peninsular Malasia: detection and classification of groups of ecologically related species by multivariate analysis. In: Rosli, M. and Rajan, A. (eds.), *Proceedings of 1st International Symposium on Weed Science in the Tropics*, Kuala Lumpur, pp. 4-27

Balasubramanian, R. and Krishnarajan, J. 2001. Weed population and biomass in direct seeded rice (*Oryza sativa*) as influenced by irrigation. *Indian J. Agron*. 46(1):101-106

Balasubramaniyan, P. and Palaniappan, S.P. 2001. *Principles and Practices of Agronomy*. Agrobios, Jodhpur. 577p.

Balaswamy, K. and Kondap, S.M. 1988. Nutreint uptake as influenced by forms of urea and herbicides in transpalted rice. *Andhra Pradesh Res. J*. 17:121-123

Baltazar, A.M. and De Datta, S.K. 1992. Weed management in rice. *Weed Abstr*. 41:308-495

Barnes, J.D., Balaguer, L., Manrique, E., Elvira, S. and Davison, A.W. 1990. A reappraisal of the use of DMSO for the extraction and determination of Chl ‘a’ and Chl ‘b’ in lichens and higher plants. *Environ. Exp. Bot*. 32:85-100

Barret, C.B., Moser, C.M., Mettugh, O.V. and Barison, J. 2004. Better technology, better plots or better farmers? Identifying changes in productivity and risk among Malagasy rice farmers. *American J. Agric. Econ*. 86(4):869-888

Barret, S.C.H. and Seaman, D.E. 1980. The weed flora of Californian rice fields. *Aquatic Bot*. 9:351-376

Batuvitage, G.P. 2006. Adopting SRI in Tamil Nadu, India. *LEISA India* 8(4): .9-10

Benvenuti, S. and Macchia, M. 2006. Seed bank reduction after different stale seed bed techniques in organic agricultural systems. *Italian J. Agron*. 1:11-21

Benvenuti, S., Macchia, M. and Miele, S. 2001. Quantitative analysis of buried weed seedling emergence with increasing soil depth. *Weed Sci*. 49:528-535

Berkelaar, D. 2001. SRI, the system of rice intensification : less can be more. *ECHO Devpt notes Issues* 70:12-18

Bhagat, R.M., Bhuiyan, S.I. and Moody, K. 1996. Water, tillage and weed interactions in low land tropical rice; a review. *Agric. Water Mgmt* 31:165-184

Bhan, V.M. 1968. Weed management in rice. *RISO* 17:149-154

Bhan, V.M. 1983. Effects of hydrology, soil moisture regime and fertility management on weed populations and their control in rice. In: *Weed Control in Rice*. International Rice Research Institute, Philippines, pp. 47-56

Bhan, V.M. 1994. Weed infestation in rice. *Indian J. Agron*.39:345

Biswas, J.C. and Sattar, S.A. 1991. Effect of nitrogen uptake by weeds on rice yield. *IRRI Newsl*. 16(5):26

Biswas, S.B. and Thakur, R.C. 1983. Weed control in direct seeded upland rice. *IRRI Newsl* 8(6):20

Bruff, S.A. and Shaw, D.R. 1992. Early season herbicide application for weed control in stale seed bed soybean (*Glycine max).* *Weed Technol*. 6(1):15-18

Buchanan, G.A. and Hoveland, C.S. 1973. Soil P and K levels on growth of warm season weed and crop species. In: *Proceedings of Weed Science Society of America*. Abstract :120

Carlson, W.L. and Hill, J.E. 1986. Wild oat (*Avena fatua*) competition with spring wheat: effect of nitrogen fertilization. *Weed Sci*. 34:29-33

Castin, E.M. and Moody, K. 1989. Effect of different seeding rates, moisture regimes and weed control treatments on weed growth and yield of wet seeded rice. In: *Proceedings of 12th Asia Pacific Weed Science Society Conference* No. 2, pp. 337-334

Chakraborthy, T. 1973. Nature of competition between weeds and rice for nitrogen under dry land conditions. *Exp. Agric.* 9(3):54-56

Chandra, D., Moorthy, B.T.S., Jha, K.P. and Manna, G.B. 1991. Agronomic practices for augmenting rice (*Oryza sativa*) production in rainfed upland ecosystems of Orissa. *Indian J. Agron*. 36(3):313-321

Chang, W.L. 1973. Chemical weed control practice for rice in Taiwan. *PANS* 19:514-522

Chang, W.L. and De Datta, S.K. 1974. Weed control in direct seeded rice. *PANS* 20:425-428

Chisaka, H. 1977. Weed management to crops: yield loss due to weed competition. In: Fryer, J.D. and Matsunaka, S. (eds.), *Integrated Control of Weeds*. University of Tokyo, pp. 16

Choudhari, C.N. and Pradhan, A.C. 1988. Weed control in direct sown upland rice. *Indian J. Weed Sci*. 20:91-93

Clements, F.E. 1970. *Plant Physiology and Ecology*. HOH and co, London. 269p.

Conn, E. and Stumpf, P.K. 1976. *Outlines of Biochemistry* (4th ed.). John Wiley and sons, New York. 417p.

De Datta, S.K. 1974. Weed control in rice: Present status and future challenges. *Philipp. Weed Sci. Bull*. 1: 1-16

De Datta, S.K. 1977. Approaches in the control and management of perennial weeds in rice. In: *Proceedings of the Asia Pacific Weed Science Society*, June, 1977. Changmai, Thailand, pp. 205-226

De Datta, S.K. 1981. *Principles and Practices of Rice Production*. John Wiley and sons, Newyork, 618p.

De Datta, S.K. 1989. Integrated nitrogen management in irrigated rice. *Adv. Soil Sci*. 10:143-169

De Datta, S.K., Park, J.K. and Hawes, J.K. 1968. Granular herbicides for controlling grasses and other weeds in transplanted rice. *IRRI Newsl*. 17(4):21-29

Dhiman, S.D., Mohan, P.S.R. and Sharma, H.C. 1985. Studies on cultural methods of weed control in wheat. *Indian J. Agron*. 36:54-59

Diekman, K.H., De Datta, S.K. and Ottow,J.C.G. 1992. *Sesbania rostrata* and *Aeschynomene afraspora* effects on crop establishsmnet of transplanted low land rice. *IRRI Newsl*. 17(3):15

Doberman, A. 2003. A critical assessment of the system of rice intensification (SRI). *Agric. Syst*. 79(3):261-281

Donald, C.M. 1963. Competition among crop and pasture plants. *Adv.Agron*. 15: 1-118.

Dotzenko, A.D., Ozkan, M. and Storer, K.R. 1969. Influence of crop sequences, nitrogen fertilizer and herbicides on weed seed population in sugar beet fields. *Agron. J*. 61:34-37

Ferrero, A., Vidotto, F., Balsari, P. and Airoldi, G. 1999. Mechanical and chemical control of red rice (*Oryza sativa var. sylvatica*) in rice (*Oryza sativa*). *Crop Prot*. 18:245-251

Fischer, C. 1921. An examination of the yield of dressed grain from Broadbalk. *J. agric. Sci*. 11:107-135

Freed, R. 2006. MSTAT - C version 7. Department of crop and soil sciences, Michigan State University

Godel, G.L. 1935. Relations between rate of seedling and yield of cereal crops in competition with weeds. *Sci. Agric.* 16:165-168

Gomez, A.K. and Gomez, A.A. 1984. *Statistical Procedures for Agricultural Research* (2nd edition). John Wiley and sons, New York. 657p.

Gomez, K.A. 1972. *Techniques for Field Experiments with Rice.* International Rice Research Institute, Philippines. 46p.

Gosh, D.C. and Singh, B.P. 1996. Effect of cultural practices on weed management and productivity of wet land rice. *Indian J. agric. Res.* 30(2):123-126

Guha, P. 1991. Control of *Chara* with oxadiazon and $CuSO_4$ in waterlogged rice fields in India. *Crop Prot.* 10(5):371-374

Gupta, A.K. and Sharma, R.S. 1991. Effect of plant spacing and fertility level on grain yield of early medium indica rice (*Oryza sativa*). *Indian J. Agron.* 36:223-225

Hartman, K.M. and Nezadal, W. 1990. Photo control of weeds without herbicides. *Naturewissenshaften*. 77:158-163

Hassan, S.M. and Rao, A.N. 1996. Weed management in rice in the near east. In: Au, B.A. and Ki, K.U. (eds.), *Weed Management in Rice*. FAO Plant Production and Protection Paper 139. Oxford and IBH , Culcutta, pp. 141-153

Holm, L., Pancho, J.V., Herberger, J.P. and Plucknett, D.L. 1977. *A Geographical Atlas of World Weeds*. John Wiley and Sons, New York. 391p.

Hooda, I.S. 2002. Weed management in organic rice. In: *First RDA/ARNOA International Conference on Development of Basic Standard for Organic Rice Cultivation*, 12-15 November, 2002, RDA and Dakook, University of Korea, Korea, pp. 15-25

Hosmani, M.M. 1991. *Cultural Methods of Weed Management*. Manohar Printing Press, Dharward, 19p.

Hosmani, M.M. and Meti, S.S. 1993. Non-chemical weed management in crop production. In: *Proceedings of an International Symposium on Integrated Weed Management for Sustainable Agriculture*, Indian Society of Weed Science, Hissar, Vol. I, pp. 299-305

Ishikawa, M. 1988. Green manuring in rice: the Japanese experience. In: *Proceedings on Symposiun on Sustainable Agriculture – The Role of Green Manure Crops in Rice Farming Systems*. IRRI, Los Banos, Philippines, pp. 285-287

IRRI [International Rice Research Institute]. 1979. Methods of land preparation for weed control in dry seeded rice. In: *Annual report, 1979*. IRRI, Los Banos, Philippines. 224p.

Iruthyaraj, M.K. and Morachan, Y.B. 1980. Effect of season and water management on LAI and yield of short duration rice varieties. *Mysore J. agric. Res*. 14:183-189

Islam, M.J. and Molla, H.R. 2001. Economic weeding method for irrigated rice production in Bangladesh. *Agric. Water Magmt.* 46(3):267-276

Jackson, M.L. 1958. *Soil Chemical Analysis*. Prentice Hall Inc, New Jersey. 498p.

Jacob, D. and Syriac, E.K. 2003. Effect of spacing and weed control treatments on weeds of scented rice. *Indian J. Weed Sci*. 35(3-4)262-263

Jacob, D., Syriac, E.K. and Pusphakumari, R. 2005. Spacing and weed management in transplanted basmati rice. *Madras agric. J*. 92(4-6):224-229

Jayasree, P.K. 1987. Efficiency of thibencarb in dry sown rice. M.Sc. (Ag.) thesis, Kerala Agricultural University, Trichur, 115p.

Jiague, Z. Lu Xianjun, Xinlu Jiang and Yonglu tang. 2004. The system of rice intensification (SRI) for super high yields of rice in Sichuan basin. In : *Proceedings of 4th international crop science congress*, Brishane, Austarlia, 26th Sept. to 1st Oct. 2004. Available: www.cropscience.org.au/icse 2004 [10-02-2007]

Jiang, R.C. 1989. The field weeds chemical control series and systematic management. In: *Proceedings of Asian Pacific Weed Science Society Conference*, China pp. 467-473

John, P.S. and Sadanandan, N. 1989. Effect of application of 2,4-D mixed with urea in low land direct sown rice. *Agric. Res. J. Kerala*. 27:44-46

John, P.S. and Mathew, R. 2001. Stale seed bed – an alternative technology for preplanting to achieve total weed control in direct seeded low land rice. *IRRI Newsl.* 26.2: 67-68

Johnson, C.W. and Mullinix, G.B. 1998. Stale seed bed weed control in cucumber. *Weed Sci*. 46(6):698-702

Johnston, M. and Onwueme, I.C. 1998. Effect of shade on photosynthetic pigments in the tropical root crops; yam, tannia, cassava and sweet potato. *Exptl. Agric.* 34:301-312

Johri, A.K. and Singh, G. 1991. Herbicide cum cultural control of weeds in wheat. *Indian J. Agron*. 36:54-59

Joseph, J., Francis, R.M., Zachariah, G. and Kumar, A.V.S. 2007. Evaluation of two short duration varieties of paddy under different systems of planting. In: Muthunayagam, A.E. (ed.), *Proceedings of the 19th Kerala Science Congress*; 29-31 January, 2007, Kannur, Kerala State Council for Science, Technology and Environment. pp.461-463

Joseph, P.A. 1986. Influence of different ecological situations on weed emergence in wetland rice. *IRRI Newsl*. 11(4):38

Joy, P.P., Syriac, E.K., Nair, P.K.C. and Joseph, C.A. 1991. Weed control in wet seeded rice in Kerala, India. *IRRI Newsl*. 16(6):25

Joy, P.P., Syriac, E.K., Ittyaverah, P.J. and Joseph, C.A. 1993. Herbicidal technology for weed control in low land rice of Kerala. In: *Proceedings of the 5th Kerala Science Congress,* January, 1993, Kottayam, Kerala State Council for Science, Technology and Environment. pp. 135-137

Karim, R.S. Man, A.B. and Sahid, I.B. 2004. Weed problems and their management in rice fields of Malaysia – an overview. *Weed Biol. Mgmt* 4(4):177-186

KAU [Kerala Agricultural University]. 2002. *Package of Practices Recommendations-'Crops' 2002*. Directorate of Extension, Kerala Agricultural University , Thrissur. 267p.

KAU [Kerala Agricultural University] 2007. *Package of Practices Recommendations-'Crops' 2007*. Directorate of Extension, Kerala Agricultural University, Thrissur.334p.

Kim, K.U. and Park, K.H. 1996. Biology of paddy weeds. In: Auld, B.A. and Kim, K.U. (eds.), *Weed Management in Rice*. FAO Plant Production and Protection Bulletin Paper 139. Oxford and IBH, New Delhi. pp. 9-23

Kim, S.C. And Moody, K. 1989. Adaptation strategy in dry matter and seed production of rice and weed species. *Korean J. Weed Sci*. 9:183-200

Korres, N.E. and William, R.J.F. 1997. The use of varietal selection and seed rates for enhanced weed suppression in winter wheat (*Triticum eastivem*). In: *Proceedings of the Brighton Crop Protection Conference on Weeds,* 1997, Brighton, U.K. pp.667-668

Kukula, S.T. 1985. *Weed Management in Dry land Cereals Production with Special Reference to Near East*. FAO Plant Production and Protection Paper No. 80, FAO, Rome, Italy. 189p.

Kumar, A. Shivay, Y.S. and Pandey, J. 2007. Effect of crop establishment methods and weed control practices on weed dynamics, productivity, nutrient removal by weeds vis-à-vis crop and quality of aromatic rice (*Oryza sativa*). *Indian J. agric. Sci*. 77(3):179-183

Kumar, B.M. 1984. Studies on the interactive effects of water regimes, weed control treatments and nitrogen levels in direct seeded rice. Ph.D thesis, IARI, New Delhi.

Kumar, B.M. and Singh, K.N. 1984. Studies on N, water and weed control in upland direct seeded rice. 1. Nitrogen depletion by weeds and crop and crop productivity. *Indian J. Agron*. 29(4):448-452

Kumar, D., Angrias, N.N. and Rana, S.S. 2002. Influence of seed bed manipulations and herbicides on leaf area index and growth rate of wheat and associated weeds. *Himachal J. agric. Res*. 28(1&2):1-10

Kumar, D., Shivay, Y.S., Mishra, B.N. and Gautam, R.C. 2005. Rice intensification: a new approach to rice cultivation. *Kurukshetra* 45(2):27-29

Lakshmi, S. 1983. Weed control method for semi dry dibbled crop of rice. M.Sc. (Ag.) thesis, Kerala Agricultural University, Trichur, 150p.

Latif, M.A. Islam, M.R., Ali, M.Y., and Saleque, M.A. 2005. Validation of the system of rice intensification (SRI) in Bangladesh. *Fld Crops Res*. 93(2-3):281-292.

Laulanie, H. 1993. Le systeme de riziculture intensive malgache. *Tropicultura* (Brussels) 11:110-114

Lonsbary, K.S., Sullivan, O.J. and Swanton, J.C. 2003. Stale seed bed as a weed management alternative for machine harvested cucumbers (*Cucumis sativus*). *Weed Technol*. 7(4):724-730

Loomis, W.E. 1958. Basic studies in botany, ecology and plant physiology. In *Proceedings of North Central Weed Conference*, Philippines. pp.15-81

Lubigan, R.T. and Vega, M.R. 1971. The effect on yield of the competition of the rice with *Echinochloa crusgalli* and *Monochoria vaginalis*. *Philipp. Agricst.* 1:210-215

Mabbayad, M.O. and Moody, K. 1984. Effect of time of application of herbicides on crop damage and weed control in wet seeded rice. *IRRI Newsl*. 9(3):22

Maheswari, S.B. 1987. Integrated weed management in transplanted medium duration rice. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 165p.

Malik, R.K. and Moorthy, B.T.S. 1996. Present status and problems of weed management in rice in South Asia. In: Auld, B.A. and Kim, K.U. (eds.), *Weed Management in*

Rice. FAO Plant Production and Protection Paper 139. Oxford and IBH, New Delhi. pp. 125-139

Mandal, R.C. 1990. *Weed, Weedicides and Weed Control – Principles and Practices*. Agro botanical Publishers (India), Bikaner. 219p.

Mani, U.C., Gautam, K.C. and Chakraborthy, T.K. 1968. Losses in crop yield in India due to weed growth. *PANS* 14:142-158

Matsunaka, S. 1983. Evaluation of rice weed control practices and research – world perspective. *Proceedings of 1981 Weed Control Rice conference*, Japan. pp. 5-18

Mc Donald, A.J., Hobbs, P.R. and Riha, S.J. 2006. Does the system of rice intensification outperform conventional best management?. A synopsis of the empirical record. *Fld Crops Res*. 96(1):31-36

Mohankumar, P.D. 1995. Effectiveness and crop selectivity of pre emergence herbicides under different methods of application in puddle rice. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur.84p.

Mohankumar, P.D., Savithri, K.E. and Sreedevi, P. 1996. Functional efficiency of pre mergence herbicides in wet seeded rice. *J. trop. Agric.* 34:149-151

Moody, K. 1977. Weed control in rice. In: *5th Biotroph Weed Science Training Couse, Lecture note 30*. Rubber research Institute, Kuala Lumpur, Malaysia, pp. 374-424

Moody, K. 1983. The status of weed control in rice in Asia. *FAO Plant Protection Bulletin* 30 (3/4):110-123

Moody, K. 1988. *Weed Management in Wet Seeded Rice*. Food and fertilizer Technology Centre, Taipei, Taiwan. 28p.

Moody, K. 1989. *Weeds reported in rice in South and South East Asia*. International Rice Research Institute, Los Banos, Philippines. 442p.

Moody, K. 1991. Weed management in rice. In: Pimental, D. (ed.), *Hand Book of Pest Management in Agriculture*. CRC Press, Florida. pp.301-328

Moody, K. 1996. Weed management in rice. In: Auld, B.A. and Kim, K.U. (eds.), *FAO Plant Production and Protection Bulletin Paper 139*. Oxford and IBH, New Delhi. pp. 89-98

Moody, K. and Mukhopadhyay, S.K. 1982. Weed control in dry seeded rice, present problems and future research directions. In : *Report of Workshop on Cropping System Research in Asia*. IRRI, Philippines. pp.147-158

Moorthy, B.T.S. 1980. Relative efficiency of some granular herbicides for weed control in direct seeded rice on puddle soil. *Oryza* 17(2):132-134

Moorthy, B.T.S. 1992. Effect of methods of land preparation and herbicide use on weed control and crop performance of rain fed upland rice. *Indian J. agric. Sci.* 62(16):382-386

Moorthy, B.T.S. and Dubey, A.N. 1978. Weed control in puddle seeded rice (Rabi). In: *Annual Report-1978*, CRRI, Cuttack. pp.131-132

Moorthy, B.T.S. and Manna, G.B. 1982. Herbicides for weed control in puddle seeded rice. In : *Annual Conference on Indian Society of Weed Science,* Hyderabad. Abstract:13

Moorthy, B.T.S. and Mittra, B.N. 1990. Uptake of nutrients by upland rice and associated weeds as influenced by nitrogen application schedules and weed management practices. *Crop Res*. 3(2):144-150

Moser, C.M. and Barret, C.B. 2003. The disappointment adoption dynamics of a yield increasing, low external input technology: the case of SRI in Madagascar. Available:www.lib.ncsu.edu/pubweb/www/ETD-db/web_root/ collection/available/etd-3172005-115144/unrestricted/etd.pdf [10-05-2007].

Moyer, J.R., Richards, K.W. and Schaalje, G.B. 1991. Effect of plant density and herbicide application on alfalfa seed and weed yields. *Can. J. Pl. Sci*. 71:481-489

Mukherjee, D. and Singh, R.P. 2005. Evaluation of sulfonyl urea herbicides to control weeds in transplanted rice. *Pest Sci. Mgmt* (IRRN 30.2). December 2005. pp. 20-21

Mukhopadhyay, S.K. 1987. Weed management in rice and rice based cropping systems. In: Shad, R.A. (ed.), *Advances in Weed Science, A Case of India and Pakistan Subcontinent.* Pakistan Agricultural Research Council, Islamabad. pp.203-212

Mukhopadhyay, S.K. Khara, A.B. and Gosh, B.C. 1972. Nature and intensity of competition of weeds with direct seeded upland IR-8 rice crop. *Int. Rice Commun. Newsl*. 21(2):10-14

Murata, Y. 1970. Physiological responses to nitrogen in plants. In: *Physiological Aspects to Crop Yield*. Crop science society of America, Madison, Wisconsis. 1969p.

Musthafa, K. 1995. Productivity of semi dry rice under simultaneous *in situ* green manuring. M.Sc (Ag.) thesis, Kerala Agricultural University, Thrissur. 90p.

Nair, G.K.B., Pillai, P.B., Nair, K.P.M. and Sasidhar, V.K. 1979. Relative efficiency of different herbicides in rice under semi dry conditions. A*gric. Res. J. Kerala* 17:14-17

Nair, R.R., Vidyadharan, K.K., Pisharody, P.N. and Gopalakrishnan, R. 1974. Comparative efficiency of new herbicides for direct seeded rice fields. A*gric. Res. J. Kerala* 12(1):24-27

Nanjappa, M.V. 1975. Chemical weed control in tall and dwarf varieties of rice (*Oryza sativa*) M.Sc. (Ag.) thesis, University of Agricultural Sciences, Bangalore. 115p.

Nanjappa, M.V. and Krishnamurthy, K. 1980. Weed control in tall and dwarf varieties of rice. *Mysore J. agric. Sci*. 15(2):245-251

Nieto, J., Brando, M.A. and Gonzavez, J.T. 1974. Methods of analysing competition with special reference to herbage plants. *J. agric. Sci*. 81:77-89

Nissanka, S.P. and Bandara, T. 2004. Comparison of productivity of rice intensification and conventional rice farming systems in the dry zone region of Srilanka. Available: http://www. regional. org.au/au/es/2004/ poster [22-10-2005]

Noda, K.K., Ozawa , K. and Ibaraki, K. 1968. Studies on the damage to rice plants due to weed competition. *Kyushu agric. Expt. Stn. Bull*. No. 13:345-367

Okafor, L.I. and De Datta, S.K. 1974. Competition between weeds and upland rice in monsoon Asia. *Philipp. Weed Sci. Bull*. 1:15-18

Okafor, L.I. and De Datta, S.K. 1976. Competition between upland rice and purple nut sedge for N, moisture and light. *Weed Sci*. 24:43-46

Oroka, O.F. and Omoregie, U.A. 2007. Competition in a rice cowpea intercrop as affected by nitrogen fertilizer and plant population. *Soils Pl. Nutr*. 64(6):8-21

Palaikudy, J.C. 1989. Sequential and combined application of herbicides in dry sown rice. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur. 116p.

Pandey, H.K. and Bhan, V.K. 1964. Effect of varying degree of soil manipulation on yield of upland paddy and/on associated weeds. *Can. J. Pl. Sci*. 20:91-93

Parida, B.C. 2002. Development and evaluation of a star-cum-cono weeder for rice. *Agric. Mechanical Asia Africa Latin America J*. 33(3):262-263

Parker, C. and Dean, M.L. 1976. Control of wild rice in rice. *Pesticide Sci*. 7:403-416

Parthasarathy, M. and Negi, N.S. 1977. Control of weeds with butachlor. In: *Proceedings of Indian Society of Weed Science Conference*, Hyderabad, India. pp-179-180

Patel, C.L., Patel, Z.G., Patel,R.B. and Patel, H.R. 1985. Herbicides for weed control in rice nurseries. *IRRI Newsl*. 35(4):11-17

Perez, C.J., Waller, S.S., Moser, L.E., Stubbendieck, J.L. and Steuter, A.A. 1998. Seed bank characteristics of a Nebraska sand hills prairie. *J. Range Mgmt* 51:55-62

Phogat, B.S. and Pandey, J. 1998. Effect of water regime and weed control on weed flora and yield of transplanted rice (*Oryza sativa*). *Indian J. Agron*. 43(1):77-81

Pillai, K.G.K. and Rao, M.V. 1974. Current status of herbicides in India. In: *Proceedings of International Rice Research Conference*, April, 1974, IRRI, Philippines. pp. 22-25

Piper, C.S. 1966. *Soil and Chemical Analysis*. Hans publishers, Bombay. 368p.

Prasad, C.S. 2006. *System of Rice Intensification in India – Innovation History and Institutional Challenges*. New concept information systems, Andhra Pradesh, 72p.

Rabenandrasana, J. 1999. Revolution in rice intensification in Madagaskar. *ILEIA Newsl.* 15(3-4)14-18

Ramamoorthy, K. 1991. Effect of integrated weed management on nutrient uptake by upland rice and associated weeds. *Indian J. Agron*. 30:213-217

Rana, S.S. and Angiras, N.N. 1999. Influence of integrated weed management on physical performance of broadcast sown puddled rice (*Oryza sativa*). *Himachal J. agric. Res*. 25(1&2):1-9

Rao, A.N., Jhonson, D.E., Sivaprasad, B., Ladha, J.K. and Mortimer, A.M. 2007. Weed management in direct seeded rice. *Adv. Agron*. 93: 153-255

Rao, V.S. 2000. *Principles of Weed Science* (2nd ed.). Oxford and IBH Ltd., New Delhi, 557p.

Rasmussen, A. 2004. The effect of sowing date, stale seed bed row width and mechanical weed control on weeds and yields of organic winter wheat. *Weed Res*. 44(1):12-20

Rathi, G.S., Patel, J.P. and Sharma, R.S. 1984. Relative performance of some dwarf varieties of rice and their response to spacing and planting pattern. *Indian J. Agron*. 29:218-221

Ravindran, C.S. 1978. Chemical control of weeds in transplanted rice during second season. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur. 160p.

Ravindran, C.S., Nair, K.P.M. and Sasidhar, V.K. 1978. A note on the effect of various herbicides on the yield and yield attributing characters of two high yielding varieties of rice. A*gric. Res. J. Kerala*. 16(1):104-107

Reddy, K.S. and Reddy, B.B. 1991. Effect of date of planting, density and age of seedling on nutrient uptake and yield of rice. *Indian J. agric. Sci*. 61(11):831-834

Reddy, S.R., Hukkeri, S.B. and Reddy, G.H.S. 1980. Weed control as a means of increasing effectiveness of fertilizers in rice production. In: *Annual Conference on Weed Science*, Bhubaneswar. Abstract:12

Reddy, T.Y. and Reddy, G.H.S. 1991. *Principles and Practices of Agronomy*. Kalyani publishers, Ludhiana. 527p.

Renu, S. 1999. Emergence and competition of polla (*Sacciolepis interrupta* (Wild) Stapf.) in semi dry rice. M. Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur. 56p.

Riemens, M.M., Weide, R.Y., Bleeker, P.O. and lap, L. 2007. Effect of stale seed bed preparation and subsequent weed control in lettuce (cv. Iceboll) on weed densities. *Weed Res*. 47(2):149-156

Saha, S., Dani, R.C., Patra, B.C. and Moorthy, B.T.S. 2005. Performance of different weed management techniques under rainfed upland rice (*Oryza sativa*) production systems. *Oryza* 42(4):287-289

Sahai, B. and Bhan, V.M. 1982. Competition for nitrogen between weeds and drilled rice – effect of time of weed removals. In: *Proceedings of Annual Conference of International Society of Weed Science*, Hissar. Abstract: 14

Saikia, T.P. and Pathak, A.K. 1993. Integrated weed management in rainfed direct seeded upland rice (*Oryza sativa*). *Indian J. Agron*. 38(2):300-301

Sankaran , S. and De Datta, S.K. 1985. Weeds and weed management in upland rice. *Adv. Agron*. 38:283-336

Sarkar, P.A. and Moody, K. 1983. Effects of stand establishment techniques on weed population in rice. In: *Weed Control in Rice*. IRRI, Philippines. pp.57-71

Scolari, P. and Young, D.L. 1975. Comparative costs of different weed control methods. *Weed Abstr*. (2):16

Sharma, H.C., Singh, H.B. and Friegen, G.H. 1977. Competition from weeds and their control in direct sown rice. *Weed Res*. 17(2):103-108

Sharma, S.K., Pandey, D.B., Ganagwar, K.S. and Tomar, O.K. 2004. Weed control in direct dry seeded rice in India: comparison of seed bed preparation and use of pendimethalin. *Rice Res. Notes*. 29(2):30-31

Shaw, D.R. 1996. Development of stale seed bed weed control programmes for southern row crops. *Weed Sci*. 44:413-416

Sheehy, J.E. Peng, S. Dobermann, A.M., Mitchell, P.L., Ferrer, A., Yang-JianLiang, Zou-Yingbin, Zhong-XuHua and Huang-Jiangchang. 2004. Fantastic yields of rice intensification: fact or fallacy? *Fld Crops Res*. 88(1):1-8

Shenk, M.D. 1982. Cultural practices for weed management. In: Labrada, R., Caseley, J.C. and Parker, C. (eds.), *Weed Management for Developing Countries*. FAO Plant Production and Protection Bulletin Paper No. 120. FAO, Rome, pp.163-170

Shetty, S.V.R. 1973. Investigations on chemical weed control in transplanted and direct sown rice (*Oryza sativa*). Ph.D. thesis, Punjab Agricultural University, Ludhiana. 152p.

Shrivasthava, S.K. and Saxena, P.K. 1982. Variations in rice physiological growth parameters. *Rice Res. Newsl*. 7:20-21

Shukla, V.K. Sharma, R.S. and Shrivasthava, S.K. 1995. Effects of planting geometry, weed management and nitrogen levels on morphological growth patterns of rice. *Oryza* 32:254-257

Singh, B. And Dash, B. 1988. Simple correlation and linear regression studies between weeds and growth and yield of direct seeded upland rice. *Oryza* 35:282-286

Singh, C.M. 1985. Control of weeds in dry seeded rice. *Indian fmg* 35(2):31-33

Singh, D.P., Bhattacharjee, D.P. and Dash, N.B. 1983. High plant population as a possible means for increasing production of water logged rice. *Indian J. agric. Sci*. 53(8):656-663

Singh, G., Kumar, R. Upadhyay, V.B. and Kewat, M.L. 2003. Effect of spacing and seedling age on yield of hybrid rice. *Oryza* 40(1&2):46-47

Singh, R.P. and Sharma, G.L. 1984. Effect of three planting methods and six herbicides on dry matter and nitrogen accumulation in rice and weeds. *Aus. Weeds* 3(2):54-56

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

Singh, S.K. and Talati, J. 2005. *Impact of the system of rice intensification (SRI) on rice yields: Results of a new sample study in Purulina district, India*. IWMT – Tata water policy research highlights No. 47. International Water Management Institute, India programme, Anand.

Singh, T., Kolar, J.S. and Sandhu, K.S. 1991. Critical period of competition between wrinkle grass (*Ishaemum rugosum*) and transplanted paddy. *Indian J. Weed Sci.* 23(1&2): 1-5

Sinha, S.K. and Talati, J. 2007. Productivity impacts of the system of rice intensification (SRI): a case study in West Bengal, India. *Agric. Water Mgmt* 87(1):55-60

Smith, R.J. 1968. Weed competition in rice. *Weed Sci*. 16:252-255

Smith, R.J. 1981. Control of red rice (Oryza sativa) in water seeded rice (*Oryza sativa*). *Weed Sci*. 29:663-666

Smith, R.J.Jr. 1964. Effects of weed competition on rice. In: *Weed Science Society of America, Absracts,* p.69

Smith, R.J.Jr. 1983. Weeds of major economic importance in rice and yield losses due to weed competition. *IRRI Newsl*.6:19

Smith, J. Jr. and Moody, K. 1979. Weed control practices in rice. In: Kommedehl, T. (ed.), *Plant Protection for Agricultural Crops and Forest Trees*. Proceedings of 9th international congress in plant protection, 5-11 August, 1979, Vol II. Washington DC, pp- 12-18

Sodhi, P.S. and Dhaliwal, B.K. 1998. Effect of crop density and cultivars on competitive interaction between wheat and wild oats. *Indian J, Ecol*. 25:138-145

Sreedevi, P. 1979. Studies on the performance of rice variety 'Aswathy' under different methods of direct seeding and weed control. M.Sc. (Ag.) thesis, Kerala Agricultural University, Trichur. 109p.

Sreedevi, P. and Thomas, C.G. 1993. Efficiency of anilofos on the control of weeds in direct sown puddle rice. In: *Proceedings of the International symposium of Indian society of weed science*, Hissar. pp.16-18

Sridhar, T.S., Rao, Y. and Reddy, G.H. 1976. Effect of granular herbicides on the control of weeds in rice directly seeded in puddled soil. *Madras agric. J.* 61(1):431-433

Stoop, W.A., Uphoff, N. and Kassam, A. 2002. A review of agricultural research issues raised by the system of rice intensification (SRI) from Madagascar: Opportunities for improving farming systems for resource poor farmers. A*gric. Systems*. 71:249-274

Subbiah, B.V. and Asija, G.L.A. 1956. A rapid procedure for the estimation of available nitrogen in soils. *Curr. Sci*. 25:259-260

Subbian, P. 1983. Effect of herbicides on transplanted rice (IR 20). *Madras agric. J.* 70(6):372:374

Sudhakara, K. and Nair, R.R. 1976. Weed control in rice under semi dry system. A*gric. Res. J. Kerala*. 24(1):38-42

Suja, G. and Abraham, C.T. 1991. Time of application of pre emergence herbicides in dry sown rice. A*gric. Res. J. Kerala* 29:27-34

Surridge, C. 2004. Rice cultivation feast or famine? *Nature* 428:360-361

Swain, D.J. Nott, M.J and Trounce, R.B. 1975. Competition between *Cyperus difformis* and rice – the effect of time of weed removal. *Weed Res*. 15:149-152

Tewari, A.N. and Singh, R.D. 1991. Crop weed competition in upland direct seeded rain fed rice. *Indian J. Weed Sci*. 23(1&2):51-52

Thomas, C.G., Abraham , C.T. and Sreedevi, P. 1997. Weed flora and their relative dominance in semi dry rice culture. *J. trop. Agric*. 35:51-53

Thomas, C.G., and Abraham, C.T. 1998. *Common Weeds in Rice Ecosystems of Kerala and Their Management*. Kerala Agricultural University, Thrissur, 80p.

Thomson, K. and Grime, J.P. 1979. Seasonal variation in the seed banks of herbaceous species in ten controlling habitats. *J. Ecol*. 67:893-897

Thyagarajan, T.M. 2002. Experiments with a modified system of rice intensification in India. *Proceedings of International conference on Assessments of the system of rice intensification (SRI)*, China April 2002, pp. 1-4

TNAU [Tamil Nadu Agrucultural University]. 2007. *Annual Report for the Year 2006-07*. Tamil Nadu Agricultural University, Coimbatore, 50p.

Trivedi, K.K., Tiwari, J.P. and Bisen, C.R. 1986. Integrated weed control in upland drilled rice. *Pesticides* 20:29-33

Uphoff, N. 1999. Agroecological implications of System of rice intensification (SRI) in Madagaskar. *Env. Devpt. Sustainability* 1(3): 297-331

Uphoff, N. 2003. Higher yields with fewer external inputs? The system of rice intensification and potential contributions to agricultural sustainability. *Int. J. agric. sustainability*. 1:38-50

Uphoff, N. 2004. SRI – the system of rice intensification – An opportunity for raising productivity in the 21st century. In: *International Rice Conference paper*, FAO, Rome, February 12-13, 2004.

Vaishya, R.D., Kumar, S., Srivasthava, A. 1992. Chemical weed control in puddle broadcast rice. *Indian J. Weed Sci*. 24(3&4):72-74

Varshney, J.G. 1985. Studies on critical periods of weed competition in rice in hilly terrains of Meghalaya. In: *Proceedings of Annual Conference of Indian Society of Weed Science*. Abstract: 84

Varughese, A. 1978. Studies on the critical periods of weed infestation and effect of weed growth on yield and quality of a short duration rice. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 167p.

Varughese, A. 1996. Ecophysiology and management of Isachne (*Isachne miliaceae*) in rice fields of Onattukara. Ph.D thesis, Kerala Agricultural University, Thrissur, 150p.

Venkataraman, N.S. and Gopalan, M. 1995. Current status of weed problems in rice production in Tamil Nadu, India. In: Papusas, H.R. and Heong, K.L. (eds.), *Weed Management in Rice Production*. IRRI, Philippines, pp. 113-126

Venkateswarlu, B. 1977. Influence of low light intensity on growth and productivity of rice (*Oryza sativa*). *Pl. Soil*. 47:713-719

Venketeswarlu, B. and Visperas, R.M. 1987. *Source Sink Relations in Crop Plants*. IRRI research paper series No. 125, pp.1-19

Verma, O.P.S., Katyal, S.K. and Sharma, H.C. 1988. Effect of planting density, fertilizer and weed control on transplanted rice. *Indian J. Agron*. 33:372-375

Vijayakumar, M. Ramesh, B., Chandrasekharan, S. and Thiyagarajan, T.M. 2006. Effect of SRI practices on the yield attributes, yield and water productivity of rice. *Res. J. agric. Biol. Sci*. 2(6):236-242

Vishnudas, C.K. 2006. SRI trials in Waynad, experiences of RASTA. *LEISA India* 8(4): 16-17

Wang, S., Weixing Cao, Dong, J., Tingbo, D and Yan, Z. 2003. Effects of SRI techniques on physiological characters and population development in rice. *Chinese J. Rice Sci*. 17(1):31-46

Weerakoon, W.L., Seneviratne, G., Ananda, M. De Silva, P. and Seneviratne, A.M. 1992. Evaluation of *Sesbania speciosa* as a green manure for low land rice in the dry zone, Sri Lanka. *Pl. Soil*. 145:131-139

Williams, R.J.F. 1982. A survey of grass weeds of cereals in southern England. *Weed Res*. 22:163-171

Yadav, P.K. Kurchania, S.P. and Tiwari, J.P. 1995. Herbicide and fertilizer compatibility under normal and stale seed bed sowing of wheat (*Triticum aestivum*) at different levels of nitrogen. *Indian J. agric. Sci.* 65(4):265-270

Yaduraju, N.T. and Mani, V.S. 1987. The influence of delayed planting and seed bed preparation on the competition of wild oats in wheat. *Indian J. Agron*. 32(3):299-301

Yenish, J.P., Doll, J.D. and Buhler, D.D. 1992. Effects of tillage on vertical distribution and viability of weed seeds in soil. *Weed Sci*. 40:429-433

Yoshida, S. 1972. *Fundamentals of Rice Crop Science*. International rice research institute, Philippines. 147p.

Younie, D. and Taylor, B.R. 1995. *Maximizing Crop Competition to Minimizing Weeds*. New Farmer and Grower Soil Association, Bristol, UK, 18p.

Zafar, M.A. 1988. Chemical weed control in transplanted rice. *IRRI Newsl*. 13(1):29

Ze-Pu-Zhang. 1996. Weed management in transplanted rice. In: Auld, B.A. and Kim, K.U. (eds.), *Weed Management in Rice*. Oxford and IBH, New Delhi., pp. 77-86

Zheng, J., Xianjun, L., Xinlu, J. and Chong De L. 2004. Testing modification for the system of rice intensification (SRI) to achieve high yields in the Sichuan basin. *South West China J. agric. Sci*. 17(2):169-173

Zimdahl, R.L. 1980. *Weed Crop Competition - A Review*. International Plant Protection Centre, Oregon, USA, 196p.

Appendices

Appendix I. Weekly weather data during the crop period of experiment on "Stale seed bed techniques suited for wet seeded rice" and "Crop weed competition in transplanted rice: Influence of plant stand"

Month	Meteorological week	Mean temperature (oC)		Mean Relative humidity (%)		Sunshine (hrs/day)	Rain fall (mm/week)	Mean evaporation (mm)
		Maxi-mum	Mini-mum	Morning	Evening			
I[st] year (October 2005 to March 2006)								
October	22/10-28/10	30.7	23.5	90	68	3.8	34.6	2.0
	29/10-4/11	30.7	23.2	91	71	6.1	6.9	2.0
November	5/11-11/11	31.3	23.7	87	65	4.2	4.1	2.8
	12/11-18/11	30.9	22.2	80	61	6.8	6.4	3.4
	19/11-25/11	29.6	22.7	77	63	3.5	0	3.3
	26/11-2/12	31.7	22.7	79	57	8.0	0	4.0
December	3/12-9/12	31.7	23.3	81	51	7.7	0.8	4.1
	10/12-16/12	30.6	23.6	78	57	5.4	2.4	5.1
	17/12-23/12	32.3	22.0	86	52	7.3	0	3.9
	24/12-31/12	31.1	20.8	77	41	8.7	0	5.3
January	1/1-7/1	31.4	23.1	67	42	8.5	0	6.3
	8/1-14/1	32.0	24.4	70	45	7.5	0	6.1
	15/1-21/1	33.6	22.0	76	38	9.6	0	6.1
	22/1-28/1	33.0	21.0	79	40	9.6	0	5.6
	29/1-4/2	32.3	22.9	70	38	10.3	0	7.5
February	5/2-11/2	33.5	22.7	60	29	9.8	0	8.0
	12/2-18/2	34.7	21.3	70	32	9.9	0	6.2
	19/2-25/2	35.6	22.2	79	21	9.1	0	6.5
	26/2-4/3	34.7	23.1	87	50	7.4	20.0	5.3
March	5/3-11/3	34.9	23.9	86	54	8.3	30.0	4.5
	12/3-18/3	34.6	22.2	85	42	8.3	0	5.5

Appendix II. Weekly weather data during the crop period of experiment on "Stale seed bed techniques suited for wet seeded rice" and "Crop weed competition in transplanted rice: Influence of plant stand"

Month	Meteorological week	Mean temperature (oC)		Mean Relative humidity (%)		Sunshine (hrs/day)	Rain fall (mm/week)	Mean evaporation (mm)
		Max-mum	Mini-mum	Morning	Evening			
II[nd] year (November 2006 to March 2007								
November	5/11-11/11	31.0	22.8	88	65	4.9	22.5	3.2
	12/11-18/11	31.2	24.5	81	61	7.7	39.8	4.6
	19/11-25/11	32.2	23.9	82	60	7.3	4.8	3.7
	26/11-2/12	31.7	24.2	76	56	7.0	0	4.4
December	3/12-9/12	31.0	24.1	67	45	8.2	0	6.4
	10/12-16/12	32.1	24.0	72	45	8.2	0	6.5
	17/12-23/12	31.3	23.7	64	44	6.9	0	6.5
	24/12-31/12	31.6	22.6	68	43	7.6	0	6.3
January	1/1-7/1	31.7	20.6	69	38	9.1	0	5.3
	8/1-14/1	32.4	23.2	69	41	9.6	0	7.1
	15/1-21/1	33.0	21.2	72	32	8.1	0	6.1
	22/1-28/1	32.9	22.0	67	36	7.3	0	6.4
	29/1-4/2	32.9	22.6	74	31	10.0	0	6.8
February	5/2-11/2	34.3	22.6	72	30	9.7	0	5.8
	12/2-18/2	33.6	21.2	88	42	9.3	0	5.0
	19/2-25/2	33.8	22.7	68	31	10.2	0	8.0
	26/2-4/3	35.8	23.3	84	36	9.3	0	5.8
March	5/3-11/3	36.1	23.6	85	34	8.4	0	5.8
	12/3-18/3	37.0	24.4	85	26	8.7	0	6.6
	19/3-25/3	35.8	25.0	92	51	7.9	0	5.9
	26/3-1/4	35.7	25.0	85	48	7.2	0.8	5.8

Appendix III. Weekly weather data during the crop period of experiment on "Stale seedbed techniques suited for dry seeded rice".

Month	Meteorological week	Mean temperature (oC)		Mean Relative humidity (%)		Sunshine (hrs/day)	Rain fall (mm/week)	Mean evaporation (mm)
		Max-mum	Mini-mum	Morning	Evening			
I^st year (April 2006 to August 2006)								
April	23/4-29/4	32.3	24.8	91	60	5.8	27.2	4.2
	30/4-6/5	33.2	25.0	90	60	7.4	14.8	4.5
May	7/5-13/5	34.1	24.9	89	56	8.0	0	4.7
	14/5-20/5	32.8	24.6	90	60	5.6	84.8	3.6
	21/5-27/5	29.9	23.6	93	72	5.9	242.1	3.3
June	28/6-3/6	28.6	22.7	94	79	1.4	366.0	2.0
	4/7-10/6	30.2	24.0	93	75	3.7	46.8	2.7
	11/6-17/6	31.1	23.7	92	69	8.0	70.6	3.4
	18/6-24/6	29.4	23.7	95	78	2.5	190.3	2.3
July	25/6-1/7	28.7	23.2	93	85	1.0	209.4	2.1
	2/7-8/7	30.2	23.5	94	75	2.7	117.8	3.3
	9/7-15/7	28.5	23.3	95	77	1.8	189.2	2.4
	16/7-22/7	29.6	23.5	95	77	1.5	99.0	3.4
	23/7-29/7	29.4	23.0	95	76	2.1	85.0	3.1
	30/7-5/8	29.4	22.7	94	76	3.1	60.8	3.3
August	6/8-12/8	29.0	22.9	90	76	3.6	263.1	12.8
	13/8-19/8	29.0	22.8	96	79	2.2	243.0	14.9
	20/8-26/8	30.9	24.0	93	65	3.9	2.2	4.2
	27/8-2/9	30.7	23.0	92	64	6.3	0.1	3.8

Appendix IV. Weekly weather data during the crop period of experiment on "Stale seedbed techniques suited for dry seeded rice"

Month	Meteorological week	Mean temperature (oC)		Mean Relative humidity (%)		Sunshine (hrs/day)	Rain fall (mm/week)	Mean evaporation (mm)
		Maxi-mum	Mini-mum	Morning	Evening			
IInd year (April 2007 to September 2007)								
April	23/4-29/4	34.6	25.2	87	58	7.8	23.6	4.9
	30/4-6/5	33.7	24.5	89	60	7.3	63.9	4.7
May	7/5-13/5	32.6	25.2	87	65	6.3	15.9	4.0
	14/5-20/5	33.5	24.8	83	57	10.4	0	5.4
	21/5-27/5	33.8	25.3	86	66	5.3	117.3	3.8
	28/5-3/6	30.5	23.3	92	72	6.5	43.4	3.4
June	4/6-10/6	32.1	24.5	91	68	6.9	93.7	3.9
	11/6-17/6	28.5	23.1	93	82	0.7	243.2	2.2
	18/6-24/6	28.0	22.5	95	87	0.9	367.7	1.8
	25/6-1/7	30.3	23.6	94	73	1.8	215.8	2.8
	2/7-8/7	28.3	22.7	94	85	0.06	365.1	2.1
July	9/7-15/7	29.3	23.0	94	80	1.3	309.9	2.6
	16/7-22/7	27.6	22.7	93	84	1.2	265.8	2.0
	23/7-29/7	28.7	23.0	92	83	0.4	90.6	2.2
	30/7-5/8	28.5	22.7	92	78	0.9	107.1	2.4
August	6/8-12/8	29.9	22.3	93	85	0.4	293.5	1.9
	13/8-19/8	30.9	23.6	91	64	7.8	0.6	4.0
	20/8-26/8	29.2	23.0	91	74	3.9	50.8	2.9
	27/8-2/9	28.8	22.5	92	78	1.8	128.8	2.1
September	3/9-9/9	30.0	22.6	92	74	1.8	156.1	2.4
	10/9-16/9	29.4	23.3	93	79	3.1	192.9	2.2
	17/9-23/9	28.7	23.1	94	86	1.5	216.6	2.4

Appendix VI. Details of field operations

Operations	Date	
Experiment on "Stale seed bed techniques suited for wet seeded rice"		
	I^st year	**II^nd year**
Land preparation for stale seed bed for 14 days	25-10-05	07-11-06
Land preparation for stale seedbed for 7 days	31-10-05	14-11-06
Land preparation for normal seedbed	16-11-05	30-11-06
Flooding in Stale seedbeds	7-11-05	20-11-06
Draining water from stale seedbeds	16-11-05	30-11-06
Sowing	16-11-05	30-11-06
Basal fertilizer application	16-11-05	30-11-06
Spraying Sofit	18-11-05	04-12-06
Weeding	10-12-05	21-12-06
Incorporation of daincha	20-12-05	30-12-06
Topdressing fertilizers	02-01-06	15-01-07
Harvesting	16-03-06	31-03-07
Experiment on "Stale seedbed techniques suited for dry seeded rice"		
	I^st year	**II^nd year**
Ploughing in stale seedbed for 14 days	26-04-06	26-04-07
Ploughing in stale seedbed for 7 days	03-05-06	03-05-07
Ploughing in normal seeding plots	10-05-06	10-05-07
Hoeing in stale seedbed for 14 days with two hoeing	03-05-06	03-05-07

Hoeing in stale seedbed for 14 days with two hoeing + one hoeing and in stale seedbed for 7 days	10-05-06	10-05-07
Dibbling seeds	11-05-06	11-05-07
Spraying of Refit	12-05-06	15-05-07
Basal fertilizer application	04-06-06	08-06-07
Weeding Ist	03-06-06	06-06-07
IInd	21-06-06	26-06-07
Top dressing of fertilizers	23-06-06	27-06-06
Harvest	31-08-06	20-09-07
Experiment on "Crop weed competition in transplanted rice: Influence of plant stand"		
	Ist year	**IInd year**
Nursery sowing for P.O.P. managed plots	27-10-05	29-10-06
Nursery sowing for SRI managed plots	06-11-05	08-11-06
Application of groundnut cake	01-11-05	01-11-06
Basal fertilizer application	16-11-05	19-11-06
Transplanting	16-11-05	19-11-06
Cono weeding	27-11-05	29-12-06
	07-12-05	09-12-06
	17-12-05	19-12-06
	27-12-05	30-12-06
	06-01-06	10-01-07
Hand weeding Ist	08-12-05	10-12-05
IInd	29-12-05	02-01-07
Topdressing fertilizers	05-01-06	07-01-07
Harvesting	06-03-05	07-03-07

ECOFRIENDLY MANAGEMENT OF WEEDS IN RICE

By

SINDHU, P.V.

ABSTRACT OF THE THESIS

submitted in partial fulfilment of the
requirement for the degree of

Doctor of Philosophy in Agriculture

Faculty of Agriculture
Kerala Agricultural University

Department of Agronomy
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR-680 656
KERALA, INDIA

2008

ABSTRACT

Competition from weeds and consequent yield reduction is a major problem in rice cultivation, which warrants proper weed management strategies. The present study was undertaken to develop and refine stale seed bed techniques and subsequent cultural practices for semi-dry and wet-seeded rice and to find out the optimum plant spacing, which can give maximum weed control efficiency coupled with better grain yield. Survey and documentation of prevailing weed control practices followed by rice farmers was another objective of the study.

Surveys conducted in Palakkad, Kole, Kuttanad and Pokkali regions revealed the popularity of physical and chemical methods of weed control among farmers. Among various herbicides available for use in rice, Fernoxone (2,4-D) is the major chemical used by the majority of farmers of Palakkad, Kole and Kuttanad regions.

The experiment on stale seed bed techniques for semi-dry rice was conducted during first crop seasons of 2006 and 2007 at Agricultural Research Station, Mannuthy and stale seed bed for wet-seeded rice was conducted in Alappad kole, Thrissur district during second crop seasons of 2005-06 and 2006-07. Seed bed preparation significantly influenced the germination and establishment of weeds both under semi-dry and wet-seeded conditions. Population and dry weight of weeds were the lowest in stale seed bed for 14 days. Stale seed bed technique adopted for forcing the germination of weed seeds showed differential response by different groups of weeds. Grass weeds gave the highest germination percentage immediately after seed bed preparation followed by broad leaf weeds. However, seed bed preparation was not effective on sedges.

Stale seed bed technique provided a partially weed free environment during the early crop growth stages and allowed the crop to yield better than normal seed bed. The yield difference between normal seed bed and stale seed bed decreased with reduction in the stale seed bed period mainly because of the short time available to achieve the optimum

environment essential for the germination of buried seeds. Among the sub plot treatments, pre emergence spraying of herbicides and concurrent growing of green manure crops gave significant reduction in the population and dry weight of weeds and thus better grain yield. Stale seed bed for 14 days gave the highest benefit ratio both under semi-dry and wet-seeded situation during both years of the experiment.

Experiment to assess the influence of plant stand on crop-weed competition was conducted in farmer's field at Alappad Kole, Thrissur district during the second crop season of 2005-06 and 2006-07. Canopy modification by altering plant spacing significantly helped the crop to maintain a dominant position over weeds as indicated by the decreased weed problems in closer plant spacing. Higher grain yields of 8858 kg ha^{-1} and 7825 kg ha^{-1} during first and second years of study were observed in closer spacing of 10 cm X 10 cm spacing under the recommended package of practices of Kerala Agricultural University followed by 20 cm x 10 cm. Among the weeded plots, the lowest grain yield was in SRI plots with cono weeding.

Plants at wider spacing (30 cm X 30 cm) produced more number of tillers per hill. However, on unit area basis a reverse trend was observed. Increase in plant density under closer spacing significantly reduced the dry matter production of weeds. The weed problem was very high in SRI management, even after four cono weedings.

The reduction in grain yield in unweeded plots under closer plant spacing was negligible when compared to weeded plots. This indicates the possibility of maintaining the field without much economic loss from weeds by transplanting 20-day old seedlings, with two seedlings per hill at a closer spacing of 10 cm X 10 cm. This is both economical and ecofriendly as the need for hand weeding or herbicides is eliminated. The present experiment indicates that SRI system does not hold much promise in regions where farmers follow recommended package of practices.