

**Studies on Crop Establishment Methods and Weed
Management in Rice (*Oryza sativa* L.)**

FAYAZ AHMAD SHAN
(2007-A-801-M)



**DIVISION OF AGRONOMY
FACULTY OF POSTGRADUATE STUDIES
SHER-E-KASHMIR UNIVERSITY OF AGRICULTURAL
SCIENCES & TECHNOLOGY OF KASHMIR**

2009

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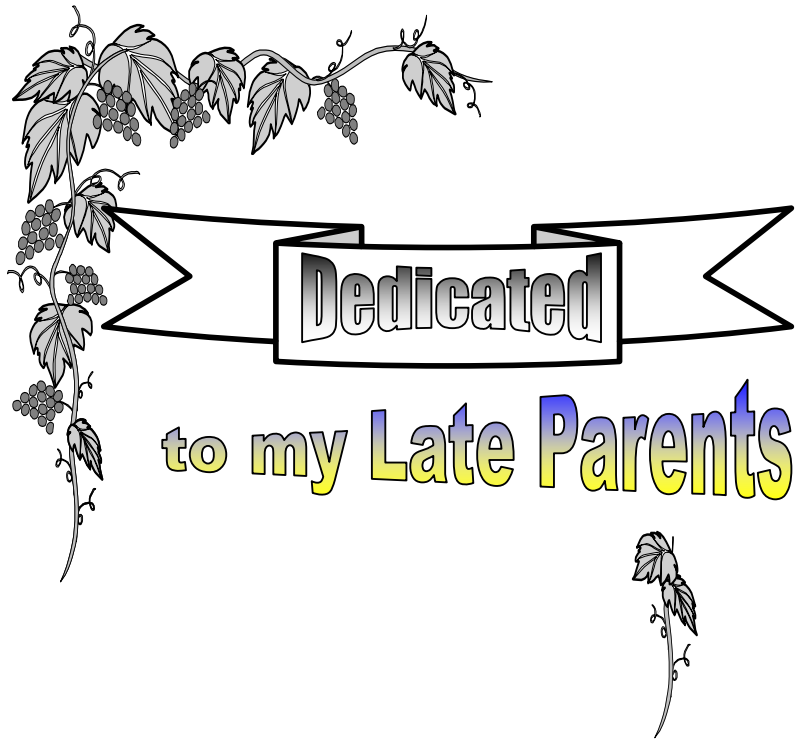
THESIS

Submitted to

**The Faculty of Postgraduate Studies
Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir in
partial fulfilment of requirement for the award of the degree of**

**MASTER OF SCIENCE IN AGRICULTURE
(Agronomy)**

2009



Dedicated

to my Late Parents

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Division of Agronomy, Shalimar Campus, Srinagar

-::o::-

Certificate – I

This is to certify that the thesis entitled “**Studies on Crop Establishment Methods and Weed Management in Rice (*Oryza sativa* L.)**” submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science in Agriculture (Agronomy)**, to the Faculty of Postgraduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, is a record of bonafide research work carried out by **Mr. Fayaz Ahmad Shan (Regd. No. 2007-A-801-M)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

(Dr. Mohd. Anwar Bhat)
Chairman
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Endorsed

**Professor & Head,
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Certificate – II

We, the members of the Advisory committee of **Mr. Fayaz Ahmad Shan (Regd. No. 2007-A-801-M)**, a candidate for the degree of **Master of Science in Agriculture (Agronomy)**, have gone through the manuscript of the thesis entitled, **“Studies on Crop Establishment Methods and Weed Management in Rice (*Oryza sativa* L.)”** and recommend that it may be submitted by the student in partial fulfilment of the requirement for the degree.

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Certificate – III

This is to certify that the thesis, “**Studies on Crop Establishment Methods and Weed Management in Rice (*Oryza sativa L.*)**” submitted by **Mr. Fayaz Ahmad Shan (Regd. No. 2007-A-801-M)** to the Faculty of Postgraduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, in partial fulfilment of the requirements for the award of the degree of **Master of Science in Agriculture (Agronomy)** was examined and approved by his Advisory Committee and external examiner on

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Title of the Thesis : **“Studies on Crop Establishment Methods and Weed Management in Rice (*Oryza sativa* L.)”**

ABSTRACT

The present investigation was conducted at Rice Research and Regional Station, Khudwani, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir during *kharif* 2008 to study the influence of different weed management practices under direct seeded and transplanted methods of crop establishment on silty clay loam soil, low in available N and K, medium in available P and neutral in reaction. The treatments consisting of two crop establishment methods and seven weed management practices were laid out in Randomized Block Design with three replications. The results revealed that the growth characters viz. periodic plant height and leaf area index of crop was not significantly affected by crop establishment methods. However, the dry matter accumulation of crop was significantly higher in transplanted rice than direct seeded method. The yield attributes viz. panicles m⁻², grains panicle⁻¹ and panicle weight were significantly higher under transplanting method

than direct seeded rice. Similar trend was also observed for grain yield, straw yield, and harvest index as well as for amylose and protein content of grain. Transplanted rice recorded a yield advantage of 7.05 percent over direct seeded method of crop establishment. Among different weed management practices application of butachlor + almix caused significant improvement in crop growth and yield attributing characters as compared to other weed management practices and weedy check, thereby provided a superiority of 42.66 and 13.03 percent over weedy check and butachlor alone respectively in respect of the grain yield. Combined application of butachlor + almix (besides weed free treatment) was quite effective in controlling the weeds (grasses as well as broad leaved) and thereby reducing the weed density and weed dry matter compared to other herbicidal treatments with higher weed control efficiency. Relative economics revealed that application of butachlor + almix in transplanted rice realized highest benefit cost ratio of 2.16 during the course of investigation.

Key words : Rice, Crop establishment, Weed control, Herbicide

Signature of Student

Signature of Major Advisor

Dated : _____

Dated:

ACKNOWLEDGEMENT

**IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST BENEFICIENT
AND THE MOST MERCIFUL**

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Fayaz Ahmad Shan

Place : Shalimar, Srinagar

Dated: _____

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CHAPTER – 1

INTRODUCTION

The greatest challenge to mankind in 21st century is to produce the basic necessities of food, fibre, fuel and raw materials from limited land. At global level rice occupies an area of about 153.77 m ha which is 30 per cent of the total area under food grains. Rice presently accounts for more than 20 per cent of the daily caloric intake of about 2.4 billion people. India occupies the highest area of 45 m ha under rice with a production of 91.05 metric tonnes next only to China, accounting for 46 per cent area under cereals and 42 per cent of total food grains (Anonymous, 2007).

In Jammu and Kashmir State, rice is cultivated on an area of 259.52 thousand hectares with a production of 5546 thousand quintals (Anonymous, 2008). In India, at the present growth rate, the demand for rice by 2025 AD is expected to be 136 million tonnes indicating that 2.5 million tonnes of enhanced rice production every year. Therefore, rice research has to be geared up to surmount the technological challenges in breaking the yield barrier through improving the input use efficiency. At present the total net cultivated area is 142.5 m ha and there is not much scope to expand this net cultivated area i.e. horizontal expansion of production, the future requirement has to be met through vertical growth by

intensification of agriculture. In the wake of shrinking land and water resources the only hope to meet the future requirement of food and ensuring food security lies in enhancing the productivity of land already under cultivation.

Transplanting of rice has been the traditional method of rice establishment but cultivation of direct seeded rice is gaining momentum in India due to the shortage of labour during peak season of transplanting and availability of water for shorter periods. In fact direct seeding is the major system of rice cultivation in Sri Lanka, Australia, Italy, Portugal and the Philippines. However, losses due to weeds are greater in direct seeded rice than in transplanted rice estimated to the extent of 50 to 60 per cent and even at times a complete crop failure (Govindarasu *et al.*, 1998).

Weeds compete with the rice plants for nutrients, moisture, sunlight and space or affect through the production of growth inhibiting compounds (allelopathy), causing a quantitative reduction in the potential yield of rice. Weed competition is more in direct seeded rice as compared to transplanted rice because the land remains almost exposed till initial seedling establishment and weed management techniques are critical. In different systems of rice culture, very often the yield losses due to weeds exceed those of the diseases and insect pests. Weeds alone account for annual loss

of produce worth Rs. 1,800 crores (Krishnamurthy, 2006). The optimum weed control could be achieved through judicious management which includes cultural, mechanical, biological and chemical means. Hand weeding has been the most effective method of getting rid of the menace of weed infestation in crop fields. However, being uneconomical and time consuming, hand weeding is losing popularity with rice growers. Chemical weed control eliminates early crop weed competition, whereas in other words weeds compete with crops during initial stages. However, a single weedicide cannot be effective against all types of weeds, nor can a common farmer use different herbicides at a time for control of grasses, broad leaved weeds and sedges because of economical concerns and phytotoxicity of these chemicals. Besides, continuous use of a single herbicide for a long time induces resistance in weeds which can be overcome by integrating different herbicides (both pre and post emergence).

Since different crop establishment methods and weed control measures can be taken up to deal with the problem but the key to effective management is to choose appropriate method and apply the right material at proper time. Any study on this aspect may be very much useful for better management strategy development on scientific lines.

Keeping in view the above facts the present study entitled “Studies

on crop establishment methods and weed management in rice (*Oryza sativa*

L.)” was planned with the following objectives :

- To investigate the effect of crop establishment methods and weed management practices on the growth and yield of rice,
- To identify the weed flora and study the weed control efficiency, and
- To work out the relative economics.

CHAPTER – 2

REVIEW OF LITERATURE

The assured availability of rice is recognized as an important factor in self-sufficiency of country's food grain production. The gap between potential and national rice yield is attributed to several production constraints, of which weed infestation is one of the important constraint. The extent of yield losses in rice under different crop establishment methods is estimated to be as high as 49-59 per cent. So development of an ideal weed management practice, which is economically viable as well as ecologically safe is of utmost importance to improve the productivity of rice. The status of workdone in India and abroad pertinent to the study has been reviewed as under.

2.1 Effect of weed control methods

2.1.1 Growth characters and yield attributes

2.1.1.1 Transplanted rice

Srinivasan *et al.* (1992) studied the influence of management practices on weed dynamics in rice based cropping sequence and observed that pre-emergence application of anilophos (0.3 kg a.i. ha⁻¹) + 2,4-DEE (0.51 kg a.i. ha⁻¹) was effective against *Echinochloa* spp. Growth characters and yield attributes of rice improved with good control of weeds.

Rathore *et al.* (1994) found that benthocarb or butachlor each at 1.5 kg a.i. ha⁻¹ followed by one hand weeding at 45 days after sowing/days after transplanting (DAS/DAT) was comparable to 3 hand weedings in increasing plant height and yield attributes of rice.

Singh (1997) reported that all weed control measures tested proved significantly superior to weedy check in increasing plant height, number of panicles m⁻², number of grains panicle⁻¹ and test weight. However, 2 hand weedings (30 and 50 DAT) were superior to other weed control measures.

Nandal *et al.* (1999) reported that amongst seven weed control measures used, two hand weedings (20 and 40 DAT) caused significant increase in panicles m⁻², grains panicle⁻¹ and 1000-grain weight of rice over other treatments but remained at par with anilophos (0.4 kg a.i. ha⁻¹), cinmethylin (0.075 kg a.i. ha⁻¹) and ethoxysulfuron + anilophos (0.015 + 0.375 kg a.i. ha⁻¹).

Singh *et al.* (1999) tested various weed control measures and found that the weed free treatment upto 60 DAT was significantly superior to other treatments in increasing panicles m⁻², panicle length, panicle weight, grains panicle⁻¹ and 1000-grain weight of rice but remained at par with two hand weedings [20 and 40 DAT, anilophos + 2,4-DEE (0.3 + 0.4 kg a.i. ha⁻¹) and butachlor + 2, 4-DEE (1.0 + 0.4 kg a.i. ha⁻¹)] treatments.

Bhowmick *et al.* (2000) reported that amongst various weed control measures tested viz. butachlor, butachlor + 2, 4-D, cinemethylin, ethoxysulfuron, weeding and weedy check, two hand weedings (20 and 40 DAT) at par with ethoxysulfuron + anilophos treatment, produced significant improvement in tiller production. LAI, panicles m^{-2} and grains panicle $^{-1}$ over rest of the treatments.

Rekha *et al.* (2002) while working on weed management in rice reported that out of several weed control measures tested, weed free treatment, at par with two hand weedings (20 and 40 DAT), proved significantly superior to other treatments in increasing panicles m^{-2} . However, in its influence on dry matter production and grains panicle $^{-1}$, weed free treatment proved significantly superior to rest of the treatments.

Bhowmick *et al.* (2002) reported that two hand weedings, at par with application of butachlor & 2, 4-D @ 1.5 kg a.i & 1.0 kg a.i.ha $^{-1}$, respectively recorded significantly higher plant height of transplanted rice than weedy check.

Kumar *et al.* (2004) obtained the highest number of panicles per unit area and 1000-grain weight of rice under zero till transplanted system which was at par with unpuddled and puddled transplanted rice.

Singh *et al.* (2005) while working on the effect of crop establishment methods on weed dynamics and grain yield of rice under Uttarakhand conditions reported that application of herbicide supplemented with two hand weedings in transplanted rice and direct seeded rice along proved significantly superior over weedy check in both methods of crop establishment.

2.1.1.2 Direct seeded rice

Kohle and Tripathi (1998) working on inceptisol soils in Raipur concluded that the hand weedings at 20 and 30 DAS in direct seeded rice produced significantly higher number of effective tillers and grains panicle⁻¹ than weedy check. However two hand weedings at 20 and 40 DAS significantly increased number of tillers m⁻², grains panicle⁻¹ and 1000-grain weight of rice over both herbicidal treatments and weedy check.

Vandana and Reddy (1999) from Hyderabad observed that hand weeding twice at 30 and 50 DAS in direct sown rice recorded significantly higher values of yield attributes over all the herbicidal treatments.

Kohle (1999) while working on inceptisol soils under Raipur conditions reported that two hand weedings, at par with weed free treatment was found significantly superior to unweeded control in increasing the test weight of direct seeded rice.

Madhavi and Reddy (2002) while working on sandy clay loam soil in Hyderabad reported that two hand weedings at 30 and 60 DAS improved number of panicles m^{-2} and recorded significantly higher number of grains panical⁻¹ in direct wet seeded rice sown under puddled conditions.

Moorthy and Sanjoy (2002) reported that two hand weedings at 20 and 40 DAS in rice, sown directly resulted in improved yield attributing characters viz., panicles m^{-2} and grain weight panicle⁻¹.

Saini (2005) from Palampur in silty clay loam soil reported that all weed control treatments produced significantly higher values of all the yield attributes and yield of direct seeded upland rice over control.

Subramanian *et al.* (2005) recorded higher number of panicles and filled grains panicle⁻¹ in direct seeded rice with application of pretilachlor + safener over other herbicidal treatments.

2.1.2 Grain and straw yield

2.1.2.1 Transplanted rice

Purushotham and Hosamani (1990) while working on clay loam soils tried four weed control measures and found that application of butachlor gave significantly higher grain yield and higher net returns over farmers practice.

Kathiresan and Veerabadran (1991) studied the effect of integrated weed management on nutrient uptake and grain yield of rice found that pre-emergence application of pendimethalin (1.0 kg a.i ha⁻¹) followed by one hand weeding (20 DAT) significantly increased the grain yield over weedy check.

Bali *et al.* (1994) studied the chemical control of weeds in transplanted rice under plain and high altitude conditions of Khudwani and Larnoo, reported that application of butachlor @ 1.5 kg a.i ha⁻¹, at par with benthocarb and hand weeding (20 and 30 DAT) reduced 97 and 102 per cent in mean grain yield over control respectively.

Jena *et al.* (1994) evaluated the efficiency of weed control measures and observed that all herbicidal treatments significantly increased grain yield of rice over control.

Nagaraju (1994) tested the efficacy of anilophos + 2, 4-D and other herbicides on transplanted rice yields and their economics. The study revealed that anilophos + 2, 4-D was more profitable compared to the herbicides used individually.

Maiti and Misra (1995) worked out the efficacy of several herbicides and found that all the herbicide treated plots produced significantly higher grain yield over control.

Singh *et al.* (1996) studied the effect of anilophos in combination with 2, 4-D on weed control in transplanted rice and found that paddy yield in plots treated with anilphos alone at 0.6 kg a.i ha⁻¹ or in combination with 2, 4-D as tank mixture at 0.266 + 0.332 kg a.i ha⁻¹ or as formulated mixture at 0.60 kg a.i ha⁻¹ was statistically similar in their effect.

Dhiman *et al.* (1998) conducted experiments to study the efficacy of herbicides used alone and in combinations and reported that weed free plots recorded the highest grain yield of rice during both the years of experimentation. Amongst herbicides butachlor treated plot produced highest yield which was at par with anilphos (granules) 0.6 kg a.i ha⁻¹, anilphos + 2, 4-DEE (0.4 + 0.53 kg a.i ha⁻¹), pretilachlor (0.75 kg a.i ha⁻¹), anilphos (0.4 kg a.i ha⁻¹) and anilphos + 2, 4-D Sodium salt (0.4 + 0.4 kg a.i ha⁻¹).

Gogoi (1998) reported that application of anilophos @ 0.4 kg a.i ha⁻¹ gave consistently higher grain yield, which was comparable to that under weed free condition.

Phogat and Pandey (1998) tested the relative efficacy of weed control measures and reported that maximum yield was recorded under weed free treatment while anilophos, butachlor, pendimethalin and

pretilachlor significantly increased grain yield and proved statistically superior to control and metsulfuron.

Sharma and Bhunia (1999) conducted field experiments for 3 years and found that pendimethalin @ 1.5 kg a.i ha⁻¹ supplemented with one hand weeding (30 DAT) produced highest yield attributes, grain and straw yield with maximum additional net returns.

Gajendra *et al.* (1999) studied weed management in rainfed lowland rice under transplanted conditions and reported that pre-emergence application of mixture of anilophos + 2, 4-DEE (0.4 + 0.5 kg a.i ha⁻¹) recorded higher grain yield than rest of the herbicidal mixture and their individual applications. Weed free treatment provided the highest grain yield followed by two hand weedings and anilophos + 2, 4-DEE (0.4 + 0.5 kg a.i a.i ha⁻¹).

In a two year study on management of weeds with herbicides in transplanted rice, Nandal *et al.* (1999) reported that during 1996, two hand weedings (20 and 40 DAT) significantly increased the grain yield over weedy check though being at par with other herbicidal treatments. However, during 1997, ethoxysulfuron + anilophos (0.015 + 0.375 kg a.i ha⁻¹) recorded the highest grain yield of rice and thus proved significantly superior to weedy check and other herbicidal treatments including butachlor

(1.5 kg a.i ha⁻¹) anilophos (0.4 kg a.i ha⁻¹) and two hand weedings (20 and 40 DAT).

Gogoi *et al.* (2001) reported that application of butachlor (0.5 kg a.i ha⁻¹) or anilophos (0.2 kg a.i ha⁻¹) markedly increased grain yield of rice.

Narwal *et al.* (2002) reported that out of 18 weed control treatments, acetachlor (150 g a.i ha⁻¹) applied 3 and 8 DAT and ready mixture of anilophos + ethoxysulfuron (750 g a.i ha⁻¹) provided effective control of weeds and were at par with butachlor (1500 g a.i ha⁻¹) applied at 3 DAT. When averaged over years the maximum grain yield of 70.44 q ha⁻¹ of rice was obtained in weed free plots and minimum of 49.07 q ha⁻¹ in weedy check.

Sharma *et al.* (2004) recorded significantly higher grain yield of paddy under clomazone + 2, 4-DEE application, but statistically similar to butachlor, anilophos and weed free treatments, than weedy check.

Singh *et al.* (2004) working under Raipur conditions recorded significantly higher rice grain yields under all the weed management treatments over weedy check.

Mukerjee and Singh (2004) reported that weed free treatment while remaining at par with herbicidal treatment of almix + 2, 4-DEE and

anilophos + 2, 4-DEE, recorded significantly higher grain yield (59.30 q ha⁻¹) of rice over unweeded treatment (31.46 q ha⁻¹).

Ahuja *et al.* (2004) reported that pre-plant application of glyphosphate, at par with pre-emergence application of butachlor, resulted in significantly higher grain yield of rice and also (B:C ratio) over paraquat application and control. They attributed the increase to reduced weed competition due to these treatments.

Chhokar *et al.* (2007) while working with evaluation of fenitazamide and flufenacet for weed control in transplanted rice under Haryana conditions reported that the application of fenitazamide @ 105 g and 120 g a.i ha⁻¹ at 4-DAT produced yield more or less similar to the application of fenitazamide @ 105 to 120 g a.i ha⁻¹, flufenacet @ 120 g a.i ha⁻¹ and weed free control.

2.1.2.2 Direct seeded rice

Higher yields of direct wet seeded rice were realized by keeping crop weed-free upto 45 DAS (Singh *et al.* 1989) as competitive period was identified to be four weeks after sowing.

Padhi *et al.* (1991) conducted an experiment in Orissa in well drained sandy loam soils and concluded that the maximum grain yield was

recorded from two hand weedings (20 and 40 DAS) which differed significantly from the weedy control.

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

Moorthy and Sanjoy (2002) from Cuttack in sandy loam soil concluded that the highest grain yield of rice during both the years in the treatment in which two hand weedings at 20 and 40 DAS were followed.

Awan *et al.* (2002) from Pakistan concluded that the maximum grain yield of direct sown rice was obtained from the plots where one hand weeding was performed after 6 weeks of seeding.

Saha *et al.* (2003) from Cuttack, observed that two hand weedings at 20 and 40 DAS influenced the grain yield of wet seeded direct sown rice significantly than weedy check and other treatments in comparison.

Beura and Reddy (2003) while working on sandy clay loam soil under Hyderabad conditions observed that two hand weedings resulted in the highest grain yield of direct sown rice.

Singh *et al.* (2005) from Uttar Pradesh reported that two hand weeding treatments at 20 and 50 DAS resulted in the highest rice grain yield over all other treatments.

Bhat *et al.* (2008) from SKUAST- J reported that all the weed control treatments brought out a significant effect on yield attributes of direct wet seeded rice as compared to weedy check and most superior yield attributes were recorded in weed free plots. Amongst various herbicides used Butachlor @ 1.5 kg a.i ha⁻¹ (7 DAS), anilophos @ 312 g a.i ha⁻¹ + ethoxysulfuron @15 g a.i ha⁻¹ (10 DAS) and Pretilachlor @ 0.75 kg a.i ha⁻¹ (3 DAS) provided maximum number of effective tillers m⁻², number of grains panicle⁻¹ and 100 grain weight with the concomitant increase in the grain yield than other weed control treatments.

2.2 Effect on weeds

2.2.1 Weed flora

Working under Jammu conditions, Dahama *et al.* (1992) observed that weed flora consists of grasses, broad leaves and sedges i.e. *E. colonum*, *E. crusgalli* and *Cynodon dactylon* in grasses; *Cyperus rotundus* and *Cyperus iria* in sedges and *Eclipta alba* as broad leaves.

Sharma (1994) found broad leaved species like *Commelina benghalensis*, *Alternanthera sessilis*; grasses like *E. crusgalli*, *Leptochloa chinensis* and sedges like *Cyperus iria* and *Scirpus maritimus* in rice.

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

Mathew and Jagadeesh (1999) from Kerala found that the experimental field was mainly dominated by *E. crusgalli*, *Isachne miliacea*, *Monochoria vaginalis*, *Ludwigia parviflora* and *Cyperus iria* weeds.

The most dominant weeds of wet seeded rice in Hyderabad as observed by Madhavi and Reddy (2002) comprised of *Cyperus iria*, *Cyperus difformis*, *E. colona*, *Panicum repens*, *Paspalum pasplodes*, *Eclipta alba*, *Marselia minuta*, *Ammania bacifera* and *Monochoria vaginalis*.

Chander and Pandey (2002) identified *Echinochloa colonum*, *E. crusgalli*, *Leptochloa chinensis*, *Eclipta alba* and *Commelina benghalensis* as main weed species in rice fields with more dominance in direct seeded over transplanted plots.

Tomar *et al.* (2003) reported that weed growth (biomass and population) was significantly affected by weed management practice. The dominant weed comprised of *Fumaria parviflora* (53.4%) followed by *Cyperus rotundus* (81%) in rice wheat cropping system under varying levels of tillage and weed management practices.

Sarkar *et al.* (2004) reported *Echinochloa colona* (33.1%), *Caesulia axillaries* (18.5%), *Cyperus iria* (14.0%), *Commelina benghalensis* (11.5%) and *Fimbristylis milliacea* (11.5%) and other weeds (11.4%) as major weeds in rice fields.

Bahar and Singh (2004) reported that different weed species infesting the experimental plots were *Echinochloa colona* (30.8%), *E. crusgalli* (15.8%), *Caesulia axillaries* (10.3%), *Ischaemum rugosum* (26.4%), *Commelina diffusa* (7.6%) and other (8.9%). The highest weed density was observed under weedy check treatment at 60 DAS.

The mean density of *Echinochloa colona* at 30 DAS was significantly higher in dry direct seeded unpuddled (DSR) over wet seeded puddled soil (WSR) and transplanting (TPR) during first season, while during second season DSR and WSR had more density of *E. colona* over TRP. The major species in their study were *Echinochloa colona*, *Caesulia axillaries* and *Cyperus rotundus* (Singh *et al.*, 2005).

Shekhar and Mankotia (2005) reported that the predominant weed flora comprised of *Monochoria vaginalis* (23.5%), *Bonnaya veronicaefolia* (18.3%), *Cyperus iria* (13.3%), *Echinochloa colona* (11.5%), *Fimbristylis miliacea* (11.3%), *Paspalum pasplodes* (7.0%), *Cyperus difformis* (4.0%) and *Commelina benghalensis* (3.0%) and remaining (9.0%) of other weeds.

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

Saini (2005) reported that major weed flora consisted of *E. colonum* and *E. crusgalli*, *D. sanguinalis* and *S. glauca* among grasses and *C. benghalensis* and *Polygonum* spp. among broad leaf weeds. The grass and broad leaf weed constituted 61.9 and 38.1 per cent of total weed flora, respectively.

Singh *et al.* (2007) while working on response of aromatic rice (Pusa Basmati-1) to establishment methods, fertility levels and weed management practices under Allahabad conditions reported that dominant weed flora observed was *E. colounm*, *E. crusgalli* and *D. sanguinalis* among grasses, *A. baccifera* and *C. bengalensis* among broad leaf weeds and *C. rotendus* and *C. difformis* among sedges.

It has been observed that grassy weeds (*Echinochloa* spp. *Cynodon dactylon*), broad leaved weeds (*Ammania densifolia*, *Blamogeton* spp., *Monochoria vaginalis*, *Marselia quadrifolia*) and sedges (*C. difformis*, *C. iria*, *Scirpus* spp.) are most commonly found in transplanted and direct seeded rice.

2.2.2 Weed dry weight

Patel (1990) recorded significant increase in weed dry weight with delay in weeding beyond 60 DAS.

Chandrakar (1991) noticed that butachlor @ 2 kg a.i ha⁻¹ applied 4 DAS was more efficient in suppressing weeds than @ 1 kg ha⁻¹, whereas Padhi *et al.* (1991) reported that amongst herbicidal treatments, butachlor 50 EC (1.5 kg a.i ha⁻¹ 2 DAS) followed by one hand weeding (40 DAS) recorded significantly lowest weed population and weed dry weight and did not differ significantly from two hand weedings.

Bajpai and Singh (1992) stated that in sprouted direct seeded rice, butachlor @ 1.5 kg a.i ha⁻¹ applied upto 10 DAS significantly reduced monocot weeds and contributed for significant reduction in weed dry weight over weedy check, whereas the dicot weeds were controlled effectively when butachlor was applied upto 8 DAS.

Application of butachlor @ 1.5 kg a.i ha⁻¹ caused reduction in weed

dry weight similar to thiobencarb formulations (Mishra *et al.*, 1992) they did not record variation in weed dry weight with butachlor @ 1.5 kg a.i ha⁻¹ or thiobencarb @ 1.5 kg a.i ha⁻¹ or anilophos @ 0.4 kg a.i ha⁻¹ applied 3, 6 and 9 DAS, respectively but delayed application of (12 DAS) significantly increased weed dry weight in direct seeded rice.

Angiras and Sharma (1998) reported that oxyfluorfen @ 0.25 kg a.i ha⁻¹ (3 DAS) significantly reduced total weed count and dry matter production of weeds. Butachlor and pendimethalin were statistically at par and next best in reducing total weed count and dry matter production of weeds.

Kolhe and Tripathi (1998) observed that two hand weedings (20 and 35 DAS), at par with application of anilophos @ 0.4 kg a.i ha⁻¹ + one hand weeding (35 DAS) and thiobencarb 1.0 kg a.i ha⁻¹ + one hand weeding (35 DAS), significantly decreased dry matter of weeds over other herbicidal treatments and unweeded control.

Singh *et al.* (2005) recorded higher weed dry weight (76.51) and (90.04 g m⁻²) at 30 DAS and at harvest, respectively under dry seeding compared to other methods of establishment.

Gopinath and Pandey (2007) while working on effect of dose and time of flufenacet application on weeds and yield of rice at IARI (Delhi) reported

that flufenacet at 100 and 120 g a.i ha⁻¹ caused similar decreases in weed population and weed biomass and was significantly superior to other treatments.

2.2.3 Weed control efficiency

Imeokparia (1990) from Nigeria reported that single herbicide treatment of oxadiazon (0.75 kg a.i ha⁻¹), butachlor (4.2 kg a.i ha⁻¹) and propanil (4.0 kg a.i ha⁻¹) alone provided inadequate weed control as compared with hand weeding. However, mixtures of propanil with butachlor or piperophos or oxadiazon recorded weed control efficiency comparable to hand weeding.

Pandey and Shukla (1990) found that butachlor @ 1.0 kg a.i ha⁻¹ recorded weed control efficiency comparable with hand weeding, whereas higher weed control efficiency under treatments of weed free, two hand weeding, butachlor (1.5 kg a.i ha⁻¹, 48 hrs after sowing) + one hand weeding and pendimethalin + one hand weeding.

Tiwari *et al.* (1991) reported that application of oxadiazon (0.8 kg a.i ha⁻¹ 2 DAS) resulted in maximum weed control efficiency followed by butachlor (2 kg a.i ha⁻¹ 2 DAS) in directed seeded rice.

Gogoi and Kalita (1992) noticed that butachlor (0.5 kg a.i ha⁻¹ 6

DAS) + one hand weeding (35 DAS) showed weed control efficiency (67%) comparable to thiobencarb, 2, 4-D (1.0 + 0.5 kg a.i ha⁻¹ 6 DAS) in direct seeded rice.

Roy (1993) reported that in direct seeded deep water rice highest weed control efficiency recorded by weed free check was followed by butachlor (1.0 kg a.i ha⁻¹ 6 DAS) + 2, 4-D (0.75 kg a.i ha⁻¹, 25-30 DA) and two weedings.

Singh and Pillai, (1993) observed that in puddled direct seeded rice highest weed control efficiency with butachlor @ 1.5 kg a.i ha⁻¹, benthocarb @ 1.5 kg a.i ha⁻¹, anilophos @ 0.4 kg a.i ha⁻¹, was maximum when herbicidal application was made at 12 DAS.

In rainfed upland rice, the mean weed control efficiencies were 50.4, 76.3, 44.3, 71.2, 63, 85.8 and 80.6 per cent with butachlor (1.5 kg a.i ha⁻¹ 6 DAS), butachlor (1.5 kg a.i ha⁻¹) + hand weeding, benthocarb (1.5 kg a.i ha⁻¹), benthocarb + hand weeding, pendimethalin, pendimethalin + hand weeding and hand weeded check, respectively and magnitude of increase in WCE with integration of one hand weeding or over butachlor, benthocarb and pendimethalin alone was 23.9, 26.8 and 22.2 per cent, respectively (Singh, 1993).

Singh *et al.* (2002) reported that application of butachlor (1500 g a.i

ha⁻¹) or anilophos (400 g a.i ha⁻¹) was significantly superior to weedy check in controlling of weeds.

Singh *et al.* (2004) reported the highest weed control efficiency under two hand weedings owing to possible competition posed by weeds which was at par with butachlor + 2, 4-D Sodium salt.

Minimum weed density was recorded in hand weedings twice at 30 and 50 DAT which was statistically at par with butachlor + 2, 4-D which had maximum weed control efficiency as reported by Rajkhowa and Gogoi (2004).

Rampool *et al.* (2007) while working on performance of trisulfuron, + pretilachlor and bensulfuron methyl in transplanted rice reported that the combination of trisulfuron + pretilachlor @ 0.009 + 0.5 kg a.i ha⁻¹ (6 DAT), resulted in 50 weeds m⁻² with dry weight of 101 g which was statistically at par with butachlor @ 1.5 kg a.i ha⁻¹ + one hand weeding (3 DAT).

CHAPTER – 3

MATERIALS AND METHODS

The present investigation entitled “Studies on Crop Establishment Methods and Weed Management in Rice (*Oryza sativa* L.)” was conducted at Rice Research and Regional Station, Khudwani of Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir (J&K) during *kharif* 2008. The techniques followed and materials used during the course of investigation are detailed in this chapter as under :

3.1 Location and climate

The experimental site (Khudwani) is situated in temperate zone of the state between 34° N latitude and 74° E longitude at an altitude of 1560 metres above mean sea level. Climatically the experimental site was in mid altitude temperate zone characterised by hot summers and very cold winters with an average annual precipitation of 812 mm (average of past 20 years) most of which is received from December to April in the form of snow and rains. The mean meteorological data for the cropping seasons recorded at Meteorological Observatory, Qazigund is presented in Fig. 1 and Appendix-I.

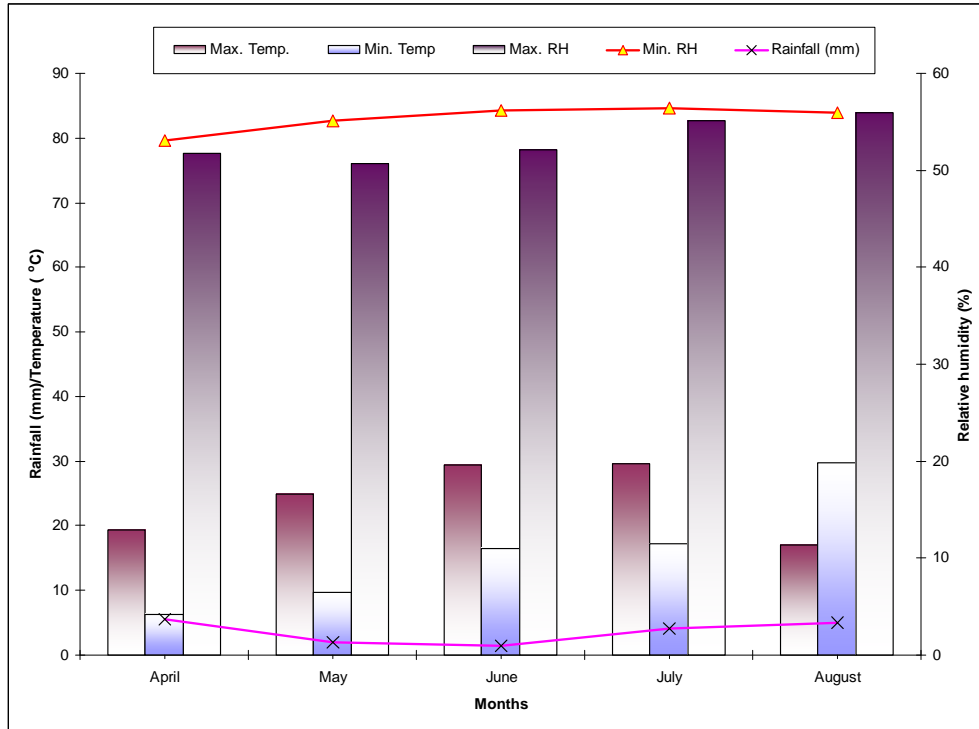


Fig. 1 : Mean monthly temperature ($^{\circ}\text{C}$), relative humidity (%) and rainfall (mm)

3.2 Soil characteristics

Composite soil samples from 0-15 cm depth from each replication in the experimental field were collected prior to sowing of crops and analysed for physico-chemical composition to know its initial fertility status. The results of the analysis are presented in Table-1.

Table-1 : Physico-chemical characteristics of soil of experimental field

Particulars	Value	Rating	Methods employed
Physical characteristics	Total = about 100		
Sand (%)	18%	-	International Pipette Method (Piper, 1966)
Silt (%)	55%	-	
Clay (%)	27%	-	
Texture (%)	Silty Clay loam	-	
Chemical characteristics			
pH	6.83	Neutral	1:2.5 soil water suspension with Beckman's glass electrode pH meter (Jackson, 1967)
Electrical conductivity (dSm ⁻¹) at 25°C	0.25	Normal	Soloubridge Conductivity Metre (Piper, 1950)
Organic carbon (%)	0.75	Medium	Walkley and Black's rapid titration method (Jackson, 1967)
Available nitrogen (kg ha ⁻¹)	215	Low	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
Available phosphorus (kg ha ⁻¹)	15.0	Medium	Extraction with 0.5 M NaHCO ₃ (Olsen <i>et al.</i> , 1954)
Available potassium (kg ha ⁻¹)	205	Medium	Extraction with neutral normal ammonium acetate (Jackson, 1967)

3.3 Cropping history of experimental site

The cropping history of experimental site for last 5 years is given in Table-2.

Table-2 : Cropping history of experimental site

Year	Kharif	Rabi
2004	Rice	Brown sarson
2005	Rice	Brown sarson
2006	Rice	Brown sarson
2007	Rice	Brown sarson
2008	Rice (Experimental)	–

3.4 Experimental details

The experiment comprised of two factors viz., (2 cultural methods and 7 weed control methods) was laid out in a Randomized Block Design with three replications as per layout plan shown in Fig. 2. The details are given below.

3.4.1 Treatment details

1. **Crop establishment methods.....02**
M₁.....Direct-seeding
M₂.....Transplanting

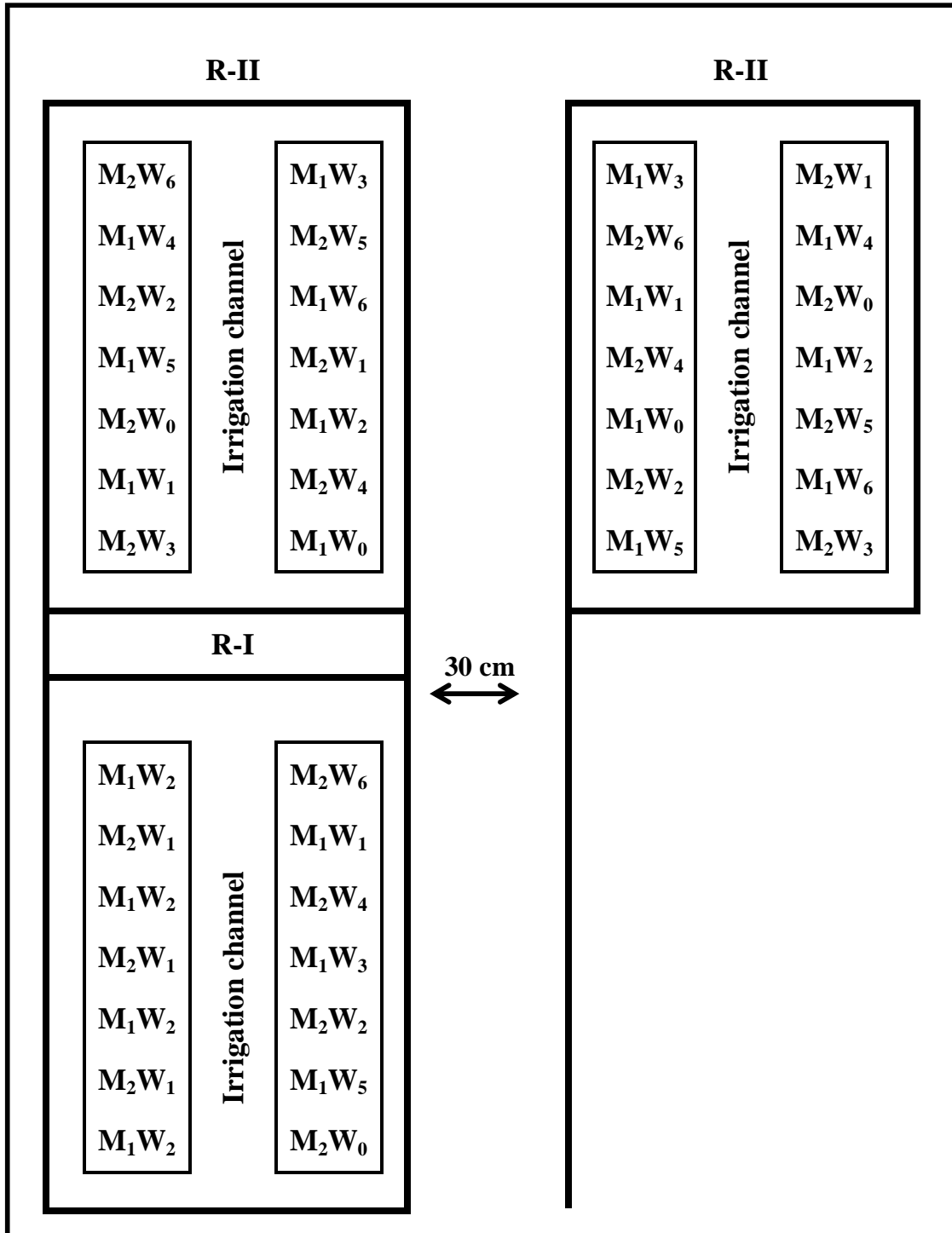


Fig. 2 : Layout of the experiment

2. **Weed control methods.....07**

W₀.....Weedy check

W₁.....Two hand weedings at 20 and 40 DAS/DAT

W₂.....Butachlor @ 1.5 kg a.i. ha⁻¹

W₃.....Pendimethalin @ 1 kg a.i. ha⁻¹

W₄.....Butachlor @ 1.5 kg a.i. ha⁻¹ + 2,4-D @ 1 kg a.i. ha⁻¹

W₅.....Butachlor @ 1.5 kg a.i. ha⁻¹+Almix @ 0.004 kg a.i. ha⁻¹

W₆.....Weed free

3.4.2 Other experimental details

No. of replications : 03

No. of treatment combinations : 14

Crop : Rice

Variety : Shalimar Rice-1 (SR-1)

Spacing : 15 cm x 15 cm

Gross plot size : 3.30m x 4.35 m

Net plot size : 3.0 m x 4.05 m

3.5 Calendar of field operations

The details of field operations are given in Table-3.

Table-3: Calendar of field operations

Operation	Date
Tractorisation with tiller	07.05.2008
Layout	11.05.2008
Making of boarders, irrigation and drainage channels and levelling of plots	12.05.2008
Seed soaking	13.05.2008
Irrigation for puddling	13.05.2008
Fertilization (application of basal dose of nitrogen, phosphorus and potassium)	15.05.2008
Broadcasting of seed	17.05.2008
Nursery sowing(in case of transplanted rice)	18.05.2008
Application of weedicides as per treatment (in case of direct seeded rice)	23.05.2008
Hand weeding (as per treatments) in case of DSR	07.06.2008
Transplantation of 20 days old seedlings (in case of transplanted rice)	08.06.2008
Application of herbicides as per treatment (in case of transplanted rice)	12.06.2008
First top dressing of nitrogen	20.06.2008
Hand weeding as per treatment	28.06.2008
Second top dressing of nitrogen	10.07.2008
Harvesting	18.09.2008
Threshing	25.09.2008
Irrigation and drainage	5cm depth of water was maintained upto semi-dough stage. Alternate wetting and drying was followed after semi-dough stage till physiological maturity. Excess water was drained out and irrigation was stopped at maximum tillering stage for 7 days till small cracks appeared. At pre-heading stage irrigation was withheld for 5 days.

3.6 Land preparation

Field was disc ploughed after harvesting of previous crop (Brown sarson). Subsequently, three ploughings were given with tiller to bring the soil to a fine tilth. Replication borders, plot-paths, irrigation and drainage channels were made manually. Water was let in the plots for puddling operation. Proper leveling of plots was done before broadcasting of seed and transplanting of seedlings.

3.7 Fertilizer application

Full recommended dose of phosphorus and potassium through diammonium phosphate and muriate of potash at the rate of 45 and 20 kg P_2O_5 and K_2O ha^{-1} , respectively was uniformly applied to each plot as basal one day before sowing of direct seeded rice and just before transplanting the seedlings. Nitrogen @ 180 kg ha^{-1} was applied through urea with half as basal and remaining half in two equal splits i.e. tillering and panicle initiation stages to both direct seeded and transplanted rice.

3.8 Method of sowing

Paddy seed variety Shalimar rice-1 (SR-1) at the rate of 80 kg ha^{-1} for transplanting method and 100 kg ha^{-1} for direct seeded method was soaked in water for 48 hours and then incubated for 48 hours for sprouting. For direct sowing method, sprouted seed was uniformly broadcasted in

rows spaced 15cm apart and in case of transplanting method, 20 days old seedlings uprooted from nursery were transplanted in the experimental field with 3 robust seedlings per hill maintaining a spacing of 15 cm x 15 cm on the same day of its uprooting.

3.9 Herbicide application

Weed control in the experimental field was done as per the treatments. Seven weed management practices were employed including weed free and weedy check. The herbicides butachlor ($1.5 \text{ kg a.i ha}^{-1}$) and pendimethaline (1.0 a.i ha^{-1}) were applied as pre emergent at 5 to 7 DAS/DAT, almix ($0.004 \text{ kg a.i ha}^{-1}$) and 2,4-D ($1.0 \text{ kg a.i ha}^{-1}$) as post emergent at 12 and 30 DAS/DAT respectively. The herbicide was sprayed with manually operated knapsack sprayer fitted with a flat fan nozzle using 500 litres of water per hectare on moist soil in the plots.

3.10 Harvesting and threshing

Harvesting of crop was done immediately after physiological maturity i.e. at 20 per cent grain moisture content, leaving border and penultimate rows from all the sides of each plot. The harvested crop after sun drying in the field for 72 hours was tied into bundles (plot-wise) and weight was taken with spring balance in kg per plot and then converted into

q ha⁻¹. Threshing was done by beating the crop against wooden logs and the grain yield was recorded in kg per plot and then expressed in q ha⁻¹.

3.11 Experimental observations

The following observations were recorded during the experiment:

3.11.1 Crop studies

3.11.1.1 Plant height

The height of ten randomly selected plants from each plot was measured periodically (30, 60, 90 DAS/DAT and at harvest) from ground level to the apex of last fully opened leaf during vegetative period and up to the tip of the panicle after flowering. It was averaged and expressed in centimetres.

3.11.1.2 Dry matter production

Plant samples contained in a quadrant 0.5 m x 0.5 m (0.25 m²) were collected from each plot. The samples were collected at different crop growth stages and after sun drying for 3-4 days, the samples were oven dried at 60-65°C for 48 hours to a constant weight. The dry weight was recorded in grams and then converted into q ha⁻¹.

3.11.1.3 Leaf area index

The periodic leaf area (30, 60, 90 DAS/DAT and at harvest) was

measured from a quadrat of 0.25 m² for each treatment with a leaf area metre (Systronics, 211). Total number of tillers m⁻² (through use of quadrant) was counted at various crop growth stages till harvest from each plot followed by counting number of leaves for 10 randomly selected tillers and then working out average number of leaves per tiller. By using metre scale, length and breadth of 10 randomly selected leaves was taken in situ with an aim to ascertain average pseudo-leaf area. Multiplying pseudo-leaf area by leaf area constant, actual leaf area was determined. Leaf area constant was calculated as under :

$$C = \frac{lm}{ls}$$

Where,

C = Leaf area constant

lm = Leaf area measured with leaf area metre (Systronics 211)

ls = Leaf area obtained by scale

The leaf area index was then calculated by dividing the leaf area by ground area.

$$\text{Leaf area index (LAI)} = \frac{\text{Total leaf area}}{\text{Ground area}}$$

3.11.1.4 Number of panicles

The number of panicle falling in quadrant 0.25 m² were counted

from each plot before harvesting and the number was converted into m^{-2} .

3.11.1.5 Panicle length

Panicle length of 10 randomly selected panicles from each plot was measured from neck node to the tip of panicle and then averaged and expressed in centimetres.

3.11.1.6 Number of grains per panicle

Total number of grains from 10 panicles was counted from each plot and expressed as grains panicle⁻¹.

3.11.1.7 Panicle weight

Ten randomly selected panicles from each plot were weighed and then averaged as weight panicle⁻¹ and expressed in grams.

3.11.1.8 1000-grain weight

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

3.11.1.9 Biological yield

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

3.11.1.10 Grain yield

The harvested crop from the respective net plots (12.15m²) was threshed, weight recorded and expressed as q ha⁻¹.

3.11.1.11 Straw yield

The straw yield of each plot was computed by deducting the grain yield from biological yield and expressed as q ha⁻¹.

3.11.1.12 Harvest index

It was calculated by the following formula :

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

3.11.1.13 Plant chemical studies

After recording the dry weight of plant samples (q ha⁻¹) collected from each plot, these were ground and subsequently used for chemical analysis.

3.11.2.1 Nitrogen content

Oven dried samples were ground in Wileys mill and passed through 32 mesh sieve. Nitrogen content was estimated by digesting 0.5 g sample with 10 ml concentrated sulphuric acid and digestion mixture. Total nitrogen was determined by micro Kjeldahls method.

3.11.2.2 Protein content in grain

Protein content in grain was determined by multiplying nitrogen content in grain by a factor 6.25.

3.11.2.3 Amylose determination

Milled rice grains were ground on a restch mill equipped with 100 mesh sieve for the determination of amylose content according to the method reported by Juliano (1971). The intensity of blue colour was read in spectrophotometer at 620 nm wave length.

3.11.3 Weed studies

3.11.3.1 Weed count and identification

Weeds falling in the quadrant 0.25 m^2 were uprooted from each plot periodically (at 30, 60 and 90 DAS/DAT and at harvest), identified, counted and expressed as weed m^{-2} .

3.11.3.2 Weed dry weight

Weeds uprooted from each plot at 30, 60, 90 DAS/DAT and at harvest for weed count were washed and after sun drying these were oven dried at $60\text{-}65^\circ\text{C}$ for 48 hours to a constant weight. The weight was expressed in grams and then converted into g m^{-2} .

3.11.3.3 Weed control efficiency (%)

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

$$\text{WCE}(\%) = \frac{\text{WDC} - \text{WDT}}{\text{WDC}} \times 100$$

Where,

WCE = weed control efficiency

WDC = weed dry weight in control plot

WDT = weed dry weight in treated plot

3.12.4 Relative economics

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

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

3.12.5 Statistical analysis

The data obtained in respect of various observations were statistically analyzed by method described by Cochran and Cox (1963). The significance of 'F' and 't' was tested at 5 per cent level of significance. The critical difference value was determined when 'F' test was significant.

CHAPTER – 4

EXPERIMENTAL FINDINGS

The results with regard to the study entitled “Studies on crop establishment methods and weed management in rice (*Oryza sativa* L.)” for the effect of various treatments on crop growth, yield attributes and yield are presented in this chapter.

4.1 Growth parameters

4.1.1 Plant height

Plant height is the primary growth determining character, its periodic values recorded at 30, 60, 90 days after sowing and at harvest have been presented in Table 4 and Fig. 3 with corresponding analysis of variance depicted in Appendix-II.

The crop establishment methods i.e. transplanted and direct seeded rice did not cause any significant influence in the plant height of rice at any of the crop growth stages during the course of experimentation. However, plant height showed an increasing trend up to the harvest stage. Numerically the transplanted crop was having taller plants than direct seeded crop but the difference were statistically non significant. At harvest stage, transplanting method recorded 4.05 per cent higher plant height than direct seeded method of crop establishment.

Table-4 : Periodic plant height (cm) of rice as affected by crop establishment methods and weed management practices

Treatment	30 DAS	60 DAS	90 DAS	At harvest
Crop establishment methods				
M ₁ (Direct seeded)	19.05	60.00	91.69	100.82
M ₂ (Transplanted)	20.44	63.24	94.79	104.91
SE ± (m)	0.69	1.34	1.40	1.47
C.D(0.05)	N S	N S	N S	N S
Weed control practices				
W ₀ (Weedy check)	15.14	49.18	79.86	88.55
W ₁ (Two hand weedings)	18.28	60.57	92.75	102.93
W ₂ (Butachlor)	20.05	62.26	93.84	104.16
W ₃ (Pendimethalin)	17.75	59.63	90.40	100.08
W ₄ (Butachlor + 2,4-D)	20.99	64.90	97.65	106.25
W ₅ (Butachlor + Almix)	22.35	66.30	98.89	107.70
W ₆ (Weed free)	23.65	68.50	99.30	110.39
SE ± (m)	1.63	3.03	3.18	3.33
C.D(0.05)	3.91	7.29	7.65	8.01

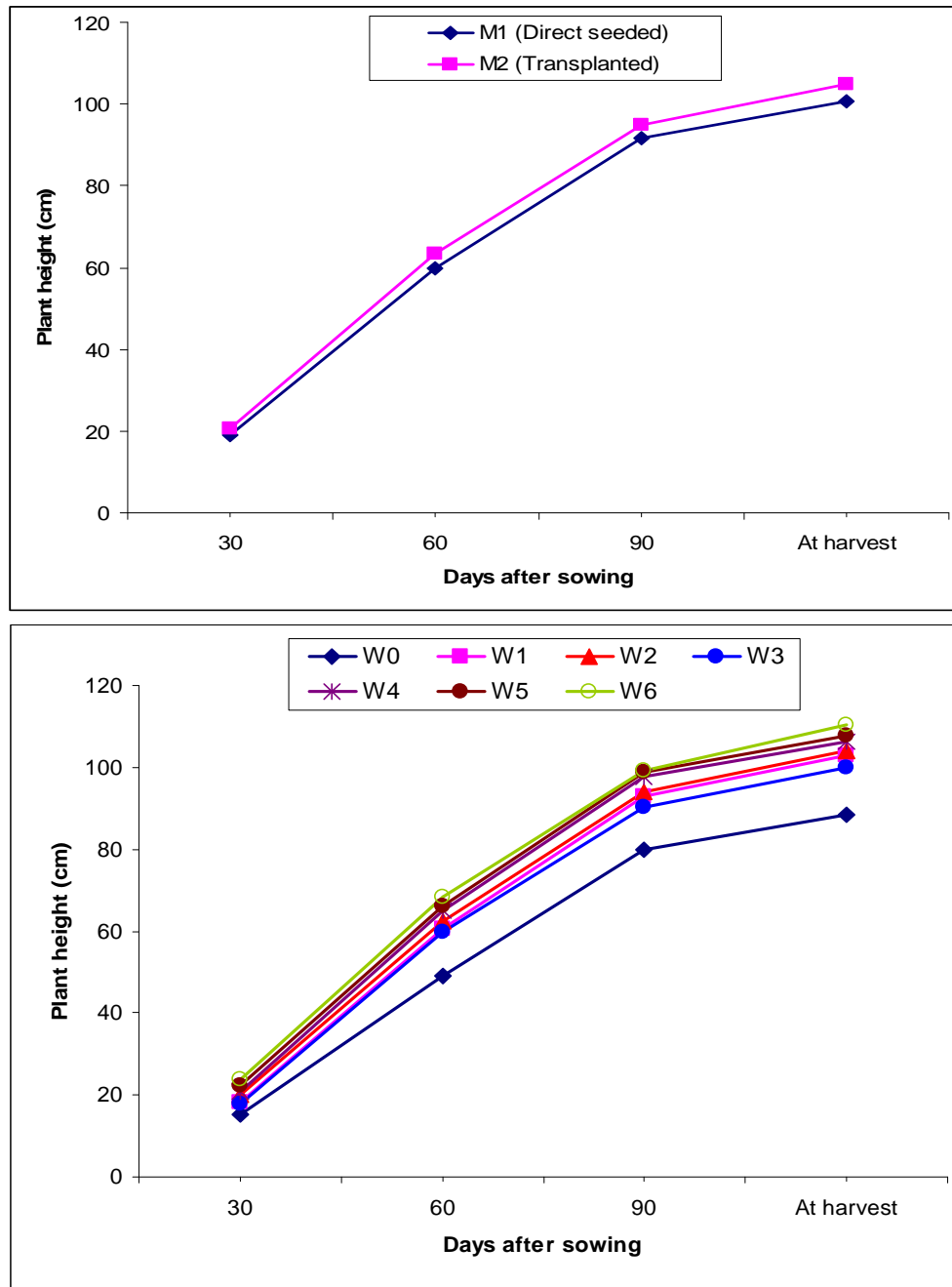


Fig. 3: Periodic plant height (cm) of rice as affected by crop establishment methods and weed management practices

W₀ (Weedy check), W₁ (Two hand weeding), W₂ (Butachlor), W₃ (Pendimethalin),

W₄ (Butachlor + 2,4-D), W₅ (Butachlor + Almix), W₆ (Weed free)

The influence of weed management practices on plant height showed that apart from weed free treatment though statistically at par with butachlor + almix (W₅), butachlor + 2,4-D (W₄) and butachlor alone, brought marked increase in the plant height at all the crop growth stages of rice over other weed control measures including weedy check (W₀). Among the herbicidal treatments, butachlor + almix (W₅) improved the plant height at all the crop growth stages over butachlor + 2,4-D (W₄), pendimethalin (W₃) and butachlor (W₂) during the course of experimentation. At 60 and 90 DAS butachlor + almix recorded 34.5 and 23.8 per cent taller plants, respectively as compared to weedy check. However, the plant height went on increasing till harvest stage of the crop. At harvest stage, weed free treatment recorded an increase of 24.66, 7.24, 5.98, 10.81, 3.89 and 2.49 per cent in plant height over weedy check (W₀), two hand weedings (W₁), butachlor (W₂), pendimethaline (W₃), butachlor + 2,4-D (W₄) and butachlor + almix (W₅) respectively. Butachlor + almix (W₅) recorded an increase of 7.6 and 21.6 per cent higher plant height than pendimethalin and weedy check respectively.

4.1.2 Leaf area index

Leaf area index is an important parameter which influences the growth and yield of a crop and is mainly responsible for photosynthetic activity of the plant. Periodic leaf area index under different treatments is presented in Table 5 and depicted by Fig.4 with corresponding analysis of variance given in Appendix-III.

Table-5 : Periodic leaf area index (LAI) of rice as affected by crop establishment methods and weed management practices

Treatment	30 DAS	60 DAS	90 DAS	At harvest
Crop establishment methods				
M ₁ (Direct seeded)	1.25	3.86	3.06	0.99
M ₂ (Transplanted)	1.27	3.92	3.11	1.00
SE ± (m)	0.04	0.08	0.03	0.02
C.D(0.05)	N S	N S	N S	N S
Weed control practices				
W ₀ (Weedy check)	1.19	3.04	2.85	0.88
W ₁ (Two hand weedings)	1.23	3.19	2.95	0.94
W ₂ (Butachlor)	1.25	4.29	3.02	0.99
W ₃ (Pendimethalin)	1.22	3.08	2.91	0.93
W ₄ (Butachlor + 2,4-D)	1.28	4.31	3.12	1.03
W ₅ (Butachlor + Almix)	1.31	4.49	3.34	1.07
W ₆ (Weed free)	1.33	4.82	3.43	1.12
SE ± (m)	1.02	0.153	0.12	0.04
C.D(0.05)	0.04	0.37	0.30	0.11

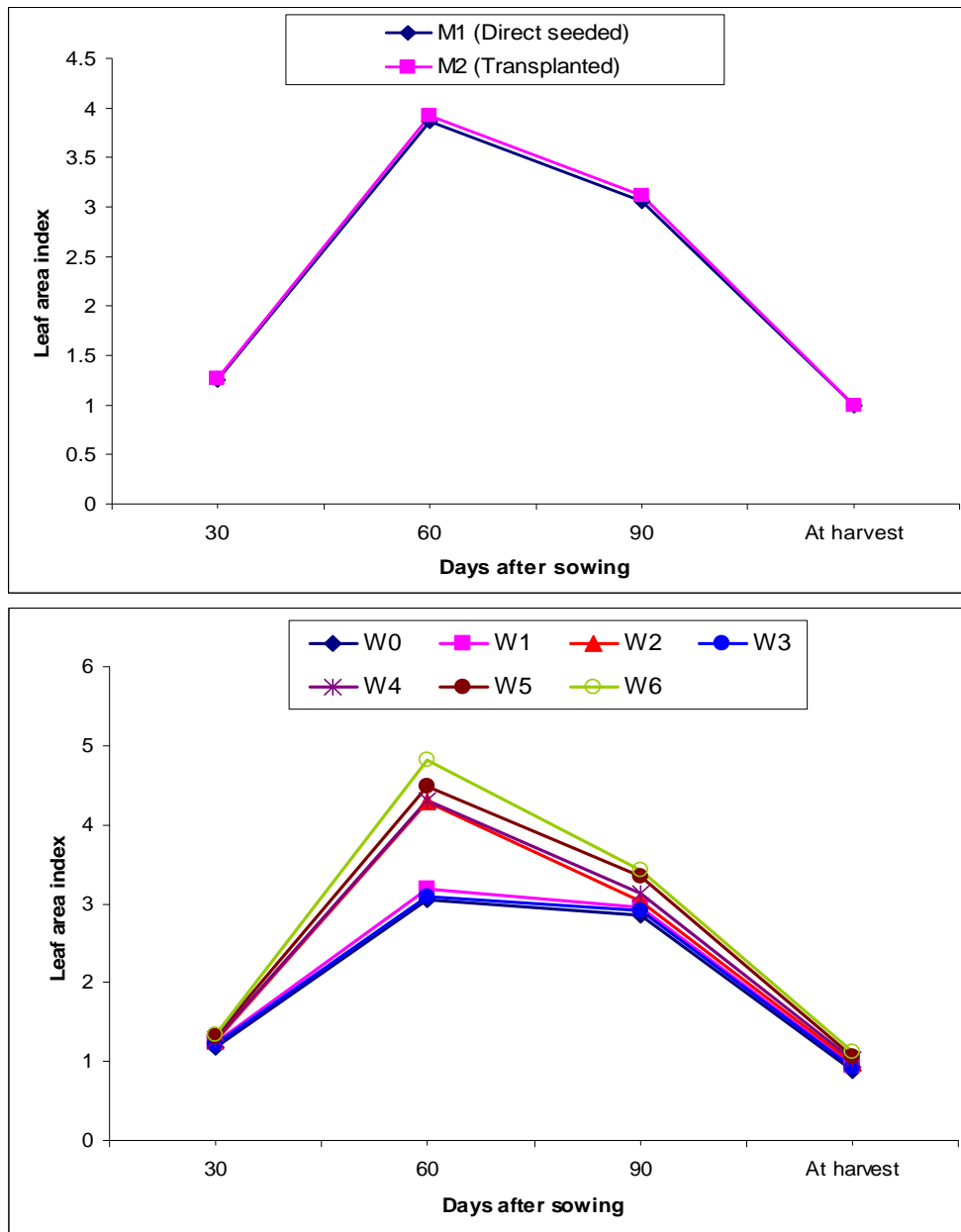


Fig. 4 : Periodic leaf area index (LAI) of rice as affected by crop establishment methods and weed management practices

W₀ (Weedy check), W₁ (Two hand weeding), W₂ (Butachlor), W₃ (Pendimethalin),
W₄ (Butachlor + 2,4-D), W₅ (Butachlor + Almix), W₆ (Weed free)

Leaf area index (LAI) was not significantly affected by different crop establishment methods at any of the stages of crop growth. The leaf area index increased up to flowering stage and then declined. The highest LAI was recorded at 60 DAS. At harvest stage, transplanting method recorded only 0.1 per cent increase of LAI over direct seeded method.

The data revealed that among different weed management practices, weed free treatment (W_6) caused significant improvement in leaf area index of rice at all the stages of crop growth over other treatments. However weed free (W_6) treatment remained statistically at par with butachlor + almix (W_5). At 60 DAS butachlor + almix recorded 47 per cent higher LAI than weedy check. At harvest stage weed free treatment recorded an increase of 27.30, 19.15, 13.13, 20.43, 0.08 and 0.05 per cent increase in leaf area index over weedy check (W_0), two hand weedings (W_1), butachlor (W_2), pendimethalin (W_3), butachlor + 2,4-D (W_4) and butachlor + almix (W_5) respectively. The crop treated with butachlor + almix at 90 DAS acquired an LAI of 3.34 which was 17.1 and 13.2 per cent higher than weedy check and two hand weedings, respectively.

4.1.3 Dry matter accumulation ($q\ ha^{-1}$)

Dry matter accumulation is another important character to express the growth and metabolic efficiency of the plant, which ultimately influences the economic yield. The relevant data on a periodic dry matter accumulation by rice is presented in Table 6 and Fig. 5. The corresponding analysis of variance is given in Appendix IV.

Table-6 : Periodic dry matter accumulation ($q\ ha^{-1}$) of rice as affected by crop establishment methods and weed management practices

Treatment	30 DAS	60 DAS	90 DAS	At harvest
Crop establishment methods				
M ₁ (Direct seeded)	6.93	33.72	78.64	130.09
M ₂ (Transplanted)	6.91	36.80	85.56	142.63
SE ± (m)	0.20	0.63	1.50	1.61
C.D (0.05)	N S	1.52	3.62	3.89
Weed control practices				
W ₀ (Weedy check)	6.70	22.51	51.43	108.70
W ₁ (Two hand weedings)	6.74	32.46	84.81	133.47
W ₂ (Butachlor)	6.81	35.86	84.60	142.20
W ₃ (Pendimethalin)	6.66	32.62	79.48	129.07
W ₄ (Butachlor + 2,4-D)	7.07	38.23	88.46	145.37
W ₅ (Butachlor + Almix)	7.15	41.79	91.35	147.22
W ₆ (Weed free)	7.30	43.37	94.57	148.51
SE ± (m)	0.50	1.18	2.82	3.03
C.D(0.05)	N S	2.84	6.77	7.29

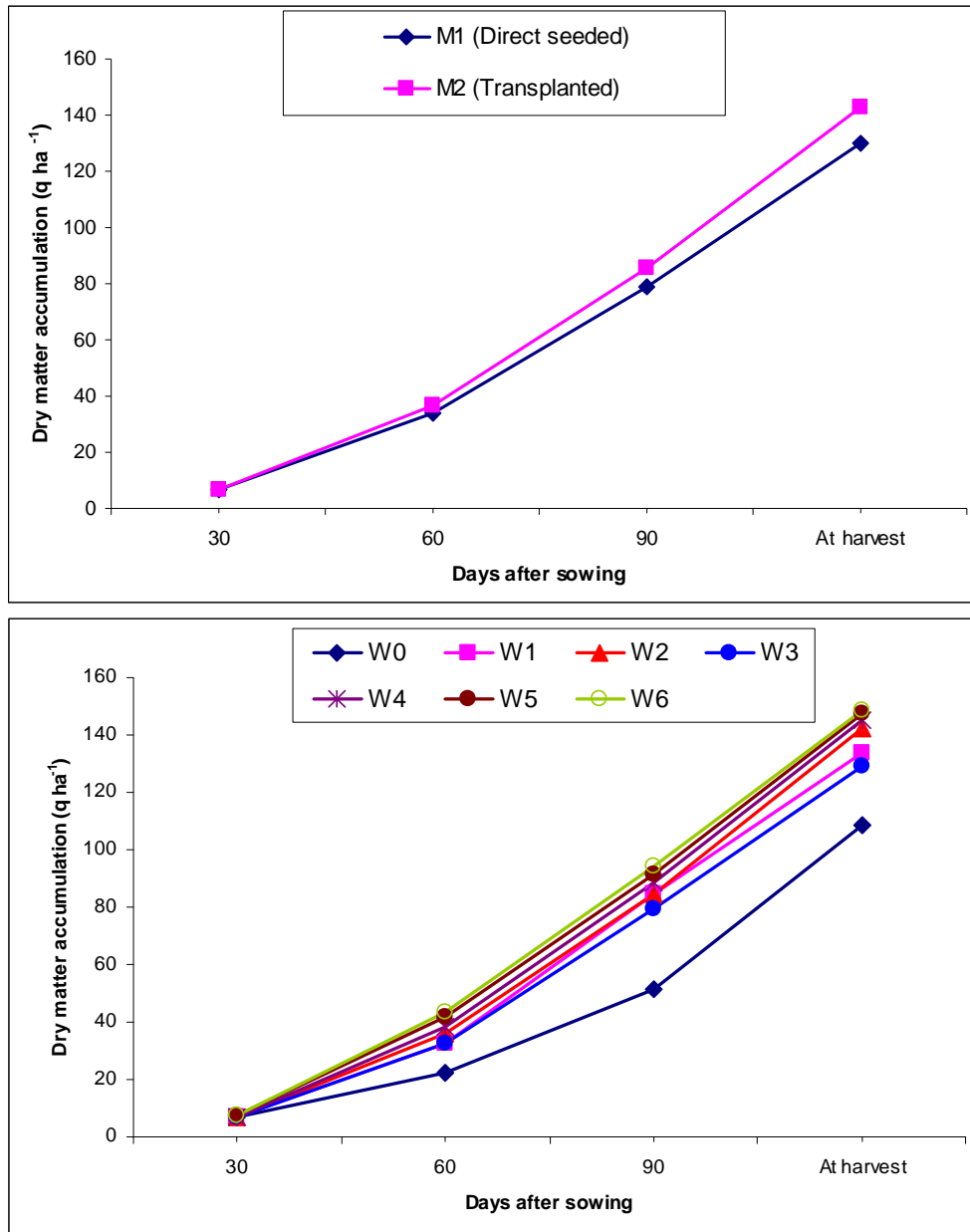


Fig. 5 : Periodic dry matter accumulation (q ha⁻¹) of rice as affected by crop establishment methods and weed management practices

W₀ (Weedy check), W₁ (Two hand weeding), W₂ (Butachlor), W₃ (Pendimethalin),

W₄ (Butachlor + 2,4-D), W₅ (Butachlor + Almix), W₆ (Weed free)

Data revealed discernible variation in dry matter of crop due to various treatments. Dry matter accumulation was significantly increased under transplanting method at all the crop growth stages over direct seeded method of crop establishment except at 30 DAS. At 60 DAS dry matter accumulation increased significantly in transplanted than direct seeded rice and the superiority in this regard was 9.1 per cent. A similar trend was also observed at 90 DAS and at harvest stage by the crop. At harvest stage transplanting method gave an increase of 9.64 per cent dry matter over direct seeding. It was also observed that dry matter accumulation continued to increase upto harvest stage of the crop.

As regards the effect of weed management practices, weed free treatment (W₆) although remained at par with Butachlor + Almix (W₅) and Butachlor+ 2,4-D (W₄), significantly enhanced the dry matter of rice at all stages of observations over other weed control methods except at 30 DAS. However, among herbicidal treatments Butachlor + Almix although statistically at par with Butachlor + 2,4-D proved significantly superior in increasing the crop dry matter at all the crop growth stages except at 30 DAS, over other treatments. It was further observed that dry matter production showed an increasing trend up to the harvest. At 60 DAS butachlor + almix recorded 85.65 per cent higher dry matter accumulation

than weedy check. The crop treated with butachlor + almix at 90 DAS recorded dry matter accumulation of 91.35 q ha⁻¹ which was 77.62 per cent higher than weedy check. At harvest butachlor + almix (W₆) treated plots recorded an increase of 35.43, 10.30, 3.53 and 11.06 and per cent dry matter accumulation over weedy check (W₀), two hand weedings (W₁), butachlor (W₂), pendimethalin (W₃), butachlor + 2,4-D (W₄) and butachlor + almix (W₅) respectively.

4.2 Yield and yield attributing characters

4.2.1 Panicles m⁻²

Number of panicles is the most important parameter directly influencing the ultimate yield of crop. The data pertaining to panicles m⁻² are presented in Table 7 and Fig. 6 and corresponding analysis of variance in Appendix V. The data reveal that transplanting method of crop establishment caused significant improvement in the number of panicles m⁻² over direct seeded method during the course of experimentation. The transplanting method proved 8.56 per cent superior in number of panicles over the direct seeded method of crop establishment.

The data also revealed that all the weed management practices improved the number of panicles significantly over weedy check. Among different weed control methods weed free treatment (W₆), though

statistically at par with butachlor + almix (W₅) but significantly enhanced the number of panicles over other weed control methods. However, amongst the herbicidal treatments butachlor + almix (W₅) although statistically at par with butachlor + 2,4 -D proved significantly superior to other chemical treatments and weedy check in this respect. Combined application of butachlor followed by almix (W₅) produced 39.47, 15.92, 7.29 and 24.34 per cent more panicles m⁻² than weedy check (W₀), two hand weedings (W₁), butachlor (W₂) and pendimethalin (W₃) respectively.

4.2.2 Number of grains panicle⁻¹

The data regarding grains per panicle as affected by crop establishment methods and weed management practices is presented in Table 7; Fig. 7 and corresponding analysis of variance given in Appendix V. Crop establishment methods caused significant differences in the number of grains per panicle of rice. Transplanting method of crop establishment markedly improved the number of grains per panicle over direct seeded method. The superiority acquired in this respect by transplanted rice was 7.88 per cent over direct seeded rice.

As regards the effect of weed management practices, number of grains panicle⁻¹ was significantly improved over weedy check by all the weed control methods. Weed free treatment (W₆) though statistically at par

with butachlor + almix recorded significantly higher number of grains panicle⁻¹ than weedy check and other weed control methods. However, herbicidal treatment butachlor followed by almix (W₅) proved significantly superior to other treatment in this respect. Application of butachlor followed by almix (W₅) recorded an increase of 60.83, 12.56, 10.22 and 27.31 per cent grains per panicle over weedy check (W₀), two hand weedings (W₁), butachlor (W₂) and pendimethalin (W₃) respectively.

4.2.3 Panicle weight

The data regarding panicle weight is presented in Table 7, Fig.8 and corresponding analysis of variance is given in Appendix V. The data shows that crop establishment methods created significant variations in panicle weight. Transplanting method proved significantly superior to direct seeded method and recorded 8.11 per cent higher panicle weight than direct seeded method.

The data further revealed that all the weed control methods recorded significantly higher panicle weight than weedy check. Plots kept weed free were statistically similar to those treated with butachlor followed by almix (W₅) and recorded significantly higher panicle weight compared to other treatments. However, herbicidal treatment butachlor followed by almix

(W₅) proved markedly superior to other herbicidal treatments as well as to weedy check with respect to panicle weight. Butachlor followed by Almix (W₅) treatment recorded an improvement of 46.66, 32.27, 21.18 and 33.64 per cent panicle weight over weedy check (W₀), two hand weedings (W₁), butachlor (W₂) and pendimethalin (W₃) respectively.

4.2.4 1000-grain weight (g)

The data regarding test weight presented in Table 7; Fig. 9 and corresponding analysis of variance is given in Appendix V. The data indicated that different crop establishment methods failed to influence the 1000-grain weight significantly. Transplanting method tended to acquire a bit more test weight than direct seeded method.

Among the different management practices weed free treatment recorded highest 1000 grain weight (25.82 g) though statistically at par with other treatments but significantly superior to weedy check (W₀) which recorded a lowest 1000-grain weight (22.64 g). The superiority recorded by treatment Butachlor followed by Almix over weedy check in respect of 1000 grain weight was 12.8 per cent.

Table-7 : Panicles m⁻² grains panicle⁻¹ panicle weight and test weight of rice as affected by crop establishment methods and weed management practices

Treatment	Panicles/m² (No.)	Panicle wt. (g)	Grains panicle⁻¹	1000 grain wt. (g)
Crop establishment methods				
M ₁ (Direct seeded)	373.00	2.34	97.33	24.65
M ₂ (Transplanted)	404.95	2.53	105.00	24.85
SE ± (m)	3.45	0.05	2.01	0.17
C.D (0.05)	8.32	0.12	4.86	N S
Weed control practices				
W ₀ (Weedy check)	309.50	1.95	71.50	22.64
W ₁ (Two hand weedings)	372.16	2.32	102.16	25.38
W ₂ (Butachlor)	402.33	2.36	104.33	24.10
W ₃ (Pendimethalin)	347.66	2.14	90.33	24.39
W ₄ (Butachlor + 2,4-D)	419.00	2.48	108.16	25.41
W ₅ (Butachlor + Almix)	431.66	2.86	115.00	25.53
W ₆ (Weed free)	440.50	2.95	116.66	25.82
SE ± (m)	6.46	0.09	3.77	0.71
C.D(0.05)	15.57	0.23	9.09	1.72

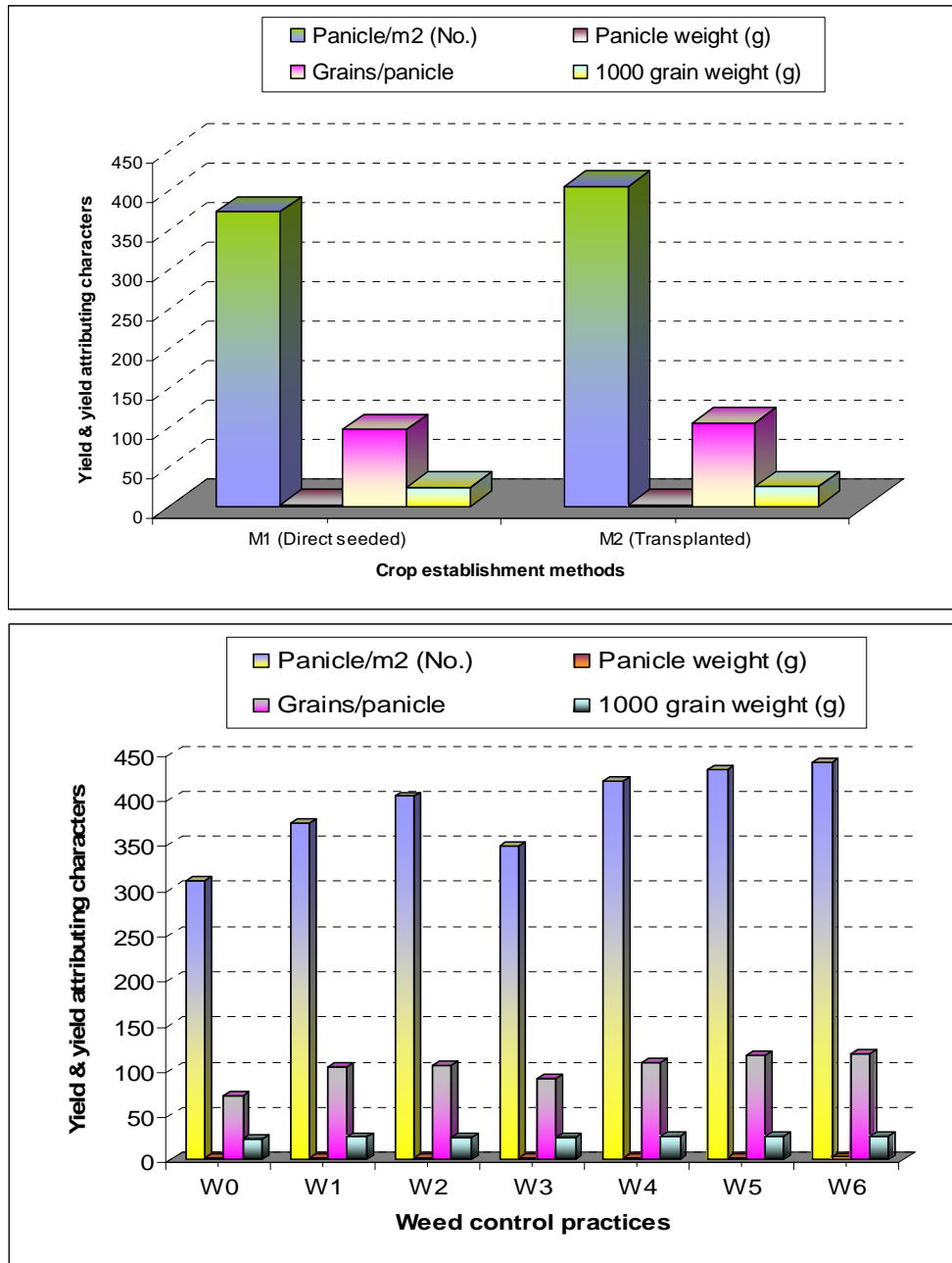


Fig. 6 : Panicles m^{-2} grains panicle $^{-1}$ panicle weight and test weight of rice as affected by crop establishment methods and weed management practices

W₀ (Weedy check), W₁ (Two hand weedings), W₂ (Butachlor), W₃ (Pendimethalin),

W₄ (Butachlor + 2,4-D), W₅ (Butachlor + Almix), W₆ (Weed free)

4.2.5 Grain and straw yield

Biological yield of crop is the most important criteria for comparing the efficiency of different treatments. The data regarding the grain and straw yield as influenced by different treatments is presented in Table 8, Fig.10 and corresponding analysis of variance has been given in Appendix VI.

4.2.5.1 Grain yield

Grain yield being an economic component of the crop is the important crop parameter, which reflects the resultant impact of all crop growth parameters and yield attributes that are affected by various input treatments.

Crop establishment methods created significant variation in the grain yield of rice. Transplanting method of crop establishment recorded significantly higher grain yield than direct seeded rice thereby providing a yield advantage of 7.05 per cent over direct seeded rice.

The yield loss due to weeds in the present experiment was estimated to be 42.66 per cent. All the weed control methods improved the grain yield significantly over weedy check. Among different weed management practices, maximum grain yield (72.63 q ha⁻¹) was recorded by the weed free treatment followed by butachlor + almix with (70.50 q ha⁻¹) which

was significantly higher than other weed management practices and weedy check. butachlor + almix (W_5) treatment recorded significantly higher grain and provided a yield advantage of 42.66, 13.90, 13.03 and 32.73 per cent over weedy check (W_0), two hand weedings (W_1), butachlor (W_2) and pendimethalin (W_3) respectively.

4.2.5.2 Straw yield

Straw yield of rice also followed the similar trend as that of grain yield and the results are presented in Table 8 and Fig.11.

The data indicated that transplanting method of crop establishment provided significantly higher straw yield (8.03%) than direct seeding method.

Among the various weed control methods weed free treatment (W_6) produced highest straw yield of 89.40 q ha⁻¹ which was statistically at par with that of butachlor + almix (89.00 q ha⁻¹) but significantly higher than other weed control treatments. Among herbicidal treatments butachlor + almix (W_5) provided a superiority of 27.23, 4.26, and 18.11 per cent over weedy check (W_0), two hand weedings (W_1) and pendimethalin (W_3) respectively.

4.2.5.3 Harvest index

The data presented in Table 8 and Fig.12 reveal that transplanting and direct seeding in rice did not vary significantly from each other with respect to harvest index. However, transplanting method tended to improve harvest index as compared to direct seeded method.

Among weed management treatments, weed free (W_6) treatment recorded significantly highest harvest index, while weedy check (W_0) recorded lowest harvest index. The harvest index obtained with Butachlor+Almix (W_5) was significantly higher than other weed management practices. Application of butachlor + almix exhibited a superiority of 5.4 and 3.75 per cent over weedy check and two hand weedings respectively.

Table-8 : Grain yield, straw yield and harvest index of rice as affected by crop establishment methods and weed management practices

Treatment	Grain yield (q ha⁻¹)	Straw yield (q ha⁻¹)	Harvest index (%)
Crop establishment methods			
M ₁ (Direct seeded)	60.65	79.98	43.12
M ₂ (Transplanted)	64.93	86.40	42.90
SE ± (m)	1.28	2.30	0.05
C.D (0.05)	3.10	5.54	N S
Weed control practices			
W ₀ (Weedy check)	50.56	69.95	41.95
W ₁ (Two hand weedings)	63.33	85.36	42.60
W ₂ (Butachlor)	63.81	85.84	42.63
W ₃ (Pendimethalin)	54.34	75.35	41.90
W ₄ (Butachlor + 2,4-D)	64.87	87.45	42.58
W ₅ (Butachlor + Almix)	70.50	89.00	44.20
W ₆ (Weed free)	72.63	89.40	44.65
SE ± (m)	2.41	4.30	0.13
C.D(0.05)	5.81	10.36	0.32

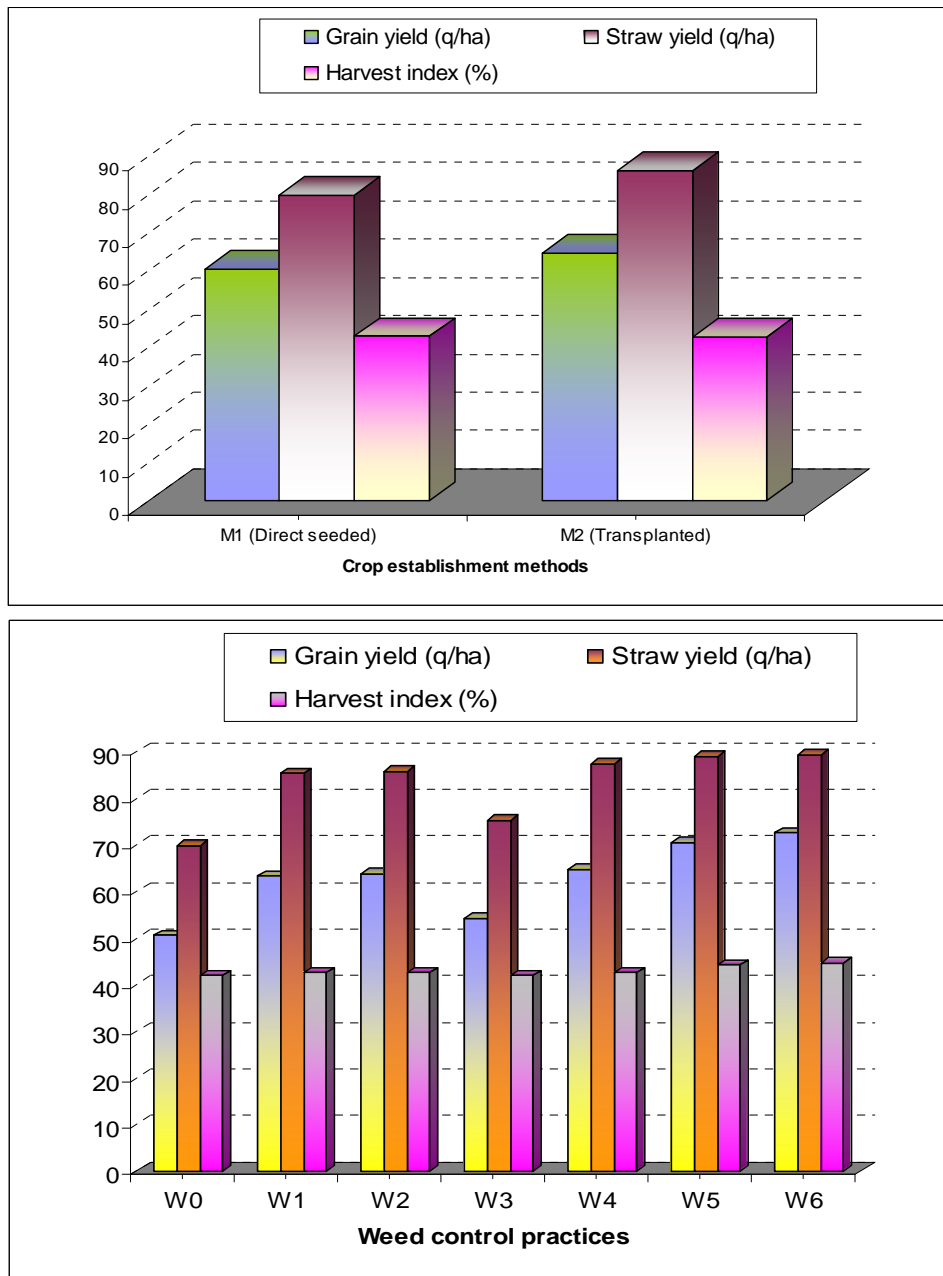


Fig. 7 : Grain yield, straw yield and harvest index of rice as affected by crop establishment methods and weed management practices

W₀ (Weedy check), W₁ (Two hand weedings), W₂ (Butachlor), W₃ (Pendimethalin),
W₄ (Butachlor + 2,4-D), W₅ (Butachlor + Almix), W₆ (Weed free)

4.3 Quality parameters

4.3.1 Crude protein

The data presented in Table 9 Fig.13 and corresponding analysis of variance is given in Appendix VII indicated that transplanting and direct seeded methods of crop establishment did not vary significantly with respect to crude protein content of grains. However, transplanting method tended to 0.06 per cent more protein content than direct seeded method.

As regards the weed control methods all the weed management practices though statistically at par with each other recorded significantly higher protein content compared to weedy check. Butachlor + almix treated plots (though at par with other weed control treatments) produced grains with 1.96 per cent higher protein than weedy check.

4.3.2 Amylose content

Amylose content followed the same trend as that of protein content and the data presented in Table 9; Fig.14 and corresponding analysis of variance is given in Appendix VII which indicated that there was no significant differences between transplanting and direct seeded methods of crop establishment so far as amylose content of grains is concerned. However, transplanting method recorded 0.65 per cent increased amylose content over direct seeded method.

Among different weed control methods, the highest amylose content was recorded in weed free (W_6) treatment and that of lowest in weedy check (W_0). The amylose content of weed free treatment (W_6) although significantly superior to weedy check (W_0) two hand weedings (W_1) and pendimethalin (W_3) but remained statistically at par with butachlor +almix (W_5), butachlor + 2,4-D (W_4) and with butachlor (W_2).

Table-9 : Protein and amylose content of rice as affected by crop establishment methods and weed management practices

Treatments	Protein content (%)	Amylose content (%)
Crop establishment methods		
M ₁ (Direct seeded)	6.93	21.98
M ₂ (Transplanted)	6.99	22.63
SE ± (m)	0.87	0.96
C.D(0.05)	N S	N S
Weed control practices		
W ₀ (Weedy check)	5.02	15.72
W ₁ (Two hand weedings)	6.76	21.75
W ₂ (Butachlor)	6.80	22.89
W ₃ (Pendimethalin)	6.74	21.65
W ₄ (Butachlor + 2,4-D)	6.86	23.89
W ₅ (Butachlor + Almix)	6.98	25.00
W ₆ (Weed free)	7.08	25.24
SE ± (m)	0.30	1.32
C.D(0.05)	0.72	3.18

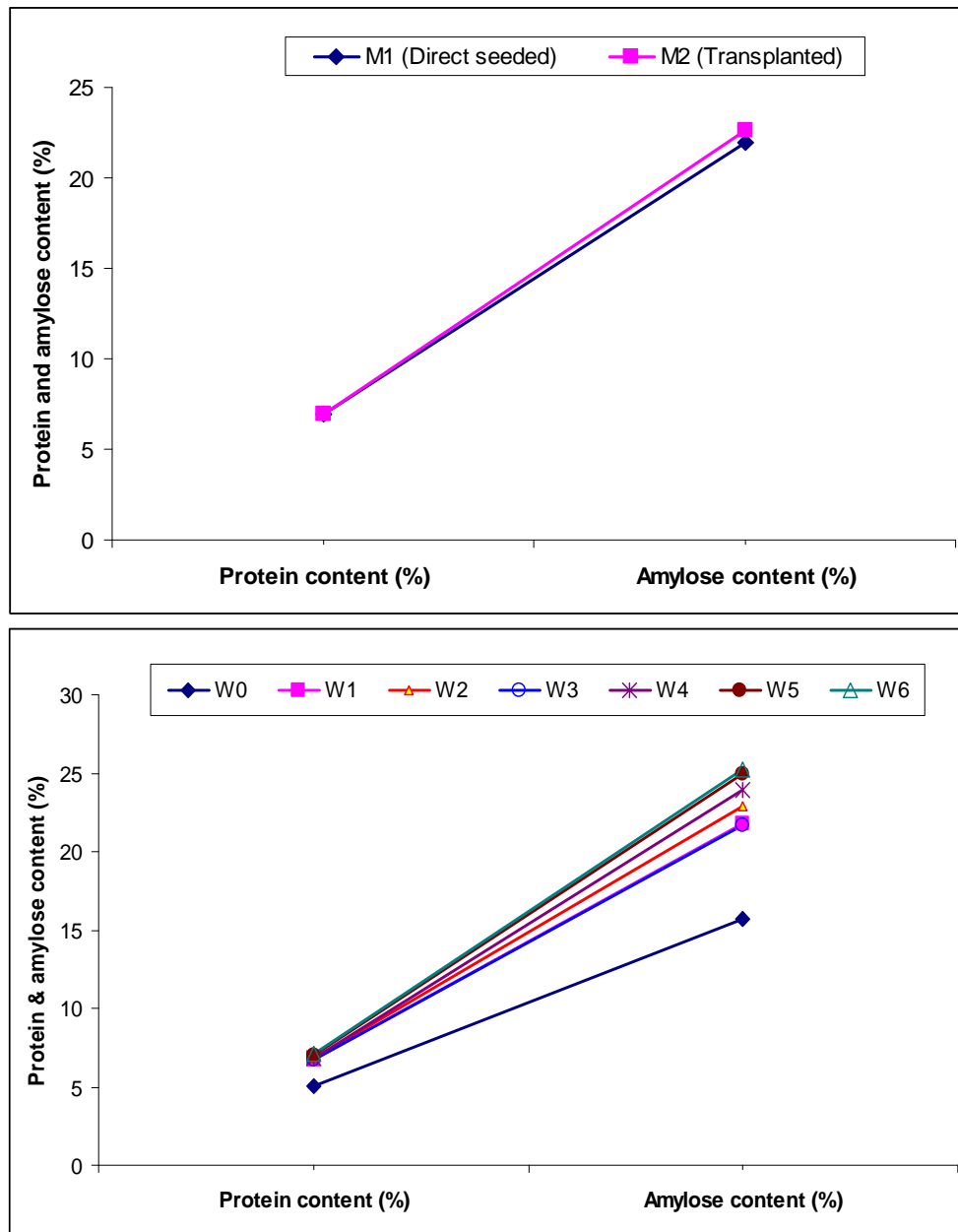


Fig. 8: Protein and amylose content of rice as affected by crop establishment methods and weed management practices

W₀ (Weedy check), W₁ (Two hand weedings), W₂ (Butachlor), W₃ (Pendimethalin),

W₄ (Butachlor + 2,4-D), W₅ (Butachlor + Almix), W₆ (Weed free)

4.4 Studies on weeds

4.4.1 Weed flora

The data depicted in Table 10 showed that the experiment field was infested with grassy, broad leaved weeds as well as sedges. The prominent grassy weeds were *Echinochloa crusgalli*, *E. colona* and *Cynodon dactylon*, broad leaved weeds were *Ammania baccifera*, *Marsilea qudrofolia*, *Monochoria vaginalis* and *Potamogeton distinctus* while the prominent sedges included *Cyperus iria*, *Cyperus defformis* and *Fimbristylis* spp. (Table-10)

Table-10 : Dominant weed flora of rice identified during experimentation

Grasses	Sedges	Broad leaved weeds
➤ <i>Echinochloa colonum</i>	➤ <i>Cyperus iria</i>	➤ <i>Ammania baccifera</i>
➤ <i>Echinchloa crusgalli</i>	➤ <i>Fimbristylis</i>	➤ <i>Potamogeton distinctus</i>
➤ <i>Cynodon dactylon</i>	➤ <i>Cyperus defformis</i>	➤ <i>Monochoria vaginalis</i>
		➤ <i>Marselia quadrifolia</i>

4.4.2 Weed density/population

The periodic data pertaining to weed density population (m^{-2}) have been presented in Table 11 which showed that weed density was highest in direct seeded rice as compared to transplanting method of crop establishment. It was further observed that among different weed management practices, weedy check (W_0) recorded highest weed density at all the observational stages. The weed density increased till 90 DAS and thereafter it declined. Besides weed free treatment lowest weed density was recorded in butachlor + amlix (W_5) which was statistically at par with butachlor + 2,4-D treatment.

At harvest stage of the crop, the density of weeds was reduced by 77.08 per cent with the combined application of butachlor + amlix as compared to unweeded control. While the use of butachlor alone reduced the population of weeds by 64.73 per cent.

Table-11 : Periodic weed density (No/m²) in rice as affected by crop establishment methods and weed control practices

Treatments	30 DAS	60 DAS	90 DAS	At harvest
Crop establishment methods				
M ₁ (Direct seeded)	12.71 (3.40)	23.28 (4.52)	39.28 (6.15)	35.90 (5.30)
M ₂ (Transplanted)	7.85 (2.70)	16.54 (3.82)	26.23 (5.03)	21.76 (3.85)
SE ± (m)	0.62 (0.08)	0.70 (0.09)	1.04 (0.09)	0.82 (0.25)
C.D (0.05)	1.48 (0.20)	1.68 (0.07)	2.50 (0.22)	1.65 (0.51)
Weed control practices				
W ₀ (Weedy check)	18.00 (4.28)	57.16 (7.54)	92.33 (9.75)	81.33 (9.25)
W ₁ (Two hand weedings)	16.00 (4.01)	23.06 (4.82)	45.66 (6.63)	38.16 (6.15)
W ₂ (Butachlor)	10.66 (3.29)	15.83 (4.00)	22.83 (5.15)	20.32 (4.45)
W ₃ (Pendimethalin)	12.66 (3.58)	16.66 (4.92)	31.05 (7.15)	30.33 (5.35)
W ₄ (Butachlor + 2,4-D)	8.50 (2.99)	13.50 (3.70)	20.83 (4.95)	18.83 (3.86)
W ₅ (Butachlor + Almix)	6.16 (2.53)	10.16 (3.24)	16.66 (4.62)	12.84 (3.14)
W ₆ (Weed free)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)
SE ± (m)	1.15 (0.16)	1.32 (0.13)	1.95 (0.18)	1.28 (0.41)
C.D (0.05)	2.78 (0.40)	3.17 (0.32)	4.46 (0.42)	3.08 (0.98)

*Values in parenthesis are transformed value $\sqrt{x+1}$

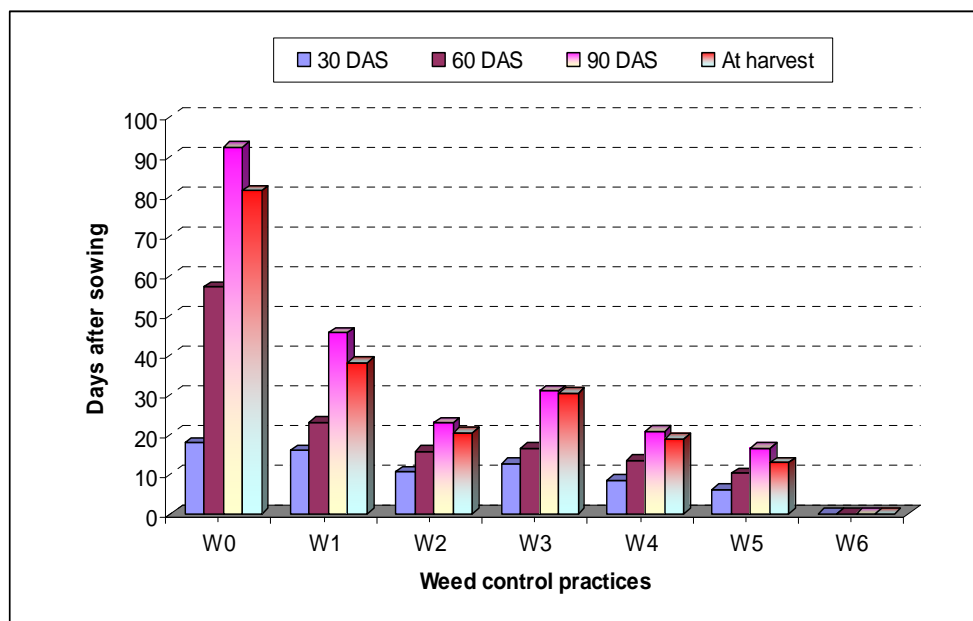
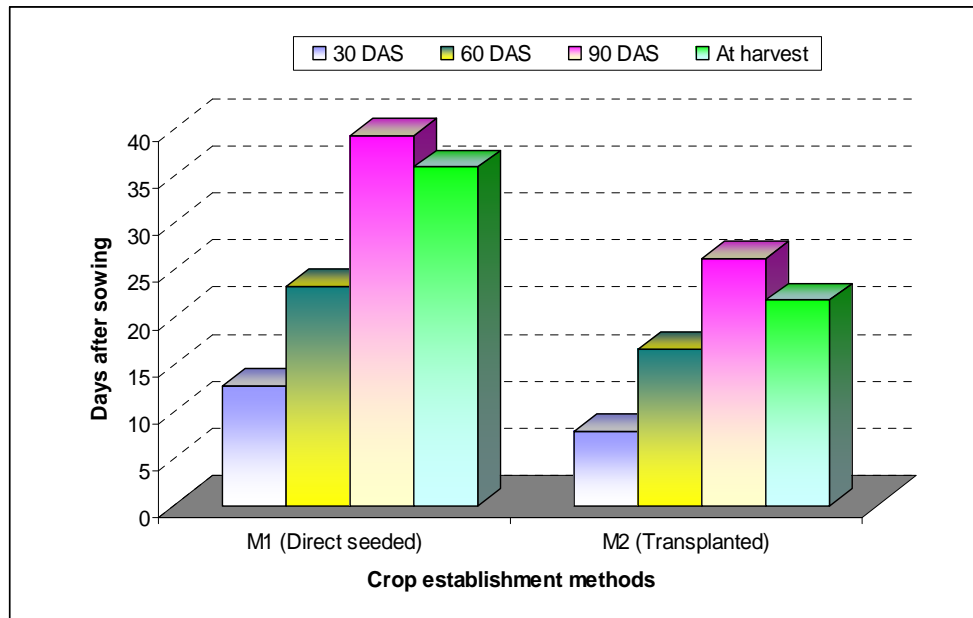


Fig. 9 : Periodic weed density (No/m²) in rice as affected by crop establishment methods and weed control practices

W₀ (Weedy check), W₁ (Two hand weedings), W₂ (Butachlor), W₃ (Pendimethalin),
W₄ (Butachlor + 2,4-D), W₅ (Butachlor + Almix), W₆ (Weed free)

4.4.3 Weed dry weight (g m^{-2})

The data presented in Table 12 and Fig.15 with corresponding analysis of variance given in Appendix X revealed that dry matter of weeds was significantly lower in transplanting method of crop establishment at all crop growth stages i.e. 30, 60, 90 DAS and at harvest over direct seeded method of crop establishment in the field thereby indicating that direct seeding of rice creates favourable environment for growth of weeds. Transplanting of rice in the present investigation has resulted in 11.3 per cent reduction in final dry matter of weeds compared to direct seeding.

Among various weed control treatments all the weed control practices recorded significantly lower weed dry matter compared to unweeded control.

Among the herbicides butachlor followed by almix (W_6) recorded lowest weed dry matter which was at par with Butachlor + 2,4-D. but significantly lower than other treatments during all crop growth stages combined application of butachlor + almix at 60 and 90 DAS reduced weed dry matter by 77.28 and 79.55 per cent respectively. At harvest stage of the crop butachlor + almix reduced the final weed dry matter by 77.08 and 35.02 per cent as compared to control and butachlor alone respectively.

Table-12 : Periodic dry matter of weeds (g m⁻²) in Rice as affected by crop establishment methods and weed control practices

Treatments	30 DAS	60 DAS	90 DAS	At harvest
Crop establishment methods				
M ₁ (Direct seeded)	7.85 (2.74)	32.20 (5.19)	53.60 (6.66)	66.01 (7.48)
M ₂ (Transplanted)	6.67 (2.53)	28.16 (4.84)	44.30 (6.07)	58.55 (7.01)
SE ± (m)	0.19 (0.03)	0.87 (0.03)	1.10 (0.11)	1.27 (0.08)
C.D (0.05)	0.47 (0.09)	1.74 (0.08)	2.64 (0.27)	3.07 (0.19)
Weed control practices				
W ₀ (Weedy check)	10.81 (3.34)	86.20 (9.30)	131.32 (11.46)	167.68 (12.96)
W ₁ (Two hand weedings)	9.49 (3.14)	30.35 (5.53)	52.69 (7.28)	68.19 (8.28)
W ₂ (Butachlor)	7.78 (2.85)	22.53 (4.78)	46.15 (6.81)	59.13 (7.71)
W ₃ (Pendimethalin)	9.34 (3.11)	31.15 (5.62)	48.64 (6.99)	62.64 (8.54)
W ₄ (Butachlor + 2,4-D)	6.80 (2.68)	21.63 (4.69)	37.11 (6.11)	39.85 (6.18)
W ₅ (Butachlor + Almix)	6.62 (2.65)	19.58 (4.47)	26.85 (5.21)	38.42 (6.33)
W ₆ (Weed free)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)
SE ± (m)	0.36 (0.07)	1.35 (0.12)	2.06 (0.13)	2.40 (0.36)
C.D (0.05)	0.88 (0.17)	3.25 (0.30)	4.96 (0.32)	5.76 (0.62)

*Values in parenthesis are transformed value $\sqrt{x+1}$

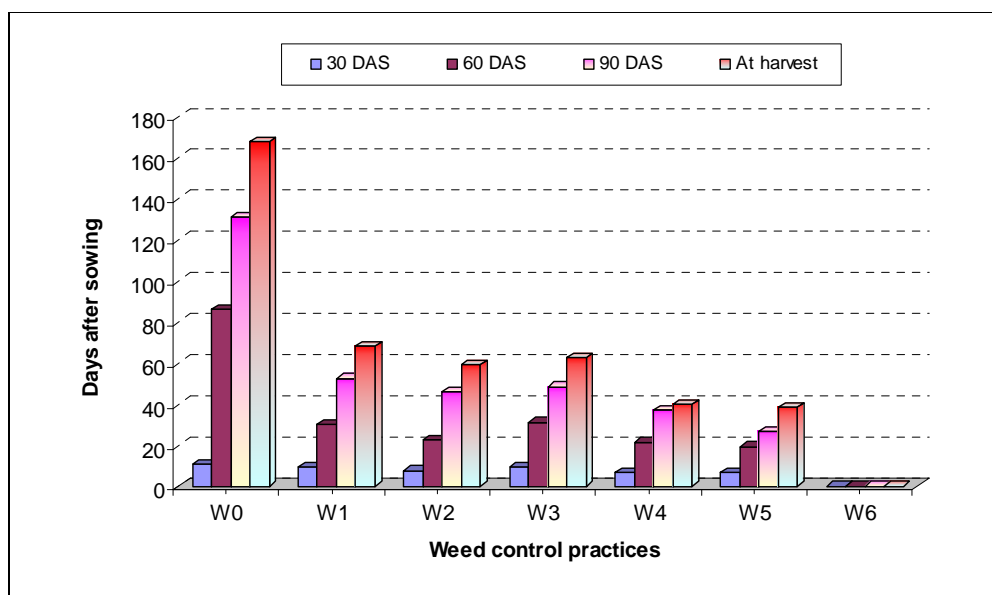
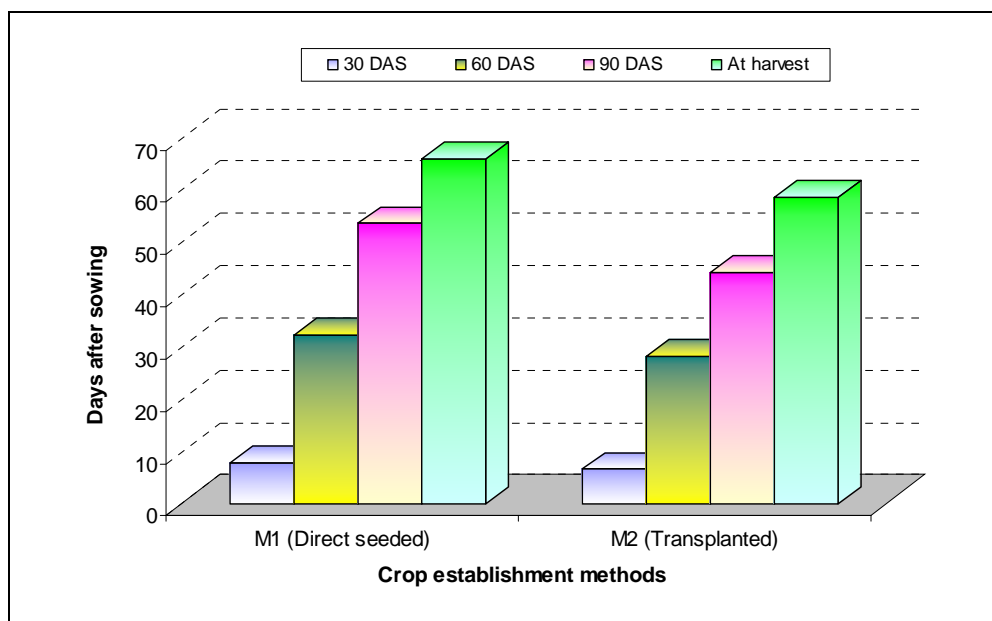


Fig. 10: Periodic dry matter of weeds (g m⁻²) in Rice as affected by crop establishment methods and weed control practices

W₀ (Weedy check), W₁ (Two hand weeding), W₂ (Butachlor), W₃ (Pendimethalin),

W₄ (Butachlor + 2,4-D), W₅ (Butachlor + Almix), W₆ (Weed free)

4.4.4 Weed control efficiency (%)

Out of two methods of crop establishments tried, transplanting method proved significantly efficient in controlling weeds at all crop growth stages than direct seeded method (Table 13 and Fig.16). The corresponding analysis of variance given in Appendix-X.

It was also observed that out of different weed control measures applied, weed free (W_6) proved cent percent efficient in controlling weeds than other treatments. Butachlor + almix (W_5) following next to weed free treatment proved efficient in controlling the weeds at all crop growth stages i.e. 30, 60, 90 DAS and at harvest stage, which was at par with Butachlor+2,4-D (W_4) but significantly efficient than other treatments in controlling the weeds. The treatments viz, W_1 (two hand weeding at 20 and 40 DAS/DAT) and W_3 (Pendimethalin) were statistically similar in their effectiveness for controlling weeds.

4.5 Relative economics

Relative economics (Table 14) revealed that transplanting method of crop establishment is more economical than direct seeded method of crop establishment. Among different weed control measures highest benefit cost ratio (2.16) was recorded by M_2W_5 (Butachlor+ Almix) followed by M_1W_5 (Butachlor+ Almix in DSR), M_2W_4 (Butachlor+ 2,4-D) and M_1W_4 with benefit cost ratios of 2.10 and 1.98 respectively. Thus the combined application of Butachlor + Almix proved economically beneficial for higher yields of rice in both methods of crop establishment.

Table-13 : Periodic weed control efficiency (%) in rice as affected by crop establishment methods and weed control practices

Treatments	30 DAS	60 DAS	90 DAS	At harvest
Crop establishment methods				
M ₁ (Direct seeded)	30.68 (4.84)	63.49 (7.47)	62.89 (7.43)	61.39 (7.34)
M ₂ (Transplanted)	35.93 (5.37)	66.12 (7.63)	63.00 (7.44)	64.38 (7.52)
SE ± (m)	1.27 (0.14)	1.17 (0.07)	0.61 (0.12)	0.68 (0.04)
C.D(0.05)	3.07 (0.35)	2.83 (0.17)	1.48 (0.29)	1.65 (0.10)
Weed control practices				
W ₀ (Weedy check)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)
W ₁ (Two hand weedings)	12.03 (3.5)	63.55 (7.99)	59.85 (7.76)	59.39 (7.73)
W ₂ (Butachlor)	28.17 (5.25)	73.38 (8.57)	64.94 (8.08)	63.76 (8.01)
W ₃ (Pendimethalin)	14.25 (3.72)	64.86 (8.07)	62.92 (7.96)	63.65 (8.00)
W ₄ (Butachlor + 2,4-D)	36.53 (6.04)	74.71 (8.68)	71.85 (8.50)	76.16 (8.81)
W ₅ (Butachlor + Almix)	42.18 (6.50)	77.17 (8.80)	81.08 (9.03)	76.25 (8.75)
W ₆ (Weed free)	100.00 (10.25)	100.00 (10.25)	100.00 (10.25)	100.00 (10.25)
SE ± (m)	2.38 (0.28)	2.21 (0.12)	1.16 (0.41)	1.28 (0.07)
C.D (0.05)	5.72 (0.68)	5.30 (0.30)	2.79 (0.98)	3.08 (0.18)

*Values in parenthesis are transformed value $\sqrt{x+1}$

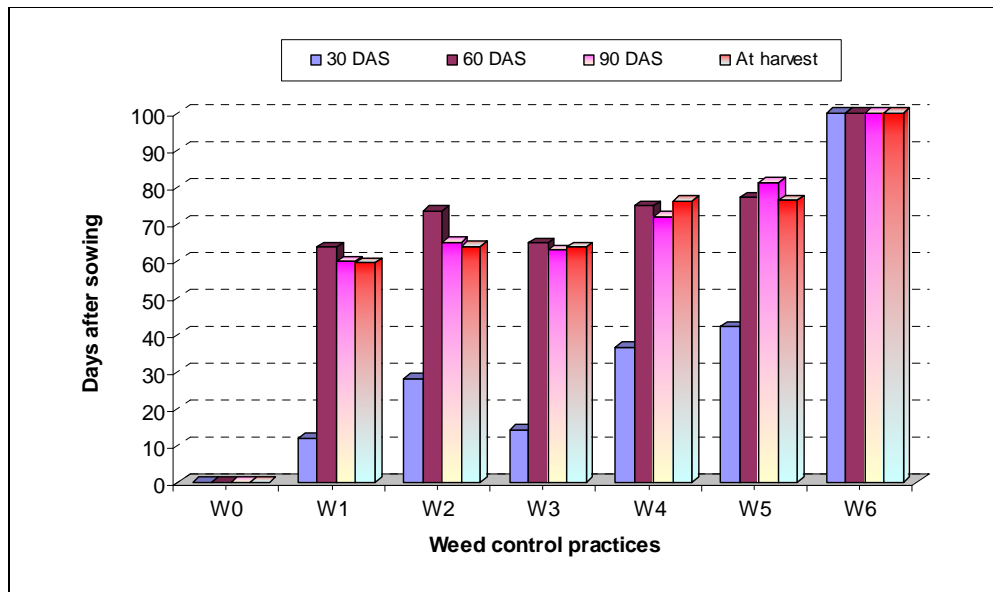
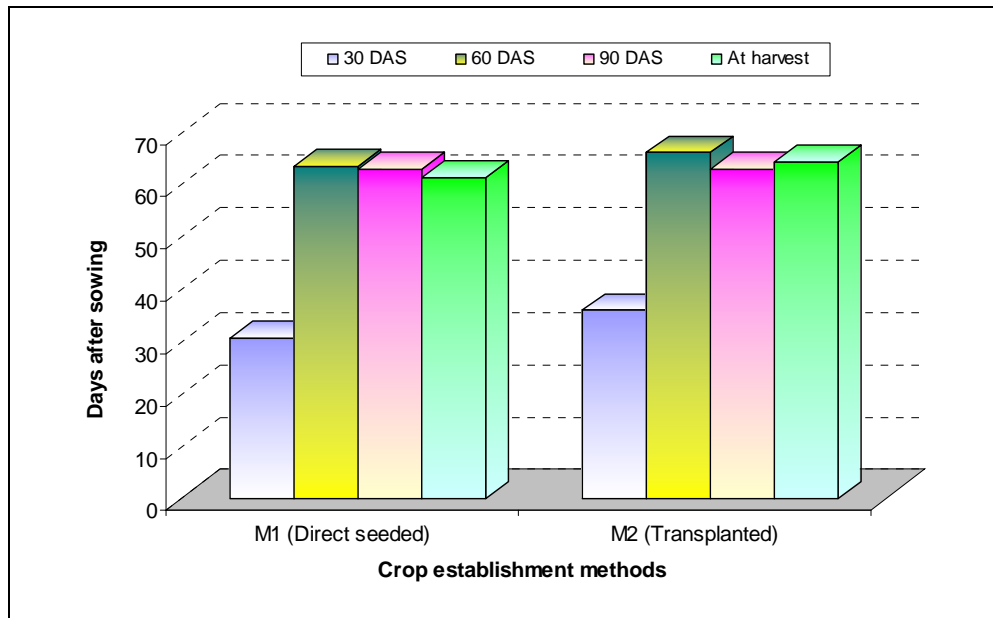


Fig. 11 : Periodic weed control efficiency (%) in rice as affected by crop establishment methods and weed control practices

W₀ (Weedy check), W₁ (Two hand weedings), W₂ (Butachlor), W₃ (Pendimethalin),

W₄ (Butachlor + 2,4-D), W₅ (Butachlor + Almix), W₆ (Weed free)

Table-14 : Relative economics of DSR and Transplanted rice under different crop establishment methods and weed management practices

Treatments	Cost of cultivation (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C ratio
Direct Seeded Rice (DSR)				
Weedy check	28634	62950	34316	1.20
Two hand weedings	34684	85380	50696	1.46
Butachlor	29234	86320	57086	1.95
Pendimethalin	29134	68230	39096	1.34
Butachlor + 2,4-D	29634	87510	57876	1.96
Butachlor + Almix	29734	92220	62486	2.10
Weed free	40684	95000	54316	1.33
Transplanted rice				
Weedy check	29500	69820	40320	1.36
Two hand weedings	35500	88790	53290	1.50
Butachlor	30100	89470	59370	1.97
Pendimethalin	29950	80500	50550	1.68
Butachlor + 2,4-D	30450	90960	60510	1.98
Butachlor + Almix	30550	96690	66640	2.16
Weed free	38500	99660	61160	1.58

CHAPTER – 5

DISUCSSION

The observations recorded from field experiments entitled “Studies on Crop Establishment Methods and Weed Management in Rice (*Oryza sativa* L.)” are discussed in this chapter with cause and effect under appropriate headings.

5.1 Crop studies

5.1.1 Growth characters

The results showed an improvement in the plant height of rice at different growth stages when grown under transplanted method over direct seeded method of crop establishment (Table 4). Higher plant height recorded in transplanted rice could be attributed to better nutrient uptake in competition free environment. Singh *et al.* (1997) while working under Sikim conditions also recorded significantly taller plants of rice in transplanted method rather than in other establishment methods.

Among various weed control measures used, apart from weed free treatment, application of butachlor + almix significantly increased the height of rice plants during the course of investigation (Table 4). This could be ascribed to better weed control with this herbicidal combination resulting in better nutrient uptake by the crop. Singh *et al.* (2004) also found that use

of almix at 4g a.i ha⁻¹ as tank mixture with butachlor at 938 or 1250 g ha⁻¹ was effective against weeds in rice resulting in the improvement of growth characters.

Transplanting method significantly increased dry matter production of rice at all growth stages over direct seeding method of crop establishment. Increased plant height and other growth attributes like leaf area index might have resulted in higher dry matter production under transplanting method of crop establishment. Besides favourable effect of puddling might have decreased weed competition and increased nutrient availability Earlier Chander and Pandey (2001) have also reported similar findings.

Among different weed control measures tested, apart from weed free check, application of butachlor + almix significantly improved dry matter production of rice at various growth stages over other weed control methods. The reduction in weed growth with the herbicide allowed the crop to grow to its potential, thereby increased dry matter production. Similar results were reported by Govindra *et al.* (2004)

Leaf area index, a vital index of crop growth and a major character influencing the assimilating capacity of the crop and ultimate productivity (Table 5). Leaf area index increased up to 60 DAS, and thereafter declined

gradually till harvest. This could be attributed to the fact that during reproductive phase of the crop shading to the lower leaves caused their senescence and death.

It was noticed that the two methods of crop establishment did not differ significantly in their effect on leaf area index of crop at various growth stages. However, transplanting method recorded higher LAI over direct seeding. This might be due to increased number of green leaves and more number of shoots per-unit area resulting from better nutrition due to reduced growth of weeds. The results are in conformity with the findings of Jaiswal and Singh (2001).

Among weed control measures apart from weed free treatment, herbicidal application of butachlor + almix significantly increased leaf area index of crop at various growth stages over other weed control treatments. The reduction in weed growth with the herbicidal application might have allowed the crop to enjoy adequate nutrient supply resulting in higher leaf area index. These result are in conformity with Singh *et al.* (2001).

5.1.2 Yield contributing characters

The important yield contributing characters viz; number of panicles m^{-2} , panicle weight, number of grains $panicle^{-1}$ and 1000-grain weight

showed significant variation due to the effect of different treatments (Table 7).

The study revealed a significant increase in the number of panicles m^{-2} , grains panicle⁻¹, panicle weight and 1000-grain weight under transplanting method of crop establishment as compared to direct seeded method during the course of investigation. This may be attributed to the puddling operation in transplanted method, since puddling has a great significance in rice establishment method, because it facilitates transplanting, increase availability of nutrients, ensures better plant establishment, control weeds and help plant to grow vigorously. Earlier Prasad *et al.* (2001) have also reported similar findings.

Out of various weed control measures, application of butachlor + almix significantly increased all the yield attributing characters viz., panicles m^{-2} , panicle weight, grains panicle⁻¹ and 1000-grain weight over other weed control measures. This could be ascribed to the fact that weed free and butachlor + almix treated plots absorbed the applied nutrients as well as other growth factors due to less competition between crop and weeds and hence all the yield attributing characters acquired higher values. Similar results were reported by Singh *et al.* (2005).

5.1.3 Grain and straw yield

Grain yield being an economic component of the crop is the important crop parameter, which reflects the resultant impact of all crop growth parameters and yield attributes that are affected by various input treatments. The data with respect to grain yield under different treatments is presented in Table 8.

There was a significant increase in the grain yield of rice under transplanted method of crop establishment over direct Seeded method. The higher grain yield under transplanted method may be attributed to better performance of yield contributing characters due to lower competition, and through optimum utilization of inputs. While over crowding in direct seeded rice might have increased the inter and intra plant competition for resources. These results are in conformity with Singh *et al.* (2005a). During the study it was also found that the straw yield showed significant improvement under transplanting method over direct seeding (Table 8). This could be due to significant increase in the plant height and dry matter production under transplanting method over direct seeding method of crop establishment. The results also confirm the results of Singh *et al.* (1997).

The study further revealed that among different weed control measures apart from weed free treatment, application of butachlor + almix

significantly increased grain and straw yield of rice over other weed control measures. Higher grain yield with butachlor + almix application could be attributed due to significant improvement in all yield attributes with the said treatment. These results are in close conformity with Subramanian *et al.* (2006).

5.2 Quality parameters

5.2.1 Amylose and protein content

The data presented in Table 9 showed that crop establishment methods did not cause any significant variation in amylose and protein content of rice grain. This can be attributed to the fact that quality parameters being greatly a varietal character. However apart from the weed free treatment the herbicidal application of almix + butachlor resulted an increase in both amylose and protein content of rice. This is due to the fact that better partitioning and allocation of sugars in weed free environment due to less competition. Similar results were reported by Khana *et al.* (2002).

5.3 Weed studies

5.3.1 Weed dry weight and weed density

Dry matter accumulation by weeds indicates to a great extent, the level of competitive stress that a plant undergoes. The study revealed a

significant variation in dry weight of weeds due to effect of various treatments (Table 11).

Weed dry weight and weed density was significantly lower in transplanted rice than in direct seeded rice during all crop growth stages. The lower dry matter of weeds in transplanted method may be due to frequent killing of weeds while ploughing to achieve puddled conditions and higher moisture content and greater crop canopy. However, under direct seeded rice higher dry weight of weeds may be attributed due to failure to maintain flooded conditions in the field owing to deep percolation of water and continuous germination of weeds and keen competition between crop and weeds for growth factor. Bajwa and Pasricha (1995) observed frequent aerobic soil environment for major period of crop growth and development due to deep percolation of water in direct seeded rice. Singh *et al.* (2005b) reported lower weed dry matter in transplanted rice as compared to direct seeded rice.

Among weed control measures, apart from weed free check, combined application of Butachlor + Almix significantly reduced dry matter of weeds and weed density over other weed control treatments. Similar findings were also made by Subramanian and Martin (2006).

5.3.2 Weed control efficiency

The study on weed control efficiency (Table 13) revealed that transplanting method proved significantly efficient in controlling weeds during all crop growth stages over direct seeded method of crop establishment. The lower dry matter of weeds recorded in transplanting could have increased efficiency of the treatment in controlling the weeds.

So far as weed control measures are concerned, apart from weed free treatment which recorded 100 per cent weed control efficiency, application of butachlor + almix proved significantly better measure for recording weed control efficiency in view of its efficiency in reducing the growth of weeds.

5.3.3 Relative economics

The efficiency of a treatment is finally decided in terms of the economics (benefit cost ratio) of the treatment. The present investigation revealed that during the course of investigation benefit cost ratio remained highest with M_2W_5 (butachlor + almix in transplanted) treatment combination. The results clearly justify the finding with regard to the significantly highest grain yield of rice realized with butachlor + almix @ $1.5 \text{ kg a.i ha}^{-1} + 0.004 \text{ kg a.i ha}^{-1}$ respectively when applied in transplanting method of crop establishment (Table 14).

CHAPTER – 6

SUMMARY AND CONCLUSION

Field experiment was conducted at Rice Research & Regional Station, Khudwani, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir during *Kharif* 2008.

The experiment was laid out in Randomized Block design with two methods of crop establishment viz; direct seeding and transplanting methods with seven weed management practices (W_0 -weedy check, W_1 -two hand weedings at 20 and 40 DAS/DAT, W_2 -Butachlor, W_3 -Pendimethalin, W_4 -Butachlor+2,4-D, W_5 -Butachlor+Almix and W_6 -weed free). The plots were given uniform recommended dose of fertilizers. The soil of the experimental field was silty clay loam, low in available nitrogen, medium in available phosphorus and potassium and neutral in reaction. The important findings of the study are summarized below:-

6.1 Effect of crop establishment methods

- Transplanting method tended to increase the plant height and leaf area index of rice crop as compared to direct seeded method of crop establishment. However they did not differ significantly between two crop establishment methods.

- Transplanting method significantly increased dry matter production of rice compared to direct seeded method of crop establishment at various crop growth stages.
- Various yield contributing characters viz; number of panicles m^{-2} , panicle weight and grains panicle⁻¹ remained significantly higher under transplanting method as compared to direct seeded method of crop establishment. However, 1000 grain weight did not differ significantly.
- Both grain and straw yield were significantly higher in transplanting method as compared to direct seeded method of crop establishment. However, harvest index did not vary significantly.

6.2 Effect of weed management practices

- Besides weed free check, combined application of Butachlor + Almix significantly increased plant height, dry matter production and leaf area index at different stages of crop growth.
- Apart from weed free check, combined application of Butachlor+Almix significantly improved yield contributing

character viz. number of panicles m^{-2} , panicle weight, grains panicle⁻¹ and 1000 grain weight during the course of investigation.

- Both grain and straw yield as well as harvest index showed significant improvement with combined application of butachlor + almix over other weed control treatments except weed free check.
- Herbicidal treatment butachlor + almix apart from weed free check, caused significant decrease in weed dry weight and weed density at various crop growth stages over other weed management practices weed control efficiency also remained significantly higher with the said treatment.
- Both weed dry matter and weed density at different crop growth stages remained significantly lower in transplanted method, as compared to direct seeded method of crop establishments, hence weed control efficiency was significantly higher under transplanted method over direct seeded method of crop establishment.

6.3 Relative economics

The study revealed that highest benefit cost ratio was realized with herbicidal application of butachlor + almix in transplanted rice.

CONCLUSION

- From the present investigation it is concluded that transplanted method of crop establishment proved superior than direct seeded method of crop establishment.
- Among the different weed management practices tried, combined application of butachlor + almix @ 1.5kg a.i ha⁻¹+0.004 kg a.i ha⁻¹ respectively followed by butachlor +2,4-D @ 1.5kg a.i ha⁻¹ + 1.0kg a.i ha⁻¹ respectively provided effective control of all types of weeds.
- Butachlor + almix @ 1.5kg a.i ha⁻¹ +0.004kg a.i ha⁻¹ when applied in transplanted method of crop establishment recorded the highest benefit cost ratio as such the said combination proved most economical.

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APPENDIX-I

Mean monthly temperature, relative humidity and rainfall

Month	Temperature (°C)		Relative humidity (%)		Rainfall (mm)
	Maximum	Minimum	Maximum	Minimum	
April	19.413	6.3167	77.56	53.03	3.6552
May	24.971	9.7323	76.09	55.12	1.2613
June	29.477	16.457	78.16	56.23	0.99000
July	29.510	17.232	82.61	56.38	2.7097
August	17.109	29.739	83.95	55.91	3.3435

Source : Division of Agronomy Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir

APPENDIX – II

Analysis of variance of plant height (cm) of rice at different growth stages

Source of variation	d.f.	Mean sum of squares			
		30 DAS	60 DAS	90 DAS	At harvest
Replication	2	24.20	9.32	0.026	0.38
Crop establishment method (M)	1	20.39	110.13	100.98	176.11
Weed management practices (W)	6	50.99*	240.28*	275.75*	305.88*
M x W	6	0.53	0.87	2.66	6.26
Error	26	10.91	37.83	41.68	45.61
Total	41	-	-	-	-

* Significant at (p = 0.05)

APPENDIX – III

Analysis of variance for leaf area index of rice at different growth stages

Source of variation	d.f.	Mean sum of squares			
		30 DAS	60 DAS	90 DAS	At harvest
Replication	2	0.010	0.47	0.112	0.121
Crop establishment method (M)	1	0.005	0.04	0.032	0.002
Weed management practices (W)	6	0.013*	3.42*	0.295*	0.042*
M x W	6	0.000	0.00	0.001	0.218
Error	26	0.001	0.09	0.066	0.895
Total	41	-	-	-	-

* Significant at (p = 0.05)

APPENDIX – IV

Analysis of variance for periodic dry matter accumulation ($q \text{ ha}^{-1}$) of rice on affected by crop establishment methods and weed control practices

Source of variation	d.f.	Mean sum of squares			
		30 DAS	60 DAS	90 DAS	At harvest
Replication	2	0.035	0.007	11.60	12.80
Crop establishment method (M)	1	0.005	99.79*	501.56*	1551.22*
Weed management practices (W)	6	0.376	294.89*	1242.38*	1207.51*
M x W	6	0.015	2.94	6.21	5.04
Error	26	0.407	5.77	32.64	37.80
Total	41	-	-	-	-

* Significant at ($p = 0.05$)

APPENDIX – V

Analysis of variance for panicles m^{-2} , grains panicle $^{-1}$, panicle weight (g) and 1000-grain (g) weight of rice as affected by different crop establishment methods and weed management practices

Source of variation	d.f.	Mean of squares			
		Panicles m^{-2}	Grain panicle $^{-1}$	Panicle weight (g)	1000-grain weight (g)
Replication	2	115.42	161.24	0.007	1.74
Crop establishment method (M)	1	10720.00*	617.17*	0.377*	0.41
Weed management practices (W)	6	13862.56*	1489.11*	0.792*	7.60*
M x W	6	431.88*	25.44	0.023*	1.10
Error	26	172.36	58.80	0.040	2.36
Total	41	-	-	-	-

* Significant at (p = 0.05)

APPENDIX – VI

Analysis of variance for grain yield (q ha⁻¹), straw yield (q ha⁻¹) and harvest index of rice as affected by different crop establishment methods and weed management practices

Source of variation	d.f.	Mean of squares		
		Grain yield (q ha ⁻¹)	Straw yield (q ha ⁻¹)	Harvest index (%)
Replication	2	11.88	18.71	0.001
Crop establishment method (M)	1	191.92*	433.60*	0.0009
Weed management practices (W)	6	373.38*	338.64*	0.001*
M x W	6	9.07	18.53	0.0001
Error	26	24.04	76.44	0.0004
Total	41	-	-	-

* Significant at (p = 0.05)

APPENDIX – VII

Analysis of variance for protein and amylase content in rice as affected by different crop establishment methods and weed management practices

Source of variation	d.f.	Mean of squares	
		Amylase content	Protein content
Replication	2	2.98	0.487
Crop establishment method (M)	1	4.37	0.038
Weed management practices (W)	6	62.82*	7.06*
M x W	6	0.604	0.008
Error	26	7.19	0.373
Total	41	-	-

* Significant at (p = 0.05)

APPENDIX – VIII

Analysis of variance for weed population/density as affected by different crop establishment methods and weed management practices in rice

Source of variation	d.f.	Mean of squares			
		30 DAS	60 DAS	90 DAS	At harvest
Replication	2	4.57	22.77	10.9	11.5
Crop establishment method (M)	1	223.93*	477.12*	1788.4*	2098.0*
Weed management practices (W)	6	247.71	1927.97*	5291.3	4104.6*
M x W	6	9.44	26.97	51.8	65.3*
Error	26	8.06	10.43*	22.8	9.9
Total	41	-	-	-	-

* Significant at (p = 0.05)

APPENDIX – IX

Analysis of variance for weed population/density as affected by different crop establishment methods and weed management practices in rice

Source of variation	d.f.	Mean of squares			
		30 DAS	60 DAS	90 DAS	At harvest
Replication	2	15.894*	10.3	57.3	60.1
Crop establishment method (M)	1	174.491	4294.1*	903.3*	585.2*
Weed management practices (W)	6	75.584*	166.7*	31.6*	16103.6*
M x W	6	0.835	18.8*	75.0*	24.6
Error	26	3.836	3.9	25.5	34.3
Total	41	-	-	-	-

* Significant at (p = 0.05)

APPENDIX – X

Analysis of variance for weed control efficiency as affected by different crop establishment methods and weed management practices in rice

Source of variation	d.f.	Mean of squares			
		30 DAS	60 DAS	90 DAS	At harvest
Replication	2	45.7	165.4	7.5	1.7
Crop establishment method (M)	1	289.1*	72.3	0.1	94.1*
Weed management practices (W)	6	6488.6*	5764.4*	5756.9*	5727.9*
M x W	6	34.0	23.0	4.4	10.0
Error	26	45.2	29.1	8.1	11.3
Total	41	-	-	-	-

* Significant at (p = 0.05)

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CERTIFICATE

Certified that all the corrections/amendments as suggested by External Examiner – Dr. Hari Ram, Agronomist, PAU, Ludhiana during evaluation and viva-voce examination held on 19.02.2010 have been incorporated in the manuscript entitled “**Studies on Crop Establishment Methods and Weed Management in Rice (*Oryza sativa* L.)**” submitted by **Mr. Fayaz Ahmad Shan** (Regd. No. 2007-A-801-M).

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