EFFECT OF CROP ESTABLISHMENT METHOD AND WEED MANAGEMENT ON GROWTH AND YIELD OF IRRIGATED DRY DIRECT SEEDED RICE (*Oryza sativa* L.)



THESIS SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENTS FOR THE DEGREE OF

Master of Science (Agriculture)

in

Agronomy

Supervisor
Dr. M. K. Singh

Submitted by
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CERTIFICATE

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Through: **The Head,**
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Dear Sir,

I have great pleasure in forwarding the thesis entitled **"Effect of crop establishment method and weed management on growth and yield of irrigated dry direct seeded rice (*Oryza sativa* L.)"** submitted by **Mr. Rajeev Ranjan** (I.D. No. A-0908) in partial fulfilment of the requirements for the degree of **Master of Science (Agriculture)** in **Agronomy,** Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (U.P.) and placing on record that he has completed the requisite requirements as contained in the statutes of the university.

It is certified that the work has been carried out under my guidance and the data forming the basis of the thesis, to the best of my knowledge are original and genuine and no part of the work has been submitted for any degree or dissertation.

Thanking you.

FORWARDED Yours faithfully,

(M. K. Singh)
Supervisor

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LIST OF SYMBOLS AND ABBREVIATIONS

%	Per cent
/	Per
@	At the rate
B: C	Benefit cost ratio
C.D.	Critical difference
cm	Centimetre
d.f.	Degree of freedom
DAS	Days after sowing
DAT	Days After Transplanting
dSm^{-1}	Deci siemen per meter
e.g.	For example
EC	Electrical conductivity
et al.	And others
fb	Followed by
Fig.	Figure
FYM	Farm yard manure
g	Gram
ha	Hectare
hrs	Hours
HW	Hand weeding
i.e.	Id est (that is)
kg	Kilogram
m ha	Million hectare
m	Meter
Max.	Maximum
Min.	Minimum
mm	Millimetre
mt	Million tonnes
No.	Number
NS	Non significant
^{o}C	Degree centigrade
pH	Puissance de hydrogen
q	Quintal
SEm±	Standard error of mean
t	Tonnes
viz.	Namely

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Chapter I

INTRODUCTION

Rice (*Oryza sativa*) is the most important crop and is a staple food for more than half of the world population. It is extensively grown in tropical and sub-tropical regions of the world. It plays unique role in producing calories to the majority of Asian and Latin American countries. It is grown in 112 countries in the world, covering every continent and is consumed by 2500 million people in developing countries (Datta and Khush, 2002). Rice provides 30–75% of the total calories to more than 3 billion Asians (Khush, 2004; Von Braun and Bos, 2004). Worldwide rice is grown on 161 million hectares, with an annual production of about 679 million tonnes paddy (FAO, 2009). About 90 percent of world's rice is grown and produced (143 million hectares of area with production of 612 million tonnes paddy) in Asia (FAO, 2009). India has the largest area under rice cultivation i.e. 42.56 million hectares and occupies second position in production (95.33 million tonnes) next to China among the rice growing countries of the world with average productivity of 2.24 t ha^{-1}. To meet the global rice demand, it is estimated that about 114 million tons of additional milled rice need to be produced by 2035, which is equivalent to an overall increase of 26% in the next 25 years. The possibility of expanding the area under rice in the near future is limited. Therefore, this extra rice production needed has to come from a productivity gain. The major challenge is to achieve this gain with less water, labour, and chemicals, thereby ensuring long-term sustainability.

Rice is commonly grown by transplanting seedlings into puddled soil (wet tillage) in Asia. This production system is labour, water and energy intensive and is becoming less profitable as these resources are becoming increasingly scarce. It also deteriorates the physical properties of soil, adversely affects the performance of succeeding upland crops, and contributes to methane emissions. Also, the drudgery involved in transplanting-a job largely done by women-is of serious concern. All these factors have posed a threat to the productivity and sustainability of rice-based systems and demand a major shift from the current system of transplanted rice production. In recent years, due to severe water and labour scarcity, farmers are

changing their rice establishment method from transplanting to direct seeding. Direct seeding offers such advantages as faster and easier planting, reduced labour and less drudgery, earlier crop maturity by 7-10 days, more efficient water use and higher tolerance of water deficit, less methane emission and often higher profit in areas with an assured water supply. The additional benefits of DSR would be water conservation, soil temperature moderation and built up of soil organic carbon status due to residue retention at the surface.

Despite all the incentives in adopting DSR, weeds acts a major constraint to the success of DSR in general and to Dry-DSR in particular (Johnson and Mortimer, 2005; Rao *et al*., 2007; and Singh *et al*., 2006). Research has shown that, in the absence of effective weed control options, yield losses are greater in DSR than in transplanted rice (Rao *et al*. 2007). Singh *et al.* (2011) reported that yield loss due to uncontrolled weed growth could be upto 98% in dry seeded rice sown without soil tillage. Weeds are more problematic in DSR than in puddled transplanting because of emerging DSR seedlings are less competitive with concurrently emerging weeds, the initial flush of weeds is not controlled by flooding in Wet- and Dry-DSR (Kumar *et al*., 2008a and Rao *et al*., 2007) and due to presence of weed seed banks in the soil. The weed control measures are mainly reliant on herbicides but evolution of herbicide resistance in the near past has strengthened the belief that besides chemical weed control treatments, there is need to develop other agronomic practices like crop establishment method which may also play vital role in weed management. If weed emergence or weed seed bank checked by some suitable tillage alternatives and the subsequent emergence of weeds during the crop growth period is controlled by the sequential application of herbicides, it would be very useful in reducing the weed competition and thus increasing the yield in direct seeded rice.

The crop establishment method which ensures uniform crop emergence with optimum plant density and reduces the weed incidence during the crop growth period is crucial for achieving good yields in direct drill-seeded rice. Preparation of stale seedbed is fast emerging as one of the option against the requirement of such crop establishment method. In this technique, after seedbed preparation, the field is

irrigated and left unsown to allow weeds to germinate. Following emergence, weeds are killed either by a non-selective herbicide (usually paraquat or glyphosate) or by carrying out tillage prior to the sowing of rice. This technique not only reduces weed emergence but also reduces the number of weed seeds in the soil seed bank (also referred to as the soil weed seed bank) (Rao *et al*., 2007). Singh *et al*. (2009b) reported 53% lower weed density in Dry-DSR after a stale seedbed than without this practice. The success of stale seedbeds depends on several factors: (a) method of seedbed preparation, (b) method of killing emerged weeds, (c) weed species, (d) duration of the stale seedbed (Ferrero, 2003), and (e) environmental conditions (e.g., temperature) during the stale seedbed period. Weed species, especially *Cyperus iria*, *Cyperus difformis*, *Fimbbristylis miliacea*, *Leptochloa chinensis*, and *Eclipta prostrata*, can be relatively more susceptible to the stale seedbed technique combined with zero-till because of their low seed dormancy and their inability to emerge from a depth greater than 1 cm (Chauhan and Johnson, 2008 a, b; and Chauhan and Johnson, 2009, 2010). Renu *et al*. (2000) found that a stale seedbed with herbicide (paraquat) was more effective in weed suppression than with the mechanical method in Dry-DSR because herbicides kill weeds without bringing new seeds to the germination zone. Ideally, the duration of the stale seedbed should be long enough to allow the maximum emergence of weeds to the two- to three- leaf stage. However, in practice, the duration of the stale seedbed may be determined by the optimal planting timing for rice.

Manual weeding is becoming a costly input for managing weeds due to scarcity of labourers during peak weed management operations and increasing labour wages due to various Government schemes. Thus, Integrated Weed Management (IWM) or sequential application of herbicides is becoming increasingly popular for weed control. Chemical control measures are generally more targeted at the early stage of weed emergence and growth when weed control is easier. Once weeds become big, they are difficult to control (Bastiaans *et al*., 2008). In dry direct drill-seeded rice, the "critical period" of weed competition has been reported to be 15–45 days after seeding (Rao and Nagamani, 2007; and Yaduraju and Mishra, 2004). If weeds can be suppressed effectively during this period, minimal yield losses occur. It

is crucial to select the right herbicide depending upon the weed flora present in a given field. In addition, the correct rate, timing, and application techniques should be used. A variety of herbicides have been screened and found effective for pre-plant/burn down, pre-emergence, and post-emergence weed control in dry direct drill-seeded rice systems. Continuous use of a single herbicide on a long-term basis should be avoided; rather, it should be rotated with another herbicide with a different mode of action to avoid/ delay resistance development. Tank mixtures of herbicides can be used when two or more herbicides are compatible to broaden the spectrum of weed control in such a way that each herbicide controls the weeds missed by the other one or it could be coupled with hand weeding.

Considering the above facts, investigation entitled "**Effect of crop establishment method and weed management on growth and yield of irrigated dry direct seeded rice (*Oryza sativa* L.)**" was done with following objectives:

- To study the effect of crop establishment method and weed management on growth and yield of irrigated dry direct seeded rice.
- To study the effect of treatments on growth and nutrient depletion by weeds.
- To workout the economics of treatments.

*****

Chapter II

REVIEW OF LITERATURE

In this chapter an attempt has been made to review the literature available on various aspects of method of crop establishment, weed population dynamics in direct seeded rice, losses caused by weeds in direct seeded rice, methods of weed management (chemical and mechanical) and its effect on crop yield.

2.1 Diversity of weed flora in direct seeded rice

Weed flora composition in a given environment varies from place to place depending on water regimes; irrigated or rainfed, method of crop establishment; transplanting or direct-seeded, soil type; hydrology, tillage practices and cultural practices. Weed infestation pose a serious problem in direct seeded rice than in any other rice culture system as there is no seedling size advantage for the crop because rice and weed seedlings emerge simultaneously. Further, there is no standing water to suppress weed emergence and growth at crop emergence. Several weed species, annual and perennials infest the rice fields in direct seeding method.

Singh *et al.* (2005) found significant variations occur in the dominance of the abundant weed species with crop establishment and weed control methods.

Kumar *et al.* (2010) observed that the predominant weed species in the direct seeded un-puddled rice were *Echinocloa colonum* among grasses. *Commelina benghalensis* and *Caesulia axillaris* among non-grasses and *Cyperus rotundus* among sedges.

Singh *et al.* (2010) found that dry direct seeded rice site was infested with grasses viz., *Echinochloa colona, Echinocloa crusgalli*, sedges viz., *Cyperus rotundus, Cyperus iria, Fimbristylis miliacea*, and broad-leaved weeds viz., *Eclipta alba, Amania auriculata* etc.

Singh and Singh (2010) mentioned that the dominant weed flora associated with direct seeded rice field were *Echinocloa colona, E. Crusgalli*, in grasses; *Cyperus rotundus, C. Iria* and *Fimbristylis miliacea* in sedges and *Eclipta alba , Caesulia axilliaris* in broad leaved weeds.

Adopting direct seeded rice may also result in weed flora shifts towards more difficult to control competitive grasses and sedges. For example, associated with direct seeding is an inevitable shift in the weed flora toward competitive grasses, including *Echinochloa* spp., *Leptochloa chinensis,* and *Ischaemum rugosum* in wet-seeded rice and in dry-seeded rice the perennial sedges *Cyperus rotundus*. These shifts have been reported in irrigated rice in Southeast Asia, where direct seeded rice has largely replaced transplanted rice. Management of such weeds requires farmers to have the ability to anticipate changes in weed populations and, to reduce losses, exploit integrated strategies comprising tillage, water, and crop management to complement herbicide application.

Direct seeded rice systems also favour sedges with *Cyperus difformis* and *Sagittaria montevidensis* in Australia and USA, and *Lindernia* spp. in Asia being the major sedges of concern. Similar changes might be expected in direct seeded rice in India. *E. crus-galli* and *I. rugosum* are currently problems in Indian rice fields and effective weed management strategies will be required to prevent these from becoming a serious threat to the sustainability of a direct-seeded system (Singh *et al.* 2001). In ongoing studies in direct seeded rice in India, densities of *E. crus-galli, Commelina diffusa*, and *Cyperus rotundus* have increased when compared with a transplanted system over the 2000–2004 period (Singh *et al.,* 2005).

In Malaysia, when direct seeded rice was introduced in the 1970s, *E. crus-galli*, *L. chinensis*, and *Ischaemum rugosum* were not common in rice fields. However, by the 1990s, these species became dominant (Azmi *et al.,* 2005).

Weed species such as *E. crus-galli* and *Leptochloa chinensis* become more prevalent within a few years of adopting direct-seeded, wet sown rice (Allard *et al,.* 2005).

Weedy rice (*O. sativa f.* spontanea), also known as red rice, has emerged as a serious threat to rice production in areas where transplanting is widely replaced by direct seeding, especially in many Asian countries. In the Philippines, weedy rice was reported in 1990, in Vietnam in 1994, and it is now widespread in the central region of Thailand. Weedy rice is highly competitive and causes severe rice yield losses ranging from 15% to 100%. Weedy rice is difficult to control because of its genetic, morphological and phenological similarities with rice. Its vigorous growth results in serious yield losses, and its rapid spread makes it a considerable threat to direct-seeded rice production. (Johnson and Moritmer, 2005)

2.2 Critical Period of Crop-Weed competition in direct seeded rice

The outcome of the process of inter-specific competition among plant species is the differential acquisition of resources for growth and yield. In plant species, the most important competition is usually pre-emptive competition that occurs among seedling, since it is almost impossible for a seedling of one species to out compete an established adult of another species. The inherent size differences between rice seedling and emerging weed species that confers a competitive advantage to transplanted rice is removed when direct – seeding is practiced.

Gibson *et al.* (2001) recorded a grain yield reduction of up to 99 % with a mixed infestation of *Ehinochloa oryzoides* and *Ehinochloa phyllopogon* in wet seeded rice. Weedy rice (*O. sativa)* ecotypes have become a major cause of yield loss in irrigated direct seeded rice in Malaysia (Azmi *et al.* 2003), Thailand, and Vietnam, particularly under dry seeding condition (Chin, 1997). Kim and Ha (2005) also recorded weedy rice along with annual grasses, such as *Echinochloa crusgalli, Digitaria ciliaris, Leptochloa chinensis,* and *Seteria viridis*, as the most predominant weeds of dry seeded rice in Korea.

Ladu and Singh (2006) in their on farm experiment found that weeds during initial 15 days after sowing (DAS) had no adverse effect on the grain yield of rice. The crop kept weed-free for the first 30 DAS produced grain yield similar to weed-free upto harvest.

Singh *et al.* (2012) in their field experiment conducted during 2006-07 and 2007-08 at Krishi Vigyan Kendra, Madurai, Tamil Nadu under the Zonal Project Directorate, Bangalore found that first 40 days after sowing was the most critical period for crop-weed competition. The crop grown under weed free condition for 40 days after sowing gave the maximum grain yield.

2.3 Losses caused by weeds

Weeds compete for moisture, nutrients, light and space and as a consequence, weeds infestation in direct seeded rice results in yield losses. Out of the losses due to various biotic stresses, weeds are known to account for nearly one third.

Pantone and Baker (1991) reported that weedy rice densities of 4, 16, and 25 m^{-2} reduced rice yield by 13%, 37%, and 48%, respectively.

Eleftherohorinos *et al.* (2002) reported up to a 58% reduction in rice yield at a density of 40 weeds m^{-2}.

In an on-farm study conducted in the rice–wheat system in India, it was found that rice yields in direct seeded rice in some cases were comparable to those of the transplanted system when weed control was adequate. However, over 36 farms had about 20% lower yields in direct seeded rice compared with transplanted rice, often because of inadequate weed control (Johnson *et al.,* 2003).

In West Africa, Johnson *et al.* (2004) reported that weeds reduced the grain yield of direct seeded rice by 50%.

In Asia, in the absence of weed control, losses due to weeds in direct seeded rice ranged from 40–100% in South Korea (Kim and Ha, 2005).

Ottis *et al.* (2005) found that weedy rice also reduces milling quality if it gets mixed with rice seeds during harvesting.

Singh, *et al.* (2005) found that if weeds were not controlled, rice yields were reduced 63% in a transplanted puddle system and that yield reductions increased to 70–76% under direct seeded rice.

In India, yield of direct seeded rice on raised beds was reduced by 65% when weeds were not controlled (Singh *et al.,* 2006).

Research has shown that, in the absence of effective weed control options, yield losses are greater in direct seeded rice than in transplanted rice (Rao *et al.,* 2007). Weeds are more problematic in direct seeded rice than in puddled transplanting because (1) emerging direct seeded rice seedlings are less competitive with concurrently emerging weeds and (2) the initial flush of weeds is not controlled by flooding in wet and dry direct seeded rice (Rao *et al.,* 2007; Kumar *et al.,* 2008a).

Singh *et al.* (2011) in their on farm experiments reported that rice yield losses due to uncontrolled weed growth were least 12 % in transplanted rice but otherwise as large as 85% where rice had been sown to dry cultivated fields or to puddled soil, rising to 98% in dry seeded rice sown without soil tillage.

2.4 Crop establishment method

Stale bed technique

Stale bed in simplest terms is described as planting system that doesn't use tillage immediately prior to planting. The primary reason that producers choose a stale seed bed approach is timely planting and crop establishment. Stale seed bed technique is recognized as weed management strategy, which is based on principle of flushing out germinable weed seeds prior to planting of the crop, thus depleting the seed bank in the surface layer of soil and reducing subsequent emergence of weeds.

Moorthy (1992) reported that appropriate land preparation and sowing seeds on a stale seed bed could be effectively used for the integrated management of weeds in rainfed upland rice.

Saikia and Pathak (1993) reported that, stale seedbed suppressed weeds better than the conventional seedbed method and allowed better crop growth than the conventional seedbed method. In this technique, seeds are not sown immediately after land preparation. Instead, weeds are allowed to emerge following rain or irrigation and then destroyed by shallow cultivation or by using non selective herbicide like glyphosate.

2.4.1 Stale bed by shallow tillage

In this technique, seeds are not sown immediately after land preparation. Instead, weeds are allowed to emerge following rain or irrigation and then destroyed by shallow cultivation.

Renu *et al.* (2000) in their on farm experiment to test the feasibility of stale seedbed technique for the management of *Sacciolepsis interrupta*, a problem grass weed in semi-dry rice cv. Jyothi found that adoption of stale seedbed technique reduced the competition from all the weeds including *S. interrupta*. Stale seedbed with paraquat showed reduced weed incidence than stale seedbed with hoeing. The yield attributing characters of rice, number of productive tillers per m^{-2} and percentage of filled grains, were significantly high in stale seedbed plots. In terms of grain yield, straw yield and uptake of nutrients also, the stale seedbed treatments were superior to normal sowing.

Sharma *et al.* (2004) reported that stale seedbed preparation was better than traditional seedbed preparation for control of weeds viz. *Cyperus rotundus*, *Echinochloa colonum*, *Echinochloa crusgalli*, *Cyperus iria*, *Eclipta alba*, *Setaria glauca* [*Setaria pumila*], *Scirpus spp*., *Monochoria spp*. and *Celosia argentea* dominant in direct seeded rice.

Sharma *et al.* (2008) reported that stale seedbed resulted in higher rice yield (3.58 tonnes/ha) compared to conventional tillage (3.27 tonnes/ha) (traditional seed bed).

Sindhu *et al.* (2011) conducted experiments to develop and refine stale seedbed technique for dry seeded rice (*Oryza sativa*) during 2006 and 2007 at Mannuthy, Kerala. Compared to normal seedbed, stale seedbed for 14 days with two shallow hoeings resulted in 80% reduction in the population and 40% reduction in the dry weight of weeds. Grass weeds were the most prominent group that germinated immediately after seedbed preparation, followed by broad leaf weeds. The yield difference between normal seedbed and stale seedbed plots decreased with reduction in stale seedbed periods. The difference in grain yield between normal seedbed and stale seedbed for 7 days was only 0.25 t ha^{-1} and that with stale seedbed for 14 days with two shallow hoeings was 0.58 t ha^{-1}. Practising stale seedbed for 14 days gave the highest benefit: cost ratio during both years of the experiment.

2.4.2 Stale bed by glyphosate

In this technique, seeds are not sown immediately after land preparation. Instead, weeds are allowed to emerge following rain or irrigation and then destroyed by using non selective herbicide.

John and Matthew (2001) in their trial conducted at the Rice Research Station, Moncumpu, Kerala, India, and in farmer's fields in larger plots for 2 years [year not given] during the main cropping season (October-February) where *Echinochloa stagnina*, *E. crus-galli* and *Oryza rufipogon*; *Fimbristylis miliacea*, *Cyperus iria* and *C. difformis*; *Monochoria vaginalis* and *Sphenoclea zeylanica* are the native grasses, sedges, and broadleaf weeds, respectively, associated with rice cropping found that direct sowing under the stale seedbed system produced the highest yield, equivalent to that of an almost totally weed-free crop environment. The results also showed the significant yield advantage of the stale seedbed system over hand weeding or chemical weed control, at no additional cost. The results clearly showed that the stale seedbed is a no-cost, weed control, productivity-facilitating system.

Caldwell and Mohler (2001) reported that Flaming or glyphosate stale seedbed techniques significantly reduced density and biomass of the principal broadleaf species, common purslane (*Portulaca oleracea*) and common chickweed (*Stellaria*

media), in most cases. A single delayed flame or glyphosate stale seedbed treatment was usually as effective as multiple treatments. Penetration was better with a springtooth harrow, but this failed to reduce weed density. None of the stale seedbed treatments fully controlled weeds. However, glyphosate or flaming a stale seedbed could be incorporated into integrated weed management programmes to improve control and reduce the need for herbicides.

Talbert *et al.* (2002) reported that there was no crop injury observed with any treatment of imazethapyr/Newpath (quite effective in the control of red rice and other rice weeds) and rice yields were good, especially in the stale-seedbed plots, 6640 to 8360 lb $acre^{-1}$. In the imazethapyr study, the stale-seedbed system yielded 15% more rice than the conventional seedbed system.

Lonsbary *et al.* (2003), in their field experiments on machine harvested cucumbers found that the optimal timing of stale-seedbed preparation was 20 to 30 days before planting (DBP). Seedbed preparation could be expanded to 40 DBP, however, an application of glyphosate at 20 DBP would be required to optimize yield. The stale-seedbed combined with herbicides was a superior integrated weed management tool compared with conventional weed management practices.

In Malaysia, proper land preparation coupled with the stale seedbed technique using non-selective herbicides (paraquat/glyphosate/glufosinate) before planting rice has been recommended to reduce the density of weedy rice (Karim *et al.,* 2004).

Riemens *et al.* (2007) reported that control of the emerged weed seedlings after a stale seedbed preparation was more effective with glyphosate than with a rotary harrow. Depending on location and year, stale seedbed preparations followed by weed control prior to planting reduced the amount of weeds during crop growth by 43–83%.

Dogan *et al.* (2009) in their on farm experiment to evaluate the effect of pre-emergence or pre-sowing glyphosate treatments in stale seedbed coton found that a combination of stale seedbed technique with glyphosate treatment can be considered

an effective alternative weed control system to reduce weeds by up to 90% during the critical period.

Pittelkow *et al.* (2012) conducted a four year field experiment from 2004 to 2007 at the CA Rice Experiment Station near Biggs and found that compared to the water seeded conventional system, water seeded stale and water seeded no-till stale treatments significantly reduced sedge weed biomass by 59 and 95%, respectively.

2.4.3 Puddled direct seeded rice

In this method, pre-soaked/pre-germinated rice seeds are broadcast by hand or motorized blower onto a puddled soil surface after drainage. Land preparation is critical to successful crop establishment under puddled direct seeded rice since seedbeds need to be levelled to prohibit premature seedling death by flooding and to ensure that pre-germinated seeds remain at or near the surface of the soil.

Vandana and Reddy (1999) in their field experiment to evaluate the effect of puddling interval and on weed control on puddled direct seeded rice found that at 60 DAS, puddling 2 weeks before sowing (WBS) resulted in significantly lower weed density as compared to puddling one and three WBS. The weed dry matter was significantly lower in puddling one WBS as compared to puddling two and three WBS. Puddling one WBS resulted in significantly higher grain yield as compared to puddling two or three WBS. The weed density and dry matter were significantly lower with puddling one WBS during critical crop growth stages.

Saha (2006) in his on farm experiment found that major weed flora with wet direct sown summer rice during the dry season comprised mainly *Echinochloa colona* (9.5 %), *Cyperus difformis* (30.2%), *Fimbristylis miliacea* (27.0%), *Sphenochlea zeylancia* (15.8%) and *Ludwigia parviflora* (17.5%).

Singh *et al.* (2006) reported that among the direct seeded rice the highest yield (4222 kg ha^{-1}) was recorded under wet seeding (WSR) employed with hand weeding and on par with application of herbicide followed by one hand weeding under transplanting (TPR).

Singh *et al.* (2011) in their on farm experiments found that average rice grain yields in the absence of weed competition were greatest (6.56 t ha^{-1}) under wet seeding (sowing pre-germinated rice seed on puddled soil), and similar to those from transplanted rice (6.17 t ha^{-1}) into puddled soil, and dry seeded rice after dry soil tillage (6.15 t ha^{-1}). Rice yield losses due to uncontrolled weed growth were least in transplanted rice (12%) but otherwise large (85%) where rice had been sown to dry cultivated fields or to puddled soil. Weed biomass in wet seeded rice was six-fold greater that in rice transplanted into puddled soil and twice as much again in dry seeded rice sown either after dry tillage or without tillage.

2.5 Methods of weed control

2.5.1 Hand weeding

Vandana and Reddy (1999) in their field experiment to evaluate the effect of puddling interval and on weed control on puddled direct seeded rice found that at 60 DAS hand weeding twice at 30 and 50 DAS resulted in significantly lower weed density as compared to other chemical weed control methods and no weeding. Significantly lower weed dry matter was observed in hand weeded plots as compared to other treatments. Hand weeding twice at 30 and 50 DAS recorded higher grain yield over all herbicide applied treatments.

Islam and Molla (2001) reported that two hand weeding or one hand weeding plus herbicides can be adopted for weed control in areas where labours are available.

Singh *et al.* (2012) in their on farm experiment found that hand- weeding followed by foliar application of urea was significantly superior to rest of the treatments and gave maximum grain and straw yields.

2.5.2 Chemical control

Chemically weeds in direct seeded rice are controlled by the application of herbicides. Chemical control measures are generally more targeted at the early stage of weed emergence and growth when weed control is easier. Once weeds become big,

they are difficult to control (Bastiaans *et al.* 2008). In dry direct drill-seeded rice, the "critical period" of weed competition has been reported to be 15–45 days after seeding (Rao and Nagamani, 2007; Yaduraju and Mishra, 2004). If weeds can be suppressed effectively during this period, minimal yield losses occur. It is crucial to select the right herbicide depending upon the weed flora present in a given field. In addition, the correct rate, timing, and application techniques should be used. A variety of herbicides have been screened and found effective for pre-plant/burn down, pre-emergence, and post-emergence weed control in dry direct drill-seeded rice systems.

Azmi and Abdullah (1998) observed that pre-plant application of soil-incorporated Molinate at 4.5 kg a.i. ha^{-1} was effective in reducing the seed bank of weedy rice.

Akbar *et al.* (2011) found that the increase in rice yield due to application of herbicides was 7-19%. The order of herbicides in suppressing the weeds as well as increasing rice yield was pretilachlor > butachlor > pendimethalin.

Chauhan and Opena (2013) reported that weed density and weed biomass were strongly influenced by the weed control treatments. All herbicides significantly reduced weed biomass compared with the control treatment, providing 75–93% weed control. Herbicide treated plots had similar grain yield and the yield in treated plots was 76–86% of the yield of the weed-free plots (4.2–4.4 t ha^{-1}).

Pendimethalin: Pendimethalin belongs to dinitroanilines group and active against grasses and broad leaved weeds in various crops. Pendimethalin used as pre emergence herbicides inhibits germination and seedling development of susceptible weeds. Where weeds are expected to be a problem, it should be applied after planting and before emergence of rice and weeds. Because soil and weeds must be completely exposed to spray coverage, no floodwater should be on the field at the time of application. The residual activity of Pendimethalin is activated by moisture. It is most effective when adequate rainfall or irrigation is received within 7 days after application.

Singh *et al.* (2001) in their field experiment found that Pendimethalin @ 1.0 kg ha^{-1} + farm wastes as mulch (7.5 t ha^{-1}) supplemented with one hand weeding at 45 days after sowing (DAS) decreased weed density, dry matter production and gave highest weed control efficiency (91.3%) which was comparable to farmer's practice of hand weeding at 30, 60 and 90 DAS. This treatment also produced the highest grain and straw yields. Pre-emergence application of Pendimethalin @1.0 kg ha^{-1} supplemented with post-emergence application of 2,4-D was economically most beneficial for controlling the weeds as it gave highest net return and benefit: cost ratio.

Singh *et al.* (2007) reported that pendimethalin (1000 g a.i. ha^{-1}) or pretilachlor with safener (500 g a.i. ha^{-1}) as pre-emergence applications followed by one hand-weeding were effective in controlling weeds, increasing grain yield of dry-seeded rice, and resulting in higher net returns than the weed-free treatment.

Mishra and Singh (2012) observed that Pendimethalin (1.0 kg a.i. ha^{-1}) *fb* 2,4-D (0.50 kg a.i. ha^{-1}) significantly reduced the population density of *Echinochloa colona*, *Cyperus iria* and sessile joyweed [*Alternanthera sessilis*].

Butachlor: Herbicide butachlor was launched by MonSanto St. Louis, USA in 1969. Butachlor + Safener @ 0.7 kg a.i. ha^{-1} applied at 3 DAS effectively controlled weeds in farmers practice (Tuong *et al.* 2000) and with controlled irrigation (De dios *et al.* 2005). Butachlor is absorbed primarily through germinating shoots and secondarily through roots. Its mode of action is inhibition of protein synthesis. It is used for pre-emergence control of most annual grasses at the 1 to 2 leaf stages and of certain broad-leaved weeds and can be applied post emergence. For direct seeded rice it is applied 10-12 days after emergence. Butachlor in soil is broken down by microbial activity. In soil or water, it is rapidly converted to water soluble derivatives. It may persist for six to ten weeks.

Rashid *et al*. (1986) found that butachlor (0.8 kg a.i. ha^{-1}) application 6 days after seeding significantly increased the grain yield and tiller number.

Rana and Angiras (1999) in their field experiment found that in weedy check, weeds depleted 107.0, 15.5 and 112.8 kg ha^{-1} of nitrogen, phosphorus and potassium, respectively which was 60.8, 6.85 and 46.6 kg more than the total uptake of these nutrients by rice crop. Pre-emergence application of pertilachlor @ 0.80 kg ha^{-1} and butachlor @ 1.50 kg ha^{-1} at 7 days after sowing (DAS) remaining statistically at par with post-*halod* (an intercultural operation in standing rice crop) hand weeding but was significantly better than all post- *halod* herbicidal treatments (pertilachlor @ 0.80 kg ha^{-1}, butachlor @ 1.50 kg ha^{-1} and 2,4-D @ 0.50 kg ha^{-1} alone and in combination with pertilachlor @ 0.40 kg ha^{-1} and butachlor @ 0.75 kg ha^{-1}), with regard to uptake of N, P and K by weeds and rice.

Moorthy and Saha (1999) in their field investigation found butachlor + safener (1.5 kg ha^{-1} controlled the prominent weeds like *Cyperus difformis* and *Fimbristylis miliacea* and produced yield comparable to that of hand weeded control.

Rajkhowa *et al.* (2001) in their field experiment found that application of butachlor @ 1.0 kg ha^{-1} three days after transplanting (DAT) significantly reduced weed infestation till 45 DAT and resulted in higher yield of rice over weedy check.

Mandal *et al.*(2011) conducted a field experiment during rainy seasons of 2007 and 2008 at Rajendra Agricultural University, Pusa, Bihar and found that highest weed control efficiency (87%) was in weed free followed by butachlor + 1 HW (80%) and *Sesbania* broadcast + 2,4-D (76.5%)

Singh *et al.*(2012) in their field experiment conducted during 2006-07 and 2007-08 at Krishi Vigyan Kendra, Madurai, Tamil Nadu under the Zonal Project Directorate, Bangalore found that post-emergence application of propanil @ 3.8 kg ha^{-1} at 20 days after sowing and soil application of urea was most effective in increasing the crop yield and minimizing the crop-weed competition. Highest weed control efficiency of 88.1% was recorded in crop treated with propanil @ 3.8 kg ha^{-1} *fb* hand weeding within rows and hoeing at 40 DAS and it is closely followed by the application of butachlor @ 2.5 $kgha^{-1}$ *fb* hand weeding within rows and hoeing at 40 DAS. In the integrated approach, post-emergence application of propanil @ 3.8 kg ha^{-}

^{1} at 20 DAS *fb* hoeing between the rows and hand weeding within rows at 40 DAS minimized crop weed competition, increased uptake of N, P and K by crop and maximized grain yield and economical returns significantly.

2, 4–D: It is the first phenoxy herbicide to be introduced and is available as salt, amine, ester and granular formulation. The doses required to control broad –leaved weed seedling are selective in small grains, maize and grain sorghum, but the crop should have at least four leaves to avoid phytotoxicity. Crop injury should be anticipated with doses required to control large annual and perennial weeds. Generally, activity via the soil is less than that achieved with foliage application.

Latif and Wahab (2007) in their field investigations carried out during October-February 2001-2002 and 2002-2003 in strip plot design to evolve an integrated crop management (ICM) package of practices for enhancing productivity and profitability of wet seeded rice in Kuttanad, Kerala found that the comprehensive weed control measures involving pre sowing weed control (by conjunctive use of burn down herbicide paraquat @ 0.12 kg or tank mix of glyphosate and 2,4-D Na salt @ 0.20 kg + 0.20 kg ai ha^{-1}, *fb* subsequent weed submergence to 40 cm depth for 10 days + sowing on clean seed bed with pre emergence herbicide (pretilachlor + safener @ 0.4 kg ha^{-1} + post emergence 2,4-D Na salt @ 0.80 kg a.i. ha^{-1} significantly reduced the weed density and weed dry matter production (WDMP) and significantly increased the grain yield.

Norsworthy *et al.* (2011) conducted research in 2007 and 2008 to evaluate weed-control options in an imazethapyr-resistant rice production system. Raised beds were formed, and imidazolinone-resistant hybrid rice 'CL 730' was drill-seeded on beds. Application of 2,4-D, helped to improve the control of weed Palmer amaranth which was insensitive to imazethapyr (possibly acetolactate synthase resistant) when applied at four to six leaf stage of rice.

Chauhan *et al.* (2012) conducted experiments in the laboratory and screenhouse to evaluate the response of three-lobe Morning glory (*Ipomoea triloba*) to commonly available post herbicides in the Philippines and found that the herbicide

2,4-D at 400 g a.i. ha^{-1} provided excellent control of threelobe morningglory (100%) when applied at the four-leaf and (97%) when applied at six-leaf stages. However, at the eight-leaf stage, percent control was reduced to 67% and herbicide rate had to be increased twofold to achieve 95% control.

Fenoxaprop-p-ethyl: It belongs to aryloxy phenoxypropionate herbicide family. Fatty acid synthesis inhibition in grasses, by inhibition of acetyl in grasses, by inhibition of acetyl COA Carboxylase (ACCase). Fenoxaprop is a herbicide for selective post emergence control of annual grassy weeds in broad leaf crops. (Bieringer *et al.* 1982). It is a selective herbicide with contact and systemic action, absorbed principally by the leaf, with translocation both acropetally and basipetally to the roots or rhizomes. It is used for post emergence control of annual and perennials grasses weed in broad leaved crops potatoes, beans etc. when applied with herbicide safener, annual and perennials grasses weeds and wild oats in wheat.

Singh *et al.* (2006) in their on farm experiments found fenoxaprop-*p*-ethyl + ethoxysulfuron at 50 + 18 g a.i. ha^{-1}, effective and economical when applied at 21 DAS for managing a mixed population of both grass and broadleaf weeds.

Singh and Bhagirath (2011) conducted experiment to manage crowfootgrass, a C-4 species, is one of the principal weeds of dry-seeded rice in Asia and found that fenoxaprop-p-ethyl + ethoxysulfuron at 45 g a.i. ha^{-1} provided excellent control of crowfootgrass when applied at the four (99%) and six-leaf (86%) stage.

Ethoxysulfuron: It belongs to sulfonyl urea groups. Ethoxysulfuron was introduced by Aventis, Straspourg, France in 1998 (Kim and Ha, 2005). It is branched chain amino acid synthesis inhibitor, acts by inhibiting biosynthesis of the essential amino acid valine and isoleucine, hence stopping cell division and plant growth. Selectivity is due to differential metabolism in crop and weed. It is used for broad leaved and sedge weed control in cereals, rice and sugarcane @ 10 -120 g ha^{-1}.

Narwal *et al.* (2002) conducted a field study during the rainy seasons of 1999 and 2000 to evaluate the performance of 2 new herbicides, viz., acetachlor and ready

mixture of anilofos + ethoxyulfuron on weed density, weed dry weight, yield and yield attributes of transplanted rice (*Oryza sativa* L.). Mixture of anilophos + ethoxysulfuron @ 390 g applied 8 DAT proved effective in controlling both grassy weeds and broad leaved weeds

Singh *et al.* (2006) conducted two experiments for two years with an objective of identifying appropriate, effective, and economical methods for managing broadleaf weeds only and a mixed population of both grass and broadleaf weeds in dry-seeded rice cultivated in the furrow-irrigated raised-bed planting system (FIRBS). The major weeds associated with dry-seeded rice in the FIRBS during both years were *Echinochloa crus-galli*, *Echinochloa colona*, *Dactyloctenium aegyptium*, *Leptochloa panicea*, *Caesulia axillaris*, *Euphorbia hirta*, *Lindernia* sp., *Commelina benghalensis*, *Eclipta prostrata*, *Trianthema portulacastrum* and *Portulaca oleracea*. Among herbicidal application of Triclopyr @ 500 g a.i. ha^{-1}, bensulfuron @ 60 g a.i. ha^{-1}, ethoxysulfuron @ 18 g a.i. ha^{-1} and 2,4-D (ester) @ 500 g a.i. ha^{-1}, all applied at 21 days after seeding (DAS), they found ethoxysulfuron @ 18 g a.i. ha^{-1} to be least expensive but effective for controlling broadleaf weeds.

Hussain *et al.* (2008) found that herbicides Nominee Gold 100SC (Bispyribac sodium) and Sunstar Gold 60WG (Ethoxysulfuron) proved as the best herbicides with 90.5 and 87.19% weed control, respectively. The paddy yield in both the herbicidal treatment was also comparatively higher than other herbicides. The highest net benefit was obtained by the application of Nominee Gold 100SC followed by Sunstar Gold 60 WG treatment while the lowest net benefit was provided by weedy check.

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Chapter III

MATERIAL AND METHODS

The present investigation entitled "**Effect of crop establishment method and weed management on growth and yield of irrigated dry direct seeded rice (*Oryza sativa* L.)**" was conducted at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi during *kharif* season of 2010. The detailed account of materials used and experimental procedures employed during the course of investigation have been described in this chapter.

3.1 Experimental site and climate

The Agricultural Research Farm of Banaras Hindu University is situated at about 10 km distance from Varanasi Railway Station in South – West direction. Geographically, experimental site falls under sub-tropical zone of North –Indo Gangetic plain and lies on the left bank of the river Ganga. It is located on 25º18′ N latitude, 83º03′ E longitudes and at an altitude of 128.93 m above the mean sea level. Varanasi is situated in the eastern part of Uttar Pradesh and enjoys sub – tropical climate often subjected to extreme weather conditions i.e. heat of summer and cold of winter with an average annual rain fall of 1081.4 mm and potential evapotranspiration (PET) accounts for 1500 mm annually.

The daily maximum and minimum temperature during the year has a tendency to increase from February onwards to June and to decrease from July to December and later drop rapidly with the minimum value in January.

On an average about 85% of total rain fall is received during summer monsoon season viz., June to September. However, an occasional mild shower occurs during winter season.

3.2 Climate and weather during the crop season

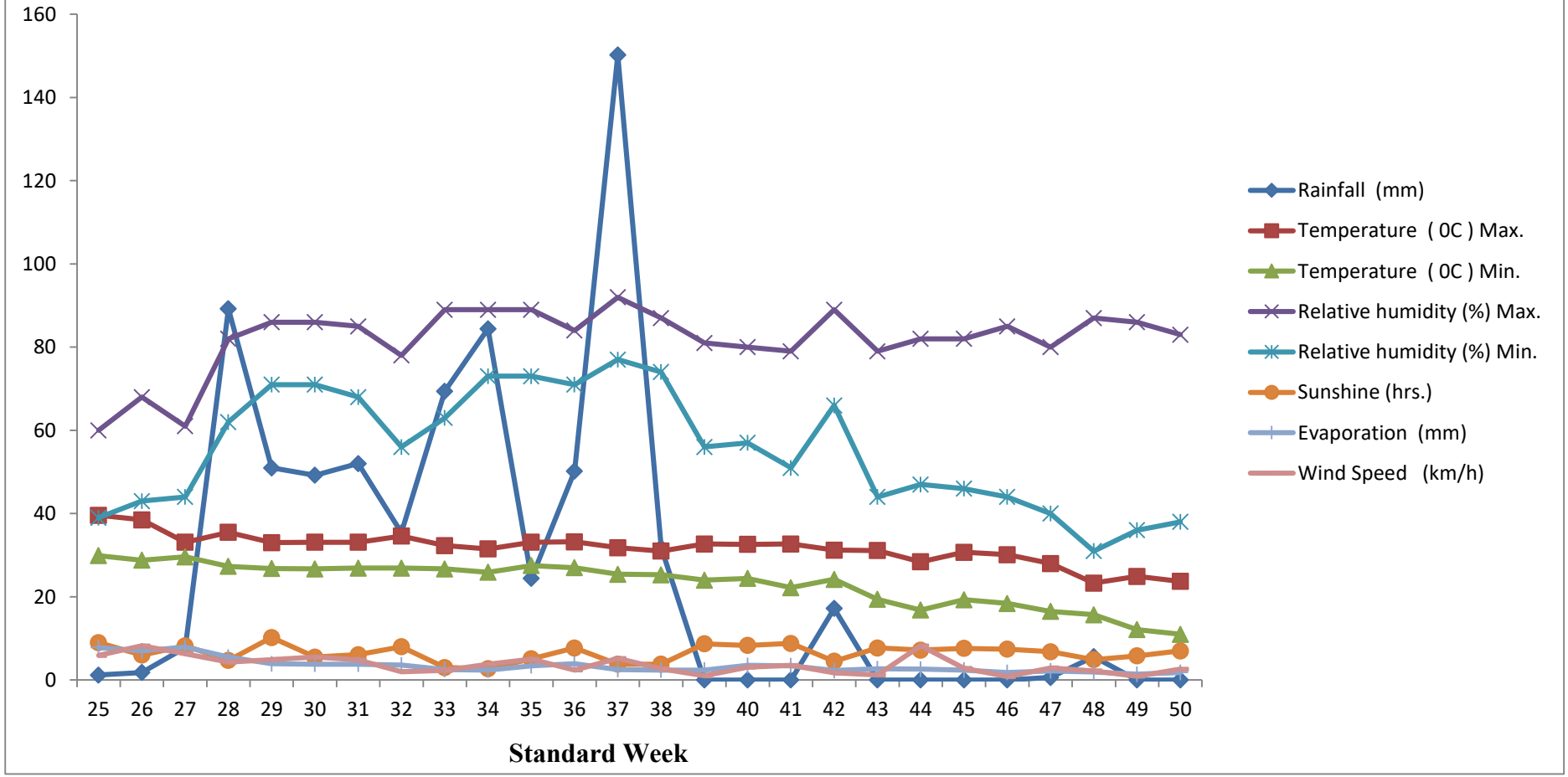
The metrological data was obtained from Metrological Observatory of All

India Co- ordinated Research Project for Dryland Agriculture, situated at Agricultural Research Farm of Banaras Hindu University. The meteorological data of 2010 is presented in Table 3.1 and depicted by graph in Fig 3.1.

Table 3.1 Weekly Meteorological data of Varanasi during cropping period (May-December 2010)

Week No.	Month & date	Rainfall (mm)	Temperature (^{0}C)		Relative humidity (%)		Sunshine (hrs.)	Evapo-ration (mm)	Wind Speed (km/h)
			Max.	Min.	Max.	Min.			
25	June 18-24	1.2	39.6	29.9	60	39	9	7.8	5.9
26	June 25-01July	1.8	38.5	28.8	68	43	6	7	8.2
27	July 02-08	7.8	33.1	29.6	61	44	8.2	7.9	6.3
28	09-15	89.2	35.5	27.3	82	62	4.7	5.5	4.3
29	16-22	51	33	26.8	86	71	10.2	3.9	4.9
30	23-29	49.2	33.1	26.7	86	71	5.5	3.8	5.5
31	July 30-05Aug	52	33.1	26.9	85	68	6.1	3.8	4.8
32	Aug.06-12	35.4	34.6	26.9	78	56	8	3.6	2
33	13-19	69.4	32.3	26.7	89	63	3	2.5	2.3
34	20-26	84.4	31.5	25.9	89	73	2.7	2.4	3.8
35	Aug 27-02 Sept	24.4	33.1	27.5	89	73	5.1	3.4	5
36	Sept.03-09	50.2	33.2	27	84	71	7.7	3.9	2.4
37	10-16	150.2	31.8	25.4	92	77	3.8	2.5	5.2
38	17-23	31.8	31	25.3	87	74	3.8	2.4	2.7
39	24-30	0	32.7	24	81	56	8.7	2.4	1
40	Oct.01-07	0	32.6	24.4	80	57	8.3	3.5	3.1
41	08-14	0	32.7	22.2	79	51	8.8	3.4	3.5
42	15-21	17.2	31.2	24.2	89	66	4.5	2.3	1.7
43	22-28	0	31.1	19.4	79	44	7.7	2.7	1.2
44	Oct.29-04 Nov	0	28.4	16.8	82	47	7.2	2.6	8.2
45	Nov 05-11	0	30.7	19.3	82	46	7.6	2.4	2.8
46	12-18	0	30.1	18.4	85	44	7.4	1.8	0.8
47	19-25	0.6	28	16.5	80	40	6.8	2.2	2.9
48	Nov 26-02 Dec	5.6	23.3	15.7	87	31	4.9	1.9	2.2
49	Dec. 03-09	0	24.9	12.1	86	36	5.8	1.4	0.9
50	10-16	0	23.7	11	83	38	7	1.8	2.6

Fig. 3.1 Standard weekwise Meteorological Observations recorded at the Meteorological Observatory of the Department of Agronomy, I. Ag. Sc, BHU during the period of Experimentation (June, 2010-Dec., 2010)



3.2.1 Rainfall (mm)

The total rainfall received during the cropping period is 721.4 mm. The month-wise distribution of the rainfall indicated that the maximum rainfall is received during the month of August (265.6 mm) and September (232.2 mm). The maximum rainfall occurred in the 37th standard week i.e. 150.2 mm.

3.2.2 Temperature (^{o}C)

The weekly maximum temperature ranged from 23.3-39.6^{o}C. The weekly minimum temperature ranged from 11-29.9 ^{o}C. The highest maximum temperature was during 25th standard week while the lowest minimum temperature was during 50th standard week.

3.2.3 Relative humidity (%)

The weekly maximum relative humidity during the crop growth period ranged from 53-92% and the weekly minimum relative humidity ranged from 26-74%. The highest maximum relative humidity was during 37th standard week and the lowest minimum temperature was during 24th standard week.

3.2.4 Sunshine duration (Hrs.)

The weekly sunshine duration varied from 2.7-10.2 hrs. Months of May and June appeared sunnier as compared to other months. The maximum sunshine duration was during 29th standard week.

3.2.5 Evaporation (mm)

The weekly variation of evaporation ranged from 1.4-8.3 mm with an average of 3.60 mm during the crop growth period. Highest evaporation occurred during 24th standard week.

3.3 Soil and its analysis

Prior to laying out experiment in the field, random soil samples from 0-15 cm

soil depth were taken to evaluate the initial fertility status of the soil of the experimental field. These sample were bought to the laboratory, air dried and crushed to pass through 2mm sieve. Processed sample were subjected to appropriate analysis for mechanical composition, physical and chemical properties of the soil. The data pertaining to soil analysis are presented in the Table 3.2.

Table 3.2. Physical and chemical properties of the experimental soil.

Particulars	**Before sowing**	**After harvesting**	**Method employed**
(A) Mechanical analysis			Hydrometer method (Bouyoucos,1962)
Soil separates			
1. Coarse sand (%)	8.58	8.57	
2. Fine sand (%)	54.4	54.4	
3. Silt (%)	19.4	19.5	
4. Clay (%)	17.5	17.5	
5. Texture class (%)	Sandy clay loam	Sandy clay loam	
(B) Physical analysis			
Bulk density (gcc^{-1})	1.31	1.31	
(C) Chemical analysis			
Electrical conductivity (dsm^{-1}) at 25^0C	0.14	0.14	Conductivity bridge (Jackson,1973)
Soil pH (1:2:5 soil and water suspension)	7.4	7.5	Glass electrode digital pH meter (Jackson,1973)
Organic carbon (%)	0.68	0.68	Walkley and Black's Method (Jackson,1973)
Available Nitrogen (kg ha^{-1})	274	280	Alkaline permanganate (Subbiah and Asija,1956)
Available P_2O_5 (kg ha^{-1})	18.0	18.4	0.5N $NaHCO_3$ extractable (Olsen *et al*.,1995)
Available K_2O (kg ha^{-1})	160	156	Ammonium acetate extractable flame photometer (Jackson,1973)

It is evident from the data in the Table 3.2 that the soil of experimental field was sandy clay loam and low in available nitrogen, medium in phosphorus and medium in available potassium.

3.4 Design and layout

The experiment was laid out in split-plot design with three replications. The crop establishment methods were assigned to main plots and weed control treatments in sub-plots.

Treatment details are as under:

Main plot treatment: Crop establishment methods- 3

- Stale seed bed by shallow tillage
- Stale seed bed by glyphosate@1kg ha^{-1}
- Puddled direct seeded

Sub plot treatment: Weed management practices -5

- Weedy
- Hand Weeding twice (20 and 40 days after sowing)
- Pendimethalin @ 1 kg ha^{-1} (Pre-emergence) *fb* 2, 4-DEE 500 g ha^{-1} (40 DAS)
- Butachlor (Pre-emergence) *fb* 2,4-DEE 500 g ha^{-1} (40 DAS)
- Fenoxaprop with safener 56g ha^{-1} *fb* ethoxysulfuron 18g ha^{-1} at 20-25DAS

Layout details

Experimental design:	Split plot
No of the treatments:	15
No. of replication:	3
Total plots:	45
Block border:	1.5m
Plot border:	0.5m
Gross plot size:	5×4 m^2
Net plot size:	4×3.5m^2
Main irrigation channel:	1.5m
Sub irrigation channel:	1.0m
Seed rate:	30 kg ha^{-1}
Method of sowing:	Direct seeded

3.5 Cropping history of experimental field

The cropping history of the experimental field is presented in the Table 3.3. The cropping history of experimental plot shows that rice was the crop of *Kharif* season.

Table 3.3. Cropping history of the experimental field.

Year	2005-06	2006-07	2007-08	2008-09	2009-10
Kharif	Rice	Rice	Rice	Rice	Rice
Rabi	Wheat	Wheat	Wheat	Fallow	Fallow

3.6 Variety

Variety used: BPT-5204 (Sambha)

Maturity time: 140 -150 days

Yield: 35-46 q ha^{-1}

Plant height: Dwarf to medium tall

Habit: Erect non-lodging open type of canopy

Maturity group: Late duration (seed to seed) (140-150) days

3.7 Seed and sowing

Sowing and seeding depth:

Dry seeding of rice cultivar was done by drilling the seed into field prepared by stale seed bed at the depth of 2-3 cm. Summer ploughing was done on 25th May, 2010. Stale bed was made as per the treatment after irrigating the field on 29th May, 2010 and initial weed flushes were controlled either by shallow tillage or by glyphosate @ 1 kg a.i.ha^{-1} as per the treatment.

Sowing was done with Zero – till cum ferti seed drill along with fertilizer on 18th June, 2010. A uniform dose of 120 kg N, 60 kg P_2O_5, 60 kg K_2O and 5 kg Zn ha^{-1} was applied in all the treatments in the form of urea, DAP, MOP and $ZnSO_4$, respectively. Half of total N and full dose of P_2O_5, K_2O and Zn was applied as basal dose. After the sowing of the seed irrigation water was applied to provide sufficient soil moisture for proper germination. Remaining half dose of N was top dressed in two equal splits at active tillering and panicle initiation stages.

3.8 Herbicide and plant protection measures

Weed control was done by use of herbicides. Details about various herbicides used in the experiment are as follows:

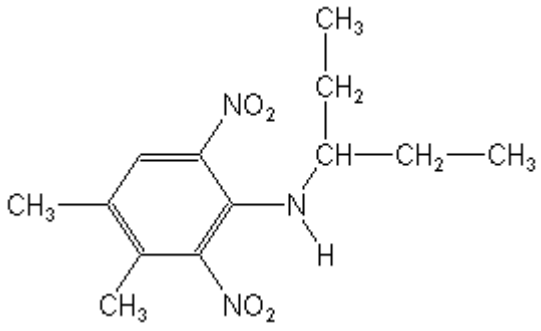
PENDIMETHALIN

Common name: Pendimethalin

Trade name: Stomp

Chemical name: N-(1-ethylpropyl)-2, 6-dinitro-3,4-xylidine

Structure:



Molecular Formula: $C_{13}H_{19}N_3O_4$

Group: Dinitroanilines

Formulation: 35EC

Appearance: Orange-yellow crystal

Melting point: 54-58ºC

Solubility: In water 0.3 mg/l (20ºC). In acetone 700, xylene 628, corn oil 148, heptanes 138, isopropanol 77 (all in g/l, 26ºC). Readily soluble in benzene, toluene, chloroform and dichiromethane. Slightly soluble in petroleum ether and petrol.

Application: Pendimethalin used as pre emergence herbicides inhibits germination and seedling development of susceptible weeds. Where weeds are expected to be a problem, it should be applied after planting and before emergence of rice and weeds. Because soil and weeds must be completely exposed to spray coverage, no floodwater should be on the field at the time of application. The residual activity of Pendimethalin is activated by moisture. It is most effective when adequate rainfall or irrigation is received within 7 days after application.

Weeds controlled: Grasses and broad-leaved weeds

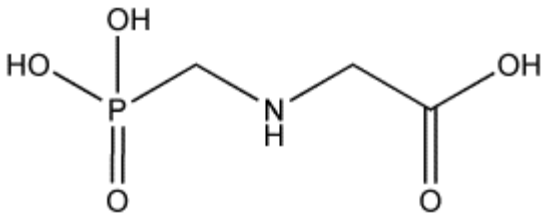
GLYPHOSATE

Common name: Glyphosate

Trade name: Round up

Chemical name: *N*-(phosphonomethyl) glycine

Molecular Structure:



Molecular Formula: $C_3H_7NO_5P$

Group: Organophosphorus

Formulation: 41 EC

Appearance: Colorless crystals

Melting point: 189.5ºC

Solubility: In water 10500 mg/l (25ºC). Also soluble in organic solvent like methanol, hexane and Ethyle acetate.

Application: It is widely used as non selective post-emergence, pre-plant herbicide. It blocks amino-acid synthesis. It is commonly available as a soluble liquid formulation of the isopropylamine salt with a range of formulations, different surfactants and amounts of active ingredient. It only enters the plant via green tissue of the shoot and is mobile in the apoplast and symplast. It moves rapidly to meristems and stops growth, foliar symptoms of chlorosis and necrosis appearing after a few days to one

week. Application timing is important for control of buds on underground propagules which depends on glyphosate moving with photosynthates from the foliage to the storage organs. As a general rule, it is applied to actively growing perennials with several newly expanded leaves, but before flowering, it is widely used prior to crop planting and, if perennial weeds are present, three to four days should be left between spraying and cultivation to allow maximum systemic action. Glyphosate is used in this way for almost all annual crops and in minimum tillage systems.

Weeds controlled: Annual and perennial weeds and some woody species.

BUTACHLOR

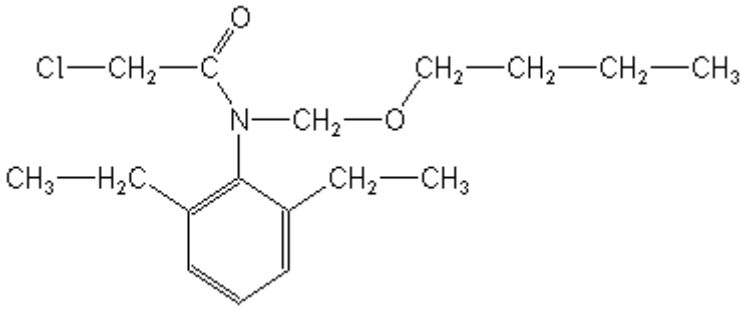
Common name: Butachlor

Trade name: Hiltachlor

Chemical name: N-(butoxymethyl)-2-chloro-N-(2,6-diethylphenyl)acetamide

Molecular Formula: $C_{17}H_{26}ClNO_2$

Molecular Structure:



Group: Amides

Formulation: 50 EC

Application: Butachlor is absorbed primarily through germinating shoots and secondarily through roots. Its mode of action is inhibition of protein synthesis. It is used for pre emergence control of most annual grasses at the 1 to 2 leaf stages and of certain broad leaf weeds and can be applied post emergence. For direct seeded rice it is applied 10-12 days after emergence. Butachlor in soil is broken down by microbial activity. In soil or water, it is rapidly converted to water soluble derivatives. It may persist for six to ten weeks.

Weeds controlled: Annual grasses

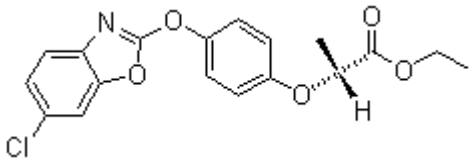
FENOXAPROP-P-ETHYL

Common name: Fenoxaprop-p- ethyl

Trade name: Whipsuper

Chemical name: (+)-Ethyl 2-[4-{(6-chloro-2-benzoxazolyl)oxy}phenoxy] propanoate

Molecular Structure



Molecular Formula $C_{18}H_{16}ClNO_5$

Group: Aryloxy phenoxypropionate

Formulation: 9 EC

Appearance: White solid

Melting point: 86°C

Solubility: Low soluble in water 0.9 mg/l (25°C). Also soluble in Toulene, acetone, ethanol and hexane.

Application: Fatty acid synthesis inhibition in grasses, by inhibition of acetyl in grasses, by inhibition of acetyl COA Carboxylase (ACCase). It is a selective herbicide with contact and systemic action, absorbed principally by the leaf, with translocation both acropetally and basipetally to the roots or rhizomes. It is used as post emergence control of annual and perennials grasses weed in broad leaved crops potatoes, beans etc. when applied with herbicide safener, annual and perennials grasses weeds and wild oats in wheat.

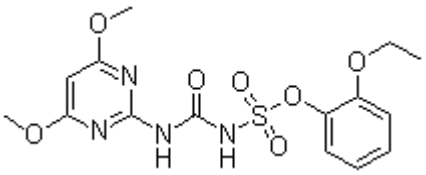
Weeds controlled: Broad leaved & sedges

ETHOXYSULFURON

Common name: Ethoxysulfuron

Trade name: Sunrice

Chemical name: 1-(4, 6-dimethoxypyrimidin-2-yl)-3-(2-ethoxyphenoxysulfonyl)urea

Molecular Structure 

Molecular Formula $C_{15}H_{18}N_4O_7S$

Group: Sulfonyl urea

Formulation: 15WDG

Appearance: White-beige powder

Melting point: 150ºC

Solubility: In water 5000 mg/l (25ºC). Soluble in methanol, acetone and toluene.

Application: It is branched chain amino acid synthesis inhibitor, acts by inhibiting biosynthesis of the essential amino acid valine and isoleucine, hence stopping cell division and plant growth. Selectivity is due to differential metabolism in crop and weed. It is used for broad leaved and sedge weed control in cereals, rice and sugarcane, at 10 -120 g ha^{-1}.

Weeds controlled: Broad leaved & sedges.

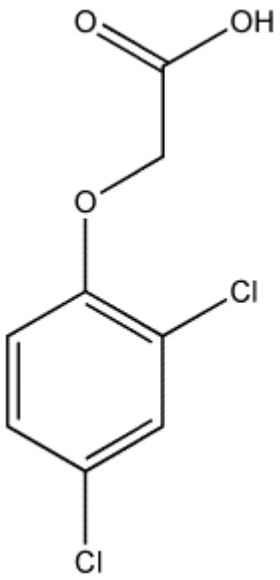
2,4-D EE

Common name: 2,4-D EE

Trade name: Weed One

Chemical name: 2,4 -dichlorophenoxy acetic acid

Molecular Structure:



Molecular formula: $C_8H_6Cl_2O_3$

Group: Phenoxy

Formulation: 18EC

Appearance: Colorless crystals

Melting point: 140.5°C

Solubility: In water 900 mg/l (25°C). Insoluble in benzene, hexane and xylene.

Application: It is available as salt, amine ,ester and granular formulation .The doses required to control broad –leaved weed seedling are selective in small grains ,maize and grain sorghum ,but the crop should have at least four leaves to avoid phytotoxicity. Crop injury should be anticipated with doses required to control large annual and perennial weeds. Generally, activity via the soil is less than that achieved with foliage application.

Weeds controlled: Broad leaved weeds.

Use of Fungicide-: Tricyazole 75 WP@0.6g/ha was applied as and when leaf blight disease of rice symptoms appeared.

3.9 Observations

During the course of investigation, observations were recorded taking all the precaution to eliminate sampling error on both the weeds as well as crop, which are being described below.

Weed and crop samples were collected from each individual plot during the course of experiment for studying various crop and weed characters. Weed samples were collected by placing a quadrate of 0.25 m^{-2} randomly at two places in each plot. Crop growth characters were noted from each plot tagged properly. The observations were taken at four stages., 30, 60, 90 DAS and at harvest stage of crop.

3.9.1 Crop studies

3.9.1.1 Growth attributes:

The following growth characters will be recorded at 30, 60, 90 DAS and at harvest.

Plant height (cm):

Five plants of each experimental plot were selected randomly and tagged. Plant height of the tagged rice plant was recorded with the help of meter scale from the base of the plant to the tip of upper most leaf of the plant before panicle emergence and upto the tip of panicle after heading, averaged and expressed in cm.

Number of tillers (No. m^{-2})

Number of tillers was recorded by using a quadrate of 0.25 m^2 (0.5m × 0.5m) in each plot at different stages of observation and counted into number of tillers m^{-2}.

Dry matter accumulation m^{-1} row (g)

Dry matter accumulation was measured by uprooting plant sample on meter scale in each plot. Plants were cut close to the ground portion to remove the root part to record dry matter accumulation at different crop growth stages. Samples were first dried in sun and then oven dried at 70ºC ± 2ºC till constant weight achieved. After drying, the samples were weighted for recording dry weight and expressed in g m^{-1} row.

Leaf area Index (LAI)

The leaf area index is the area of the leaf surface per unit area of land surface. Plants from 50cm × 50cm (0.25 m^2) area were cut to the ground at 30, 60 and 90 DAS stage from each plot and their green leaves with the sheath portion were separated from the plants.

Leaf area of collected leaves/0.25 m^2 was determined by portable leaf area meter and finally total leaf area was expressed in per unit ground area basis. The leaf area index was obtained by the following formula:

$$LAI = \frac{\text{Total area of green leaves}}{\text{Ground area}}$$

Relative Growth Rate (RGR) (g g^{-1} day^{-1})

This parameter indicates rate of growth per unit dry matter. It is similar to compound interest, wherein interest is also added to the principal to calculate interest.

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

Where,

W_1 = Dry matter at time '**t_1**'

W_2 = Dry matter at time '**t_2**'

Crop Growth Rate (CGR) (g day^{-1})

It indicates at what rate the crop is growing i.e. whether the crop is growing at a faster rate or slower rate than normal.

$$CGR = \frac{W_2 - W_1}{t_2 - t_1}$$

Where,

W_1 = Dry weight of plant at time 't_1'

W_2 = Dry weight of plant at time 't_2'

3.9.1.2 Yield and yield attributes

Number of panicles m^{-2}

Number of panicles m^{-2} was counted by placing quadrate of 0.25 m^2 (0.50m ×

0.50m) in each plot and finally total number of panicles m^{-2} was expressed in average number of panicles m^{-2} row.

Panicle length (cm)

Five panicles were sampled from the tagged plants in each plot. The length was measured from the base of the panicle to the tip of the top most spikelet. The mean panicle length was computed and expressed in cm.

Number of grains panicle^{-1}

The grains of five panicles selected for panicle length from each plot were counted carefully and averaged to obtain the number of grains panicle^{-1}.

Test weight

One thousand filled grains from the produce of the net of each treatment were conducted and their weight was recorded in gram and expressed as test weight.

Grain yield (kg ha^{-1})

Produce of net plots was threshed, and grains thus obtained were winnowed, cleaned and weighted. The yield recorded in kg plot^{-1} was standardized to 14 % moisture and then weight was converted into kg ha^{-1}.

Straw yield (kg ha^{-1})

Dry weight of straw collected from net plot was recorded after sun drying for 5-6 days and expressed in kg ha^{-1}.

Biological yield (kg ha^{-1})

Dry weight of tagged bundle collected from net plot was recorded after sun drying for 5-6 days and expressed in kg ha^{-1}.

Harvest Index (%)

Harvest index was calculated by following formula:

$$\text{Harvest index} = \frac{\text{Economic yield (kg ha}^{-1})}{\text{Biological yield (kg ha}^{-1})} \times 100$$

3.9.2 Weed growth studies

Following weed growth studies were made at 30, 60, 90 DAS and at harvest.

Weed density (No. m^{-2})

Species-wise weed counts were recorded at 30, 60, 90 DAS and at harvest. A weed count, for estimating weed density, was recorded with the help of a quadrate of 0.25 m^2 placed randomly at two spots in each plot. Individual species-wise counts were grouped into grasses, sedges and broad-leaved weeds and expressed as number m^{-2}.

Weed dry matter (g m^{-2})

Weed enclosed in a quadrate of 0.25 m^2 (0.50m × 0.50m) were cut at ground level and separated at grasses, sedges and broad-leaved weeds at 30, 60, 90 DAS and at harvest stage, washed with tap water, sun dried, dried at 70°C for 48 hours, and then weighed. The total weed dry weight was obtained by adding the weight of these three groups. The dry weight was expressed in g m^{-2}.

Weed Index (%)

Weed index is per cent reduction in grain yield due to weeds as compared to total yield of weed free treatment. The weed index was calculated by using the formula as followed:

$$WI = \frac{X - Y}{X} \times 100$$

Where,

X = Grain yield from weed free plot

Y = Grain yield from treatment for which weed index is to be worked out

It is expressed in percentage.

Chemical analysis of crop and weed

The plant sample from rice crop (grain and straw) and weed flora collected treatment-wise at harvest stage of crop and 60 DAS of weeds, respectively. The samples thus collected were washed with tap water followed by treatment with 0.1 N HCL, distilled water and finally with double distilled water. They were chopped, dried under shade then in hot air oven at 65 ± 5 ^{o}C for 48 hours. After recording oven dry weight, the plant samples were grounded treatment wise separately in Willey's mill and stored in butter paper covers. The powdered plant samples were used for analysis of nitrogen, phosphorus and potassium. The methodologies followed are presented in the Table 3.4

Table 3.4. Methods of chemical analysis (N, P, K content) of plant

Nutrient	Analytical method	References
Nitrogen	Chlorimetric (Nessler's reagent) method	Lindner (1944)
Phosphorus	Vanado molybdate yellow colour method	Jackson (1958)
Potassium	Flame-photometric method	Jackson (1958)

Nutrient (N, P, K) uptake in grain and straw (kg ha^{-1})

Nutrient (N, P, K) uptake by grain and straw of rice crop was calculated in kg ha^{-1} in relation to dry matter production ha^{-1} by using following formula (Black, 1967).

$$\text{Uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient (\%) in grain/straw} \times \text{grain/straw yield (kg ha}^{-1}\text{)}}{100}$$

N,P, K depletion by weed at 30 and 60 DAS

Nitrogen, phosphorus and potassium removal by weeds were calculated by the following formula.

$$\text{Nutrient removal by weeds (kg ha}^{-1}\text{)} = \frac{\text{Nutrient (\%) in weed} \times \text{weed dry matter (kg ha}^{-1}\text{)}}{100}$$

3.9.3 Economics

The economics of various treatments was calculated taking into account market price of inputs and produce prevailing in year 2010. The investment for fertilizers, labour and power for performing different operations such as ploughing, weeding, irrigation, harvesting, threshing and winnowing etc. were worked out (Rs. ha^{-1}) as per rate prevalent at the Research Farm, Institute of Agricultural Sciences, BHU, Varanasi. The cost of cultivation was taken into account for calculating economics of treatments and expressed as net return (Rs.ha^{-1}) and benefit cost ratio.

Cost of cultivation (Rs. ha^{-1})

The term "cost of Cultivation" and "Cost of production" is used as synonyms for the purpose of cost study. However, nice distinction can be made between the two, the cost of cultivation includes factor costs up to the stage of gathering the harvest and that cost of production to include factor costs up to the stage of marketing the produce. The cost of cultivation was calculated taking into account cost of various

inputs and operations involved like land preparation, cost of fertilizers, cost of seed drilling, irrigation, cost of fungicide (0.6 g/l), harvesting& bundling, threshing & winnowing and labor charges.

Gross return (Rs. ha^{-1}):

The yield of rice crop was converted into gross return in Rs. ha^{-1} on the basis of market price of the produce for the relevant year i.e. for the year 2010.

Net return (Rs. ha^{-1})

The net return was worked out by using following formula:

Net return (Rs. ha^{-1}) = Gross return (Rs. ha^{-1}) - cost of cultivation (Rs. ha^{-1})

Benefit Cost Ratio (B: C ratio):

The benefit cost ratio was worked out on the basis of net return per unit cost of cultivation (Rs. ha^{-1}).

$$\text{B:C ratio} = \frac{\text{Gross return (Rs. ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs. ha}^{-1}\text{)}}$$

3.9.4 Statistical analysis

Data generated in the experiment were analyzed as per standard statistical procedure of split plot design suggested by Gomez & Gomez (1976).

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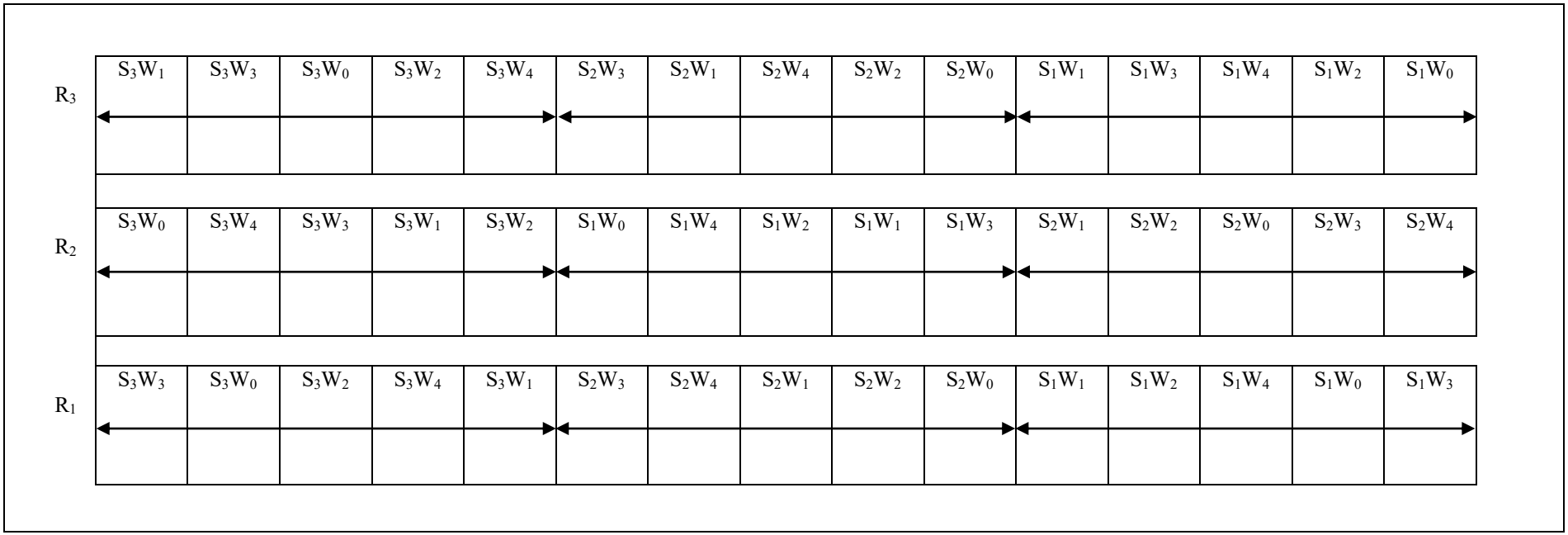


Fig. 3.2. LAYOUT PLAN

Main plot treatments

S1- Stale seedbed by shallow tillage

S2-Stale seedbed by glyphosate@1kg/ha

S3-Puddled direct seeded

Sub-plot treatments

W0-Weedy

W1- Weed free(2HW 20&40DAS)

W2-Pendimethalin@1kg ha^{-1}(Pre-E) *fb* 2,4-DEE 0.5kg ha^{-1} (40DAS)

W3-Butachlor@1kg ha^{-1}(Pre-E) *fb* 2,4-DEE 0.5kg ha^{-1}(40DAS)

W4-Fenoxaprop with safener 56g ha^{-1} + Ethoxysulfuron 18g ha^{-1} (15-20 DAS)

Chapter IV

EXPERIMENTAL FINDINGS

In an attempt has been made to ascertain the degree of variation exhibited by various crop and weed parameters due to treatment variables in the experiment entitled **"Effect of crop establishment method and weed management on growth and yield of irrigated dry direct seeded rice (*Oryza sativa* L.)"**. The data collected during the course of investigation have been statistically analysed and presented in tables and figures. The treatment effects have been described in this chapter in light of statistical interpretation.

4.1 Studies on weed

Weed flora and their relative composition

Weed flora present in the experimental field during 2010 were collected, identified and grouped as grasses, sedges and broad leaved weeds and are presented in Table 4.1.

The extent of yield losses depends on the magnitude of weed infestation, type of weed species, time of weed association with the crop, fertilization, competitive ability of the cultivar, and cultural management. Common weeds infesting experimental field were *Cynodon dactylon* (9.25), *Dactyloctenium aegypticum, Echinochloa colonum* (24.54)*, Echinochloa crusgalli* (14.2) and *Leptochloa chinenis* Nees amongst narrow leaved weeds; *Ammannia baccifera*, *Caesulia axillaries* (5.62), *Commelina benghalensis* (4.54), *Physalis minima* (6.81)*, Eclipta alba, Ipomoea aquatic* (2.14)*, Euphorbia hirta, Parthenium hysterophorus, Phyllanthus niruri* (2.27)*, Ludwigia* spp (13.9), *Solanum nigrum* (3.43) and *Traianthema monogyna* amongst broad leaved weeds; common sedge (*Cyperus difformis*) rice flat sedge (*Cyperus iria*), globe fringe rush (*Fimbristylis miliaceae*) and others (13.2) amongst sedges

Weed density

The data pertaining to effect of crop establishment method and weed management on weed density at different growth stages have been presented in Table 4.2 & 4.3. Puddled direct seeded rice resulted in significant decrease in the total weed density at 30 and 60 DAS in comparison to stale bed by glyphosate @ 1 kg ha^{-1} and stale bed by shallow tillage. Puddled direct seeded rice significantly reduced the density of broad leaved weeds at 30 DAS and it was superior to both stale bed by shallow tillage and stale bed by gylphosate @ 1 kg ha^{-1}. Puddled direct seeded rice and stale bed by shallow tillage were found to be equally effective in controlling *Echinochloa colonum* at 60 DAS and were statistically superior to stale bed by glyphosate @ 1.0 kg ha^{-1}. The effect of crop establishment method on weed density at 90 DAS and at harvest was found non-significant.

Amongst methods of weed management, all the sequential herbicidal application significantly reduced weed density of narrow leaved weeds especially *Echinochloa colonum* & *Echinochloa crusgalli*, broad leaved and sedges thereby reducing the total weed density at 30, 60 and 90 DAS. Pre-emergence application of butachlor @ 1 kg ha^{-1} *fb* post emergence application of 2, 4-D@ 0.5 kg ha^{-1} was found to significantly reduce the weed density of broad leaved weeds at 90 DAS in comparison to post emergence application of fenoxaprop-p-ethyl 56 g ha^{-1} *fb* ethoxysulfuron 18 g ha^{-1} and pendimethalin pre-emergence @ 1 kg ha^{-1} *fb* 2, 4-D post emergence application @ 0.5 kg ha^{-1} and was superior to both the latter treatments. Pre-emergence application of both butachlor @ 1 kg ha^{-1} *fb* post emergence application of 2, 4-D@ 0.5 kg ha^{-1} and pendimethalin @ 1 kg ha^{-1} *fb* 2, 4-D post emergence application @ 0.5 kg ha^{-1} were found statistically at par to each other and were superior over post emergence application of fenoxaprop-p-ethyl 56 g ha^{-1} *fb* ethoxysulfuron 18 g ha^{-1} for control of *Echinochloa colonum*, *Echinochloa crusgalli* & broad leaved weeds, thus reducing the total weed density at harvest. Post emergence application of fenoxaprop-p-ethyl 56 g ha^{-1} *fb* ethoxysulfuron 18 g ha^{-1} was found to significantly reduce the weed density of sedges at harvest and was

superior over other two sequential herbicidal applications. Weed free and weedy recorded the minimum and the maximum weed density respectively among all the weed management treatments.

Weed dry weight

The data pertaining to effect of crop establishment method and weed management on weed dry weight at different growth stages have been presented in Table 4.4 & 4.5. Variation in total weed dry weight due to various crop establishment methods was found non-significant at all the stages of crop growth except at 90 DAS. Stale bed by glyphosate @ 1.0 kg ha^{-1} significantly reduced the weed dry weight of sedges at 60 DAS in comparison to both stale bed by shallow tillage and puddled DSR and was superior over both the latter two crop establishment method. Stale bed by glyphosate @ 1.0 kg ha^{-1} and puddled DSR were statistically at par with each other and were superior over stale bed by shallow tillage in reducing the total weed dry weight at 90 DAS and in particular the weed dry weight of *Echinochloa colonum* at 90 DAS & at harvest.

In case of weed management treatment, significant variations in weed dry weight were observed at all the stages of crop growth. All the sequential herbicidal treatments were statistically at par with each other and significantly reduced the weed dry weight of both broad and narrow leaved weeds thereby reducing the total weed dry weight in comparison to weedy check at 30 DAS. Both the herbicidal treatments i.e. post emergence application of fenoxaprop-p-ethyl 56 g ha^{-1} *fb* ethoxysulfuron 18 g ha^{-1} and pre-emergence application of pendimethalin @ 1 kg ha^{-1} *fb* 2, 4-D post emergence application @ 0.5 kg ha^{-1} were equally effective in reducing the total weed dry weight in comparison to pre-emergence application of butachlor @ 1 kg ha^{-1} *fb* post emergence application of 2, 4-D@ 0.5 kg ha^{-1} and thus former two treatments were superior in reducing total weed dry weight at 60, 90 DAS and at harvest, over the latter one. Weed free and weedy recorded the minimum and the maximum weed dry weight respectively in comparison to rest of the weed management treatments.

4.2 Crop growth studies

Plant height

The data pertaining to effect of crop establishment methods and weed management on plant height have been presented in Table 4.6. Variation in plant height due to crop establishment methods was non-significant except at 90 DAS. Stale bed by glyphosate @1kg ha^{-1} and by shallow tillage were found statistically at par with each other and recorded taller plants than that in puddled DSR at 90 DAS.

Variations in plant height due to sequential herbicidal treatments were significant over weedy treatment and statistically at par with each other at 30, 60 and 90 DAS. While significantly taller plants were observed at harvest in post emergence application of fenoxaprop-p-ethyl 56 g ha^{-1} *fb* ethoxysulfuron 18 g ha^{-1} in comparison to both pre-emergence application of butachlor @ 1 kg ha^{-1} *fb* post emergence application of 2, 4-D@ 0.5 kg ha^{-1} and pre-emergence application of pendimethalin @ 1 kg ha^{-1} *fb* 2, 4-D post emergence application @ 0.5 kg ha^{-1}. Further, the former treatment was found statistically superior over the latter two treatments. Weed free and weedy recorded the tallest and the shortest plant respectively in comparison to rest of the weed management treatment.

Dry matter accumulation

The data pertaining to effect of crop establishment method and weed management on dry matter accumulation have been presented in Table 4.6. Variation in dry matter accumulation due to crop establishment method was non-significant except at 90 DAS. Stale bed by glyphosate @1kg ha^{-1} and by shallow tillage were found to be statistically at par with each other and both the treatments recorded more dry matter accumulation than that in puddled DSR at 90 DAS.

Variations in dry matter accumulation due to sequential herbicidal treatments were significant over weedy treatment and statistically at par with each other at all crop growth stages i.e. at 30, 60, 90 DAS and at harvest. Weed free and weedy

recorded the maximum and the minimum dry matter accumulation respectively among all the weed management treatments.

Number of tillers

The data pertaining to effect of crop establishment method and weed management on number of tillers m^{-2} have been presented in Table 4.7. Stale bed by glyphosate @ 1 kg ha^{-1} and puddled DSR were statistically at par with each other and both recorded higher number of tillers m^{-2} than in stale bed by shallow tillage at 60 DAS. However, variations in number of tillers due to crop establishment methods were found to be non-significant at 90 DAS.

Variations in number of tillers m^{-2} due to sequential herbicidal treatments were significant over weedy treatment and statistically at par with each other at all crop growth stages i.e. at 60 and 90 DAS. Weed free and weedy recorded the maximum and the minimum number of tillers m^{-2} respectively among all the weed management treatments.

Leaf area index

The data pertaining to effect of crop establishment method and weed management on leaf area index have been presented in Table 4.7. Stale bed by glyphosate @ 1 kg ha^{-1} and puddled DSR were statistically at par with each other and both recorded more leaf area index than in stale bed by shallow tillage at 60 DAS. However, variations in leaf area index due to crop establishment methods were found to be non-significant at 90 DAS.

Variations in leaf area index due to sequential herbicidal treatments were significant over weedy treatment and statistically at par with each other at all crop growth stages i.e. at 60 and 90 DAS. Weed free and weedy check recorded the highest and the lowest leaf area index respectively among all the weed management treatments.

Crop growth rate

Data pertaining to effect of crop establishment method and weed management on crop growth rate have been presented in Table 4.8. Variations in crop growth rate (g m^{-2} day^{-1}) due to crop establishment method were non-significant at all the stages of observations.

Variations in crop growth rate due to sequential herbicidal treatments were significant over weedy treatment and statistically at par with each other at all the crop growth stages i.e. at 30, 60, 90 DAS and at harvest. Weed free and weedy check recorded the maximum and the minimum crop growth rate respectively among all the weed management treatments.

Relative growth rate

Data pertaining to effect of crop establishment method and weed management on relative growth rate have been presented in Table 4.8. Variations in relative growth rate (g g^{-1} day^{-1}) due to crop establishment method were non-significant at all the stages of observations.

Variations in relative growth rate due to sequential herbicidal treatments were significant over weedy treatment and statistically at par with each other at all crop growth periods i.e. at 30-60, 60-90 and 90-120 DAS. Weed free and weedy check recorded the maximum and the minimum relative growth rate respectively among all the weed management treatments.

4.3 Yield attributes

Number of panicles m^{-2}

Data pertaining to effect of crop establishment method and weed management on number of panicles m^{-2} have been presented in Table 4.9. Variations in number of panicles m^{-2} due to crop establishment method were significant. Stale bed by

glyphosate @ 1 kg ha^{-1} and puddled DSR were statistically at par with each other and both recorded higher number of panicles m^{-2} than that in stale bed by shallow tillage.

Amongst the sequential herbicidal treatments, fenoxaprop-p-ethyl 56 g ha^{-1} *fb* ethoxysulfuron @ 18 g ha^{-1} had statistically more number of panicles m^{-2} as compared to both butachlor @ 1 kg ha^{-1} *fb* 2, 4-D @ 0.5 kg ha^{-1} and pendimethalin @ 1 kg ha^{-1} *fb* 2, 4-D @ 0.5 kg ha^{-1}. Weed free and weedy recorded the maximum and the minimum number of panicles m^{-2} respectively among all the weed management treatments.

Panicle length

Data pertaining to effect of crop establishment method and weed management on panicle length have been presented in Table 4.9. Variations in panicle length were non-significant due to crop establishment methods.

However, variations in the panicle length due to sequential herbicidal treatments were significant over weedy treatment and were statistically at par with each other. Weed free and weedy recorded the longest and the shortest panicle respectively among all the weed management treatments.

Number of grains $panicle^{-1}$

Data pertaining to effect of crop establishment method and weed management on number of grains $panicle^{-1}$ have been presented in Table 4.9. Effects of crop establishment methods on number of grains $panicle^{-1}$ were non-significant.

Amongst the sequential herbicidal treatments, fenoxaprop-p-ethyl 56 g ha^{-1} *fb* ethoxysulfuron @ 18 g ha^{-1} had statistically more number of grains $panicle^{-1}$ as compared to both butachlor @ 1 kg ha^{-1} *fb* 2, 4-D @ 0.5 kg ha^{-1} & pendimethalin @ 1 kg ha^{-1} *fb* 2, 4-D @ 0.5 kg ha^{-1}. Weed free and weedy recorded the maximum and the minimum number of grains $panicle^{-1}$, respectively amongst all the weed management treatments.

Panicle weight

Data pertaining to effect of crop establishment method and weed management on panicle weight have been presented in Table 4.9. Effects of crop establishment methods on panicle weight were non-significant.

However, variations in the panicle weight due to sequential herbicidal treatments were significant over weedy treatment and all were statistically at par with each other. Weed free and weedy recorded the highest and the lowest panicle weight, respectively among all the weed management treatments.

Test weight

Data pertaining to effect of crop establishment method and weed management on test weight have been presented in Table 4.9. Effects of crop establishment methods on test weight were non-significant.

However, variations due to sequential herbicidal treatments on test weight were significant over weedy treatment. Amongst the sequential herbicidal treatments fenoxaprop-p-ethyl 56 g ha^{-1} *fb* ethoxysulfuron @ 18 g ha^{-1} and pendimethalin @ 1 kg ha^{-1} *fb* 2, 4-D @ 0.5 kg ha^{-1} were statistically at par with each other and the former treatment had statistically comparable test weight as compared to butachlor @ 1 kg ha^{-1} *fb* 2, 4-D @ 0.5 kg ha^{-1}. Weed free and weedy recorded the highest and the lowest test weight, respectively among all the weed management treatments.

4.4 Yield

Grain yield

Data pertaining to effect of crop establishment method and weed management on grain yield have been presented in Table 4.10. Crop establishment methods did not cause significant variations in grain yield.

However, all the sequential herbicidal treatments gave significantly higher grain yield over the control treatment. Weed free and weedy recorded the highest and the lowest grain yield, respectively among all the weed management treatments.

Straw yield

Data pertaining to effect of crop establishment method and weed management on straw yield have been presented in Table 4.10. Crop establishment methods did not produce significant variation in straw yield.

However, all the sequential herbicidal treatments resulted in significantly higher straw yield over the control treatment. All the sequential herbicidal treatments were statistically at par with each other. Weed free and weedy recorded the highest and the lowest straw yield, respectively among all the weed management treatments.

Biological yield

Data pertaining to effect of crop establishment method and weed management on biological yield have been presented in Table 4.10. Variations in biological yield due to crop establishment methods were non- significant.

However, all the sequential herbicidal treatments gave significantly higher biological yield over the control treatment. All the sequential herbicidal treatments were statistically at par with each other. Weed free and weedy recorded the highest and the lowest biological yield, respectively among all the weed management treatments.

Harvest index

Data pertaining to effect of crop establishment method and weed management on harvest index have been presented in Table 4.10. The effect of crop establishment methods and weed management treatments on harvest index was found to be non-significant.

Weed index

Data pertaining to effect of crop establishment method and weed management on weed index have been presented in Table 4.10. The effect of crop establishment methods on weed index was found non-significant.

All the sequential herbicidal treatments significantly reduced weed index as compared to weedy treatment and were statistically at par with each other. From the table it can be seen that all the sequential herbicidal treatments were unable to completely eliminate the crop-weed competition, as a result of which there is appreciable loss in yield. Under weed free condition maintained by hand weeding at 20 DAS & 40 DAS, there was no crop-weed competition and no yield loss was observed in it during the course of investigation. However, crop-weed competition was highest under weedy condition suffering maximum yield loss amongst all the weed management treatments.

Nutrient uptake by crop plants

Data pertaining to effect of crop establishment method and weed management on nutrient uptake have been presented in Table 4.11. The data in the table revealed that nutrient uptake (N, P & K) by grain and straw did not vary significantly due to crop establishment methods.

All the sequential herbicidal treatments exhibited significant variations in the nutrient uptake (N, P & K) when compared with the control and were statistically at par with each other. Weed free recorded the maximum nutrient uptake (N, P and K) in grain *fb* pre-emergence butachlor @1kg ha^{-1} *fb* 2, 4-D (post 0.5 kg ha^{-1}), fenoxaprop-p-ethyl (post 56 g ha^{-1}) *fb* ethoxysulfuron 18 g ha^{-1} and pendimethalin(pre 1 kg ha^{-1}) *fb* 2, 4-D (post 0.5 kg ha^{-1}). In contrast, weed free recorded the maximum uptake (N, P and K) in straw followed by pre-emergence butachlor @1kg ha^{-1} *fb* 2, 4-D (post 0.5 kg ha^{-1}), Pendimethalin (pre 1 kg ha^{-1}) *fb* 2, 4-D (post 0.5 kg ha^{-1}) and fenoxaprop-p-ethyl (post 56 g ha^{-1}) *fb* ethoxysulfuron 18 g ha^{-1}.

Nutrient depletion by weeds

Data pertaining to effect of crop establishment method and weed management on nutrient depletion by weeds have been presented in Table 4.12. Variations in nutrient depletion (N, P and K) by weed were non-significant due to crop establishment methods at 30 and 60 DAS.

All the sequential herbicidal treatments had significant effects on reducing the nutrient depletion (N, P and K) by weeds over weedy treatment and were statistically at par with each other at 30 DAS. While at 60 DAS, both the treatments i.e. fenoxaprop-p-ethyl (post 56 g ha^{-1}) *fb* ethoxysulfuron 18 g ha^{-1} and pendimethalin pre-emergence @ 1 kg ha^{-1} *fb* 2, 4-D (post 0.5 kg ha^{-1}) were statistically at par with each other and both the treatments recorded significantly less nutrient (N, P & K) depletion by weed than butachlor @1kg ha^{-1} *fb* 2, 4-D (post 0.5 kg ha^{-1}).

Economics

Data pertaining to effect of crop establishment method and weed management on economics have been presented in Table 4.13. Amongst different crop establishment methods, stale bed by glyphosate @ 1kg ha^{-1} recorded highest gross return *fb* puddled DSR and stale bed by shallow tillage. However, net return and benefit cost ratio were highest in case of puddled DSR among the crop establishment methods.

Among sequential herbicidal treatments, butachlor @1 kg ha^{-1} *fb* 2, 4-D (post 0.5 kg ha^{-1}) recorded the highest gross return, net return and benefit cost ratio *fb* fenoxaprop-p-ethyl (post 56 g ha^{-1}) *fb* ethoxysulfuron 18 g ha^{-1} and pendimethalin (pre. 1 kg ha^{-1}) *fb* 2, 4-D (post 0.5 kg ha^{-1}). Weed free had the highest gross return, net return and benefit cost ratio among all the weed management treatments.

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Table 4.11. Effect of crop establishment method and weed management on nutrient uptake in irrigated dry direct seeded rice

Treatment	Grain (kg ha^{-1})			Straw (kg ha^{-1})		
	Nitrogen	**Phosphorus**	**Potassium**	**Nitrogen**	**Phosphorus**	**Potassium**
Crop establishment method						
Stale bed by shallow tillage	32.63	5.26	9.92	25.78	3.34	72.62
Stale bed by glyphosate @ 1 kg ha^{-1}	32.82	5.28	9.98	34.12	4.42	96.11
Puddled DSR	32.87	5.04	9.99	31.77	4.11	89.50
SEm ±	1.41	0.23	0.42	3.09	0.40	8.71
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Weed management						
Butachlor (Pre. 1 kg ha^{-1}) *fb* 2,4-D (Post 0.5 kg ha^{-1})	33.70	5.33	10.24	28.51	3.69	80.33
Pendimethalin (pre. 1 kg ha^{-1}) *fb* 2,4-D (Post 0.5 kg ha^{-1})	29.71	4.72	9.03	25.92	3.35	73.01
Fenoxaprop-p- ethyl (post 56 g ha^{-1}) *fb* Ethoxysulfuron 18 g ha^{-1})	32.91	5.13	10.00	25.87	3.35	72.88
Weed free	53.54	8.57	16.27	63.86	8.27	179.88
Weedy	14.03	2.20	4.26	8.62	1.11	24.28
SEm ±	1.56	0.62	0.47	3.41	0.44	9.61
CD (P=0.05)	4.57	1.83	1.38	9.96	1.29	28.06

Table 4.12. Effect of crop establishment method and weed management on nutrient depletion by weeds in irrigated dry direct seeded rice

Treatment	Nutrient depletion by weeds at 30 DAS			Nutrient depletion by weeds at 60 DAS		
	Nitrogen	Phosphorus	Potassium	Nitrogen	Phosphorus	Potassium
Crop establishment method						
Stale bed by shallow tillage	8.66	2.93	16.57	18.51	7.58	38.63
Stale bed by glyphosate @ 1 kg ha^{-1}	8.83	2.98	16.89	17.42	7.14	36.35
Puddled DSR	6.23	2.11	11.93	16.82	6.90	35.09
SEm ±	2.06	0.69	3.95	0.50	0.20	1.05
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Weed management						
Butachlor (Pre 1 kg ha^{-1}) *fb* 2,4-D (Post. 0.5 kg ha^{-1})	10.89	3.68	20.84	21.35	8.65	44.74
Pendimethalin (pre 1 kg ha^{-1}) *fb* 2,4-D (Post 0.5 kg ha^{-1})	7.11	2.40	13.60	20.11	8.14	42.12
Fenoxaprop-p- ethyl (post 56 g ha^{-1}) *fb* Ethoxysulfuron 18 g ha^{-1})	7.16	2.42	13.71	19.48	7.89	40.82
Weed free	0.00	0.00	0.00	0.70	0.70	0.70
Weedy	14.37	4.86	27.51	26.28	10.65	55.06
SEm ±	1.58	0.53	3.02	0.50	0.20	1.05
CD (P=0.05)	4.61	1.56	8.83	1.47	0.59	3.08

Table 4.13. Effect of crop establishment method and weed management on economics in irrigated dry direct seeded rice

Treatment	Cost of cultivation (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	Benefit : Cost ratio
Crop establishment method				
Stale bed by shallow tillage	23266.00	50852.56	27586.56	2.19
Stale bed by glyphosate @ 1kg ha^{-1}	25627.60	54045.60	28418.00	2.11
Puddled DSR	24026.60	53268.67	29242.07	2.22
Weed management				
Butachlor (Pre 1 kg ha^{-1}) *fb* 2,4-D (Post 0.5 kg ha^{-1})	24288.00	53177.67	28889.67	2.19
Pendimethalin (pre 1 kg ha^{-1}) *fb* 2,4-D(Post 0.5 kg ha^{-1})	24786.00	47156.92	22370.92	1.90
Fenoxaprop-p- ethyl (post 56 g ha^{-1}) *fb* Ethoxysulfuron 18 g ha^{-1})	24073.00	51244.38	27171.38	2.13
Weed free	26994.66	91019.38	64024.72	3.37
Weedy	21372.00	20997.54	-374.46	0.98

Table 4.1. Relative composition of weeds at 30, 60 and 90 DAS

Scientific name	Common name	Family	Growth habit	Relative composition 60 DAS
Narrow leaved weeds				
Cynodon Dactylon L	Bermuda grass	Poaceae	Perennial	9.25
Dactyloctenum aegypticum		Poaceae	Annual	
Echinochloa colonum	Barnyard grass	Poaceae	Annual	24.54
Echinochloa crusgalli	Barnyard grass	Poaceae	Annual	14.2
Leptochloa chinensis (L.) Nees	Spranletop	Poaceae	Annual	
Broad leaved weeds				
Ammannia baccifera Roxb.	Henna	Lythraceae	Annual	
Caesulia axillaries Roxb.	Caesulia	Compositae	Annual	5.62
Commelina benghalensis	Tropical spider wort	Commeliaceae	Annual	4.54
Physalis minima	Berry	Solanaceae	Annual	6.81
Eclipta alba	False daisy	Compositae	Annual	
Ipomoea aquatica	Morning glory	Convolvulaceae	Perennial	2.14
Euphorbia hirta	Red spurge	Euphobiaceae	Annual	
Parthenium hysterophorus	Carrot grass	Compositae	Perennial	
Phyllanthus niruri	Tropical shrubby plant	Euphobiaceae	Annual	2.27
Ludwigia spp.				13.9
Solanum nigram		Solanaceae	Annual	3.43
Traianthema monogyna L.	Horse purselane	Aizoaceae	Annual	
Sedges				
Cyperus difformis L.	Common sedge	Cyperaceae	Annual	
Cyperus iria L.	Rice flat sedge	Cyperaceae	Annual	
Fimbbristylis miliaceae (L.) Vahi.	Globe fringe rush	Cyperaceae	Annual	
Others				13.2

Table 4.2. Effect of crop establishment methods and weed management on weed density at 30 and 60 DAS in irrigated dry direct seeded rice

Treatment	Weed Density (m^{-2})									
	30 DAS				60 DAS					
	Narrow leaved weed	Broad leaved weeds	Sedges	Total	Broad leaved weed	*Echinochloa colonum*	*Echinochloa crusgalli*	Sedges	Narrow leaved weeds	Total
Crop establishment method										
Stale bed by shallow tillage	3.66	10.18	2.48	11.14	8.40	17.20	8.90	7.50	7.80	23.80
Stale bed by glyphosate @ 1 kg ha^{-1}	3.17	8.96	3.17	10.10	8.70	18.60	8.50	6.60	7.50	24.30
Puddled DSR	3.38	7.22	2.74	8.53	8.80	16.10	8.80	6.80	7.70	22.80
SEm ±	0.43	0.40	0.28	0.35	0.50	0.30	0.20	0.30	0.20	0.10
CD (P=0.05)	NS	1.57	NS	1.36	NS	1.40	NS	NS	NS	0.50
Weed management										
Butachlor (Pre. 1 kg ha^{-1}) *fb* 2,4-D (Post. 0.5 kg ha^{-1})	4.20	10.36	2.81	11.69	9.20	20.90	9.50	7.10	8.40	27.30
Pendimethalin (pre. 1 kg ha^{-1}) *fb* 2,4-D (Post. 0.5 kg ha^{-1})	3.44	9.17	3.31	10.63	9.60	19.90	9.80	7.60	8.90	27.00
Fenoxaprop-p- ethyl (post. 56 g ha^{-1}) *fb* Ethoxysulfuron 18 g ha^{-1})	3.27	10.09	3.49	11.30	9.30	19.30	9.60	7.70	7.70	26.10
Weed free	0.71	0.71	0.71	0.71	0.70	0.70	0.70	0.70	0.70	0.70
Weedy	5.41	13.61	3.68	15.27	14.40	25.60	14.20	11.90	12.60	37.10
SEm ±	0.56	0.53	0.42	0.52	0.40	0.50	0.40	0.40	0.40	0.40
CD (P=0.05)	1.63	1.53	1.22	1.50	1.30	1.60	1.20	1.10	1.40	1.20

Note: The data pertaining to weed density at different growth stages are transformed one.

Table 4.3. Effect of crop establishment methods and weed management on weed density at 90 DAS and at harvest in irrigated dry direct seeded rice

Treatment	Weed density (m^{-2})									
	90 DAS					At harvest				
	Echinochloa colonum	**Sedges**	***Echinocloa crusgalli***	**Broad leaved weeds**	**Total**	***Echinochloa colonum***	***Echinocloa crusgalli***	**Broad leaved weed**	**Sedges**	**Total**
Crop establishment method										
Stale bed by shallow tillage	8.78	4.86	6.50	6.72	13.78	8.16	6.46	7.23	3.00	12.91
Stale bed by glyphosate @ 1 kg ha^{-1}	8.91	5.06	6.75	7.50	15.16	8.61	7.03	7.96	3.65	14.04
Puddled DSR	9.47	5.09	7.15	6.88	14.60	8.68	8.18	7.05	4.08	14.31
SEm ±	0.27	0.33	0.38	0.55	0.68	0.15	0.51	0.34	0.22	0.44
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Weed management										
Butachlor (Pre. 1 kg ha^{-1}) *fb* 2,4-D (Post. 0.5 kg ha^{-1})	10.54	6.26	7.45	7.79	16.49	9.99	7.92	8.18	4.11	15.73
Pendimethalin (pre. 1 kg ha^{-1}) *fb* 2,4-D (Post. 0.5 kg ha^{-1})	11.70	4.95	7.39	8.96	17.40	9.62	8.68	8.70	4.44	16.28
Fenoxaprop-p- ethyl (post. 56 g ha^{-1}) *fb* Ethoxysulfuron 18 g ha^{-1})	10.29	6.21	8.19	9.71	17.64	10.24	8.73	9.07	3.69	16.67
Weed free	12.90	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
Weedy	12.03	6.87	10.27	8.00	19.09	11.86	10.08	10.41	4.93	19.36
SEm ±	0.54	0.51	0.49	0.29	0.53	0.17	0.27	0.29	0.13	0.23
CD (P=0.05)	1.58	1.50	1.43	0.86	1.54	0.50	0.79	0.84	0.39	0.67

Note: The data pertaining to weed density at different growth stages are transformed one.

Table 4.4. Effect of crop establishment method and weed management on weed dry weight at 30 and 60 DAS in irrigated dry direct seeded rice

	Weed dry weight (g m^{-2})							
	30 DAS			60 DAS				
Treatment	**Narrow leaved weed**	**Broad leaved weeds**	**Total**	***Echinochloa colonum***	**Sedges**	***Echinochloa crusgalli***	**Broad leaved weeds**	**Total**
Crop establishment method								
Stale bed by shallow tillage	3.57	3.11	5.64	9.65	6.19	8.38	7.26	15.98
Stale bed by glyphosate @ 1 kg ha^{-1}	3.03	3.45	5.66	9.02	5.30	7.94	7.16	15.04
Puddled DSR	2.94	2.76	4.81	8.21	5.63	7.74	7.19	14.52
SEm ±	0.38	0.30	0.58	0.59	0.08	0.43	0.47	0.43
CD (P = 0.05)	NS	NS	NS	NS	0.32	NS	NS	NS
Weed management								
Butachlor (Pre. 1 kg ha^{-1}) *fb* 2,4-D (Post. 0.5 kg ha^{-1})	3.94	3.96	6.82	11.98	6.47	9.31	7.74	18.41
Pendimethalin (pre. 1 kg ha^{-1}) *fb* 2,4-D(Post. 0.5 kg ha^{-1})	3.02	3.37	5.79	9.51	6.09	9.37	9.03	17.34
Fenoxaprop-p- ethyl (post. 56 g ha^{-1}) *fb* Ethoxysulfuron18 g ha^{-1})	3.21	3.32	5.72	8.63	6.64	9.52	8.14	16.80
Weed free	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
Weedy	5.02	4.16	7.81	13.98	8.65	11.20	10.40	22.66
SEm ±	0.49	0.27	0.40	0.43	0.45	0.53	0.57	0.43
CD (P=0.05)	1.44	0.79	1.18	1.26	1.32	1.55	1.66	1.27

Note: The data pertaining to weed dry weight at different growth stages are transformed one.

Table 4.5. Effect of crop establishment method and weed management on weed dry wt. at 90 DAS and at harvest in irrigated dry direct seeded rice

Weed dry weight (g m^{-2})										
	90 DAS					At harvest				
Treatment	***Echinochloa colonum***	***Echinochloa crusgalli***	**Sedges**	**Broad leaved weeds**	**Total**	**Broad leaved weeds**	**Sedges**	***Echinochloa colonum***	***Echinochloa crusgalli***	**Total**
Crop establishment method										
Stale bed by shallow tillage	12.13	10.10	5.08	8.17	18.43	6.35	8.62	10.90	8.62	15.52
Stale bed by glyphosate @ 1 kg ha^{-1}	9.98	8.77	5.06	7.29	15.96	6.24	9.35	9.17	9.35	14.81
Puddled DSR	9.97	9.48	5.33	7.65	16.55	6.00	8.51	8.23	8.51	13.54
SEm ±	0.33	0.33	0.10	0.34	0.26	0.51	0.30	0.24	0.30	0.49
CD (P=0.05)	1.28	NS	NS	NS	1.03	NS	NS	0.94	NS	NS
Weed management										
Butachlor (Pre. 1 kg ha^{-1}) *fb* 2,4-D (Post.0.5 kg ha^{-1})	13.40	11.75	5.96	9.13	21	7.54	11.01	10.91	11.01	17.74
Pendimethalin (pre. 1 kg ha^{-1}) *fb* 2,4-D (Post.0.5 kg ha^{-1})	11.89	11.34	5.73	10.03	20.19	7.06	10.12	10.45	10.12	16.60
Fenoxaprop-p-ethyl (post. 56 g ha^{-1}) *fb* Ethoxysulfuron 18 g ha^{-1})	11.87	10.39	6.58	8.75	19.27	6.71	9.59	9.80	9.59	15.72
Weed free	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
Weedy	15.61	13.05	6.80	9.89	23.73	8.97	12.72	15.30	12.72	22.34
SEm ±	0.45	0.40	0.40	0.47	0.37	0.38	0.48	0.68	0.48	0.55
CD (P=0.05)	1.32	1.16	1.17	1.38	1.09	1.10	1.40	2.00	1.40	1.62

Note: The data pertaining to weed dry weight at different growth stages are transformed one.

Table 4.6. Effect of crop establishment method and weed management on plant height and dry matter accumulation at 30, 60, 90 DAS and at harvest in irrigated dry direct seeded rice

Treatment	Plant height (cm)				Dry matter accumulation (g m^{-1} row)			
	DAS				DAS			
	30	60	90	At harvest	30	60	90	At harvest
Crop establishment method								
Stale bed by shallow tillage	17.60	42.90	54.90	63.50	15.20	28.70	82.70	108.60
Stale bed by glyphosate @ 1 kg ha^{-1}	18.70	43.30	56.70	62.30	15.50	27.60	90.00	110.50
Puddled DSR	18.30	42.30	51.70	61.10	14.60	25.90	80.20	104.20
SEm ±	0.60	2.06	0.50	0.70	0.40	1.60	1.90	1.40
CD (P=0.05)	NS	NS	2.20	NS	NS	NS	7.50	NS
Weed management								
Butachlor (Pre. 1 kg ha^{-1}) *fb* 2,4-D (Post. 0.5 kg ha^{-1})	17.40	45.10	54.70	60.80	13.50	23.30	71.00	89.00
Pendimethalin (pre. 1 kg ha^{-1}) *fb* 2,4-D (Post. 0.5 kg ha^{-1})	18.50	42.70	52.40	58.20	12.90	23.20	62.60	85.50
Fenoxaprop-p- ethyl (post. 56 g ha^{-1}) *fb* Ethoxysulfuron 18 g ha^{-1})	17.20	42.40	54.30	60.90	14.40	27.40	65.70	86.90
Weed free	25.10	56.00	71.80	85.60	30.70	53.60	185.60	228.90
Weedy	12.80	27.90	38.90	45.90	4.00	9.40	36.70	48.30
SEm ±	0.50	2.40	0.90	0.90	1.00	2.00	38.20	4.10
CD (P=0.05)	1.50	7.20	2.60	2.60	3.00	6.00	11.10	12.10

Table 4.7. Effect of crop establishment method and weed management on no. of tillers and LAI at 30, 60 and 90 DAS in irrigated dry direct seeded rice

Treatment	No. of tillers m^{-2}		Leaf Area Index	
	60 DAS	90 DAS	60 DAS	90 DAS
Crop establishment method				
Stale bed by shallow tillage	75.80	174.93	1.05	3.77
Stale bed by glyphosate @ 1 kg ha^{-1}	82.87	178.07	1.22	3.83
Puddled DSR	82.87	146.87	1.29	3.63
SEm ±	1.06	8.91	0.03	0.39
CD (P=0.05)	4.17	NS	0.11	NS
Weed management				
Butachlor (Pre. 1 kg ha^{-1}) *fb* 2,4-D (Post. 0.5 kg ha^{-1})	67.22	125.44	0.76	2.15
Pendimethalin (pre. 1 kg ha^{-1}) *fb* 2,4-D (Post. 0.5 kg ha^{-1})	64.78	105.56	0.77	1.80
Fenoxaprop-p- ethyl (post. 56 g ha^{-1}) *fb* Ethoxysulfuron 18 g ha^{-1})	60.00	113.44	0.74	1.97
Weed free	179.78	404.89	3.45	11.94
Weedy	30.44	83.78	0.22	0.86
SEm ±	4.61	9.51	0.07	0.42
CD (P=0.05)	13.45	27.77	0.22	1.24

Table 4.8. Effect of crop establishment method and weed management on crop growth rate & relative growth rate at 30, 60, 90 DAS and at harvest in irrigated dry direct seeded rice

Treatment	Crop growth rate (g m^{-2} day^{-1})				Relative growth rate (g g^{-1} day^{-1})		
	DAS				DAS		
	0-30	30-60	60-90	At harvest	30-60	60-90	90-120
Crop establishment method							
Stale bed by shallow tillage	0.51	0.45	1.80	0.96	37.50	27.22	9.72
Stale bed by glyphosate @ 1 kg ha^{-1}	0.52	0.40	2.08	0.82	32.93	28.37	9.75
Puddled DSR	0.49	0.40	1.79	0.80	34.27	34.60	7.80
SEm ±	0.01	0.05	0.10	0.09	1.48	1.80	1.87
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS
Weed management							
Butachlor (Pre. 1 kg ha^{-1}) *fb* 2,4-D (Post. 0.5 kg ha^{-1})	0.45	0.37	1.55	0.71	39.63	27.14	7.01
Pendimethalin (pre. 1 kg ha^{-1}) *fb* 2,4-D (Post. 0.5 kg ha^{-1})	0.43	0.34	1.31	0.96	41.68	23.00	8.03
Fenoxaprop-p- ethyl (Post. 56 g ha^{-1}) *fb* Ethoxysulfuron 18 g ha^{-1})	0.48	0.43	1.29	0.76	35.20	28.65	6.66
Weed free	1.02	0.77	4.40	1.44	34.29	33.94	15.42
Weedy	0.13	0.18	0.91	0.44	24.75	37.69	8.40
SEm ±	0.03	0.06	0.15	0.15	3.32	2.59	1.23
CD (P=0.05)	0.10	0.17	0.44	0.44	9.68	7.55	3.58

Table 4.9. Effect of crop establishment method and weed management on yield attributes in irrigated dry direct seeded rice

Treatment	No. of panicle (m^{-2})	Panicle length (cm)	No. of grains $panicle^{-1}$	Panicle weight (g)	Test weight (g)
Crop establishment method					
Stale bed by shallow tillage	236.93	18.99	94.73	7.25	9.62
Stale bed by glyphosate@ 1kg ha^{-1}	289.60	19.29	88.33	7.62	10.84
Puddled DSR	273.40	19.53	86.37	7.39	9.72
SEm ±	5.78	0.22	3.14	0.28	0.41
CD (P=0.05)	22.71	NS	NS	NS	NS
Weed management					
Butachlor (Pre. 1 kg ha^{-1}) *fb* 2,4-D (Post. 0.5 kg ha^{-1})	234.89	19.53	78.17	7.39	8.49
Pendimethalin (pre. 1 kg ha^{-1}) + 2,4-D (Post. 0.5 kg ha^{-1})	236.56	19.59	77.78	7.53	9.78
Fenoxaprop-p- ethyl (post. 56 g ha^{-1}) *fb* Ethoxysulfuron 18 g ha^{-1})	295.44	19.41	88.33	7.40	9.34
Weed free	444.78	21.31	134.11	9.36	13.88
Weedy	121.56	16.50	70.67	5.42	8.37
SEm ±	13.28	0.36	3.34	0.32	0.37
CD (P=0.05)	38.77	1.05	9.75	0.93	1.09

Table 4.10. Effect of crop establishment method and weed management on grain and straw yield, biological yield, harvest index and weed index in irrigated dry direct seeded rice

Treatment	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)	Weed index (%)
Crop establishment method					
Stale bed by shallow tillage	2610.80	3631.30	6242.20	46	39.80
Stale bed by glyphosate @ 1kg ha^{-1}	2626.90	4805.80	7432.20	38	41.50
Puddled DSR	2630.20	4475.30	7105.50	43	33.90
SEm ±	112.80	435.55	482.98	4.01	3.20
CD (P=0.05)	NS	NS	NS	NS	NS
Weed management					
Butachlor (Pre. 1 kg ha^{-1}) *fb* 2,4-D (Post. 0.5 kg ha^{-1})	2696.30	4016.60	6712.90	40	36.80
Pendimethalin (pre. 1 kg ha^{-1}) *fb* 2,4-D (Post. 0. 5 kg ha^{-1})	2376.80	3650.90	6027.70	40	43.80
Fenoxaprop-p-ethyl (post 56 g ha^{-1}) *fb* Ethoxysulfuron 18 g ha^{-1})	2633.30	3644.40	6277.70	43	37.90
Weed free	4283.30	8994.40	13277.70	37	0.00
Weedy	1122.50	1214.44	2337.04	51	73.50
SEm ±	125.30	480.79	503.82	4.02	2.83
CD (P=0.05)	365.76	1403.30	1470.00	NS	8.27

Fig. 4.1. Effect of crop establishment method and weed management on grain yield in irrigated dry direct seeded rice

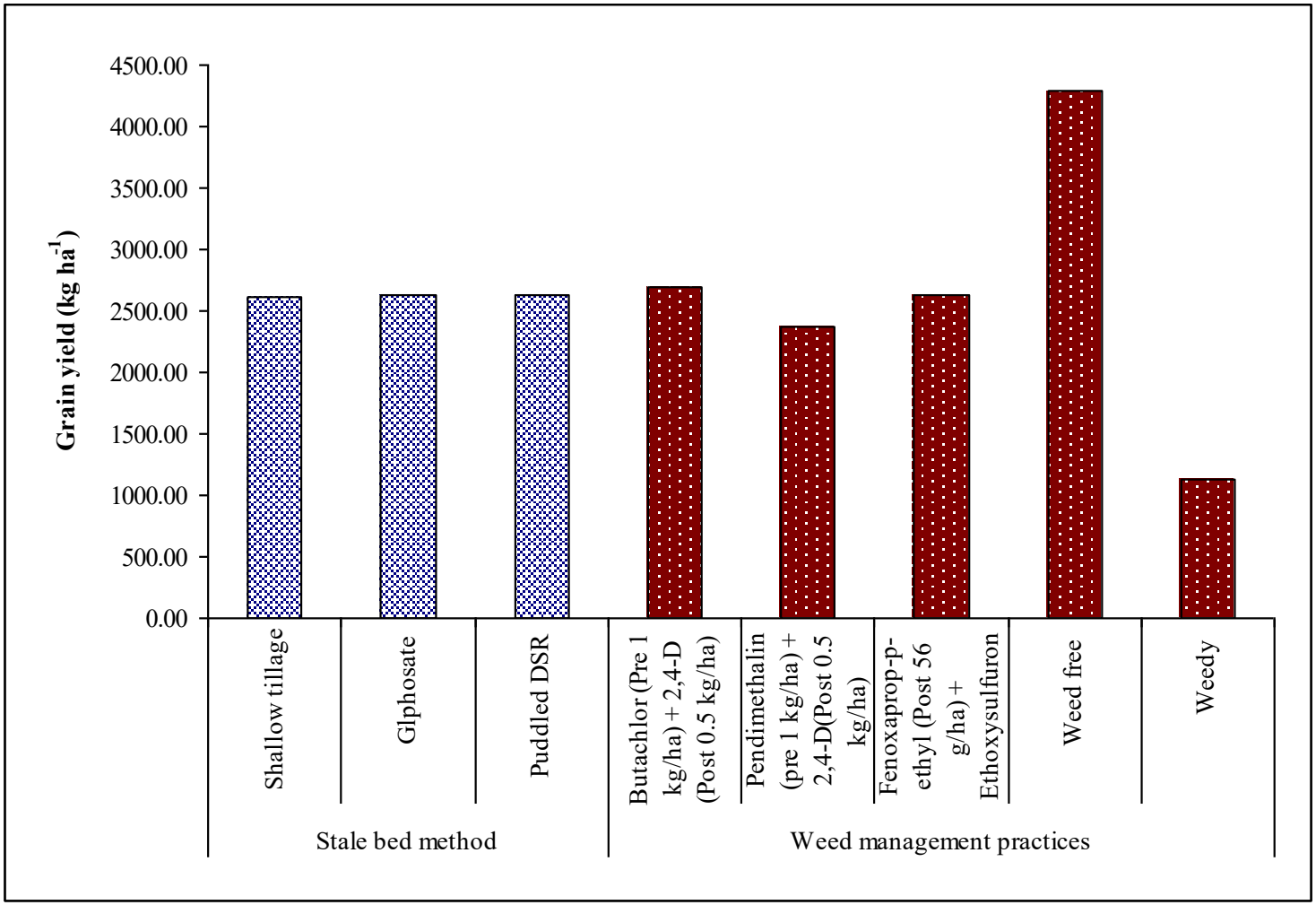
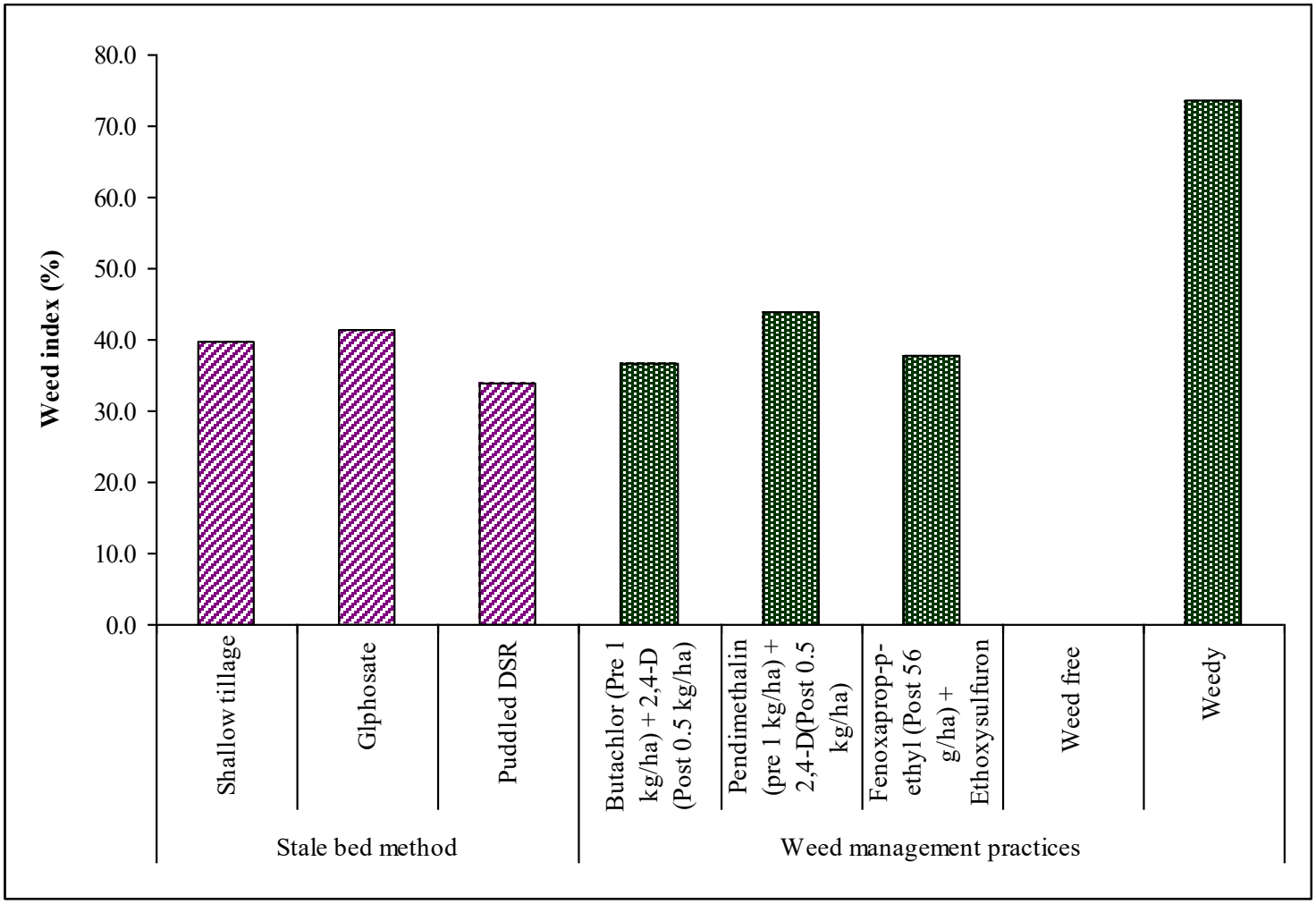


Fig. 4.2. Effect of crop establishment method and weed management on weed index in irrigated dry direct seeded rice



Chapter V

DISCUSSION

The final yield of a crop is net result of the extent of successful completion of the growth and development activities of plant which in turn, would depend upon interaction between its genotype and the environment to which it is exposed during the course of life cycle. Several agronomic manipulations are possible for altering the micro-environment so that the real potential of the cultivar could be exploited to its maximum. Therefore, to realize the maximum potential under a set of agro-climatic conditions, it is essential that various factors of plant environment should be maintained at optimum level.

Weeds are considered to be the growth reducing factor and have been found to cause considerable economic loss due to their luxuriant growth thus accelerating the intensity of competition for nutrients, moisture, space and light without leaving obvious sign of stress. In crop, apart from other factors, method of crop establishment has profound influence on crop and weed growth. In view of the enormous losses caused by weeds in direct seeded rice during *kharif* season, weed management has been recognized as a major input in increasing the productivity of rice. As crop and weeds have similar requirements for growth and development, competition begins when crop and weeds grow in close proximity to each other and supply of necessary factors are not sufficient to meet the requirement of crops and weed together. The intensity of crop-weed competition depends upon type of weed species, severity of weed infestation, duration of weed infestation, competing ability of crop plants and climatic conditions which affect weed and crop growth. As most of the weeds are C_4 plants with extensive root system and faster growth in a particular agro-climatic condition, weeds can compete for growth factors more efficiently than crop plants.

Taking into account the extent of losses caused by weeds, successful weed management for rice crop becomes much more important in order to exploit its maximum production potential. An array of integrated approach involving crop establishment method and selective and sequential herbicidal application provides

farmer with a wide choice of practices to control a broad spectrum of weed population.

In this chapter, an attempt has been made to discuss the results of the experiment presented in preceding chapter and to offer scientific explanation and experimental evidences in light of established physiological and biochemical processes wherever possible for the variations recorded with a view to understand the causes and effect relationship as far as possible, to draw valid conclusions. This investigation not only aimed at identifying an effective weed control measure but also to gather information on feasibility of a suitable crop establishment for direct seeded rice to adopt the system in eco-friendly and economic terms.

5.1 Effect of weather on crop and weeds

Results of field investigations are affected by weather conditions. The weather factors *viz*. rainfall, temperature (minimum & maximum), relative humidity, evaporation and sunshine hours recorded during crop duration of the present experimentation are given in Table 3.1 and depicted in Fig. 3.1. The variation in weather parameters has pronounced bearing on growth and development of the crop. For achieving its yield potential, every crop has its own cardinal point of atmospheric temperature, relative humidity, vapour pressure and sunshine duration. If the fluctuation becomes too wide from optimum, the plants suffer leading to poor growth, development and yield. This effect is more pronounced in direct seeded rice grown in diverse agro-climatic conditions.

In rice the duration of vegetative and reproductive phase is almost equally distributed. The total rainfall received during the crop growth period was 721.4 mm. Analysis of weather data shows that the distribution of rainfall was quite uneven during the crop growth period as most of the rainfall was received during the vegetative phase and the reproductive phase has received almost negligible rainfall. The uneven distribution of rainfall during the reproductive phase might have induced sterility, thus adversely affecting the yield. The maximum and the minimum temperature had remained quite favourable during the vegetative as well as

reproductive stage. The maximum and minimum relative humidity was found conducive for the optimum crop growth. The weekly mean sunshine hour duration was 6.48 hours. The weekly mean evaporation rate was 3.42 mm.

Unavailability of sufficient rainfall during the reproductive stage and ability of weeds to compete for growth resources more efficiently than the crop might have created a stress condition for the crop, thus causing appreciable reduction in its yield. Unfavourable weather conditions might have induced better weed growth due to their better competing ability over the crop under limited availability of growth factors.

5.2 Effect on weeds

Twenty weed species, which belong to ten families, were identified in the experimental field during course of experimentation (Table 4.1). Among these, five species *viz. Cynodon Dactylon, Dactyloctenum aegypticum, Echinochloa colonum, Echinochloa crusgalli* and *Leptochloa chinensis* were narrow leaved weeds; twelve species *viz*. *Ammannia baccifera, Caesulia axillaries, Commelina benghalensis, Physalis minima, Eclipta alba, Ipomoea aquatiac, Euphorbia hirta, Parthenium hysterophorus, Phyllanthus niruri, Ludwigia* spp*., Solanum nigrum* and *Traianthema monogyna* were broad-leaved weeds and remaining three species *viz. Cyperus difformis, Cyperus iria* and *Fimbbristylis miliaceae* were sedges.

Crop establishment is one of the most important factors which influence the type of weed flora in rice and different crop establishment methods exhibit significant variation on relative composition of weed flora however, among the weed flora narrow leaved weeds/grasses especially *Echinochloa colonum and Echinochloa crusgalli* constituted the maximum percentage in all the crop establishments methods. Prevalence of the narrow-leaved species in all the crop establishment methods might be due the absence of early and deep flooding in direct seeded rice (Chauhan and Johnson, 2011). Although in puddled DSR, seeds were broadcast under puddled condition, but absence of late flooding condition might have encouraged the late emergence of these grasses, (as they have the ability to germinate throughout the year when moisture is available) (Das, 2008).

Crop establishment method showed a marked difference on weed density (Table 4.2 and 4.3). Puddled direct seeded rice recorded the minimum total weed density among all the crop establishment methods during early growth stages which might be due to puddling and the presence of early flooded condition which suppressed the weed emergence. Stale seedbed by shallow tillage was found to be comparable to puddled DSR in controlling *Echinochloa colonum* at 60 DAS which might be due to burial of the weed seed below the soil surface by shallow tillage thereby reducing its emergence. Weed seed burial depth had a marked influence on seedling emergence. Weed seeds placed on the soil surface have maximum germination and its emergence decreases exponentially with increase in the burial depth (Chauhan and Johnson, 2011). However, the effect of crop establishment methods on total weed dry weight was found to be non-significant (Table 4.4 and 4.5).

All the sequential herbicidal applications significantly reduced weed density over weedy treatment (Table 4.2 and 4.3). However, pre-emergence application of butachlor @ 1 kg ha^{-1} *fb* post emergence application of 2, 4-D@ 0.5 kg ha^{-1} gave better control of grasses and broad leaved weeds. Similar findings were reported by Koger *et al*. (2006), Singh *et al.* (2008a) and Akbar *et al*. (2011). All the sequential herbicidal applications significantly and equally reduced weed dry weight over weedy check at 30 DAS (Table 4.4 and 4.5). However, post emergence application of fenoxaprop-p-ethyl 56 g ha^{-1} *fb* ethoxysulfuron 18 g ha^{-1} and pre-emergence application of pendimethalin @ 1 kg ha^{-1} *fb* 2, 4-D post emergence application @ 0.5 kg ha^{-1} were equally effective in reducing the total weed dry weight at 60, 90 DAS and at harvest in comparison to pre-emergence application of butachlor @ 1 kg ha^{-1} *fb* post emergence application of 2, 4-D@ 0.5 kg ha^{-1}. These findings are in conformity to the results obtained by Akbar *et al*. (2011) and Singh and Bhagirath (2011).

5.3 Effect on crop growth attributes

Effect of crop establishment method on plant height and dry matter accumulation was found to be non-significant except at 90 DAS (Table 4.6). However, stale bed by glyphosate @ 1 kg ha^{-1} and puddled DSR both recorded higher

number of tillers m^{-2} and greater leaf area index than stale bed by shallow tillage at 60 DAS (Table 4.7). However, variations in number of tillers and leaf area index due to crop establishment method were found to be non-significant at 90 DAS. Variations in crop growth rate (g m^{-2} day^{-1}) and relative growth rate (g g^{-1} day^{-1}) due to crop establishment method were non-significant at all the stages of observations (Table 4.8).

Sequential herbicidal treatments recorded significant variations in plant height over weedy treatment and statistically at par with each other at 30, 60, 90 DAS except at harvest whereas post emergence application of fenoxaprop-p-ethyl 56 g ha^{-1} *fb* ethoxysulfuron 18 g ha^{-1} recorded significantly taller plants as compared to other sequential herbicidal treatments (Table 4.6). Variations in dry matter accumulation, number of tillers, leaf area index, crop growth rate and relative growth rate due to sequential herbicidal treatments were significant over weedy treatment and statistically at par with each other at all crop growth stages (Table 4.6, 4.7 and 4.8). The results are in conformity with findings of Rashid and Datta (1986).

5.4 Effect on yield attributes

Crop establishment did not significantly influence yield attributes *viz.* panicle length, number of grains $panicle^{-1}$, panicle weight and test weight except number of panicle m^{-2} (Table 4.9). Stale bed by glyphosate @ 1 kg ha^{-1} and puddled DSR both recorded significantly higher number of panicles m^{-2} than that in stale bed by shallow tillage. Yield attributing characters are the function of growth and development of the crop during its vegetative phase. The higher number of panicles in stale seedbed by glyphosate @ 1 kg ha^{-1} and in puddled DSR might be due to better weed control during early growth stages thereby minimising the crop-weed competition for the crop growth factors like nutrients, water etc. during the critical growth period.

Amongst the sequential herbicidal treatments, fenoxaprop-p-ethyl 56 g ha^{-1} *fb* ethoxysulfuron @ 18 g ha^{-1} had statistically more number of panicles m^{-2} and more number of grains $panicle^{-1}$ as compared to both butachlor @ 1 kg ha^{-1} *fb* 2, 4-D @ 0.5 kg ha^{-1} and pendimethalin @ 1 kg ha^{-1} *fb* 2, 4-D @ 0.5 kg ha^{-1} (Table 4.9). Similar

results were also reported by Singh *et al.* (2006). All the sequential herbicidal treatments recorded significant and similar effects on panicle length and panicle weight over weedy treatment. However, amongst the sequential herbicidal treatments fenoxaprop-p-ethyl 56 g ha^{-1} *fb* ethoxysulfuron @ 18 g ha^{-1} and pendimethalin @ 1 kg ha^{-1} *fb* 2, 4-D @ 0.5 kg ha^{-1} recorded significantly similar test weight and both were better than butachlor @ 1 kg ha^{-1} *fb* 2, 4-D @ 0.5 kg ha^{-1}. All the above noted increase in yield attributing characters may be attributed to the better weed control during the critical crop growth period enabling the crop to make maximum utilization of the available inputs for realizing its yield potential. The results are in conformity with the findings of Singh *et al.* (2006) and Chauhan and Opena (2013).

5.5 Effect on yield

Crop establishment method did not have significant effect on the yields *viz.* grain, straw and biological yields (Table 4.10). However, all the sequential herbicidal treatments resulted in significantly higher grain, straw and biological yields over the weedy check (Table 4.10). These may be due to better weed control in the treated plots leading to the improvement in dry matter accumulation, yield attributes and photosynthate partitioning. The yields were minimum in weedy treatment due to maximum weed density causing maximum crop-weed competition during the critical growth period. Maximum yield were observed in weed-free due to complete absence of the crop-weed competition during the entire crop growth period. The results are in conformity to the findings of Singh *et al.* (2006) and Chauhan and Opena (2013).

5.6 Weed index

The effect of crop establishment methods on weed index was found to be non-significant (Table 4.10). However, all the sequential herbicidal treatments recorded significantly lower weed index as compared to weedy treatment (Table 4.10). During the course of investigation it was observed that all the sequential herbicidal treatments were unable to completely eliminate the crop-weed competition, as a result of which there was appreciable loss in yield. Under weed free condition (hand weeding at 20 DAS & 40 DAS), there was no crop-weed competition and thus no yield loss was

observed in it. However, crop-weed competition was highest under weedy condition thus, suffering maximum yield loss amongst all the weed management treatments.

5.8 Nutrient uptake by crop plants

The nutrient uptake (N, P & K) by grain and straw did not vary significantly due to different crop establishment methods (4.11). However, all the sequential herbicidal treatments exhibited significant variations in the nutrient uptake (N, P & K) when compared with the weedy check. The improved uptake of the nutrients by the plants in treated plots was due to the reduced weed infestation which in turn reduces the crop-weed competition for the available nutrients. The maximum nutrient uptake was observed under weed free condition because there was apparently no crop-weed competition for the available nutrients and the minimum nutrient uptake was observed in weedy treatment due to maximum crop-weed competition. This showed the importance of keeping the field free from weeds in order to enable the crop to absorb sufficient nutrients for realizing its yield potential (Azmi and Abdullah, 1998; Rana and Angrias, 1999).

5.9 Nutrient depletion by weeds

Variations in nutrient depletion (N, P and K) by weed were non-significant due to crop establishment methods at all the crop growth stages (Table 4.12). However, all the sequential herbicidal treatments had significantly brought down nutrient depletion (N, P and K) by weeds over weedy treatment at 30 DAS. While at 60 DAS, both the treatments i.e. fenoxaprop-p-ethyl (post 56 g ha^{-1}) *fb* ethoxysulfuron 18 g ha^{-1} and pendimethalin pre-emergence @ 1 kg ha^{-1} *fb* 2, 4-D (post 0.5 kg ha^{-1}) recorded significantly lesser nutrient (N, P & K) depletion by weed than butachlor @1kg ha^{-1} *fb* 2, 4-D (post 0.5 kg ha^{-1}). As nutrient removal is dependent on dry matter accumulation of weeds, thus the reduction in weed dry weight would have a direct effect on the nutrient depletion by weeds. Similar findings were reported by Rana and Angrias (1999).

5.10 Economics

The adoption of any technology in modern agriculture can only be feasible and acceptable to farmers if it is economically viable. Economic viability is a function of input and output. The gross return obtained by yield of the crop varied markedly due to different treatments, which ultimately influenced the net return and benefit: cost ratio. Among different crop establishment methods, puddled DSR recorded the maximum net return of Rs. 29,242 ha^{-1} and benefit: cost ratio of 2.22 (Table 4.13). This may be due to the fact that the increase in cost of cultivation due to puddling operation in puddled DSR was compensated by the increased return through higher grain and straw yields.

Among all the sequential herbicidal treatments, butachlor @1 kg ha^{-1} *fb* 2, 4-D (post. 0.5 kg ha^{-1}) recorded the highest net return of Rs. 28,889 ha^{-1} and benefit cost ratio of 2.19. The higher net return and benefit: cost ratio under this treatment was mainly due to lower weed infestation, more grain yield and comparatively low cost of cultivation in comparison to rest of the herbicidal treatments.

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Chapter VI

SUMMARY AND CONCLUSION

The present investigation entitled **"Effect of crop establishment method and weed management on growth and yield of irrigated dry direct seeded rice (*Oryza sativa* L.)"** was conducted at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi during *kharif* season of 2010 with a view to study the effect of crop establishment method and weed management practice in direct seeded rice.

The experiment was laid out in a split plot design with combination of three crop establishment methods *viz*. stale bed by shallow tillage, stale bed by glyphosate @ 1 kg ha^{-1} and puddled DSR in main plot and five weed management treatments viz. weedy, weed free (2 HW at 20 &40 DAS), Pendimethalin @1kg ha^{-1} (Pre-E) *fb* 2,4-DEE 0.5 kg ha^{-1} (40 DAS), butachlor @1kg ha^{-1}(pre-E) *fb* 2,4-DEE 0.5 kg ha^{-1}(40 DAS) and fenoxaprop with safener 56g ha^{-1} *fb* ethoxysulfuron 18g ha^{-1} (15-20 DAS) in sub plot, replicated thrice. Various observations were recorded including growth attributes, yield attributes and yields; weed growth studies *viz*. weed density and weed dry matter accumulation during the course of investigation. Growth parameters were recorded at various phenological stages at 30, 60, 90 days stage and at harvest which included plant height, number of tillers, dry matter accumulation, Leaf Area Index (LAI), Relative Growth Rate (RGR) and Crop Growth Rate (CGR). Similarly, yield attributes included number of panicles, panicle length, number of grains $panicle^{-1}$, panicle weight and test weight and the yields included grain, straw and biological yields.

Stale seedbed was made as per the treatment after irrigating the field on 29th May, 2010 and initial weed flushes were controlled either by shallow tillage or by glyphosate @ 1 kg a.i.ha^{-1} as per the treatment. A uniform dose of 120 kg N, 60 kg P_2O_5, 60 kg K_2O and 5 kg Zn ha^{-1} was applied in all the treatments in the form of urea, DAP, MOP and ZnSO4, respectively. Half of total N and full dose of P_2O_5, K_2O and Zn was applied as basal dose. Remaining half dose of N was top dressed in two equal

splits at active tillering and panicle initiation stages. Sowing of rice variety, BPT-5204 (Sambha) was done with Zero – till cum ferti-seed drill along with fertilizer on 18th June, 2010 using a seed rate of 30 kg ha^{-1} at a row to row distance of 12 cm.

The data collected during the course of experimentation were subjected to statistical analysis to draw valid conclusion. Finally the different treatments were assessed for their gross, return, net return and benefit: cost ratio.

The important findings and specific conclusions emerging from the investigation are summarized as under:

1. Puddled direct seeded rice significantly reduced the total weed density at 30 and 60 DAS in comparison to stale bed either by glyphosate @ 1 kg ha^{-1} or stale bed by shallow tillage. Amongst methods of weed management, all the sequential herbicidal application significantly reduced the total weed density at 30, 60 and 90 DAS.
2. Variation in total weed dry weight due to various crop establishment methods was found non-significant at all the stages of crop growth except at 90 DAS. However, in case of weed management treatment, significant variations in weed dry weight were observed at all the stages of crop growth. All the sequential herbicidal treatments were statistically at par with each other and significantly reduced the total weed dry weight in comparison to weedy at 30 DAS. Both the herbicidal treatments i.e. post emergence application of fenoxaprop-p-ethyl 56 g ha^{-1} *fb* ethoxysulfuron 18 g ha^{-1} and pre-emergence application of pendimethalin @ 1 kg ha^{-1} *fb* 2, 4-D post emergence application @ 0.5 kg ha^{-1} were equally effective in reducing the total weed dry weight in comparison to pre-emergence application of butachlor @ 1 kg ha^{-1} *fb* post emergence application of 2, 4-D@ 0.5 kg ha^{-1} at 60, 90 DAS and at harvest.
3. Variations in plant height due to crop establishment methods were non-significant except at 90 DAS. Stale bed by glyphosate @1kg ha^{-1} and by shallow tillage were found statistically at par with each and recorded taller plants than that in puddled DSR at 90 DAS. However, variations in plant height due to sequential herbicidal treatments were significant and statistically

at par with each other at 30, 60 and 90 DAS. While significantly taller plants were observed at harvest in post emergence application of fenoxaprop-p-ethyl 56 g ha^{-1} *fb* ethoxysulfuron 18 g ha^{-1} in comparison to both pre-emergence application of butachlor @ 1 kg ha^{-1} *fb* post emergence application of 2, 4-D@ 0.5 kg ha^{-1} and pre-emergence application of pendimethalin @ 1 kg ha^{-1} *fb* 2, 4-D post emergence application @ 0.5 kg ha^{-1}.

4. Variation in dry matter accumulation due to crop establishment method was non-significant except at 90 DAS. Variations in dry matter accumulation due to sequential herbicidal treatments were significant and statistically at par with each other at all crop growth stages i.e. at 30, 60, 90 DAS and at harvest.
5. Stale bed by glyphosate @ 1 kg ha^{-1} and puddled DSR were statistically at par with each other and both recorded higher number of tillers m^{-2} than in stale bed by shallow tillage at 60 DAS. However, variations in number of tillers due to crop establishment methods were found to be non-significant at 90 DAS. However, variations in number of tillers m^{-2} due to sequential herbicidal treatments were significant and statistically at par with each other at all crop growth stages i.e. at 60 and 90 DAS.
6. Stale bed by glyphosate @ 1 kg ha^{-1} and puddled DSR were statistically at par with each other and both recorded more leaf area index than in stale bed by shallow tillage at 60 DAS. However, effect of crop establishment methods on leaf area index was found to be non-significant at 90 DAS. Variations in leaf area index due to sequential herbicidal treatments were significant and statistically at par with each other at all crop growth stages i.e. at 60 and 90 DAS.
7. Variations in crop growth rate (g m^{-2} day^{-1}) due to crop establishment method were non-significant at all the stages of observations while variations in crop growth rate due to sequential herbicidal treatments were significant and statistically at par with each other at all the crop growth stages.
8. Variations in relative growth rate (g g^{-1} day^{-1}) due to crop establishment method were non-significant at all the stages of observations. Unlike crop establishment methods, variations in relative growth rate due to sequential

herbicidal treatments were significant and statistically at par with each other at all crop growth periods.

9. Among the crop establishment methods, stale bed by glyphosate @ 1 kg ha^{-1} and puddled DSR were statistically at par with each other and both recorded higher number of panicles m^{-2} than that in stale bed by shallow tillage. However, amongst the sequential herbicidal treatments, fenoxaprop-p-ethyl 56 g ha^{-1} *fb* ethoxysulfuron @ 18 g ha^{-1} was statistically superior to both butachlor @ 1 kg ha^{-1} *fb* 2, 4-D @ 0.5 kg ha^{-1} and pendimethalin @ 1 kg ha^{-1} *fb* 2, 4-D @ 0.5 kg ha^{-1} and recorded significantly more number of panicles m^{-2} than both the latter treatments.
10. Effect of crop establishment methods on panicle length and panicle weight was non-significant. However, variations in the panicle length and panicle weight due to sequential herbicidal treatments were significant and were at par with each other.
11. Effect of crop establishment methods on number of grains $panicle^{-1}$ was non-significant. Amongst the sequential herbicidal treatments, fenoxaprop-p-ethyl 56 g ha^{-1} *fb* ethoxysulfuron @ 18 g ha^{-1} was statistically superior to both butachlor @ 1 kg ha^{-1} *fb* 2, 4-D @ 0.5 kg ha^{-1} and pendimethalin @ 1 kg ha^{-1} *fb* 2, 4-D @ 0.5 kg ha^{-1} and recorded significantly more number of grains $panicle^{-1}$ than both the latter treatments.
12. Effect of crop establishment methods on test weight was non-significant. However, amongst the sequential herbicidal treatments, fenoxaprop-p-ethyl 56 g ha^{-1} *fb* ethoxysulfuron @ 18 g ha^{-1} and pendimethalin @ 1 kg ha^{-1} *fb* 2, 4-D @ 0.5 kg ha^{-1} were statistically at par with each other and both the treatments recorded higher test weight than butachlor @ 1 kg ha^{-1} *fb* 2, 4-D @ 0.5 kg ha^{-1}.
13. Crop establishment methods did not cause significant variations in grain, straw and biological yields. However, all the sequential herbicidal treatments had produced significantly similar effects on grain, straw and biological yields and were statistically at par with each other.
14. The effect of crop establishment methods and weed management treatments on harvest index was found non-significant.

15. The effect of crop establishment methods on weed index was found non-significant. However, all the sequential herbicidal treatments significantly reduced weed index and were statistically at par with each other.
16. Nutrient uptake (N, P & K) by grain and straw did not vary significantly due to crop establishment methods. All the sequential herbicidal treatments exhibited significant variations in the nutrient uptake (N, P & K) and were statistically at par with each other.
17. Variations in nutrient depletion viz. N, P and K by weed were non-significant due to crop establishment methods at 30 and 60 DAS. All the sequential herbicidal treatments had significant effects on reducing the nutrient depletion viz. N, P & K by weeds and were statistically at par with each other at 30 DAS. Whereas at 60 DAS, both the treatments i.e. fenoxaprop-p-ethyl (post. 56 g ha^{-1}) *fb* ethoxysulfuron 18 g ha^{-1} and pendimethalin (pre. 1 kg ha^{-1}) *fb* 2, 4-D (post 0.5 kg ha^{-1}) were statistically at par with each other and both the treatments recorded significantly less nutrient (N, P & K) depletion by weed than butachlor @1kg ha^{-1} *fb* 2, 4-D (post. 0.5 kg ha^{-1}).
18. Among crop establishment methods, stale bed by glyphosate @ 1kg ha^{-1} recorded highest gross return *fb* puddled DSR and stale bed by shallow tillage. However, net return and benefit cost ratio was highest in case of puddled DSR among the crop establishment methods. Among sequential herbicidal treatments, butachlor @1kg ha^{-1} *fb* 2, 4-D (post 0. 5 kg ha^{-1}) recorded the highest gross return, net return and benefit cost ratio *fb* fenoxaprop-p-ethyl (post 56 g ha^{-1}) *fb* ethoxysulfuron 18 g ha^{-1} and pendimethalin (pre. 1 kg ha^{-1}) *fb* 2, 4-D (post. 0.5 kg ha^{-1}).

Conclusion

Butachlor pre-emergence @ 1 kg ha^{-1} *fb* 2,4-D post emergence @ 0.5 kg ha^{-1} under puddled direct seeded rice was found more remunerative, however the investigation may be repeated to ascertain these findings.

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APPENDIX

Common cost of cultivation (Rs. ha^{-1}) for irrigated dry direct seeded rice.

S.No.	Operation	Rate (Rs.)	Cost (Rs.)
1.	Preparation of the field ploughing- 3 and	400/- Ploughing	1600
	One planking	400/-Planking	
2.	Cost of fertilizers:		
	(a) DAP	18.05 kg^{-1}	2347.00
	(b) MOP	28.69 kg^{-1}	2869.00
	(c) Urea	6.70 kg^{-1}	1400.00
3.	Cost of seed drilling	300.0 kg^{-1}	300.00
4.	Irrigation (3)	300.00	900.00
	Labour charge	125 day^{-1}	
5.	Cost of Fungicide (0.6g/l)	260/100 g	936.00
6.	Harvesting and bundling labour charge	194 day^{-1}	3750.00
7.	Threshing and winnowing labour charge	194 day^{-1}	2875.00
		Total	**16977**
8.	Interest on working capital		1214.00
9.	Rental value of land		1500.00
10.	Interest on fixed capital	@ 10%	150.00
		Total	2864.00
		Grand total	**19841.00**