INFLUENCE OF INTEGRATED WEED MANAGEMENT AND SPACING ON THE GROWTH AND YIELD OF TRANSPLANTED AMAN RICE

MOHAMMAD ALI

DEPARTMENT OF AGRONOMY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA-1207

JUNE, 2007

INFLUENCE OF INTEGRATED WEED MANAGEMENT AND SPACING ON THE GROWTH AND YIELD OF TRANSPLANTED AMAN RICE

BY

MOHAMMAD ALI

REGISTRATION NO. 01519

A Thesis
Submitted to the Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfilment of the requirements
for the degree of

MASTER OF SCIENCE

IN

AGRONOMY

SEMESTER: JANUARY-JUNE, 2007

Approved by:

(Prof. Md. Sadrul Anam Sardar)	**(Prof. Dr. Parimal Kanti Biswas)**
Supervisor	**Co-supervisor**

(Prof. Dr. Parimal Kanti Biswas)
Chairman
Examination Committee

CERTIFICATE

This is to certify that thesis entitled **“INFLUENCE OF INTEGRATED WEED MANAGEMENT AND SPACING ON THE GROWTH AND YIELD OF TRANSPLANTED AMAN RICE”** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE** in **AGRONOMY,** embodies the result of a piece of bona fide research work carried out by **MOHAMMAD ALI**, Registration No. **01519** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated:

Place: Dhaka, Bangladesh

(Prof. Md. Sadrul Anam Sardar)
Supervisor

Dedicated to

My

Beloved Parents

INTRODUCTION

Bangladesh is an agro-based country. Most of her economic activities mainly depend on agriculture. Geographical and agronomic conditions of Bangladesh are favourable for rice (*Oryza sativa L.*) cultivation. Rice is the leading food for more than two billion people in Asia and for hundreds of millions of people in Africa and Latin America (IRRI, 1985). Rice is the staple food of Bangladesh where it's production has increased more than two times during the last 3 decades and reached more than 25 million tons in 2001-2002 (BBS, 2002). The population of Bangladesh will increase to 173 million in 2020 which is 31 percent higher than the present level (FAO, 1998). National Agricultural Commission says that to feed the increased population in 2020, 47 million tons of rice will be needed to produce in the country. For food security of the country, rice production is needed to be increased from 3 tons ha^{-1} to 5 tons ha^{-1} in next 20 years (Mahbub *et al.,* 2001).

In Bangladesh rice occupies 10.66 million hectares which is about two thirds of the cultivated land area. The majority of rice area is covered by aman (Autumn) rice comprising about 52.77% of the total rice area of which transplanted aman rice and broadcast aman rice cover 87.05% and 12.95%, respectively (BBS, 2003). But the yield of transplanted aman rice in Bangladesh is much lower than that of transplanted aman rice in other rice growing countries of the world. Among the various factors, severe weed infestation is the most important for such low yield (Kurmi and Das, 1993). The prevailing climatic and edaphic conditions are highly favorable for luxuriant growth of numerous species of weeds which offer a keen competition with rice crop. Mamun (1990) reported that weed growth reduced the grain yield by 68-100% for direct seeded aus rice, 16-48% for transplanted aman rice and 22.36% for modern boro rice.

Subsistence farmers of the tropics spend more time and energy on weed control than any other aspects of rice cultivation. Manual weeding (hand weeding) is generally practiced in major area of rice cultivation in Bangladesh. But the availability of agricultural labourers has now decreased due to employment scope of the labourers in other sectors consequently in recent years for increased cost of agricultural labourers. To reduce the cost of rice production, it has been urgently needed to adopt alternative method of weed control viz. mechanical weed control, biological weed control, and chemical weed control in combination with manual weeding. Mechanical weeding and herbicides are the alternatives to hand weeding. Japanese rice weeder is in use in some areas of the country. But due to some disadvantages to use it, it has not gained widespread popularity. BRRI has developed new weeder of low cost and very easy to handle. Herbicides are now gaining popularity among the farmers. Now a good number of pre-emergence herbicides are available in the market with different trade names. These herbicides are effective in controlling weeds along with hand weeding (Ahmed *et al.,* 2003). So, an integrated weed management practice comprising herbicide + hand weeding; BRRI rice weeder + hand weeding etc. are needed to be evaluated in transplanted aman rice cultivation.

The yield potential of a variety can be realized only if full package of production practices is followed. The growth, development, yield and yield components of rice and the absolute density, weight and intensity of weed infestations are greatly influenced by plant spacing. Optimum plant spacing ensures the plants to grow properly with their aerial and under ground parts utilizing more solar radiation and nutrients (Miah *et al.*, 1990). When the planting densities exceed an optimum level, competition among plants of same species for light or for nutrients become severe, consequently the plant growth slows down and grain yield decreases. Again, when the planting densities do not cover an optimum level, the remaining space will be filling up by the other plant species like weed species and the interplant competition is at a maximum level which ultimately slows down the crop growth and grain yield decreases. So, to find out the optimum plant population of transplanted aman rice by manipulating the plant spacing in relation to weed management is needed to be examined. Thus, a research trial was undertaken to evaluate the influence of integrated weed management and spacing on the growth and yield of transplanted aman rice with the following objectives.

1. To compare the efficiency of different weed management techniques on the growth and yield of transplanted aman rice.
2. To find out the effect of different plant spacing on weed control and growth and yield of transplanted aman rice.
3. To determine the interaction effect between different weed management techniques and plant spacing on weed control and growth and yield of transplanted aman rice.
4. To find out the economic benefit in controlling weeds with the combined effect of different weed management techniques and plant spacing in transplanted aman rice.

CHAPTER 2

REVIEW OF LITERATURE

Weed is one of the limiting factors for successful rice production. Among various cultural practices, plant spacing play a vital role in the production and yield of rice through controlling the weeds as well as make the environment favourable for rice production. To justify the present study attempts have been made to incorporate some of the important findings of renowned scientists and research workers in this country and elsewhere of the world.

2.1 Weed vegetation in transplanted aman rice

Weed vegetation in crops is the result of cropping, cropping season, topography of land and management practices like time and degree of land preparation, plant spacing, time of planting date, fertilizer management, weeding method and intensities.

Venkataraman and Goplan (1995) observed that the most important weed species in transplanted low land rice in Tamil Nadu, India, were *Echinochloa crus-galli, Cyperus difformis, Echinochloa Colonum, Cyperus iria, Fimbristylis miliacea, Scirpus spp, Eclipta alba, Ludwigia parviflora, Marsilea quadrifolia* and *Monochoria vaginaliz.*

Bari *et al.* (1995) observed 53 weed species to grow in transplanted rice field. In respect of abundance value the three most important weeds were *Fimbristylis miliacea, Paspalum scrobiculaturm* and *Cyperus rotundus*.

Mamun *et al.* (1993) from the same location identified 60 weed species in T. aman rice of which *Fimbristylis miliacea, Lindernia antipoda* and *Eriocaulen cinereesm* were the most important weed species.

Elliot *et al.* (1984) reported that in transplanted rice *Monochoria vaginalis* was the important weed and other weed species were *Ischaemum rogusum, Scirpus supinus, Cyperus difformis, Ipomoea aquatica* and *Marsilea minuta*.

In the irrigated and rainfed area, Carbonell and Moody (1983) observed various weed species in transplanted rice in Nueva Ecija, Philippines. The most important weeds in the rainfed area were *Ischaemum rogusum, Fimbristylis miliacea, Echinochloa crus-galli* and *Monochoria vaginalis*.

2.2 Weed control efficiency

Weed control efficiency is one of the important measurements of weed control in crop field. High weed control efficiency throughout the growing period by a weed control treatment ensures proper crop growth and profitable weed control. Weed control efficiency varies with weed control technology.

Sharma and Bhunia (1999) reported that Pendimethalin @ 1.5 kg/ ha plus one hand weeding resulted in highest weed control efficiency than any other treatments.

Ahmed *et al.* (1997) reported that higher wed control efficiency (90.35%) was observed in herbicides with one hand weeding treatment than sole herbicides or conventional weed control methods.

Weed control efficiency was higher in two hand weeding (90.67%) than dose of Oxadiazon and Cinosulfuron treatments (Alam *et al.,* 1996).

In another experiment Singh and Bhan (1992) found that two hand weeding resulted better weed control efficiency (72.3%) than Butachlor @ 1.5 kg ha^{-1} (54.4%) in transplanted rice under medium land condition.

Burhan *et al.* (1989) reported that Cinosulfuron @ 20 g ha^{-1} resulted in 85% control of *Monochoria vaginalis, Marsilea crenata, Cyperus spp Fimbristylis miliacea* and *Scirpus juncoides* but only 50-60% control of *Echinochloa crus-galli* in transplanted rice.

2.3 Effect of no weeding

Gogoi *et al.* (2000) from Assam reported that different weed control practices significantly reduced the dry matter accumulation of weed and increased the rice yield over the unweeded control in transplanted rice.

Singh and Kumar (1999) reported that maximum weed dry weight and the lowest grain yield was observed in the unweeded control in the scented rice variety Pusa Basmati-1.

Singh *et al.* (1999) studied the effect of various weed management practices on the weed growth and yield and nitrogen uptake in transplanted rice and weeds and reported that weedy control until maturity removed significantly higher amount of nitrogen through weeds (12.97 kg ha^{-1}) and reduced the grain yield of rice by 49% compared to that of weed free crop up to 60 DAT.

Sanjoy *et al.* (1999) observed that control of weeds played a key role in improving the yield of rice because of panicle m^{-2} increased 18% due to weed control over its lower level, number of filled grains $panicle^{-1}$ increased 32% due to weed control over its lower level and significant yield increase was observed (43%) with weed control.

Thomas *et al.* (1997) reported that rice weed competition for moisture was heavy during initial stages and yield losses from uncontrolled weeds might be as high as 74%.

Kamalam and Bridgit (1993) reported that the average reduction in grain yield due to weed competition was 56 percent.

2.4 Effect of hand weeding

Ashraf *et al.* (2006) made an experiment in Lahore, Pakistan, during 2004 and 2005 kharif seasons, for screening of herbicides for weed management in transplanted rice (cv. Basmati-2000). In the second year the maximum control of weeds was 94.67% in the case of hand weeding. Regarding the number of tillers $plant^{-1}$, hand weeding resulted in 20.8 compared to 16.6 for the control in second year, whereas the highest number of grains per panicle was 135.50 during the second year. In terms of paddy yield, hand weeding gave the highest grain yield but remained statistically at par with certain herbicides.

Baloch *et al.* (2006) made an experiment in NWFP, Pakistan to evaluate the effect of weed control practices on the productivity of transplanted rice. Among weed management tools, the maximum paddy yield was obtained in hand weeding, closely followed by Butachlor (Machete 60EC) during both cropping seasons.

Manish *et al.* (2006) said that *Alternanthera triandra, Echinochloa colona, Fimbristylis miliacea* and *Xanthium strumarium* were the dominant weeds associated with the transplanted rice crop. Results revealed that hand weeding at 15 and 30 DAT (days after transplanting) gave the highest grain yield, straw yield and harvest index. Maximum weed density and dry matter were recorded in the unweeded control, while the minimum values were obtained with hand weeding at 15 and 30 DAT.

Other than weed free condition, the highest grain yield (5.9 t ha^{-1}) was produced by BR 11 under two hand weeding. It was further identified to reduce the weed seed bank status in rice soils and rice grains to the lowest extent in both farmer's field as well as experimental field (Bijon, 2004).

Chandra and Solanki (2003) studied the effect of herbicides on the yield characteristics of direct sown flooded rice. The treatments were two hand weeding, Butachlor 2.0 kg $ha^{-1}$and Oxadiazon 0.8 kg ha^{-1}. They found that two hand weeding produced the highest ear length (23.49cm), number of grains ear^{-1}, grain yield (33.65 g ha^{-1}), straw yield (65.35 g ha^{-1}) and harvest index (33.97%).

Bhowmick (2002) said two hand weeding at 20 and 40 days after transplanting (DAT) in transplanted rice showed the highest control of weeds.

Bhowmick *et al.* (2002) revealed that *Echinochloa crus-galli*, *Cyperus iria*, *Cyperus rotundus* were the dominant weeds in transplanted rice. He observed that two hand weeding at 20 and 40 days after transplanting were able to control almost all categories of weeds.

Chandra and Pandey (2001) showed that hand weeding was the most effective in mitigating the weed dry matter accumulation and also reported that higher grain and straw yield were obtained with hand weeding.

Hossain (2000) observed experiment oriented impact of different weeding approaches on rice like one hand weeding, two hand weeding, three hand weeding, Oxadiazon, Oxadiazon in combination with one hand weeding and observed that yield and yield contributing traits in rice production had upgraded by degrees with the higher frequency of hand weeding.

Balaswamy (1999) found that hand weeding twice at 20 and 40 days after transplanting resulted in low weed numbers, followed by herbicides.

Gogoi (1998) observed that Anilofos at 0.4 kg ha^{-1} gave significantly higher yield and the yield was not significantly different from the hand weeding at 20 days after transplanting.

Nandal *et al.* (1998) evaluated the herbicide in direct seeded puddled rice during Kharif season. They observed that Pretilachlor (1.0 kg ha^{-1}) + hand weeding reduced weed population and weed dry weight significantly than other treatments. They also found that the highest grain yield and gross margin was obtained from the Pretilachlor (1.0 kg ha^{-1}) + hand weeding.

Angiras and Rana (1998) observed that greatest yield and desired weed control was achieved form the Pretilachlor (0.8 kg ha^{-1}) + hand weeding.

BRRI (1997) reported that two hand weeding performed best than chemical treatments but two hand weeding gave the higher weeding cost than herbicidal treatments.

Shivamdiah *et al.* (1987) investigated that Oxadiazon 0.75 kg ha^{-1} + one hand weeding gave significantly greater yields than herbicides alone. They also found that combination of herbicidal treatment and one hand weeding gave higher straw yield.

Navarez *et al.* (1982) showed in rainfed condition that the lack of weed control in tall rice cultivars resulted in the yield reduction by 41% but one hand weeding at 40 days after transplanting reduced the grain yield by 31%.

2.5 Effect of mechanical weeding

Singh (2005) conducted an experiment at Bihar, India, during the wet season to assess the effectiveness of Beushening (a kind of mechanical weed control) in controlling weeds under rainfed lowland conditions as well as to make a comparison between Beushening and chemical weed control (i.e. 2,4-D and Butachlor). It was found that common practice of Beushening alone was not effective in controlling weeds of rainfed lowland rice but standard practice of Beushening along with one hand weeding 40 days after sowing (DAS) was better in controlling weeds than other chemical treatments with or without one hand weeding 40 DAS and both (common and standard) practices of Beushening as effective as two hand weedings (25 and 40 DAS) in terms of grain yield, net return and benefit: cost ratio.

Ahmed *et al.* (2003) said that Cinosulfuron, Pretilachlor and the BRRI push weeder performed better than farmer existing weed control practices of hand weeding with reduced weeding cost.

Sharma and Gogoi (1995) observed that the peg type dry land weeder and a twin wheel hoe gave best weed control which was comparable to that achieved with Butachor + hand weeding.

Moorthy and Das (1992) stated that the paddy wheel hoe use twice resulted in the greatest weed control (80%), higher grain yield (1.65 t ha^{-1}) and straw yields (3.54 t ha^{-1}) and the finger weeder used twice resulted in the greatest weed control (80%), highest grain yield (1.65 t ha^{-1}) and straw yields (3.54 t ha^{-1}) and the finger weeder used twice resulted in the greatest weed control (80.7%) and grain yield (2.81 t ha^{-1}) but the paddy wheel hoe used gave twice higher straw yield (4.68 t ha^{-1}).

Kulmi (1990) stated that plots receiving cultural control methods, manual or rotary weeding at 40 and 35 days after transplanting resulted in lower weed densities (8.9-9.7 plants m -2) and higher grain yield (18.5-20.3% above the unweeded control value of 2.36 t ha^{-1}) than the plot treated with 0.75-2.0 kg ha^{-1} Oxadiazon as pre-emergence at 6 days after transplanting or with 0.75-2.0 kg ha^{-1} Pretilachlor as post- emergence at 30 days after transplanting.

Chandra and Mama (1990) observed that rotary weeder controlled weeds effectively and increased grain yield by 29.7% and hand weeding also controlled weed successfully and increased yields.

Islam and Haq (1987) concluded that use of a low cost weeder could eliminate 90% weeds in the sandy loam soil with a weed density of 375 m^{-2}.

Singh *et al.* (1985) reported that two inter row cultivation with hand hoe plus hand weeding in the row 14 and 28 days after emergence (DAE) resulted in equivalent yields with those from the weed control and there was no significant differences in grain yields between the plots where hand weeder used twice.

2.6 Effect of M.chlor 5 G (Common name: Butachlor)

Rangaraju (2002) in India determined the effect of herbicide application and application time on weed flora and weed dynamics of dry seeded rainfed rice and observed that application of either Butachlor at 1.5 kg a.i. ha^{-1} effectively controlled the weeds.

Gnanasambandan and Murthy (2001) studied the efficiency of preemergence herbicide Butachlor @1250 g ha^{-1} which was applied at 4 days after transplanting and reported that treatments effectively controlled weed density and increased grain yield.

Rajkhowa *et al.* (2001) reported that Butachlor 1.0 kg ha^{-1} applied three days after transplanting (DAT) significantly reduced weed infestation till 45 DAT and resulted in higher yield of rice over weedy check.

BRRI (1998 a) evaluated a new pre-emergence herbicide Golteer 5G (Butachlor) at Gazipur in transplanted aus rice and results indicated that hand weeding produced a slightly higher grain yield than Golteer application and weed biomass was lower in hand weeded plots followed by Golteer (Butachlor) treated plots.

Madhu *et al.* (1996) at Bangalore, to evaluate the effectiveness of four herbicides, pendimethylin, Anilofos, Butachlor and oxyfluorfen at 2 application rates during dry and wet seasons in puddled seeded rice field and the results showed that grain and straw yields were higher in the plots treated with Butachlor @ 1.5 kg ha^{-1}.

Bhattacharya *et al.* (1996) reported that although the hand weeding treatment gave the highest grain yield, the results indicated that this was laborious, time consuming and costly and hand weeding could be replaced by application of Butachlor at 1 kg a.i. ha^{-1}.

Chon *et al.* (1994) reported that 3.6 kg ha^{-1} pre-emergence application of Butachlor inhibited shoot growth and development of *Echinochloa cruss-galli* and the rice plants showed a reduction and constriction of thickness of the leaf primordium while *Echinochloa cruss-galli* formed tubular like leaves and inhibited the elongation of the apical meristem.

Savithri *et al.* (1994) observed the efficiency of different pre emergence herbicides in transplanted rice and they concluded that among the different herbicides, application of granular formulation of Butachlor @ 1.5 kg a.i. ha^{-1} six day after transplantation was found to be the most effective for controlling weeds in transplanted rice.

Shah *et al.* (1990) observed that hand weeding (15 and 30 days after transplanting) gave the best weed control while Butachlor 5% granules at 1.5 kg ha^{-1} was the most beneficial treatment. Weed dry matter was significantly reduced and the grain yield was significantly increased by all Butachlor treatments.

2.7 Effect of Oxastar 25 EC (Common name: Oxadiazon)

Jena *et al.* (2002) observed that weed control treatments reduced weed density, dry matter and increased rice yield and Oxadiazon gave better weed control. They also found that application of Oxadiazon with hand weeding gave the highest weed control efficiency, grain and straw yield and harvest index.

Gogoi *et al.* (2000) observed that combined weed control treatment like Oxadiazon 2.0 l ha^{-1} + 1 hand weeding significantly reduced weed density and dry mater accumulation of weed and also increased grind yield (5.12 t ha^{-1}).

Ahmed *et al.* (1999) compared Oxadiazon and Cinosulfuron with hand weeding control and observed that Oxadiazon and Cinsolfuron controlled weeds in rice effectively providing 91-92% and 90-92% weed control efficiency, respectively.

Agazzani *et al.* (1999) determined the best chemical control programme against weeds in irrigated fields of dry sown rice. They found that effective weed control was obtained with pre emergence applications of Pendimethalin alone or mixed with Thiobencarb and Oxadiazon followed by post-emergence treatments.

Chandra *et al.* (1998) observed that Oxadiazon 0.8 kg ha^{-1}, Butachlor 2 kg ha^{-1} and Thiobencarb 2 kg ha^{-1} provided 80.5, 78.3 and 35.1% weed control respectively. They found that Oxadiazon and Thiobencarb increased grain yield. Among the herbicides, Oxadiazon was the most effective herbicidal treatments.

Razzaque *et al.* (1998) evaluated the efficiency of Oxadiazon as herbicide in transplanted aman rice. They observed that the application of Oxadiazon 2.0 1 ha^{-1} achieved effective control of all the weed masses growing in the field and produced significantly higher grain yield. Also they observed that application of Oxadiazon 2.0 l ha^{-1}achieved the greatest profit.

Cinosulfuron and Oxadiazon showed better performance than Butachlor in terms of biomass and plant population and also stated two hand weeding gave the highest weeding cost of herbicide treatment (BRRI, 1998 b).

Brar *et al.* (1997) assessed the efficacy of 0.5 kg Oxadiazon applied 5-15 days after transplanting compared to 0.3 kg Anilofos applied 3 days after transplanting (DAT) and hand weeding twice, for control of *Echinochloa crus-galli* in rice cv. PR-110 in sandy loam soil. Results indicated that best weed control and crop yield were achieved with Oxadiazon treatment applied < 10 DAT, these results were comparable to those achieved with Anilofos or hand weeding.

Samanta *et al.* (1995) observed the effectiveness of weed control by manual weeding and with Oxadiazon in transplanted aman rice (BR 11). Oxadiazon 2.0-4.0 l ha^{-1} and manual weeding twice were found effective in reducing the dry matter of total weeds significantly over the control, but none of the treatments except manual weeding twice controlled *Paspalum distichum* effectively.

Prasad and Rafey (1995) observed that application of Oxadiazon at pre emergence and hoeing 30 days after sowing gave the maximum net return and showed a higher benefit cost ratio of 1.71.

Chowdhury *et al.* (1995) observed the effect of Oxadiazon in weed management and growth and yield of rice. Six different doses of Oxadiazon viz. 0, 1.5, 1.75, 2, 2.25 and 2.50 l ha^{-1} were used to control weeds in rice. They found that Oxadiazon significantly reduced weed infestation and increased the yield of rice irrespective of the doses used. Out of these doses, 2.0 l ha^{-1} was found to be most effective with respect to all the studied parameters.

Singh and Singh (1994) observed that all weed control treatments decreased weed number and weed dry weight. The best weed control was given by Oxadiazon 0.4 kg a.i. ha^{-1} which gave the highest grain yield.

Haque (1993) evaluated the efficiency of Oxadiazon in transplanted aman rice and observed that Oxadiazon 2.0 l ha^{-1} controlled the weeds effectively and produced significantly the tallest plant, maximum effective tillers $hill^{-1}$ and grains $panicle^{-1}$.

Biswas *et al.* (1991) evaluated that Oxadiazon 1.0 and 0.5 kg a.i. ha^{-1} applied at 30 days after sowing with or without one supplemental hand weeding was compared with normal hand weeding and the results indicated that the use of Oxadiazon at 0.5 kg a.i. ha^{-1} was more economic than hand weeding for effective weed management.

There was no significant difference in rice yield for using Oxadiazon as well as hand weeding. The highest grain yield was obtained from Oxadiazon @ 0.5 kg a.i. ha^{-1} (BRRI, 1990).

Purushotham *et al.* (1990) observed that Oxadiazon (0.5 kg a.i. ha^{-1}) reduced the dry weight of grasses, sedges and broad leaved weeds and increased the grain and straw yields significantly than two manual weeding at 25 and 45 DAT.

2.8 Effect of Rifit 500 EC (Common name :Pretilachlor)

Samar *et al.* (2007) conducted an experiment to evaluate the effects of herbicides for managing weeds and optimizing the yield of wet seeded rice. It was concluded that application of 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 rice, and resulting in higher net returns than the weed-free treatment.

Raju *et al.* (2003) observed the effect of pre emergence application of Pretilachlor plus Safener 0.3 kg ha^{-1}, Butachlor 1 kg ha^{-1} and post emergence herbicide like Butanil 3.0 kg ha^{-1} on 4, 8 and 15 days after sowing. They found that Pretilachlor plus Safener 0.3 kg ha^{-1} gave the highest yield attributes (productive tillers m $^{-2}$, number of grains panicle^{-1} and 1000 grain weight) and grain yield.

Mahajan *et al.* (2003) observed that application of Pretilachlor alone or in combination with Safener and hand weeding resulted in the lowest total weed density and dry matter and grain yield and number of panicles.

Kalhirvelan and Vaiyapuri (2003) observed the effect of weed management pratices on transplanted rice. The application of Pretilachlor at 187, 250 or 375 g ha^{-1}, Pretilachlor and 2, 4 D at 180 + 180, 240+ 240 and 300+ 300 g ha^{-1} with twice hand weeding. They found that hand weeding recorded the lowest weed population (2.78 m -2) and weed dry weight (155.7 kg ha^{-1}). Pretilachlor and 2, 4-D at 300 + 300 g ha^{-1} caused the lowest weed density and weed dry weight. Hand weeding recorded the highest grain and straw yields (5.81 and 7. 26 t ha^{-1}, respectively) than Pretilachlor and 2, 4-D (5. 55 and 6.89 t ha^{-1}).

Moorthy *et al.* (2002) investigated the efficacy of pre and post emergence herbicides in controlling weeds in rainfed upland direct sown rice. The application of Pretilachlor 625 g ha^{-1}, and Butachlor 1600 g ha^{-1} on 2 days after sowing and the treatments gave effective weed control and produced highest grain yield compared with twice hand weeding on 20 and 40 DAT.

Tamilselvan and Budhar (2001) studied the effects of pre emergence herbicides Pretilachlor 0.4 kg ha^{-1}, Pretilachlor 0.4 kg a.i. ha^{-1} on rice cv. ADT 43. The herbicides were applied 8 days after sowing . The density and dry weight of weeds at 40 DAS were lower in herbicide treated plots than in unweeded and hand weeded plots. The highest number of productive tillers hill^{-1} was obtained with Pretilachlor 0,40 kg a.i. ha^{-1} (14.2). The number of filled grain panicle^{-1} was the highest with Pretilachlor 0.40 kg a.i. ha^{-1} (126.3). The weed control treatment had effect in increasing grain yield .

Selvam *et al.* (2001) observed the effect of time of sowing along with weed management practices in semidry rice. The treatments included sowing practices and herbicide, Pendimethalin 1.24 kg ha^{-1} 8 days after rainfall, Pretilachlor 1.00 kg ha^{-1} at 4 DAS and 8 DAS, Pretilachlor + Safener 4 DAS and 8 DAS, hand weeding twice and unweeded control. All herbicides receiving plots were suppplemented with one hand weeding at 25 DAS. Among the herbicides, Pendimethalin recorded the highest grain yield (3773 kg ha^{-1} and was at par with Pretilachlor at 8 DAS.

Islam *et al.* (2001) investigated the application of few doses of Pretilachlor (312.50-562.50 g a.i. ha^{-1} and one hand weeding in transplanted rice. They found that Pretilachlor (312.50-562.50 a.i. ha^{-1}) and hand weeding reduced weed population and dry matter weight.

Moorthy *et al.* (1999) observed the performance of the pre emergence herbicides Pretilachlor + safener, Butachlor+ safener, Butachlor, Anilofos + ethoxysulfuron, Thiobencarb and Anilofos for their efficiency to control weeds in direct sown rice under puddled soil condition. They observed that Pretilachlor + safener (0.4 kg ha^{-1} and 0.6 kg ha^{-1}, Butachlor + safener (1.5 kg ha^{-1})and Anilofos+ ethoxysulfuron (0.37+0.04 kg ha^{-1}) controlled the most dominant weeds (*Cyperus difformis* and *Fimbristylis miliacea*) and produced yields comparable to those of the hand weeded control.

Rajendran and Kempuchetty (1998) observed the application of Thiobencarb 1.5 kg and hand weeding at 25 days after sowing, Pretilachlor 0.3 kg and hand weeding at 25 days after sowing as well as two hand weeding (25 and 45 days after sowing) in dry seeded low land rice cv. ADT 38. They found that the highest grain yield (5.5 t ha^{-1}) was achieved with Pretilachlor 0.3 kg + hand weeding treatment compared with Thiobencarb+ hand weeding (4.7 t ha^{-1}, 74.9% respectively).

Mandal *et al.* (1995) reported the efficacy Pretilachlor as herbicide in comparison to hand weeding in BR 11 variety . The major weeds in the rice field were *Cyperus iria, Scirpus muronatus, Monochoria hastata* and *Eleusine indica*. The lower doses of Pretilachlor at 1 l ha^{-1} failed to kill the weeds properly. The grain yield reduction due to weed infestation was 20.3 percent.

Janardhan *et al.* (1993) evaluated pre emergence Pretilachlor 0.5-1 kg ha^{-1} on weed control in transplanted rice . They found that herbicidal treatment decrease weed dry weight and increased grain yield.

2.9 Effect of integrated weed management

Belz (2007) said since varietal differences in allelopathy of crops against weeds were discovered in the 1970s, much research has documented the potential that allelopathic crops offer for integrated weed management with substantially reduced herbicide rates. Research groups worldwide have identified several crop species possessing potent allelopathic interference mediated by root exudation of allelochemicals. Rice, wheat, barley and sorghum have attracted most attention.

Otsuka *et al.* (2006) made an experiment to clarify the characteristics of the floristic composition with 3 different weed management techniques in Chiba, Japan. The mean number of species at quadrates in herbicide non-application paddy was significantly bigger than that in the herbicide application paddy fields.

Dhiman *et al.* (2006) showed that preemergence application of 1.5 kg Butachlor ha^{-1} + hand weeding at 35 DAT reduced weed biomass significantly and recorded the lowest weed dry weight (31.77 g m^{-2}) and the highest weed control efficiency (81.40). All the other weed control methods recorded higher 1000-seed weight than the control while butachlor + one hand weeding recorded significantly higher filled grain (136.00 $panicle^{-1}$) and effective tillers (246.10 m^{-2}) than the other treatments. Butachlor + one hand weeding gave the highest grain yield (70.61 q ha^{-1}), straw yield inputs (84.13 q ha^{-1}) and additional net return (Rs. 3756 ha^{-1}).

Kalyanasundaram *et al.* (2006) conducted field experiments in Tamil Nadu, India, during the 2000 and 2001 kharif season to determine the suitable integrated weed management practice without causing any phytotoxicity to rice seedlings. 1.5 kg Butachlor ha^{-1} with Safener at 4 DAS + hand weeding at 30 DAS gave the highest number of panicles m^{-2}, filled grains $panicle^{-1}$, test weight and grain yield. All the Butachlor with Safener combinations decreased weed dry weight significantly. Butachlor at 1.5 kg a.i. ha^{-1} without Safener applied at 4 or 8 DAS exhibited toxicity to rice seedlings.

A field experiment was conducted by Subramanian *et al.* (2006) in Tamil Nadu, India to study the effect of integrated weed management practices on weed control and yield of wet-seeded rice. Presowing application of Glyphosate (1.5 kg a.i. ha^{-1}) effectively reduced the sedges when combined with preemergence application of Pretilachlor+Safener (0.4 a.i. ha^{-1}) followed by two hand weeding at 25 and 45 days after sowing.

Dhiman (2005) made an experiment to see the efficacy of different preemergence herbicide for weed control in rice (cv. Sarju 52) in Uttar Pradesh, India. The pre-emergence herbicides were applied at 8 DAT. All treatments significantly reduced the total weed density over the control. Hand weeding resulted in the lowest weed dry matter (4.47 g m^{-2} in 2001 and 4.62 g m^{-2} in 2002). In general, the application of herbicides significantly increased the straw and grain yields. Hand weeding and Almix + 2,4-D registered the highest mean grain yields (5.9 and 5.8 t ha^{-1}), straw yields (7.3 and 7.1 t ha^{-1}), and harvest index (44.88 and 44.90).

Ranjit and Suwanketnikom (2005) initiated an experiment in 2002, Nepal to assess the performance of rice (*Oryza sativa*) under dry direct seeded environment with different weed management treatments. Both Anilofos and Bispyribac-sodium reduced narrow leaf and broad leaf weeds compared with the unweeded control. No phytotoxic effect on the rice plants was observed due to both herbicides. Anilofos + one hand weeding, hand weeded twice and Bispyribac-sodium alone gave higher yield compared with the unweeded control. Promising grain yield could be achieved with the Anilofos or Bispyribac-sodium with additional physical or mechanical control methods in dry direct seeded rice.

The maximum weed dry matter reduction was achieved under herbicide (Butachlor at 1.5 kg ha^{-1}) plus two hand weedings in transplanted rice. The highest yield (4623 kg ha^{-1}) was obtained with the application of herbicide supplemented with hand weedings in transplanted rice (Singh *et al.,* 2005).

Jena *et al.* (2002) reported that all weed control treatment reduced weed density, dry matter and nutrient uptake increased thus rice yield increased. Oxadiazon had better weed control than Thiobencarb and the preemergence application of Oxadiazon supplemented with hand weeding at 45 DAT recorded the highest weed control efficiency, grain and straw yields and harvest index.

Nair *et al.* (2002) observed that application of Butachlor @ 1.25 kg ha^{-1} along with one hand weeding 40 days after transplanting (DAT) recorded higher panicle m -2, panicle length, grains $panicle^{-1}$ and 1000 grain weight and ultimately increased the grain yield.

Singh *et al.* (1999) concluded that pre emergence spray of Anilofos + one had weeding at 40 days after transplanting significantly reduced the weed density and dry weight and resulted in higher net income and benefit: cost ratio.

Singh *et al.* (1998) evaluated the following weed control treatments in rice weeding with a paddy weeder at 15 days after transplanting (DAT), weeding with a three wheel hoe at 20 DAT, weeding with sweep hoe at 15 DAT, hand weeding twice at 20 and 40 DAT and hand weeding at 35 DAT + 1.5 kg ha^{-1} Butachlor. Results indicated that weed dry weight was reduced to 1.00-1.79 by the weeding treatments compare to 2.68 in the unweeded control, and rice yield was increased from 1.31 to 1.91-2.49 t ha^{-1}, the best treatment being hand weeding + Butachlor. The treatment also gave the highest benefit: cost ratio (1.72).

Prasad and Rafey (1995) stated that integrated weed management was compared with weed free practice upto 60 days after sowing (DAS) and hoeing three times with a wheel hoe for rice grain yield. Combined application of Oxadiazon at pre emergence + hoeing 30 DAS gave the maximum net return and showed a higher benefit: cost ratio of 1.71.

Dutta and Gogi (1994) stated that hand weeding at 15, 25 and 35 days after sowing (DAS) resulted in a significantly lower weed population (10.3 weeds m^{-2}) and dry weight(6.3 g m^{-2}). Use of the twin wheels hoe, peg type dry land weeder and Bindha + hand weeding reduced weed dry weight and increased rice grain yield. Application of Butachor + weeding with the twin wheel hoe resulted in the highest rice grain yield (1.84 t ha^{-1}).

Singh *et al.* (1994) reported that application of Butachlor plus two mecchanical weeding might be potential substitute for conventional manual weeding for achieving good returns and saving man hours.

Kathiresan and Veerabadran (1991) studied the integrated weed management system of herbicide plus one hand weeding which was compared with manual weeding and herbicides alone, along with unweeded control. They observed that weed infestation was lower on integrated weed management plots which affected higher nutrient uptake by crop and consequently increased yield.

2.10 Effects of spacing

The closer rice plants are shown more competitive against weeds. As a result, fewer weeds grow in association with them and in case of wider spacing it is reverse.

Studies were conducted in 2002 through 2004 at the Rice Research and Extension Center, Arkansas, USA to evaluate 3 new rice cultivars at plant densities ranging from 79 to 392 plants m^{-2} grown in competition with barnyard grass. Rice density and barnyard grass control affected rice total aboveground biomass production, panicle weight, and harvest index. As rice density decreased or barnyard grass control increased, total aboveground biomass production and harvest index increased. Rice density had no effect on panicle density or yield. Panicle density increased 14 panicles m^{-2} for every 10% increase in barnyard grass control (Ottis and Talbert, 2007)

Hakkansson (1984) reported that, the yield in 10 cm apart was 0.2 to 0.3% higher than that in 5cm row spacing, and 6% lower at a spacing of 20cm. The differences increased at higher weed population. Effects on weed weight were greater and opposite to the effects on cereal yield. When seed spacing in the row was uneven, grain yield decreased by an average number of 0.4-05% and increase in gap size in rows 10 cm apart and the reduction in yield was associated with a larger increase in weed weight.

Ahissou and Akobundu (1983) in Nigeria observed that the weeds reduced yield of Adnu 11 by 63% at the widest spacing compared with the control. Grain yields of all cvs. weeded once were significantly higher when grown in rows 15cm x 30cm apart that at the traditional wider spacing of 45cm.

Tosh *et al.* (1981) observed that with short duration high yielding dry land rice cultivars in Eastern India, sown in rows led to higher plant population, lower weed dry matter and higher grain yields than when broadcast.

Kim and Moody (1980) observed that transplanted rice at a 10cm x 10cm spacing lead to a significant reduction in weed weight compared to a 20cm x 20cm plant spacing in herbicide treated and untreated plots but not in the hand weeded plots. A significant reduction in grain yield due to competition occurred in at the wider plant spacing but not at the closer plant spacing.

IRRI (1975) reported that the decrease in rice yield of the two cv. IR 28 and IR 30 due to weed compared with yields of the weed free check plots, averaged 18.1, 29.5 and 51.6 percent for plant spacing of 15cm x 15cm, 20cm x 20cm and 25cm x 25cm respectively. Weed weight were lower when the distances between plants were less. Significant yield and weed competitive ability could be appreciably improved by decreasing the plant spacing.

2.11 Effect of spacing on yield and yield contributing characters of transplanted aman rice

Yield and yield contributing characters of transplanted aman rice greatly influenced by plant spacing. Optimum plant spacing produce optimum numbers of plants unit area^{-1}, which enhanced better yield and yield contributing characters and ultimately higher grain yield.

2.11.1 Plant height

Haque (2002) conducted an experiment with 20 x 20cm, 30cm x 30cm and 40cm x 40cm spacing and found the tallest plant from wider spacing.

Mia (2001) reported that plant height was influenced significantly due to spacing at all DAT except 15 DAT. It was observed that the widest spacing (20cm x 25cm) produced the tallest plant (120.80 cm) at 90 DAT and the shortest plant stature was (112.98 cm) in the closest spacing.

BRRI (1991) reported variation on plant height and maturity duration of BR 1, BR 3, BR 12, BR14 and BR 20 due to the plant densities where seedlings were planted with 25cm x 30cm, 25cm x 20 cm, 25cm x 10 cm and 15cm x 10cm respectively.

Shah *et al.* (1991) reported that plant height of rice were maximum with 15 cm x 15 cm spacing.

Miah *et al.* (1990) conducted an experiment where rice cultivars Nizersail and mutant lines Mut. NS 1 and Mut. NS 5 were transplanted at 15, 20, 25 and 30 cm row spacing. Plant heights were more in Mut. NS 1 than in Nizersail.

2.11.2 Total tillers hill^{-1}

Rashid and Khan (2006) made an experiment to study the tillering dynamics and the productivity of rice cv. BRRI dhan 44 under four spacing viz. 20cm x 15cm, 25cm x 15cm, 20cm x 20cm and 25cm x 25cm in Gazipur, Bangladesh. The highest number of tillers hill^{-1} was recorded at 25cm x 25cm spacing and decreased with a decrease in spacing. The effectivity index of tillers was highest in 25cm x 25cm spacing (58.12%), which was comparable to 20cm x 20cm spacing (52.38%) and significantly higher than spacing at 25cm x 15cm (46.62%) and 20cm x 15cm (50.63%).

Karim *et al.* (2002) conducted an experiment on SRI in Boro season 2000-2001. In that experiment, the spacing trail of 30 cm x 30cm, 35cm x 35cm and 40 cm x 40cm was tested for seedling age of 12 to 15 days. Results of the experiment showed that SRI performed the best in respect of total tillers hill^{-1} in wider spacing of 35 cm x 35 cm or 40cm x 40 cm.

Chris (2002) stated that among three plant spacing (20cm x 20cm, 30cm x 30cm and 40cm x 40cm), the highest number of tillers hill^{-1} (60) was recorded in case of 20cm x 20cm spacing.

Sarker (2001) reported that row spacing exerted significant effect on the production of tillers hill^{-1} at all sampling dates. There was an increasing trend of tillers production with the increase in spacing on all the dates of observation.

Srinivasan and Purushothaman (1990) observed that in rice cv. Ponni and Bhavanis when transplanted at 15cm, 20cm or 25cm x 10cm the increased number of productive tillers and higher total plant DM at higher plant density in main and ratoon crops.

2.11.3 Number of effective tillers hill^{-1}

In 3 field trials with Jinliangyou 36, the effects of different spacings, N application levels and application patterns on rice yield were investigated in 2004 in Fujian, China. The effective panicles unit area^{-1} increased with increasing spacing, whereas the total grains panicle^{-1}, seed setting rate and yield decreased. The highest yield was recorded with a spacing of 16.7 x 30 cm followed by 23.3cm x 23.3 cm (Han *et al.*, 2006).

Aziz and Hasan (2000) reported that the average number of tillers hill^{-1} and effective tillers hill^{-1} were 117 and 103, respectively in Parija variety at Rajshahi. The spacing 35 cm x 35 cm seemed more promising both in locally. On the other hand, farmers practice the average number of effective tillers m $^{-2}$ was 290 and 393 with 20cm x 20cm and 20cm x 15cm, respectively.

2.11.4 Characteristics of grains panicle^{-1}

Rekhashri *et al.* (1997) stated that rice cv. Kapilee was grown at 20cm x 20cm, 10cm x 10cm, 15cm x 10cm and 10cm x 10cm spacing. Closer spacing decreased yield components including number of grains panicle^{-1}, panicle lengths and panicle weight but increased panicle numbers m $^{-2}$ and slightly increased grain yield.

Rao *et al.* (1990) reported that grain yield was the highest at 20cm x 25cm spacing and decreased with closer spacing due to the unfilled spikelets panicle^{-1} and lower panicle weight and yield was also found to be decreased at wider spacing despite of slightly increased of panicle weight.

Ghosh *et al.* (1998) obtained the highest number of grains per panicle at spacing of 30cm x 30 cm than those of closer spacing of 20 cm x 20cm and 20cm x 25 cm, respectively.

Tsai (1987) conducted an experiment where rice cv. Pegonil and Tainung 67 were grown at spacing of 30 cm x 15cm or 30cm x 7.5 cm with 1 or 4 to 6 plants hill^{-1} with the wider spacing and several seedlings hill^{-1} headed earlier and produced lower tillers and panicle numbers than Tainung 67 while closer planting tended to decrease panicle number $hill^{-1}$ but significantly increase panicle number unit $area^{-1}$.

Thangamuthu and Subramanian (1983) studied the effect of population on yield and yield components of rice cv. CO 43 and found that 20cm x 15cm spacing produced the highest grain yield 5.2 and 6.6 t ha^{-1} during the wet and dry seasons, respectively. The number of panicle m^{-2} was higher in a conventional planting at 15 cm x 10 cm spacing during the wet season but was higher at 20 cm x 15 cm spacing during the dry season.

Murty and Murty (1981) stated that the number of spikelets $panicle^{-1}$ was decreased in plants with closer spacing of 10cm x 10cm and 15cm x 15cm from those of plants cultivated with spacing of 20 cm x 20cm and 30 cm x 30 cm.

Hwu and Thseng (1982) also expressed similar results that increasing spacing increased the number of spikelet $panicle^{-1}$

2.11.5 Weight of 1000 grains

Yan (2002) reported that rice var. Yaza 1 gave a maximum yield of 12.79 t ha^{-1}, had 240 effective panicles m^{-2} and 198 grains $panicle^{-1}$ with a 1000 grain weight of 27.5 g when plant spacing was 50 cm x 50cm in SRI technique.

Wang *et al.* (2002) reported that in SRI Technique 1000 grain weights were 26.33, 26.27, 26.96 and 26.27 g with spacing distance of 25cm x 25cm, 25cmx 15cm, 30cmx 30cm, 30cm x 15cm, respectively.

2.11.6 Grain yield

Mobasser *et al.* (2007) conducted an experiment in Iran, to see the effects of seedling age (25, 35 or 45 days) and spacing (15x15, 20x20, 25x25 or 30x30 cm) on the yield and yield components of rice (cv. Neda). For this cultivar, transplanting of 25 days old seedlings at a spacing of 15cm x15 cm is optimum with regard to yield attributes.

A field experiment was conducted by Bali (2006) during the kharif (rainy) seasons of 1999 and 2000 in India, to test the performance of scented rice (Mushk budgi)under various planting geometry and fertility levels. Plant geometry of 20 cm x 10 cm gave higher yield and economic returns than dense or wider spaced crop.

Dongarwar *et al.* (2005) conducted field experiments in Maharashtra, India, during the 1996, 1997 and 1998 wet seasons, to study the effect of spacing (20 x 5, 20 x 10 and 15 x 15 cm) on the grain yield of three scented rice cultivars. Three years pooled data on grain yield revealed that scented rice planted at 15 cm x15 cm (44 hills m^{-2}) spacing gave significantly higher yield compared to the 20cm x 15cm (33 hills m^{-2}) and 20cm x 10cm (50 hills m^{-2}).

Verma *et al.* (2002) conducted a field experiment in Raipur, Madhya Pradesh, India, during the rainy season of 1998-99 to study the effect of spacing 20cm x 20cm, 20cm x15cm and 20cm x 10cm and crop density or transplanted rice hybrid Proagro 6201. They found that seedlings planted at 20cm x 20cm and 20cm x 15cm produced higher number of productive tillers, grain yield and harvest index than seedlings planted at 20cm x 10cm. Closer spacing (20cm x10cm) gave higher sterility percentage than wider spacing.

The overall performance of BRRI dhan 38 at the spacing of 20cm x 15cm was found to be the best and it produced the highest grain yield of 4.27 t ha^{-1} and the second highest grain was in BRRI dhan 37 at the same spacing (Khalil, 2001).

Reddy *et al.* (2001) reported that planting of rice at a closer spacing of 15cm x 10cm resulted in higher grain yields (40.66 and 50.33 q ha^{-1} during 1996 and 1997, respectively) as compared to normal planting at a spacing of 20 cm x 10cm (35.39 and 48.11 q ha^{-1} during 1996 and 1997, respectively) and recorded a mean increase of 7.6 % higher grain yield over the normal spacing. Among the yield components, number of panicles unit $area^{-1}$ and grains $panicle^{-1}$ appeared to have been increased significantly by closer planting. Closer planting of seedlings (15cm x 10cm) also significantly increased the number of grains $panicle^{-1}$ (463) compared to the other treatments.

Yang *et al.* (1999) studied growth and yield of rice cv. Jinongda 3 at plant spacing of 30cm x 40cm, 30cm x 17cm and 30cm x 10cm, respectively and reported that tillers number and growth period increased as plant density increased. The optimum plant density was 20 hills m^{-2} (30cm x 17cm) at which yield reached the highest of 8.7 t ha^{-1}.

Siddique *et al.* (1999) grew rice cv. Mahamaya, Kranti, R-296-260 and Suraksha at spacing of 10cm x 10cm or 10cm x 20cm and reported that grain yield of rice under closer spacing (10cm x 10cm) was significantly higher than the wider spacing (20 cm x 10 cm).

Geethadevi *et al.* (2000) conducted an experiment by 15cm x10cm and 20cm x 10cm spacing to find out the effect on the growth and yield of hybrid rice. They found that maximum grain yield (5.14 t ha^{-1}) was obtained with 20 cm x10 cm spacing.

Zhao *et al.* (1998) conducted an experiment with five planting densities (16.7cm x 13.3cm, 20cm x 13.3cm, 23.3 cm x 13.3cm, 26.7cm x 13.3cm and 30.3cm x 13.3cm) and observed that grain yield with the medium density (23.3cm x 13.3cm) was significantly higher than the highest density or the lowest density.

Rafiq *et al.* (1998) conducted an experiment where rice cv. Basmati 385 were transplanted at 30cm x 25cm, 30cm x 20cm, 30cm x 6cm and 20 cm x 20 cm spacing and found that 20cm x 20cm spacing produced the highest grain yield of 4.88 t ha^{-1}.

Hu *et al.* (1997) conducted an experiment with spacing of 30cm x 10cm, 30cm x17cm, 30cm x 27cm, 40cm x 20cm or 33cm x 27cm. The amount of dry matter $panicle^{-1}$ was the highest with the higher plant densities. Yields were 8.35 t ha^{-1} with a spacing of 30cm x 10cm and 9.14 t ha^{-1} with a spacing of 30cm x 17cm and decreased with decreasing plant density to 8.56 t ha^{-1} with a spacing of 30cm x 27cm.

Padmajarao (1995) observed that rice cv. Basmati 370 and IET 8580 were transplanted at 20cm x 20cm, 20cm x 15cm or 20cm x 10cm spacing (25, 33 and 50 plants m^{-2} respectively) grain yield highest at the closest plant spacing.

Azad *et al.* (1995) observed that by transplanting rice seedling at 20cm x10cm, 25cm x15cm and 30cm x 20cm spacing a decrease in grain yield observed by the widest spacing.

Hegazy *et al.* (1995) found that rice was planted at 15cm x 15cm, 20cm x 20cm and 25cm x 25cm. The grain yield was the highest at the 20cm x 20cm spacing.

Islam *et al.* (1994) found that grain and straw yields increased with closer spacing in both row and hill direction. The closer spacing 20cm x 15cm with six hills produce 61 per cent higher grain yield over 40cm x 30cm spacing with 10 seedlings hill^{-1}.

Virida *et al.* (1993) stated that rice cv. Mahsuri and 1-30-1-1 were grown at spacing of 20cm, 25cm or 30cm x 15cm and found that grain yields at the 3 spacing were 5.12, 4.43 and 3.95 t ha^{-1}, respectively.

BRRI (1992) reported that local transplanted rice variety Kumaragoir with planting 2-3 seedlings hill^{-1} at 25 cm x 15cm spacing appeared to be better in terms of yield than the local farmer's practices of planting at a wider spacing and with more seedlings hill^{-1}.

Ramakrishna *et al.* (1992) conducted an experiment where rice cv. Jaya transplanted at 10cm x 10cm, 20cm x 10cm, 20cm x15cm spacing and found that grain yield decreased with increasing plant spacing.

Mannan and Siddique (1991) reported that the number of tillers, panicles and yield unit area^{-1} increased with the increase in plant densities. Planting at 25cm x 10cm and 15cm x 10 cm spacing gave identical but significantly higher yield.

Verma *et al.* (1988) conducted an experiment where rice seedlings were transplanted at a spacing of 15cm x15cm and that spacing was appeared to be significantly superior to other spacings. The highest yield was recorded when planted on 30th of June at the 15cm x15cm (8.73 t ha^{-1}).

2.11.7 Straw yield

Mustapha (2000) claimed that the differences in population density in rice cv. IET 3137 and ITA 306 gave relatively similar grain between 20 cm x 20cm and 30cm x 30cm spacing. Straw yield increased with an increase in spacing, but that did not correspond to an increase in yield. Transplanting at a spacing of 40cm x 40cm gave the highest straw mass but the grain yield was the lowest.

Chavan *et al.* (1989) found from an experiment on different spacing that grain yield and grain straw: ratio increased with wider spacing.

Sarkar *et al.* (1988) observed that straw yield was significantly higher with 5 cm hill spacing.

2.11.8 Biological yield

The yield performance at a spacing of 20cm x 20cm was significant and recorded 16.1% and 16.4% and 6.5% and 5.7% higher grain and straw over the spacing of 20cm x 10cm and 20cm x 15 cm, respectively. Nitrogen uptake by grain significantly increased with increasing plant spacing, while it was reverse for N uptake by straw (Gautam *et al.,* 2005).

2.11.9 Harvest index

Hossain (2002) conducted a field trial during aman season with cv. BRRI dhan 32 and results revealed that the highest harvest index (48.62 %) was obtained from SRI planting method, which was 15 days old seedlings with the spacing 25cm x 25cm and the lowest harvest index (45.94) obtained from conventional method, which was 25 days old seedlings coupling with 25cm x 15cm.

Bhab *et al.* (1987) said that the harvest index was maximum with 25m x 15cm spacing.

2.11.10 Benefit cost ratio (BCR)

The benefit cost analysis showed abit different trend than that of grain and straw yields where the maximum profit was noticed in Cinmethylin @ 0.75 t ha^{-1} + 1 weeding with Japanese rice weeder which was followed by Cinmetylin @ 0.75 t ha^{-1} + 1 hand weeding (Toufiq, 2003).

2.12. Combined effect of different weed management and spacing for controlling weeds

Unchecked weed competition resulted in a 46% reduction in grain yield. Significantly higher grain yield was achieved through the adoption of 20cm x 10cm spacing and the use of Anilofos + 2,4-DEE @ 0.40 + 0.53 kg a.i. ha^{-1} (ready mix) at 6 days after transplanting

(DAT) supplemented with 2,4-D sodium salt at 1 kg a.i. ha^{-1} at 20 DAT (Jacob and Syriac, 2005 a).

Jacob and Syriac (2005 b) conducted a field experiment to study the effects of spacing and weed management practices on transplanted scented rice (Pusa Basmati 1) in India.He said that adoption of 20 cm x 10 cm spacing and pre-emergence application of Anilofos + 2,4-D ethyl ester (0.40+0.53 kg a.i. ha^{-1}) at six days after transplanting supplemented with 2,4-D Na salt (1.0 kg a.i. ha^{-1}) at 20 days after transplanting generally favoured increased yield and net income. The benefit-cost ratio for Anilofos + 2,4-D ethyl ester was 2.07 as against 0.93 for unweeded check.

Weed control by Pretilachlor @ 1.0 l ha^{-1} appeared to be the best weed management practice for BR 22 transplanted aman rice grown at a spacing of 25cm x 15cm (Nurujjaman, 2001).

Gogoi *et al.* (2001) reported that close planting and pre emergence application of herbicides reduced the weed growth effectively and improved the yield components and increased grain yield of rice.

Akobundu and Ahissou (1985) observed that weed weight and number of tillers and panicles $plant^{-1}$ decreased as inter-row distance was reduced. When rice was kept weed free, yield was not affected by row spacing. When it was weeded once, yield was reduced at the widest spacings.

Balasubramiyan (1983) reported that when rice grown in normal and paired rows, population and dry weight of weeds with Butachlor were lower than in unweeded check plots before the first hand weeding, but were higher than in the hand weeded plots before the second weeding, they were higher in the paired rows than in normal rows.

Ahmed (1981) in Bangladesh, reported that at plant spacing from 20cm x 25cm to 20cm x 10cm, number of panicles ha^{-1} and grain yield were not significantly different between weeding regimes, suggesting that hand weeding is not necessary at closer spacing. The number of weeds at harvest was significantly lower with hand weeding than with no weeding at all plant spacing. Weed weight at harvest was significantly affected by weeding regimes at all spacing except at 20cm x 15cm.

From the literature reviewed above it is revealed that the best weed control treatment is achieved in transplanted aman rice field through the interaction of two methods applied simultaneously particularly application of a preemergence herbicide followed by one hand weeding . It is further evident that different plant spacing played a vital role for controlling weeds under different weed control treatments resulting in profitable transplanted aman rice production.

CHAPTER 3

MATERIALS AND METHODS

Details of different materials used and methodologies followed in the experiment are presented in this chapter.

3.1 Description of the experimental site

3.1.1 Location

The field experiment was conducted at the Agronomy field laboratory, Sher-e-Bangla Agricultural University, Dhaka during the period from July to December, 2006. The location of the experimental site has been shown in Appendix I.

3.1.2 Soil

The soil of the experimental area belonged to the Modhupur tract (AEZ No. 28). It was a medium high land with non-calcarious dark grey soil. The pH value of the soil was 5.6. The characteristics of the experimental soil have been shown in Appendix II.

3.1.3 Climate

The experimental area was under the subtropical climate and was characterized by high temperature, high humidity and heavy precipitation with occasional gusty winds during the period from April to September, but scanty rainfall associated with moderately low temperature prevailed during the period from October to March. The detailed meteorological data in respect of air temperature, relative humidity, rainfall and sunshine hour recorded by the Dhaka meteorology centre, Dhaka for the period of experimentation have been presented in Appendix III.

3.1.4 Test crop

Rice cv. BRRI dhan 37 was the test crop. It is modern transplanted aman rice developed from a cross of Basmati (D) and BR5 and released in 1998. The grains are of medium size and slender. The colour, size and scent of BRRI dhan 37 rice is about Katarivog. The end point of the rice grain is slightly bended and possesses a needle like small awn. The cultivar is photosensitive. It takes about 140 days to mature. The plant height of this cultivar is about 125cm. It has the average yield potential of about 3.5 t ha^{-1}(BRRI, 2000 a).

3.2 Treatment

The experiment consisted of two factors as mentioned below:

a) Factor A: Weed control

i)	No weeding (Control)	W_1
ii)	Two hand weeding	W_2
iii)	One weeding with BRRI rice weeder + one hand weeding	W_3
iv)	M.chlor 5G(Butachlor) @ 13 kg ha^{-1} + one hand weeding	W_4
v)	Oxastar 25 EC(Oxadiazon) @ 1.9 l ha^{-1} + one hand weeding	W_5
vi)	Rifit 500EC (Pretilachlor) @ 0.97 l ha^{-1} + one hand weeding	W_6

b) Factor B: Spacing

i)	20 cm x 10cm	S_1
ii)	25cm x 15cm	S_2
iii)	30cm x 20cm	S_3

The description of the weeding treatments is given below.

1) No weeding: Weeds were allowed to grow in the plots from transplanting to harvesting of the crop. No weeding was done.
2) Two hand weeding: Two hand weeding were done at 15 and 40 DAT, respectively.
3) BRRI rice weeder + one hand weeding: One weeding with BRRI rice weeder was done at 15 DAT and one hand weeding was done at 40 DAT.
4) M. Chlor 5 G (Butachlor) + one hand weeding : M. Chlor 5 G was applied @ 13 kg ha^{-1} at 5 DAT in 4-5 cm standing water and one hand weeding was done at 40 DAT.
5) Oxastar 25 EC (Oxadiazon) + one hand weeding: Oxadiazon 25 EC was applied @ 1.9 L ha^{-1} at 5 DAT and one hand weeding was done at 40 DAT.
6) Rifit 500EC (Pretilachlor) + one hand weeding: Pretilachlor 500EC was applied @ 970 ml ha^{-1} at 5 DAT and one hand weeding was done at 40 DAT.

3.3 Description of herbicides

A short description of the herbicides used in the experiment is given in Table 1.

Table1. Short description of the herbicides used in the experiment

Trade name	Common name	Mode of action	Selectivity	Time of application
M. Chlor 5G	Butachlor	Systemic	For rice	Pre emergence
Oxastar 25 EC	Oxadiazon	Systemic	For rice and wheat	Pre emergence
Rifit 500 EC	Pretilachlor	Systemic	For rice and wheat	Pre emergence

3.4 Design and layout

The experiment was laid out in a randomized complete block design (factorial) with three replications. The size of the individual plot was 4.0m x 2.5 m and total number of plots were 54. There were 18 treatment combinations. Each block was divided into 18 unit plots and the treatments were assigned in the unit plots at random. Lay out of the experiment was done on August 2, 2006 with interplot spacing of 0.75m and inter block spacing of 1.0 m.

3.5 Seed collection, sprouting and sowing

Seeds of the rice variety was collected from Bangladesh Rice Research Institute, Joydebpur, Gazipur. Initially seed soaking was done in water for 24 hours and after wards they were kept tightly in jute stack air for 2 days. When about 90% of the seeds were sprouted, they were sown uniformly in well prepared wet nursery bed on July 10, 2006. Seed bed size was 10 m long and 1.5 m wide.

3.6 Land preparation

The experimental field was opened by a tractor driven rotavator 15 days before transplanting. It was then ploughed well to make the soil nearly ready for transplanting. Weeds and stubble were removed and the field was leveled by laddering. The experimental field was then divided into unit plots that were spaded one day before transplanting for incorporating the fertilizers applied as basal. Finally individual plot was prepared before transplantation.

3.7 Fertilizer application

The field was fertilized with urea, triple super phosphate, muriate of potash, gypsum and zinc sulphate at the rate of 150, 100, 70, 60 and 10 kg ha^{-1} respectively. The whole amount of all the fertilizers except urea were applied at the time of final land preparation and thoroughly incorporated with soil with the help of a spade. Urea was top dressed in three equal splits on 15, 30, and 45 DAT (BRRI, 2000 b).

3.8 Uprooting and transplanting of seedling

The seedbeds were made wet by the application of water both in the morning and evening on the previous day before uprooting on August 5, 2006. The seedlings were then uprooted carefully to minimize mechanical injury to the roots and kept on soft mud in shade before they were transplanted. The twenty five days old seedlings were transplanted on the well puddled experimental plots on August 5, 2006 by using two seedlings hill^{-1}.

3.9 Intercultural operations

The following intercultural operations were done for ensuring the normal growth of the crop.

3.9.1 Gap filling

Seedlings in some hills were died off and those were replaced by healthy seedling within seven days of transplantation.

3.9.2 Weeding

Weeding was done as per the experiment treatment.

3.9.3 Irrigation and drainage

The experimental plots required two irrigations during the crop growth season and sometimes drainages were done at the time of heavy rainfall.

3.9.4 Plant protection measure

There were negligible infestations of insect-pests during the crop growth period. Yet to keep the crop growth in normal, Basudin was applied at tillering stage @ 17 kg ha $^{-1}$ while Diazinon 60 EC @ 850 ml ha^{-1} were applied to control stem borer and rice bug.

3.10 Harvest and post-harvest operation

The maturity of crop was determined when 85% to 90% of the grains become golden yellow in colour. The crop was harvested plot wise at maturity on December 2, 2006 by cutting the whole plants at the ground level with sickle. The harvested crop of each plot was bundled separately, tagged properly and brought to threshing floor. The bundles were dried in open sunshine, threshed and then grains were cleaned. The grain and straw weights for each plot were recorded after proper drying in sun. Before harvesting, five hills were selected randomly for each plot and cut at the ground level for collecting data on yield contributing characters.

3.11 General observations

Regular observations were made to see the growth stages of the crop. In general, the field looked nice with normal green plants which were vigorous and luxuriant in the treatment plots than that of control plots. The crop started flowering at 80 DAT.

3.12 Detecting the panicle initiation stage and observation of heading

With experience, it was felt that identifying the panicle initiation stage should need to follow some special technique rather than mere field observations. Therefore, arrangements were made accordingly. The method of detection the panicle initiation stage involved the selection, dissection and inspection to the rice stems starting from maximum tillering stage (about 50 DAT) onwards. A tiller from the middle of the border hills of the unit plot was cut off at the base of the plant where the stem and root join. Then with a sharp blade carefully slice the stem lengthwise at the centre starting from the base up. If the panicle has started to develop a small growth, the beginning of the panicle like a tiny swollen spongy tip will be seen.

3.13 Collection of data

3.13. A Weed parameters

3.13.A.1 Weed density

The data on weed infestation as well as density were collected from each unit plot at 30 and 60 DAT. A plant quadrate of 0.25 m^2 was placed randomly at three different spots outside an area of 10 m^2 in the middle of the plot. The infesting species of weeds within each quadrate were identified and their number was counted species wise. The average number of three samples was then multiplied by 4 to obtain the weed density m^{-2}.

3.13.A.2 Weed biomass

The weeds inside each quadrate for density count were uprooted, cleaned and separated species wise. The collected weeds were first dried in the sun and then kept in an electrical oven for 72 hours maintaining a constant temperature of 80^0c. After drying, weight of each species was taken and expressed to g m^{-2}.

3.13.A.3 Weed control efficiency

Weed control efficiency was calculated with the following formula developed by Sawant and Jadav (1985):

Weed control efficiently (WCE) = $\frac{DWC - DWT}{DWC} \times 100$

Where,

DWC = Dry weight of weeds in unweeded treatment

DWT = Dry weight of weeds in weed control treatment

3.13.B Crop growth parameters

i. Plant height (cm)
ii. Total number of tillers hill^{-1}
iii. Leaf area index
iv. Total dry matter hill^{-1} (g)
v. Crop growth rate (g hill^{-1} day^{-1})
vi. Relative growth rate (mg g^{-1} day^{-1})

3.13.C Yield and yield components

i. Plant height at harvest (cm)
ii. Total number of tillers hill^{-1}
iii. Number of effective tillers hill^{-1}
iv. Number of non effective tillers hill^{-1}
v. Total number of grains panicle^{-1}
vi. Number of filled grains panicle^{-1}
vii. Number of sterile grains panicle^{-1}
viii. 1000 grain weight (g)
ix. Grain yield (t ha^{-1})
x. Straw yield (t ha^{-1})
xi. Biological yield (t ha^{-1})
xii. Harvest index (%)

3.14 Procedure of sampling for growth study during the crop growth period

3.14. i Plant height (cm)

The height of the rice plants was recorded from 15 days after transplanting (DAT) at 15 days interval upto 75 DAT, beginning from the ground level upto tip of the flag leaf was counted as height of the plant. The average height of five hills was considered as the height of the plant for each plot.

3.14. ii Total number tillers hill^{-1}

Total tiller number was taken from 15 DAT at 15 days interval upto 75 DAT. The average number of tillers of five hills was considered as the total tiller no hill^{-1}.

3.14. iii Leaf area index (LAI)

Leaf area index were estimated measuring the length and width of the leaf and multiplying by a factor of 0.75 followed by Yoshida (1981).

3.14. iv Crop growth rate (g hill^{-1} day^{-1})

Crop growth rate was calculated by using the following standard formula (Radford, 1967 and Hunt, 1978) as shown below:

$$CGR = \frac{W_2 - W_1}{T_2 - T_1} \text{ g hill}^{-1} \text{ day}^{-1}$$

Where, W_1= Total plant dry matter at time T_1

W_2 = Total plant dry matter at time T_2

3.14. v Relative growth rate (mg hill^{-1} day^{-1})

Relative growth rate was calculated by using the following formula (Radford, 1967) as shown below:

$$RGR = \frac{LnW_2 - LnW_1}{T_2 - T_1} \text{ mg g}^{-1} \text{ day}^{-1}$$

Where, W_1 = Total plant dry matter at time T_1

W_2 = Total plant dry matter at time T_2

Ln = Natural logarithm

3.15 Procedure of data collection for yield and yield components

For assessing yield parameters except the grain and straw yields data were collected from 5 randomly selected hills from each of the plots. For yield measurement, an area of 5 m^2 was harvested.

3.15. i Plant height

Plant height was measured from the soil level to the apex of the leaf or panicle in randomly 5 hills of each plot.

3.15. ii Total number of tillers hill^{-1}

The total number of tillers hill^{-1} was counted from selected samples and were grouped in effective and non effective tillers hill^{-1}.

3.15. iii Total grains panicle^{-1}

The number of filled grains panicle $^{-1}$ plus the number of sterile grains panicle $^{-1}$ gave the total number of grains panicle^{-1}.

3.15. iv Number of filled grains and sterile grains panicle^{-1}

Number of filled grains and sterile grains from randomly selected 5 hills were counted and average of which gave the number of filled grains and sterile grains panicle^{-1}. Presence of any food material in the grains was considered as filled grain and lacking of any food material in the grains was considered as sterile grains.

3.15. v Weight of 1000 grains (g)

One thousand cleaned dried grains were randomly collected from the seed stock obtained from 5 hills of each plot and were dried in an oven at 14% moisture content and weight by using an electric balance.

3.15. vi Grain and straw yield (t ha^{-1})

An area of 5 m^2 harvested for yield measurement. A sample of 500 g of both rice grain and straw from each plot was taken separately and dried in the oven at 80 ± 5^0c until a constant weight was obtained. This was done to find out the moisture percentage of grain and straw samples. The grain and straw yields were adjusted at 14% level of moisture by using the formula suggested by Abedin and Chowdhury (1982).

$$\text{\% Moisture content (MC)} = \frac{\text{Fresh weight - Ovendry weight}}{\text{Fresh weight}} \times 100$$

$$\text{So, adjusted yield plot}^{-1}\text{ at 14\% moisture content} = \frac{100 - \%MC}{86} \times W\left[100 - 14 = 86\right]$$

Were, MC = Percent moisture content of the grain or straw

W = Fresh weight of yield

The yield per hectare was then determined as follows:

$$\text{Yield (t ha}^{-1}\text{)} = \frac{\text{Adjusted yield plot}^{-1}\text{ (g)}}{\text{10 00 g x 1000 kg}}\, x \,\frac{\text{10,000 m}^2}{\text{Harvested plot area (m}^2\text{)}}$$

3.15.vii Biological yield

Biological yield was calculated by using the following formula:

Biological yield= Grain yield + straw yield

3.15.viii Harvest index (%)

Harvest index is the relationship between grain yield and biological yield (Gardner *et al.,* 1985). It was calculated by using the following formula:

$$\text{HI (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

3.16 Statistical analysis

The recorded data were subjected to statistical analysis. Analysis of variance was done following two factor randomized completed block design with the help of computer package MSTAT. The mean differences among the treatments were adjusted by least significant difference (LSD) test at 5% level of significance.

3.17 Economic analysis

From beginning to ending of the experiment, individual cost data on all the heads of expenditure in each treatment were recorded carefully and classified according to Mian and Bhuiya (1977) as well as posted under different heads of cost of production.

The rates of different items in transplanted aman rice were given in Appendix IX to XIII.

3.17.1 Input cost

Input costs were divided into two parts. These were as follows:

A. Non-material cost (labour)

The human labour was obtained from adult male labourers. Eight working hours of a labourer was considered as a man day. The animal labour was obtained from bullocks. A period of eight working hours of a pair of bullocks was taken to be an animal day. The mechanical labour came from the tractor. A period of eight working hours of a tractor was taken to be tractor day.

B. Material inputs

The seed of test rice variety (BRRI dhan 37) was purchased from BRRI Headquarter @ Tk.10 per kg. Chemical fertilizers eg. Urea, TSP, MP, Gypsum and Zinc sulphate were bought from the authorized dealer at local market. Irrigation was done from the existing facilities of irrigation system of the Sher-e-Bangla Agricultural University field. Herbicides, fungicide and insecticide were bought from the respective dealers at local market.

3.17.2 Overhead cost

The interest on input cost was calculated for 6 months @ Tk. 12.5% per year based on the interest rate of the Bangladesh Krishi Bank. The value of land varies from place to place and also from year to year. In this study, the value of land was taken Tk. 200000 per hectare. The interest on the value of land was calculated @ 12.5% per year for 2 months for nursery and 4 months for main field.

3.17.3 Miscellaneous overhead cost (common cost)

It was arbitrarily taken to be 5% of the total inputs cost. Total cost of production has been given in Appendix IX to XIII.

3.17.4 Gross return

Gross return from transplanted aman rice cultivation (Tk. ha^{-1}) = Value of grain (Tk ha^{-1}) + Value of straw (Tk ha^{-1}).

3.17.5 Net return

Net return was calculated by using the following formula:

Net return (Tk ha^{-1}) = Gross return (Tk. ha^{-1}) – Total cost of production (Tk. ha^{-1})

3.17.6 Benefit cost ratio (BCR)

Benefit cost ratio indicated whether the cultivation is profitable or not which was calculated as follows:

$$\text{Benefit cost ratio (BCR)} = \frac{\text{Gross return (Tk. per ha)}}{\text{Cost of production (Tk. per ha)}}$$

CHAPTER 4

RESULTS AND DISCUSSION

This chapter comprises presentation and discussion of the results obtained from a study to investigate the influence of integrated weed management and spacing on the growth, development and yield of transplanted aman rice cv. BRRI dhan 37. The results of the weed parameters, crop characters and economic evaluation of the production of the crop as influenced by different weed control treatments and spacings have been presented and discussed in this chapter.

4.1 Infested weed species in the experimental field

It is a general observation that conditions favourable for growing transplanted aman rice are also favourable for exuberant growth of numerous kinds of weeds that compete with crop plants. This competition of weeds tends to increase when the weed density increases. Twelve weed species belonging to seven families were found to infest the experimental crop. Local name, scientific name, family, morphological type and life cycle of the weed species have been presented in Table 2. The density and dry weight of weeds varied considerably in different weed control treatments and spacing.

The most important weeds of the experimental plot were *Sphenoclea zeylanica, Eclipta alba, Ludwigia, octovalvis, Echinochloa colona and Fimbristylis miliacea respectively.* Among the twelve species five were grasses, three were sedges and four were broad leaved (Table 2). From a survey in Boira village, Mymensingh district, Bangladesh Bari *et al.* (1995) also reported that abundance of the three important weeds of transplanted aman rice fields were *Fimbristylis miliacea, paspalum scrobiculaturm and Cyperus rotundus.* But from the same location, Mamun *et al.* (1993) reported that *Fimbristylis milicea, Lindernia antipola* and *Eriocaulen cinereesm* were important weed species of transplanted aman rice. The present results varied a little bit from those reports and these might be due to seasonal variation and different location.

Table 2. Weed species found in the experimental plots in transplanted aman rice

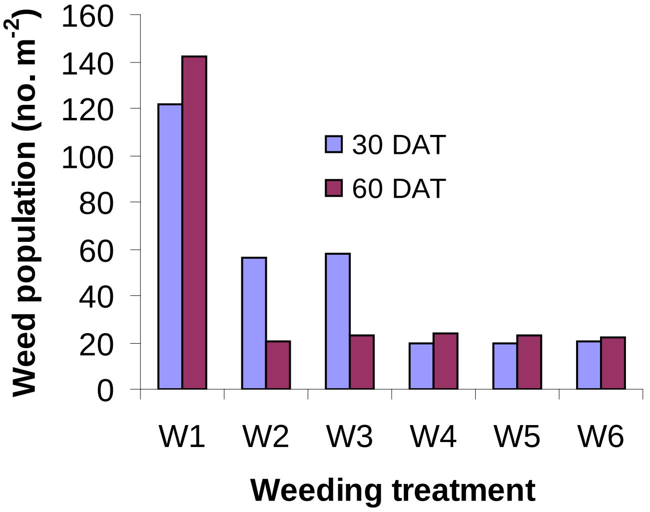
Sl. No.	Local name	Scientific name	Family	Lifecycle	Type
1.	Jhilmorich	*Sphenoclea zeylanica*	Sphenocleaceae	Annual	Broad leaf
2.	Keshuti	*Eclipta alba*	Asteraceae	Annual	Broad leaf
3.	Panilong	*Ludwigia octovalvis*	Onagraceae	Annual	Broad leaf
4.	Khude shyma	*Echinochloa colona*	Gramineae	Annual	Grass
5.	Jaina	*Fimbristylis miliacea*	Cyperaceae	Annual	Sedge
6.	Holde mutha	*Cyperus difformis*	Cyperaceae	Perennial	Sedge
7.	Pani kachu	*Monochoria vaginalis*	Pontederiaceae	Perennial	Broad leaf
8.	Chechra	*Scirpus maritimus*	Cyperaceae	Perennial	Sedge
9.	Shyma	*Echinochloa cruss-galli*	Gramineae	Annual	Grass
10.	Kakpaya	*Dactyloctenium aegyptium*	Poaceae	Annual	Grass
11.	Angata	*Paspalum scrobiculatum*	Gramineae	Perennial	Grass
12.	Arail	*Leersia hexandra*	Gramineae	Perennial	Grass

4.2 Weed density

Weed density varied considerably due to different weed control treatments (Fig. 1). At 30 DAT, the highest weed density (121.30 m^{-2}) was found in the unweeded plot (W_1) which was significantly highest than that in other treatments. Ahmed *et al.* (1997) also reported similar results. The least number of weeds were found in the herbicidal treatments along with one hand weeding each at 30 DAT. At 60 DAT, the highest weed density (142.20 m^{-2}) was found in the unweeded plot (W_1), which was significantly highest than that in other treatments. At 60 DAT, the weed density (no. m^{-2}) was sharply decreased for the treatments W_2 and W_3 but it increased for the herbicidal treatment plots. One weeding with BRRI push weeder at 15 DAT along with one hand weeding at 40 DAT (W_3) gave the second highest weed density (58.22 m^{-2}) at 30 DAT. At 60 DAT, all the treatments gave statistically similar weed density (no. m^{-2}) except the control treatment (W_1). Preemergence herbicides application along with one hand weeding resulted significantly lower weed density at 30 DAT, than that in other treatments, but thereafter weeds infestation increased in this treatment. Mechanical weeding with BRRI push weeder contributed to higher weed density at 30 DAT but when manual weeding was applied at 40 DAT weed density became lower than the earlier stage. Similar findings were also reported by Trivedi *et al.* (1986), Rekha *et al.* (2002) and Bijon (2004).

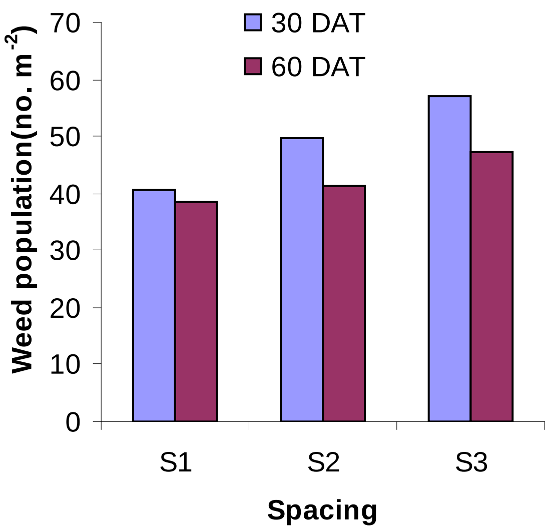
Weed density also varied considerably due to different spacings (Fig.2). At 30 DAT, the maximum weed density (57.17 m^{-2}) was found in 30cm x 20 cm spacing (S_3) that was significantly different from other spacings. The lowest weed density (40.56 m^{-2}) was found in the narrowest spacing (20 cm x 10 cm) at 30 DAT. Thereafter weed density sharply decreased at 60 DAT in all spacings. At 60 DAT the maximum weed density (47.33 m^{-2}) was found also in 30cm x 20 cm spacing which was statistically similar with other spacing. From the experimental results it was evident that wider spacing allowed more weed population and closer spacing decreased weed population per unit area. Similar results were also reported by Nurujjaman (2001).

The interaction between different weed control treatments and spacings had significant effect on weed density at 30 and 60 DAT (Table 3). At 30 DAT, the highest weed density (127.00 m^{-2}) was found in W_1S_3 treatment combination (Unweeded at 30cm x 20cm spacing) which was statistically similar to unweeded at 25cm x 15cm treatment combination (124.00 m^{-2}) and unweeded at 20cm x 10cm treatment combination (113.00 m^{-2}). Unweeded treatment resulted the highest weed density in all spacings throughout the growing season. At 60 DAT, the highest weed density (158.70 m^{-2}) was found in W_1S_3 treatment which was statistically similar to W_1S_2 and W_1S_1 treatment combinations. At 30 and 60 DAT, all the herbicidal treatments along with one hand weeding (W_4, W_5 and W_6) contributed to the lowest weed density. For the treatment combination of W_3S_3 (mechanical weeding with BRRI push weeder at 15 DAT along with one hand weeding at 40 DAT at 30cm x 20 cm spacing) contributed to the highest weed density (84.67 m^{-2}) than the other integrated weed management treatments at 30 DAT. This was happened mainly because the weeds were frequently grown in the wider spacings. But at 60 DAT, the weeds were more controlled within that treatment because the integrated approach was already imposed to that treatment. In case of manual weeding (W_2), at 30 DAT the narrower spacing (20cm x10 cm) provided much lower weed infestation than the wider spacing (25cm x 15 cm and 30cm x 20 cm). Statistically all the integrated weed management treatments contributed to the lowest weed infestation at 60 DAT in all spacings. At 60 DAT, the lowest weed density was found in W_2S_1 (hand weeding at 15 and 40 DAT at 20cm x 10 cm spacing) treatment (16.33 m^{-2}). Similar finding was also reported by Nurujjaman (2001).



Here, W_1= No weeding, W_2= Two hand weeding (HW), W_3= BRRI push weeder + 1 HW,
W_4=Butachlor + 1 HW, W_5= Oxadiazon + 1 HW, W_6= Pretilachlor + 1 HW

Fig.1. Weed density as affected by weed control treatment in transplanted aman rice (LSD 0.05 at 30 and 60 DAT were 20.14 and 13.83, respectively)



Here, S_1 = 20 cm x 10 cm, S_2 = 25 cm x 15 cm, S_3 = 30 cm x 20 cm

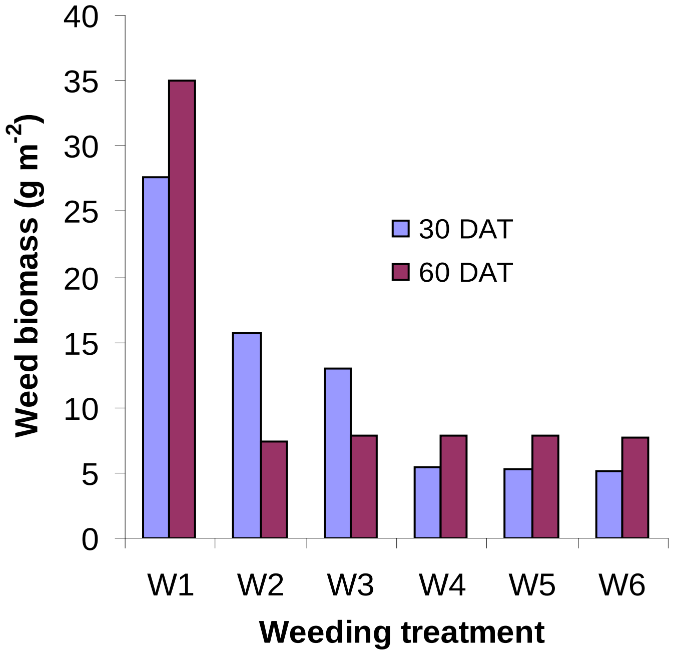
Fig. 2. Weed density as affected by spacing in transplanted aman rice
(LSD 0.05 at 30 and 60 DAT were 14.24 and 9.78, respectively)

4.3 Weed biomass

There was significant effect of weed control treatments on weed biomass over time (Fig.3). Significantly, the highest weed biomass (27.59 g m^{-2} and 35.08 g m^{-2}) were obtained in unweeded treatment at both periods (30 DAT and 60 DAT respectively). At 30 DAT all the herbicidal treatments gave significantly the lowest weed biomass compared to other treatments. But at 60 DAT all the treatments gave statistically similar results except the control one. At 30 DAT, W_6 treatment gave the lowest weed biomass (5.18 g m^{-2}) but at 60 DAT W_2 treatment gave the lowest weed biomass (7.32 g m^{-2}) compared to the other treatments. The weed biomass increased over time for the herbicidal treatment where as it was reverse for the treatment W_2 and W_3.

There was a significant variation in weed biomass due to different spacings (Fig. 4). Weed biomass increased with the increase of spacings. At 30 and 60 DAT, 30cm x 20cm spacing (S_3) gave the highest weed biomass (14.95 and 14.81 g m^{-2} respectively) which was statistically similar to S_2 (25 cm x 15 cm) spacing (12.74 and 12.04 g m^{-2} respectively). At 60 DAT, the narrowest spacing (20cm x 10 cm) gave the lowest weed biomass (8.41 and 10.02 g m^{-2}) at 30 and 60 DAT respectively.

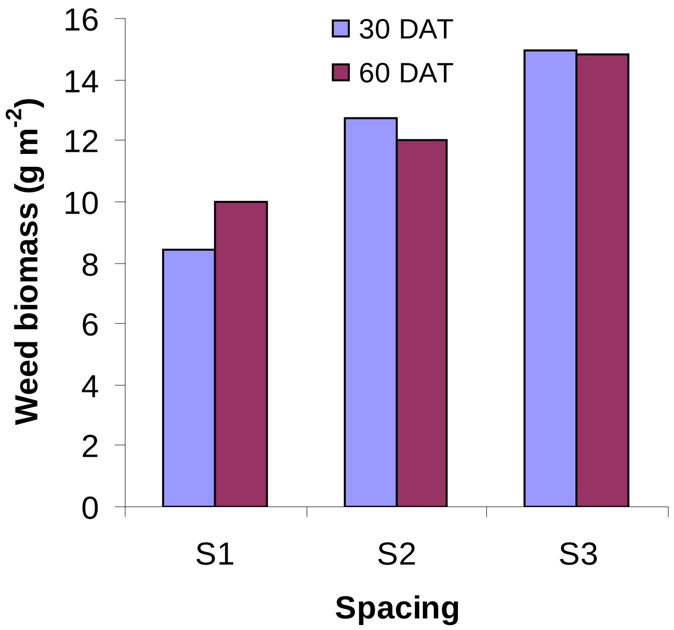
The interaction between weed control treatment and spacing had significant effect on total weed biomass over time (Table 3). AT 30 DAT, the treatment W_1S_3 (Unweeded at 30cm x 20 cm spacing) contributed to the highest weed biomass (33.23 g m^{-2}) which was statistically similar to unweeded at 25cm x 15 cm spacing (28.75 g m^{-2}) and hand weeding at 15 and 40 DAT at 30cm x 20cm (21.54 g m^{-2}) treatment combinations but was statistically higher than the biomass obtained from other treatment combinations. Similarly, at 60 DAT the treatment combination of W_1S_3 produced the highest weed biomass (40.20 g m^{-2}) which was statistically similar to W_1S_2 (36.50 g m^{-2}) but was significantly higher than the other treatment combinations while the treatment combination W_1S_1 produced the similar biomass with that of W_1S_2 which was also significantly higher than the biomass produced by the treatment combinations of different spacings with BRRI push weeder and all herbicidal treatments. All the herbicidal treatments along with one hand weeding gave the similar statistical results both at 30 and 60 DAT. Among the integrated weed management approach W_2S_3 (hand weeding at 15 and 40 DAT at 30cm x 20cm spacing) gave the highest weed biomass (21.54 g m^{-2}) at 30 DAT. Treatment combinations of W_6S_1 and W_3S_1 contributed to the lowest weed biomass (4.00 and 6.26 g m^{-2}) at 30 DAT and 60 DAT respectively.



Here, W_1= No weeding, W_2= Two hand weeding (HW), W_3= BRRI push weeder + 1 HW,

W_4=Butachlor + 1 HW, W_5= Oxadiazon + 1 HW, W_6= Pretilachlor + 1 HW

Fig. 3. Weed biomass as affected by weed control treatment in transplanted aman rice (LSD 0.05 at 30 and 60 DAT were 4.311 and 4.867, respectively)



Here, S_1 = 20 cm x 10 cm, S_2 = 25 cm x 15 cm, S_3 = 30 cm x 20 cm

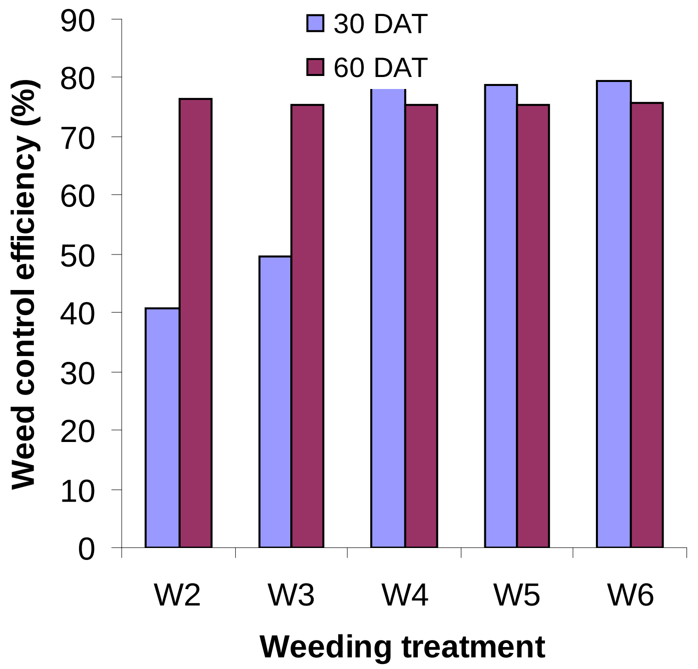
Fig. 4. Weed biomass as affected by spacing in transplanted aman rice
(LSD 0.05 at 30 and 60 DAT were 3.048 and 3.442, respectively)

4.4 Weed control efficiency (WCE)

Integrated weed management (W_4, W_5 and W_6) had a significant effect for controlling weeds at 30 DAT but at 60 DAT all the approaches had no significant effect for controlling weeds (Fig 5). At 30 DAT, all the herbicidal treatments had significantly greater effect in controlling weeds over control treatment. The highest weed control efficiency (79.53%) was obtained from W_6 treatment which was statistically similar to the other herbicidal treatments but significantly higher than W_2 and W_3 treatments. At 60 DAT, the highest WCE (75.65%) was obtained from W_6 treatment although there were no significant differences among the treatments.

There were no significant differences among the spacings for WCE. Numerically at 30 DAT, treatment S_3 gave the maximum WCE (55.3%) among the spacings but at 60 DAT treatment S_2 gave the maximum WCE (64.06 %) among the spacings (Fig 6).

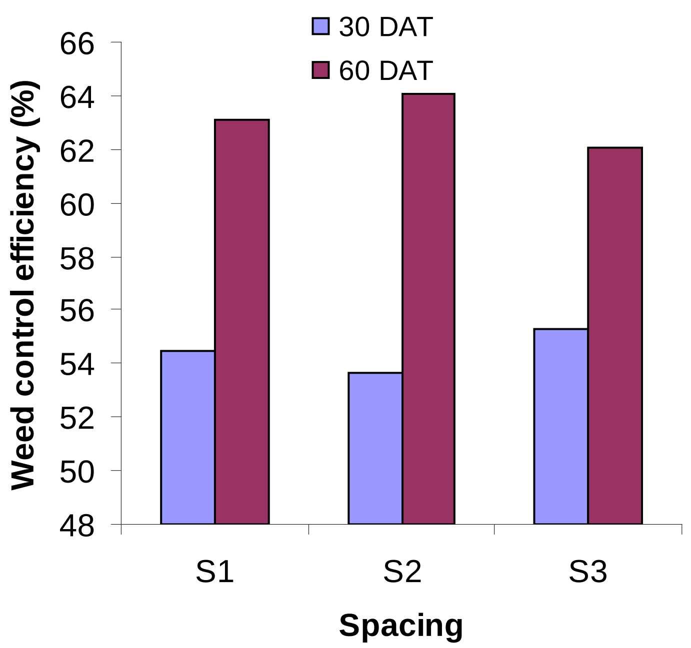
Among the treatment combinations, W_6S_2 (preemergence application of Rifit 500 EC (Pretailachlor) @ 970 ml ha^{-1} at 5 DAT along with one hand weeding at 40 DAT at 25cm x 15 cm spacing) gave significantly the highest WCE (81.31%) which was statistically similar to WCE obtained from all other herbicidal treatments along with one hand weeding each at different spacing (Table 3) and also to the treatment combination of W_3S_2 (57.62%) but was higher than WCE of other treatment combinations. Treatment W_2S_2 (two hand weeding at 15 and 40 DAT at 25cm x 15 cm spacing) gave the lowest WCE (23.07%) at 30 DAT. At 60 DAT, there had no significant differences among the treatment combinations. Treatment combination W_2S_1 (Two hand weeding at 20 and 40 DAT at 20cm x 10 cm spacing) contributed to the highest WCE (78.82%) among the treatments.



Here, W_1= No weeding, W_2= Two hand weeding (HW), W_3= BRRI push weeder + 1 HW,

W_4=Butachlor + 1 HW, W_5= Oxadiazon + 1 HW, W_6= Pretilachlor + 1 HW

Fig. 5. Weed control efficiency as affected by weed control treatment in transplanted aman rice (LSD 0.05 at 30 and 60 DAT were 13.96 and 5.786, respectively)



Here, S_1 = 20 cm x 10 cm, S_2 = 25 cm x 15 cm, S_3 = 30 cm x 20 cm

Fig. 6. Weed control efficiency as affected by spacing in transplanted aman rice (LSD 0.05 at 30 and 60 DAT were 9.868 and 4.092, respectively)

Table 3. Interaction effect of different weed management and spacing on weed density, weed biomass and weed control efficiency in transplanted aman rice.

Treatments	Weed density (no. m $^{-2}$)		Weed biomass (g m $^{-2}$)	
	30 DAT	60 DAT	30 DAT	60 DAT
$W_1 S_1$	113.00	125.00	20.80	28.54
$W_1 S_2$	124.00	143.00	28.75	36.50
$W_1 S_3$	127.00	158.70	33.23	40.20
$W_2 S_1$	36.67	16.33	8.38	5.49
$W_2 S_2$	63.67	20.67	17.28	6.98
$W_2 S_3$	67.33	24.67	21.54	9.51
$W_3 S_1$	43.00	17.67	8.63	6.26
$W_3 S_2$	47.00	23.33	10.51	7.30
$W_3 S_3$	84.67	27.00	19.76	10.05
$W_4 S_1$	17.00	24.00	4.50	6.72
$W_4 S_2$	20.67	20.00	5.08	7.09
$W_4 S_3$	21.33	26.67	6.58	9.74
$W_5 S_1$	18.00	24.33	4.18	6.58
$W_5 S_2$	20.00	20.67	5.53	7.23
$W_5 S_3$	21.33	24.33	6.32	9.73
$W_6 S_1$	15.67	23.67	4.00	6.54
$W_6 S_2$	23.33	21.00	5.01	7.14
$W_6 S_3$	21.33	22.67	6.54	9.61
LSD 0.05	34.88	23.96	7.47	8.43
CV (%)	12.76	14.03	11.39	11.34

Here, W_1= No weeding, W_2= Two hand weeding (HW), W_3= BRRI push weeder + 1 HW, W_4=Butachlor + 1 HW, W_5= Oxadiazon + 1 HW, W_6= Pretilachlor + 1 HW and S_1 = 20 cm x 10 cm, S_2 = 25 cm x 15 cm, S_3 = 30 cm x 20 cm

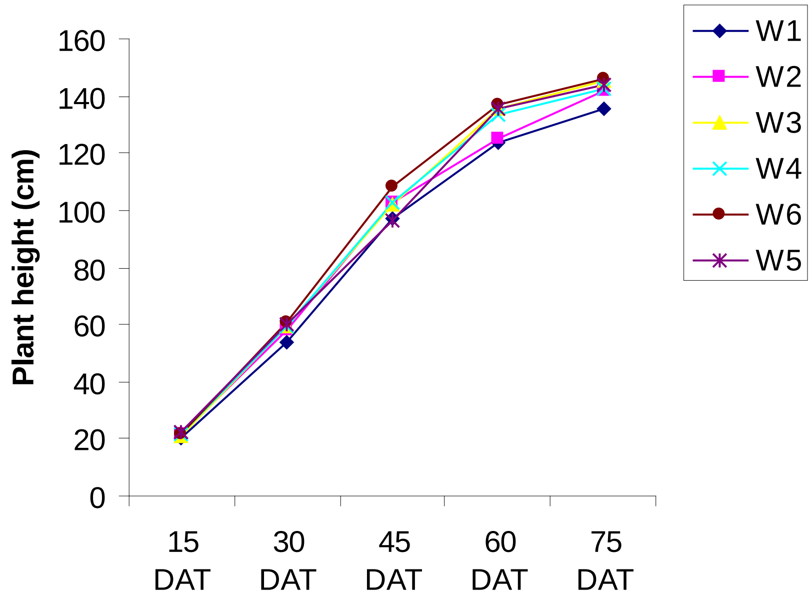
4.5 Crop growth parameters

4.5.1 Plant height

The height of the plant was significantly influenced by different weed control treatments during the periods from 15 DAT to 75 DAT except at 45 DAT. The Fig.7 showed that W_6 treatment produced the tallest plant in all dates of sampling except at 15 DAT and attained to its highest value (146.10 cm) at 75 DAT. The lowest plant height was observed at every sampling period in no weeding treatment (W_1) which was significantly inferior to rest of the weed control treatments except at 45 DAT. All the treatments except W_1 and W_2 gave statistically similar results at 60 DAT. Results indicated that heavy weed infestation in the no weeding treatment might hamper the normal growth and development of rice plant and ultimately plants became shorter. Similar findings were also observed by Toufiq (2003) and Attalla and Kholosy (2002).

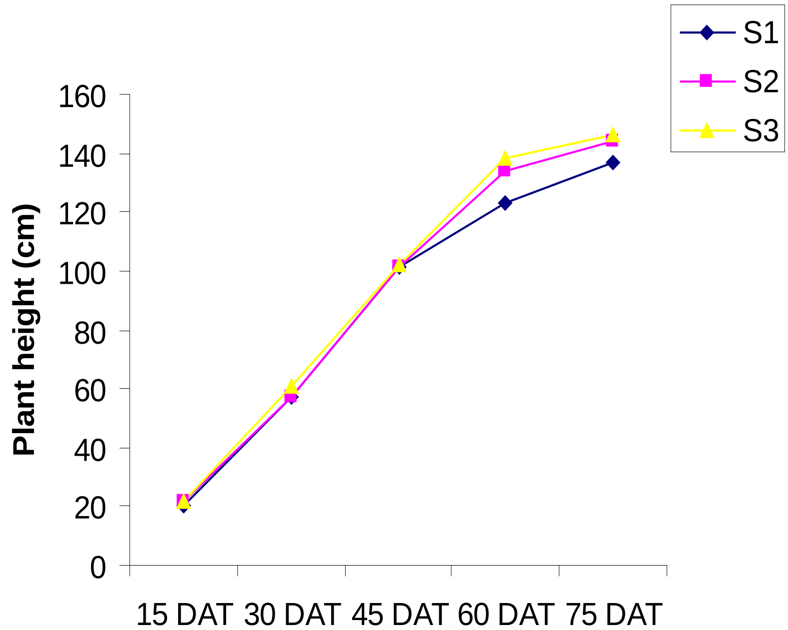
The plant height varied significantly due to different spacings during the periods from 15 DAT to 75 DAT except at 45 DAT (Fig 8). Plant height increased with the advancement of crop duration and with wider spacing. It was observed that at 75 DAT the widest spacing 30 cm x 20 cm produced the tallest plant stature (146.60 cm) and the closest spacing 20cm x 10cm produced the shortest plant stature (136.80 cm). It might be due to the fact that widely spaced plants absorbed more light, air, moisture and nutrient which facilitated the plant to fully developed. Ayub *et al.* (1987) in an experiment with fine rice stated that the plant height increased with low plant density. Similar findings was also observed by Nurujjaman (2001).

Interaction effect of plant spacing and different weed control treatments had significant effect on plant height (Table 4). Plant height increased over time in all the treatment combinations of weed control and plant spacing. In most of the cases the unweeded plot with all spacings (W_1S_1, W_1S_2 and W_1S_3) obtained the lowest plant height over days upto 75 DAT. For instance it might be mentioned here that against the treatment combination of W_1S_1 the plant height obtained were 19.83, 53.03, 96.98, 118.20 and 133.40 cm at 15, 30, 45, 60 and 75 DAT respectively. The treatment W_6S_3 contributed to almost highest plant height (110.50, 141.70 and 149.40 cm) from 45 DAT to 75 DAT. From the result it was clear that the integrated weed control treatments contributed to the maximum plant height at 25 cm x 15 cm and 30 cm x 20 cm spacings and lowest plant height at narrower spacing of 20 cm x 10 cm. Similar finding was also observed by Nurujjaman (2001).



Here, W_1= No weeding, W_2= Two hand weeding (HW), W_3= BRRI push weeder + 1 HW,
W_4=Butachlor + 1 HW, W_5= Oxadiazon + 1 HW, W_6= Pretilachlor + 1 HW

Fig.7. Plant height as affected by weed control treatment in transplanted aman rice
(LSD 0.05 at 15,30,45,60 and 75 DAT were 0.89, 3.35, 13.17, 5.23 and 3.91, respectively)



Here, S_1 = 20 cm x 10 cm, S_2 = 25 cm x 15 cm, S_3 = 30 cm x 20 cm

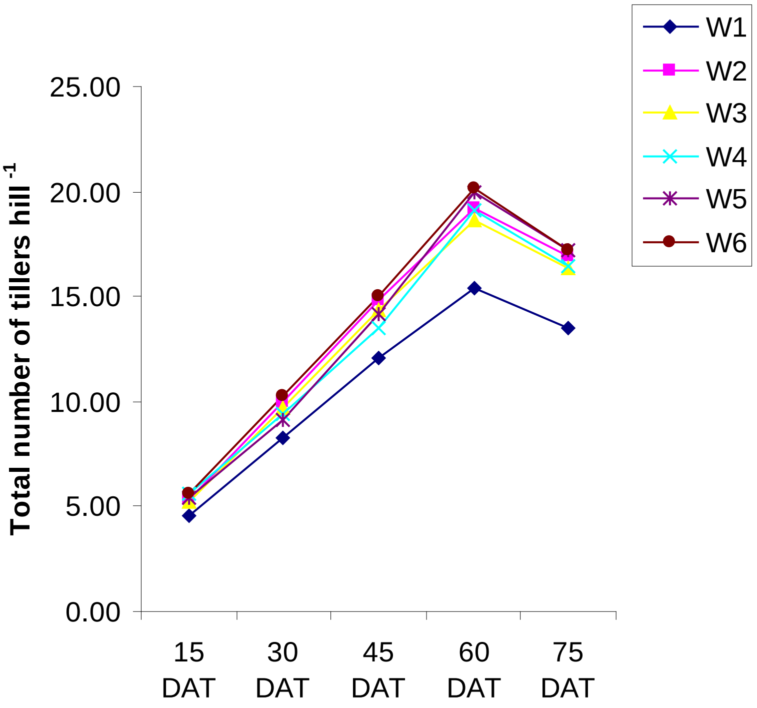
Fig. 8. Plant height as affected by spacing in transplanted aman rice
(LSD 0.05 at 15,30,45,60 and 75 DAT were 0.63, 2.34, 9.31, 3.70 and 2.76, respectively)

4.5.2 Total tillers hill^{-1}

Different weed control treatments affected tiller production significantly. Tillers hill^{-1} increased gradually upto 60 DAT and then decreased in the all weed control treatments due to mortality of ineffective tillers at later stages (Fig. 9). Incase of unweeded treatment (W_1) tillers hill^{-1} decreased dramatically after 60 DAT, it might be due to high crop weed competition for light and nutrients. All weed control treatments contributed to significantly higher number of tillers hill^{-1} than unweeded and that trend continued throughout the growing period. At 60 DAT the highest number of tiller hill^{-1}(20.13) was found in W_6 (Pretilachlor + one hand weeding) treatment which was statistically similar to 19.99, 19.07, 18.64, 19.16 obtained from the treatments W_5, W_4, W_3 and W_2 respectively but was significantly higher than W_1 (unweeded) treatment (15.44).

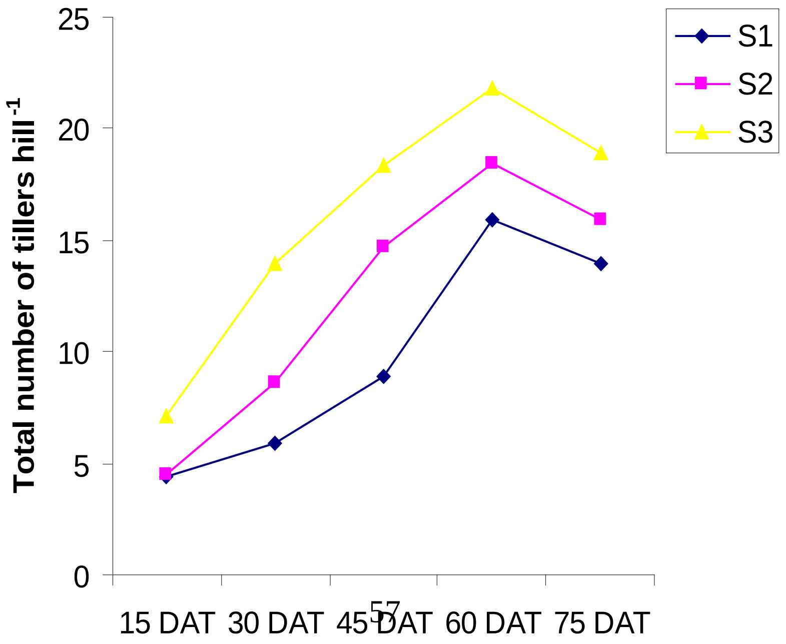
Plant spacing had a highly significant effect on the formation of total tillers hill^{-1}. Total number of tillers hill^{-1} as influenced by different spacings has been shown in Fig. 10. There was a gradual trend of increasing number of tillers hill^{-1} with the widening of the spacing. All spacings used in the experiment produced highest number of tillers hill^{-1} at 60 DAT but it was reduced after that. Out of three plant spacings, the widest spacing 30cm x 20 cm produced the highest total number of tillers hill^{-1} over time and reached at peak (21.84) at 60 DAT while the closest spacing 20 cm x 10 cm possessed the lowest total number of tillers hill^{-1} (15.87) at the same DAT. This was perhaps due to the fact that the widely spaced plants absorbed more light, water and nutrient elements which facilitated the plant to produce more number of tillers hill^{-1}. Haque and Nasiruddin (1988) and Khalil (2001) also observed that wider spacing produced higher number of total tillers hill^{-1}.

The interaction effect of different weed control treatments and spacing significantly influenced the number of total tillers hill^{-1} at different DAT (Table 4). The widest spacing 30 cm x 20cm in each weed control treatment had the highest total tillers hill^{-1} at each sampling period and it reached maximum at 60 DAT and afterwards it declined with the advancement of crop growth duration. On the contrary, the closest spacing (S_1) in combination with all weeding treatments produced the lowest number of tillers hill^{-1} at each period except 15 DAT where S_2 produced the lowest. At 15 DAT significantly the highest total tillers hill^{-1} (7.27) was observed in the treatment combination of W_6S_3 which increased upto 23.73 at 60 DAT while the lowest total tillers hill^{-1} (3.87) was found in W_1S_2 at 15 DAT which increased upto



Here, W_1= No weeding, W_2= Two hand weeding (HW), W_3= BRRI push weeder + 1 HW,
W_4=Butachlor + 1 HW, W_5= Oxadiazon + 1 HW, W_6= Pretilachlor + 1 HW

Fig. 9. Total number of tillers hill^{-1} as affected by weed control treatment in transplanted aman rice (LSD 0.05 at 15,30,45,60 and 75 DAT were 0.5334, 0.649, 1.204, 1.521 and 0.9464, respectively)



Here, S_1 = 20 cm x 10 cm, S_2 = 25 cm x 15 cm, S_3 = 30 cm x 20 cm

Fig. 10. Total number of tillers hill^{-1} as affected by spacing in transplanted aman rice (LSD 0.05 at 15,30,45,60 and 75 DAT were 0.3772, 0.4589, 0.8515, 1.075 and 0.6692, respectively)

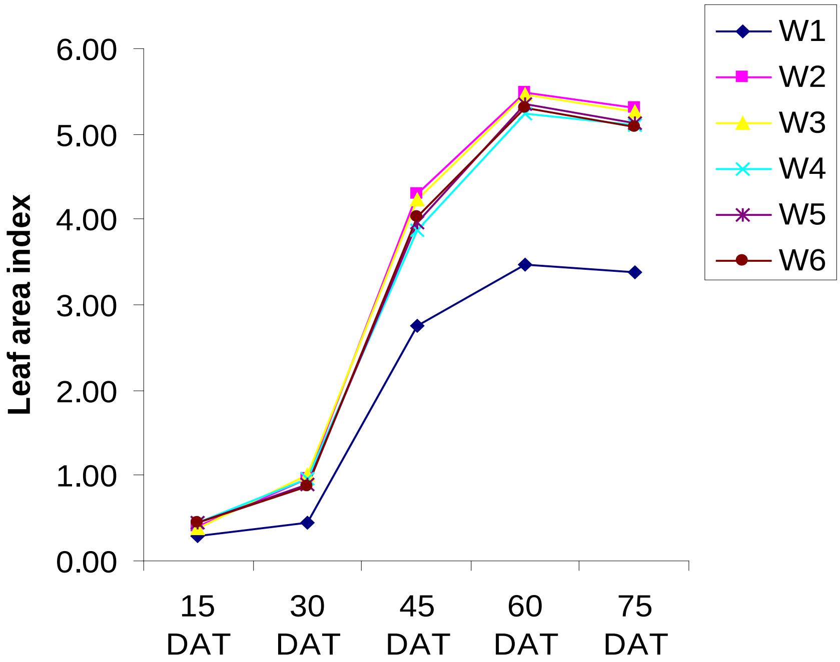
15.60 at 60 DAT. The highest number of tillers hill^{-1} (23.73) which was produced by the treatment W_6 (Pretilachlor) in combination with the widest spacing S_3 was found to be similar with 23.33, 22.93 and 22.6 total tillers hill^{-1} observed in W_5 (Oxadiazon + 1 hand weeding), W_3 (BRRI push weeder + 1 hand weeding) and W_4 (Butachlor + 1 hand weeding) in combination with the widest spacing (S_3) respectively.

4.5.3 Leaf area index (LAI)

The rice crop under the experiment reached maximum LAI at 60 DAT. Weed control treatments showed significant variations in LAI throughout the growing periods. LAI increased upto 60 DAT for all weed control treatments and then decreased gradually (Fig 11). AT 15 DAT, W_6 treatment gave the highest LAI (0.45) which was statistically similar to other treatment except W_1. At 30 DAT, W_3 treatment gave the highest LAI (1.01) which was statistically similar with W_2 and W_4 but significantly different from W_5 and W_6. At 45, 60 and 75 DAT, W_2 treatment gave the highest LAI (4.30, 5.49 and 5.30 respectively). In all cases unweeded treatment gave the lowest LAI.

The results showed that LAI was significantly influenced by spacing in all dates of sampling (Fig. 12). In all growth stages, the spacing 25 cm x 15 cm produced the highest LAI viz. 0.44, 0.93, 4.17, 5.41 and 5.21 which were significantly higher than the corresponding LAI viz. 0.36, 0.94, 3.52, 4.67 and 4.50 obtained at 15, 30, 45, 60 and 75 DAT respectively from the closest spacing 20cm x 10cm (S_1) but they were similar to their corresponding LAI of 0.41 and 0.92 obtained at 15 and 30 DAT respectively but superior to 3.89, 5.08 and 4.91 obtained at 45, 60 and 75 DAT respectively produced by the widest spacing 30cm x 20cm (S_3). LAI increased with the advancement of growth duration until 60 DAT. However, it was reduced after that. Leaf area index increased linearly and the highest LAI obtained at booting stage and then it decreased due to faster leaf senescence in the densely populated stands.

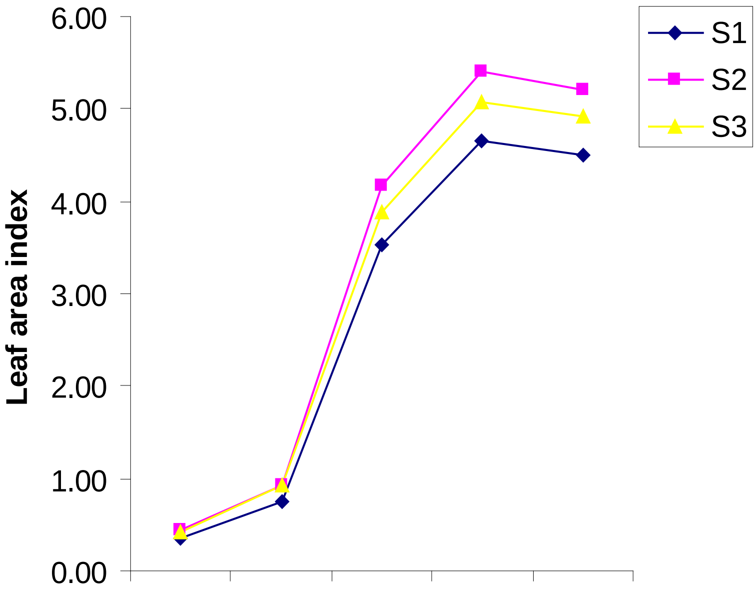
The interaction of different weed management and spacing had significant effect on LAI at all dates of observations (Table 4). Unweeded treatment in combination with all spacings produced the lowest LAI. Maximum LAI was found in all treatment combinations at 60 DAT. AT 60 DAT, the highest LAI (6.05) was found in W_3S_3 treatment which was statistically similar to W_2S_2 and W_6S_2 treatments (5.97 and 5.90 respectively). This result indicated that widest spacing 30cm x 20 cm responded more to BRRI push weeder and hand weeding contributed to higher leaf area development.



Here, W_1= No weeding, W_2= Two hand weeding (HW), W_3= BRRI push weeder + 1 HW,

W_4=Butachlor + 1 HW, W_5= Oxadiazon + 1 HW, W_6= Pretilachlor + 1 HW

Fig.11. Leaf area index (LAI) as affected by weed control treatment in transplanted aman rice (LSD 0.05 at 15,30,45,60 and 75 DAT were 0.04284, 0.05247, 0.2206, 0.1285 and 0.2285 respectively)



Here, S_1 = 20 cm x 10 cm, S_2 = 25 cm x 15 cm, S_3 = 30 cm x 20 cm

Fig.12. Leaf area index as affected by spacing in transplanted aman rice
(LSD 0.05 at 15,30,45,60 and 75 DAT were 0.03029, 0.0371, 0.156, 0.09088 and 0.09088 respectively)

Table 4. Interaction effect of different weed management and spacing on different growth attributes of transplanted aman rice.

Treatments	Plant height (cm)					Total number of tillers hill^{-1}					LAI				
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT
$W_1 S_1$	19.83	53.03	96.98	118.20	133.40	4.00	5.6	8.73	14.17	12.90	0.26	0.38	2.58	3.32	3.20
$W_1 S_2$	21.61	52.05	88.45	116.50	130.00	3.87	7.8	12.40	15.60	13.63	0.32	0.50	3.08	3.81	3.68
$W_1 S_3$	19.23	55.90	106.20	137.30	142.40	5.87	11.33	15.13	16.57	13.97	0.28	0.49	2.64	3.31	3.25
$W_2 S_1$	20.19	55.95	99.09	115.00	133.50	4.30	6.33	10.60	17.07	14.77	0.38	0.83	4.15	5.19	5.01
$W_2 S_2$	22.01	56.33	102.50	128.60	144.90	4.53	9.27	15.53	18.50	16.07	0.46	0.96	4.61	5.97	5.73
$W_2 S_3$	22.01	60.67	106.80	131.80	147.70	7.20	14.40	18.47	21.90	19.83	0.34	1.10	4.13	5.30	5.15
$W_3 S_1$	21.05	59.35	103.60	129.80	141.90	4.33	6.60	9.47	14.93	13.17	0.35	0.86	3.69	4.92	4.77
$W_3 S_2$	20.48	55.98	95.98	139.10	147.50	4.73	8.60	14.67	18.07	15.33	0.44	1.07	4.41	5.43	5.23
$W_3 S_3$	20.46	63.38	106.10	137.40	146.30	6.73	14.00	18.93	22.93	20.47	0.36	1.10	4.63	6.05	5.79
$W_4 S_1$	19.65	55.30	99.28	122.90	134.70	4.87	5.73	7.40	16.47	14.00	0.39	0.82	3.43	4.91	4.79
$W_4 S_2$	22.20	60.97	103.60	138.00	145.90	4.13	7.40	14.27	18.13	16.30	0.46	1.06	4.18	5.57	5.42
$W_4 S_3$	23.03	62.23	105.70	139.50	147.60	7.80	15.13	18.90	22.60	19.10	0.48	1.01	3.99	5.21	5.08
$W_5 S_1$	20.87	59.18	105.20	126.30	137.70	4.33	5.33	8.40	16.90	14.83	0.39	0.77	3.58	4.92	4.73
$W_5 S_2$	22.4	58.93	108.3	139.8	148.6	4.40	8.20	15.00	19.73	16.39	0.47	0.99	4.42	5.80	5.54

	7		0	0	0										
W_5 S_3	23.20	61.10	76.03	140.80	146.00	7.60	13.73	19.00	23.33	20.40	0.50	0.94	3.91	5.35	5.12
W_6 S_1	20.69	61.43	104.50	128.10	139.70	4.33	5.67	8.67	15.80	14.23	0.40	0.79	3.70	4.74	4.51
W_6 S_2	22.80	59.50	109.00	141.80	149.20	5.17	10.13	16.47	20.87	17.90	0.46	0.97	4.33	5.90	5.62
W_6 S_3	22.00	61.67	110.50	141.70	149.40	7.27	14.93	19.93	23.73	19.60	0.50	0.89	4.04	5.28	5.08
LSD 0.05	1.55	5.80	22.81	9.06	6.77	0.92	1.12	2.09	2.63	1.64	0.074	0.091	0.382	0.223	0.223
CV (%)	4.37	5.98	13.53	4.14	4.86	10.49	7.17	8.98	8.47	6.07	4.99	5.97	5.17	4.68	4.76

Here, W_1= No weeding, W_2= Two hand weeding (HW), W_3= BRRI push weeder + 1 HW, W_4=Butachlor + 1 HW, W_5= Oxadiazon + 1 HW, W_6= Pretilachlor + 1 HW and

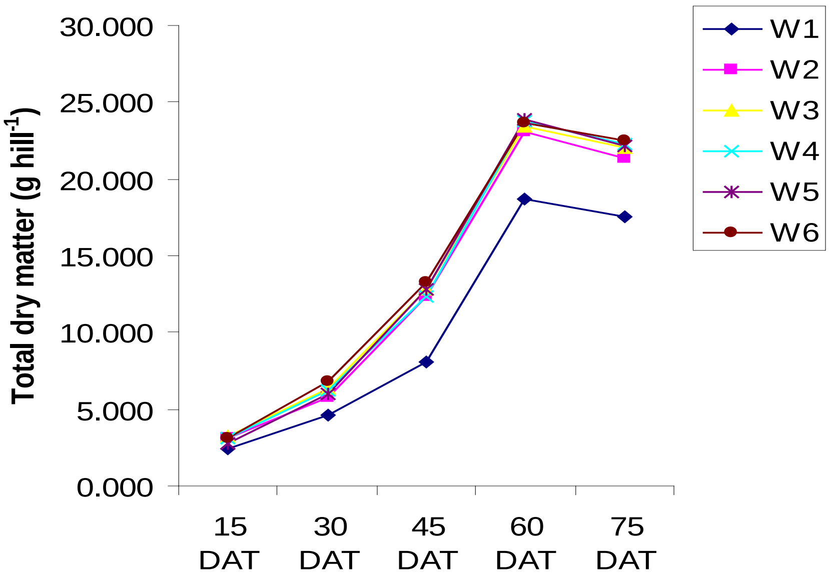
S_1 = 20 cm x 10 cm, S_2 = 25 cm x 15 cm, S_3 = 30 cm x 20 cm

4.5.4 Total dry matter hill^{-1}

Total dry matter (TDM) increased exponentially with time. TDM was significantly affected by different weed control treatments (Fig.13). From the early stages distinct differences were visible among the weed control treatments in TDM production. The TDM production was increased upto 60 DAT and after that it declined due to tiller mortality. The lowest TDM throughout the growing period was observed in unweeded treatment (W_1). All of the integrated weed managements gave statistically similar results from 15 DAT to 75 DAT except W_2 treatments at 30, 45, 60 and 75 DAT, W_3 treatment at 60 and 75 DAT, W_4 treatment at 30 and 45 DAT and W_5 treatment at 30 and 75 DAT.

The results showed that TDM hill^{-1} was significantly influenced by spacing except at 15 DAT. TDM hill^{-1} was gradually increased with the widening of the spacing (Fig. 14). TDM was increased upto 60 DAT and then it declined due to tiller mortality. At 60 DAT, TDM production was highest (24.53 g hill^{-1}) by the widest spacing (30 cm x 20 cm) which was statistically superior to other spacings. Spacing 25 cm x 15 cm produced the second highest TDM (23.80 g hill^{-1}). Higher TDM were mainly contributed by higher number of tillers hill^{-1}, higher number of leaves plant^{-1} and tallest plant stature which were influenced by spacing.

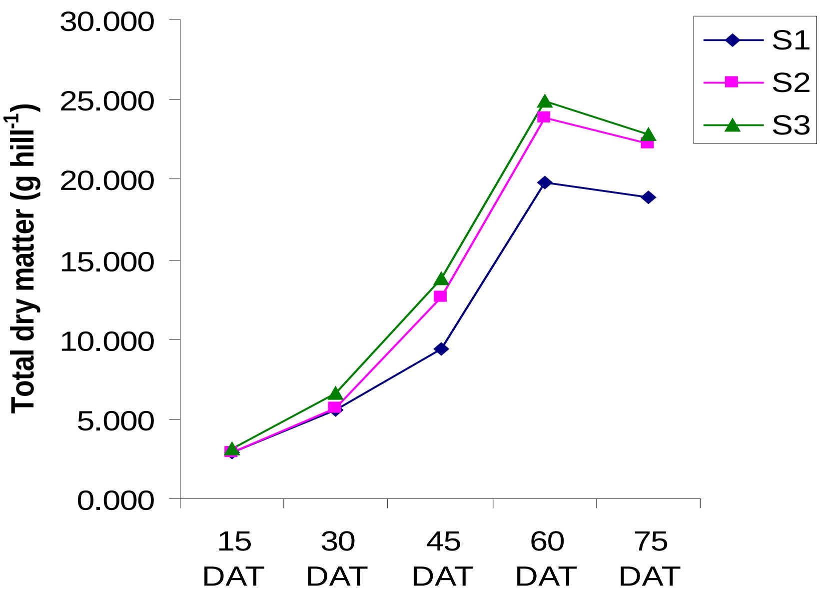
The interaction of weed control treatments and spacing had significant effect on TDM production throughout the growing period (Table 5). All the weed control treatments gave higher TDM over time at the widest spacing and gave lower TDM at closer spacing except the W_4S_1 treatment at 15 DAT. The W_3S_3 treatment produced the higher TDM from 30 DAT to 75 DAT (8.16, 15.95, 26.33 and 24.65 g hill^{-1} respectively). It might be due to the the luxuriant growth of weeds upto 15 DAT in the treatment plot was well controlled by BRRI push weeder.



Here, W_1= No weeding, W_2= Two hand weeding (HW), W_3= BRRI push weeder + 1 HW,

W_4=Butachlor + 1 HW, W_5= Oxadiazon + 1 HW, W_6= Pretilachlor + 1 HW

Fig.13. Total dry matter (TDM) as affected by weed control treatment in transplanted aman rice (LSD 0.05 at 15,30,45,60 and 75 DAT were 0.57, 0.54, 0.53, 0.39 and 0.32 respectively)



Here, S_1 = 20 cm x 10 cm, S_2 = 25 cm x 15 cm, S_3 = 30 cm x 20 cm

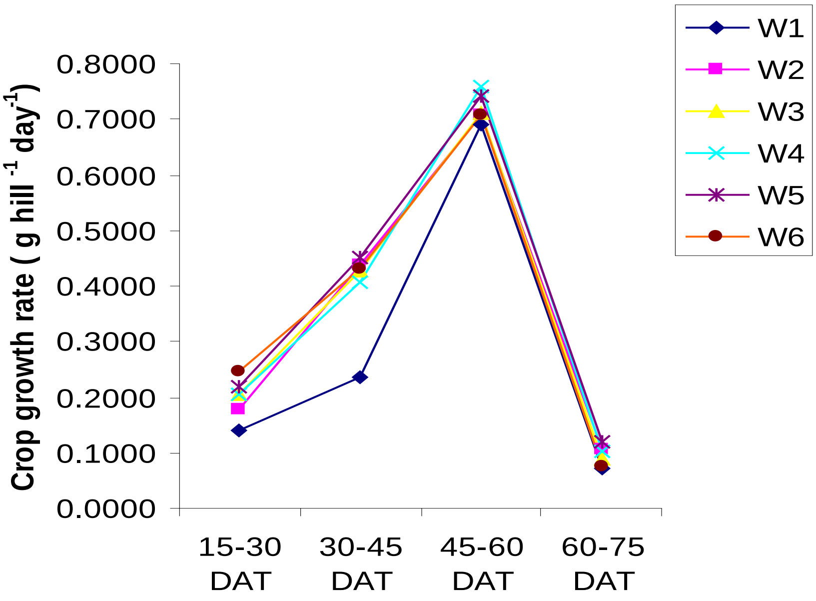
Fig.14. Total dry matter (TDM) as affected by weed control treatment in transplanted aman rice (LSD 0.05 at 15,30,45,60 and 75 DAT were 0.40, 0.38, 0.38, 0.27 and 0.22 respectively)

4.5.5 Crop growth rate (CGR)

The growth rate of rice crop was significantly influenced by different weed control treatments over time except at 60-75 DAT. Unweeded treatment showed the lowest CGR throughout the growing period. It revealed that severe weed infestation might hampered the growth and development of rice plants drastically (Fig.15). At 15-30 DAT, the treatment W_6 gave the highest CGR (0.25 g hill^{-1} day^{-1}) which was statistically similar to other weed control treatments except W_2. At 30-45 DAT, all the weed control treatments contributed to the superior CGR over the control treatment and treatment W_5 gave the highest CGR (0.45 g hill^{-1} day^{-1}). At 45-60 DAT, treatment W_4 gave the highest CGR (0.76 g hill^{-1} day^{-1}) which was statistically similar to W_5 treatment (0.74 g hill^{-1} day^{-1}). From the results, it was seen that the higher CGR was obtained from 45-60 DAT and then it declined. It might be due to the late season weed infestation which put adverse impact on CGR.

It was observed that CGR was always higher at wider spacing compared to those of closer spacings during the period from 15-30 DAT to 30-45 DAT (Fig.16). This result was similar with the findings of Yoshida (1981) and Khalil (2001) who reported that CGR values were higher when planted at wider spacing. But during the period from 45-60 DAT to 60-75 DAT, treatment S_2 gave the highest CGR (0.7417 and 0.1065 g hill^{-1} day^{-1} respectively) which was statistically similar to S_3 treatment. The CGR was at the peak during the period from 45-60 DAT and after that it declined. Wider spaced plants received more nutrients, moisture and light to promote crop growth rate.

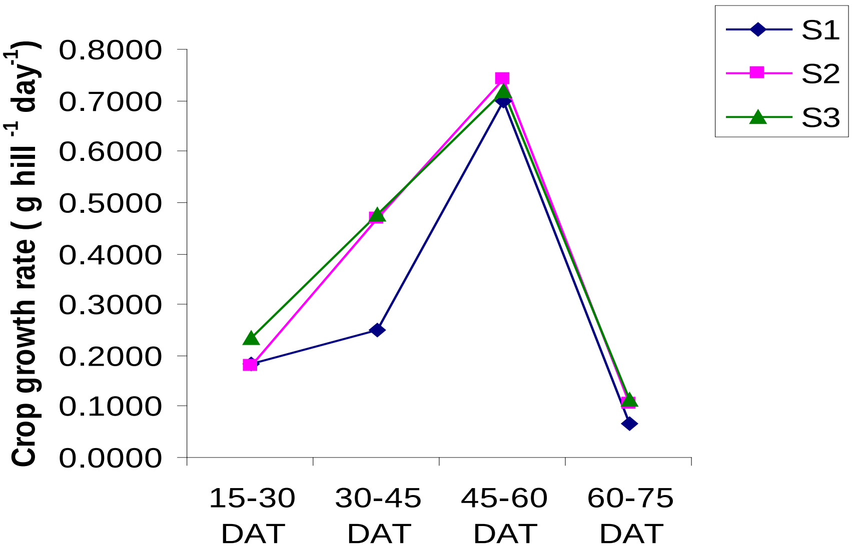
The interaction of weed control treatments and spacing significantly influenced the CGR throughout the growing period (Table 5). In most of the treatment combinations, CGR increased gradually upto 45-60 DAT and then declined. At the beginning of the crop growth (15-30 DAT), W_3S_3 showed the highest CGR (0.328 g hill^{-1} day^{-1}). At 30-45 DAT, W_3S_2 showed the highest CGR (0.585 g hill^{-1} day^{-1}). At 45-60 DAT, W_2S_2 gave the highest CGR (0.800 g hill^{-1} day^{-1}) among all the treatment combinations. It implied that several integrated weed management effectively controlled the weeds in wider spacing than the narrower spacing.



Here, W_1= No weeding, W_2= Two hand weeding (HW), W_3= BRRI push weeder + 1 HW,

W_4=Butachlor + 1 HW, W_5= Oxadiazon + 1 HW, W_6= Pretilachlor + 1 HW

Fig.15. Crop growth rate (CGR) as affected by weed control treatment in transplanted aman rice (LSD 0.05 at 15-30, 30-45, 45-60 and 60-75 DAT were 0.525, 0.428, 0.043 and 0.052, respectively)



Here, S_1 = 20 cm x 10 cm, S_2 = 25 cm x 15 cm, S_3 = 30 cm x 20 cm

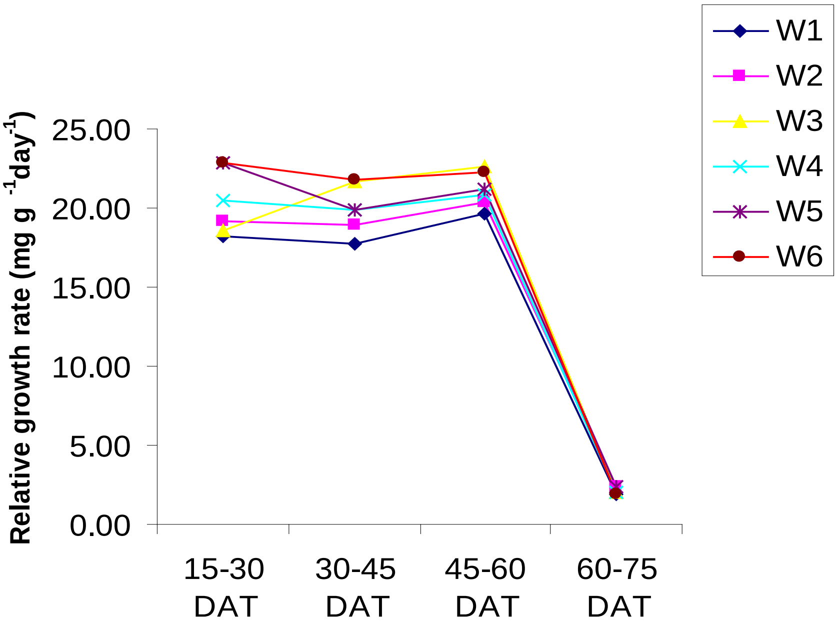
Fig.16. Crop growth rate (CGR) as affected by weed control treatment in transplanted aman rice (LSD 0.05 at 15-30, 30-45, 45-60 and 60-75 DAT were 0.371, 0.303, 0.030 and 0.037, respectively)

4.5.6 Relative growth rate (RGR)

Relative growth rate was significantly affected by different weed control treatments over time except at 15-30 DAT. At 30-45 DAT, W_6 treatment gave the highest RGR (21.80 mg hill^{-1} day^{-1}) which was statistically similar to the other treatments. At 45-60 DAT, W_3 treatment gave the highest RGR (22.61 mg hill^{-1} day^{-1}) which was statistically similar to the herbicidal treatments. RGR increased upto 45-60 DAT and then it declined sharply (Fig.17). The highest RGR value (22.61 mg hill^{-1} day^{-1}) at 45-60 DAT came down to 2.02 mg hill^{-1} day^{-1} at 60-75 DAT. At 60-75 DAT RGR ranged from 1.87 to 2.34 mg hill^{-1} day^{-1}. It revealed that weeds affected RGR of transplanted aman rice in the later stages of the crop. A similar finding was also reported by Ahmed *et al.* (1997).

RGR was significantly affected by spacing during the period from 30-45 DAT to 60-75 DAT. RGR was not significantly affected by spacing at the beginning stage (15-30 DAT) of the crop (Fig.18). At 45-60 DAT, treatment S_3 gave the highest RGR (23.42 mg hill^{-1} day^{-1}) over other treatments. The lowest RGR (18.63 mg hill^{-1} day^{-1}) was recorded from the spacing S_1at 45-60 DAT which was inferior to S_2 treatment (21.61 mg hill^{-1} day^{-1}). At 60-75 DAT, RGR declined sharply over all the spacings. At this period treatment S_3 gave the highest RGR (2.47 mg hill^{-1} day^{-1}) which was statistically similar to S_2 treatment (2.30 mg hill^{-1} day^{-1}).

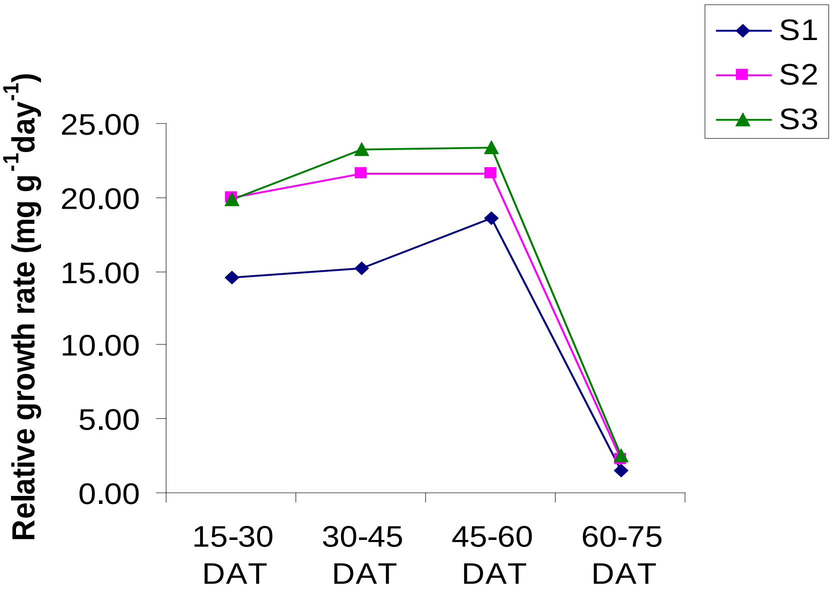
The interaction between the weed control treatments and spacing significantly influenced RGR in all dates of observations. During 15-30 DAT, highest RGR (26.70 mg hill^{-1}day^{-1}) was found by the treatment W_3S_3. During 30-45 DAT, highest RGR (26.17 mg hill^{-1}day^{-1}) was found by the treatment W_2S_3. During 45-60 DAT, highest RGR (25.25 mg hill^{-1} day^{-1}) was found in the treatment W_3S_3. The initial high rate of RGR during the period of 15-30 DAT and 30-45 DAT was observed from the results (Table 5). This might be due to the rapid tiller emergence of the crop during this period. A growing organ is consumer of photosynthate and RGR is balanced between sources and sink (Khan *et al.* 1981).



Here, W_1= No weeding, W_2= Two hand weeding (HW), W_3= BRRI push weeder + 1 HW,

W_4=Butachlor + 1 HW, W_5= Oxadiazon + 1 HW, W_6= Pretilachlor + 1 HW

Fig.17. Relative growth rate (RGR) as affected by weed control treatment in transplanted aman rice (LSD 0.05 at 15-30, 30-45, 45-60 and 60-75 DAT were 6.47, 3.08, 1.93 and 0.33, respectively)



Here, S_1 = 20 cm x 10 cm, S_2 = 25 cm x 15 cm, S_3 = 30 cm x 20 cm

Fig.18. Relative growth rate (RGR) as affected by weed control treatment in transplanted aman rice (LSD 0.05 at 15-30, 30-45, 45-60 and 60-75 DAT were 4.58, 2.18, 1.37 and 0.24, respectively)

Table 5: Interaction effect of different weed management and spacing on different growth attributes of transplanted aman rice.

Treatment	Total dry matter (g hill^{-1})					CGR (g hill^{-1} day^{-1})				RGR (mg g^{-1} day^{-1})			
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	15-30 DAT	30-45 DAT	45-60 DAT	60-75 DAT	15-30 DAT	30-45 DAT	45-60 DAT	60-75 DAT
$W_1 S_1$	2.16	4.36	6.90	16.07	15.71	0.146	0.170	0.610	0.024	20.23	13.94	15.12	0.96
$W_1 S_2$	2.41	4.88	9.66	20.53	18.90	0.165	0.318	0.730	0.109	20.47	19.90	20.05	2.33
$W_1 S_3$	2.82	4.45	7.75	19.41	18.17	0.109	0.220	0.780	0.083	13.47	19.40	23.81	2.42
$W_2 S_1$	2.86	5.44	9.49	19.68	17.94	0.172	0.270	0.680	0.120	19.67	16.13	17.84	2.03
$W_2 S_2$	2.88	5.82	12.66	24.91	22.79	0.196	0.456	0.800	0.120	21.50	22.57	22.08	2.54
$W_2 S_3$	3.43	5.99	14.77	24.47	23.25	0.171	0.585	0.640	0.078	16.47	26.17	21.10	2.44
$W_3 S_1$	3.26	5.21	8.92	20.12	19.18	0.130	0.2473	0.750	0.060	13.50	15.23	19.48	1.70
$W_3 S_2$	3.35	5.64	13.41	23.83	22.35	0.153	0.518	0.690	0.100	15.43	25.10	23.11	2.10
$W_3 S_3$	3.24	8.16	15.95	26.33	24.65	0.328	0.519	0.690	0.110	26.70	19.47	25.25	2.27
$W_4 S_1$	3.51	5.99	9.63	21.01	20.64	0.165	0.243	0.760	0.030	15.77	14.40	20.82	1.86
$W_4 S_2$	3.11	5.69	13.41	24.79	22.68	0.172	0.514	0.760	0.140	18.97	25.07	20.15	2.53
$W_4 S_3$	2.85	7.09	14.10	25.56	23.41	0.282	0.467	0.760	0.140	26.63	20.13	21.46	2.54
$W_5 S_1$	2.69	5.73	10.57	21.59	20.15	0.203	0.323	0.730	0.100	21.93	17.73	20.11	1.93
$W_5 S_2$	2.66	5.51	13.50	24.35	22.67	0.190	0.533	0.720	0.110	21.20	26.03	21.16	2.30
$W_5 S_3$	2.86	6.74	14.15	25.82	23.54	0.258	0.500	0.780	0.150	25.30	21.63	22.47	2.79
$W_6 S_1$	2.84	6.95	10.65	20.55	19.67	0.274	0.247	0.660	0.060	25.90	12.37	18.41	1.30
$W_6 S_2$	3.24	6.31	13.42	24.71	23.80	0.205	0.474	0.750	0.060	19.87	21.83	23.12	1.97
$W_6 S_3$	3.30	7.24	15.76	25.60	24.17	0.263	0.568	0.660	0.110	22.70	22.60	25.19	2.33
LSD	0.99	0.93	0.92	0.67	0.55	0.091	0.074	0.074	0.091	11.21	5.33	3.35	0.58
% CV	10.04	9.46	4.64	4.9	5.47	7.96	11.52	10.37	6.66	3.21	4.56	8.61	7.23

Here, W_1= No weeding, W_2= Two hand weeding (HW), W_3= BRRI push weeder + 1 HW, W_4=Butachlor + 1 HW, W_5= Oxadiazon + 1 HW, W_6= Pretilachlor + 1 HW and

S_1 = 20 cm x 10 cm, S_2 = 25 cm x 15 cm, S_3 = 30 cm x 20 cm

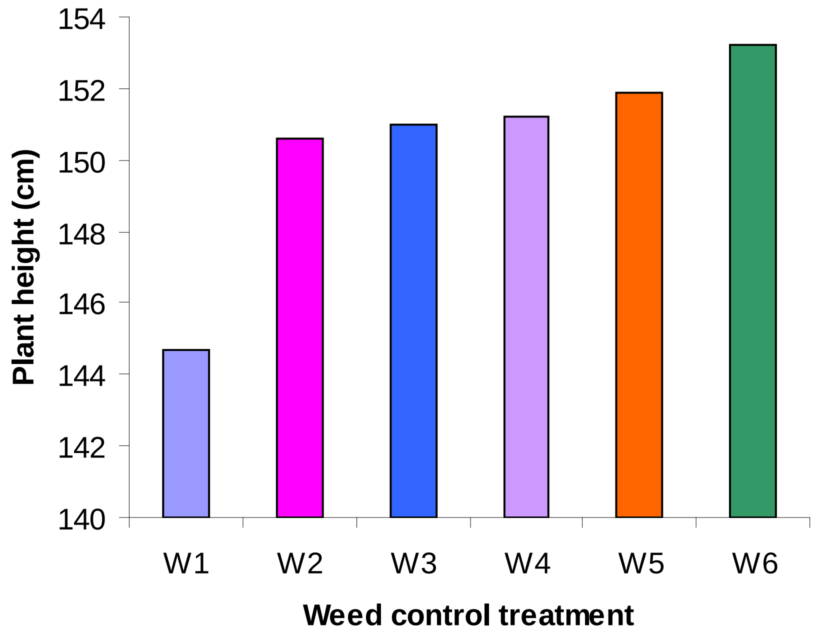
4.6. Yield and yield contributing characters

4.6.1. Plant height at harvest

Plant height was significantly influenced by weed control treatments (Fig.19). There were no significant differences among the herbicidal treatments although numerically W_6 treatment gave the maximum plant height (153.20 cm). The lowest plant height (144.70 cm) produced in no weeding treatment (W_1) which was significantly inferior to rest of the weed control treatments. Treatment W_2 and W_3 produced similar plant height (150.60 cm and 151.00 cm respectively) which were superior to W_1 treatment but inferior to herbicidal treatments. Similar results were also reported by Patil *et al.* ,(1986), Atalla and Kholosy (2002) and Toufiq (2003).

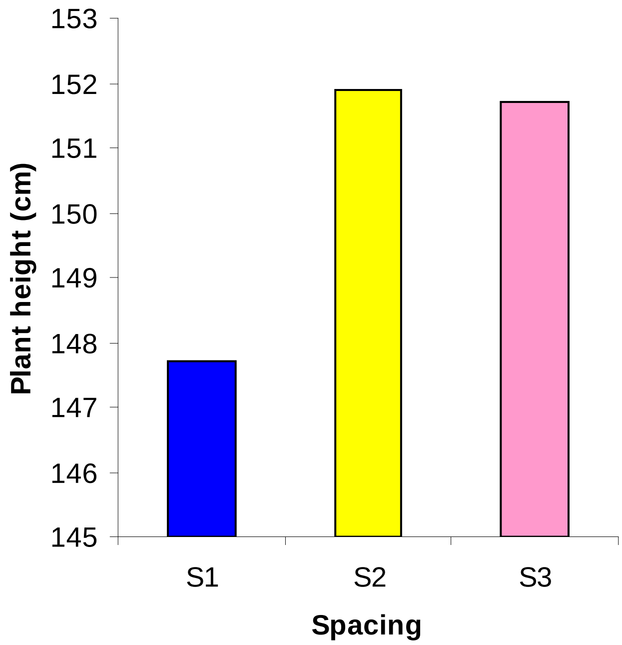
Plant height was significantly affected by plant spacing (Fig. 20). Plant height (151.90 cm) was found highest at spacing of 25cm x 15cm which was statistically similar to the spacing of 30cm x 20cm (151.70 cm) but statistically superior to the spacing of 20 cm x 10cm (147.70 cm). Interplant competition for nutrients, space, water and light might be responsible for this stunted growth. Similar results were also found by Ayub *et al.* (1987) and Nurujjaman (2001).

Interaction effect of plant spacing and different weed control treatments had significant effect on plant height (Table 6). It was found that at plant spacing 25cm x 15 cm all the herbicidal treatments along with one hand weeding gave the highest plant height. From the overall treatment combinations, W_6S_2 gave the highest plant height (155.30 cm) which was statistically similar to the treatment combinations of W_5S_2, W_6S_3, W_2S_3, W_2S_2, W_3S_3, W_4S_2 and W_4S_3. In all the spacings plant height was lower in no weeding treatment (W_1) compared to weeded treatments. Similar observation was found by Nurujjaman (2001).



Here, W_1= No weeding, W_2= Two hand weeding (HW), W_3= BRRI push weeder + 1 HW,
W_4=Butachlor + 1 HW, W_5= Oxadiazon + 1 HW, W_6= Pretilachlor + 1 HW

Fig.19. Plant height as affected by weed control treatment in transplanted aman rice (LSD 0.05 is 2.10)



Here, S_1 = 20 cm x 10 cm, S_2 = 25 cm x 15 cm, S_3 = 30 cm x 20 cm

Fig. 20. Plant height as affected by spacing in transplanted aman rice

(LSD 0.05 is 1.48)

Table 6: Interaction effects of different weed management and spacing on the yield and yield contributing characters of transplanted aman rice.

Treatments	Plant height (cm)	Total tillers hill^{-1} (No.)	Effective tillers hill^{-1} (No.)	Non effective tillers hill^{-1} (No.)	Total grains panicle^{-1} (No.)	Filled grains panicle^{-1} (No.)	Sterile grains panicle^{-1} (No.)	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
$W_1 S_1$	142.50	11.64	5.82	5.82	96.76	58.71	38.05	13.37	1.46	4.36	5.82	22.23
$W_1 S_2$	145.10	12.92	7.23	5.69	107.40	72.85	34.53	13.90	1.61	4.25	5.86	27.42
$W_1 S_3$	146.70	12.77	7.01	5.77	106.63	69.58	37.05	13.70	1.24	3.98	5.22	23.77
$W_2 S_1$	144.90	13.85	8.28	5.57	119.10	84.42	34.67	15.30	3.27	4.84	8.10	40.31
$W_2 S_2$	152.20	15.05	10.94	4.11	119.30	90.93	28.33	18.31	3.57	4.81	8.38	42.68
$W_2 S_3$	154.60	18.63	14.97	3.65	124.80	100.80	24.00	17.25	3.65	4.75	8.40	43.69
$W_3 S_1$	148.90	12.28	7.99	4.29	111.04	75.93	35.11	15.65	2.99	4.72	7.71	38.80
$W_3 S_2$	151.10	14.15	9.99	4.16	114.40	86.40	28.00	18.89	3.20	4.52	7.72	41.40
$W_3 S_3$	153.10	18.81	14.98	3.84	111.80	95.85	15.93	19.02	3.82	4.42	8.24	46.35
$W_4 S_1$	149.20	13.24	8.99	4.24	109.30	74.97	34.30	15.84	3.36	4.67	8.03	41.87
$W_4 S_2$	152.40	14.57	10.99	3.58	114.30	89.24	25.03	19.36	3.69	4.64	8.33	44.28
$W_4 S_3$	151.90	18.02	12.98	5.04	112.00	93.24	18.75	19.76	3.35	4.49	7.84	42.68
$W_5 S_1$	151.00	13.86	9.93	3.93	103.20	72.12	31.07	15.12	3.35	4.43	7.78	43.13
$W_5 S_2$	155.20	14.8	11.98	2.82	110.90	82.43	28.50	19.12	3.70	4.68	8.38	44.27
$W_5 S_3$	149.50	18.32	13.00	5.31	111.90	90.27	21.61	19.73	3.24	4.47	7.70	42.02
$W_6 S_1$	149.90	13.94	10.49	3.45	102.90	71.20	31.67	14.32	3.37	5.09	8.46	39.83
$W_6 S_2$	155.30	16.61	13.00	3.61	107.00	80.75	26.24	18.94	3.87	4.61	8.49	45.65
$W_6 S_3$	154.50	18.26	14.00	4.26	109.40	89.90	19.50	20.32	3.55	4.50	8.05	44.13
LSD 0.05	3.63	1.241	2.78	2.96	11.49	15.38	8.16	2.18	0.48	0.20	0.20	0.71
CV (%)	7.45	4.95	5.57	11.04	6.25	11.27	17.26	3.69	9.24	4.62	4.61	5.08

Here, W_1= No weeding, W_2= Two hand weeding (HW), W_3= BRRI push weeder + 1 HW, W_4=Butachlor + 1 HW, W_5= Oxadiazon + 1 HW, W_6= Pretilachlor + 1 HW

and S_1 = 20 cm x 10 cm, S_2 = 25 cm x 15 cm, S_3 = 30 cm x 20 cm

4.6.2 Total tillers hill^{-1}

Total number of tillers hill^{-1} was significantly affected by different weed control treatments (Fig. 21). Among the integrated weed managements, the highest number of total tillers hill^{-1} (16.27) was observed by W_6 treatment which was statistically similar to W_2 (15.84) and W_5 (15.66) treatments but superior to W_3 and W_4 treatments (15.08 and 15.28 respectively). The W_1 (unweeded) treatment gave the lowest number of total tillers hill^{-1} (12.44). Unweeded treatment failed to produce more tillers due to severe weed infestation in the experimental plots. Similar results were also reported by BRRI (1998 b) and Atalla and kholosy (2002).

Production of total tillers hill^{-1} was significantly affected by plant spacing (Fig 22). Production of total tillers hill^{-1} was found to be severely depressed when the plants were densely planted. Tiller production was observed progressively decreased when spacing was decreased. The highest number of total tillers hill^{-1} was produced when the crop transplanted at 30cm x 20cm spacing (17.47). Similar findings were also observed by Haque and Nasiruddin (1988) and Khalil (2001).

Interaction effect of plant spacing and different weed control treatments significantly influenced the number of total tillers hill^{-1} (Table 6). The highest number of total tillers hill^{-1} produced by the interaction between plant spacing 30cm x 20cm along with all the integrated weed management. The lowest number of total tillers hill^{-1} was found in interaction between plant spacing 20cm x 10 cm and unweeded treatment (11.64).

4.6.3 Effective tillers hill^{-1}

Weed control treatments caused considerable variations in the number of effective tillers hill^{-1} (Fig 21). Effective tillers varied from 10.98 to 12.50 hill^{-1} among the integrated approaches. The highest number of effective tillers hill^{-1} was obtained in W_6 treatment (12.50) which was statistically similar with other integrated weed management treatments. Unweeded treatment produced the lowest number of effective tillers hill^{-1} (7.05).

Effective tillers hill^{-1} differed significantly due to different spacing used (Fig 22). The results of spacing 30cm x 20cm produced the highest number of effective tillers hill^{-1} (12.82) whereas closest spacing 20cm x 10cm produced the lowest number of effective tillers hill^{-1}

(8.59). A gradual decrease in tiller number was observed as the spacing became closer between lines and hills. The wider spacing allowed much more area for growth of the plant and brought in less competition between them resulting in more number of effective tillers hill^{-1}. Similar findings were also reported by Dunand and Dilly (1982) and Khalil (2001).

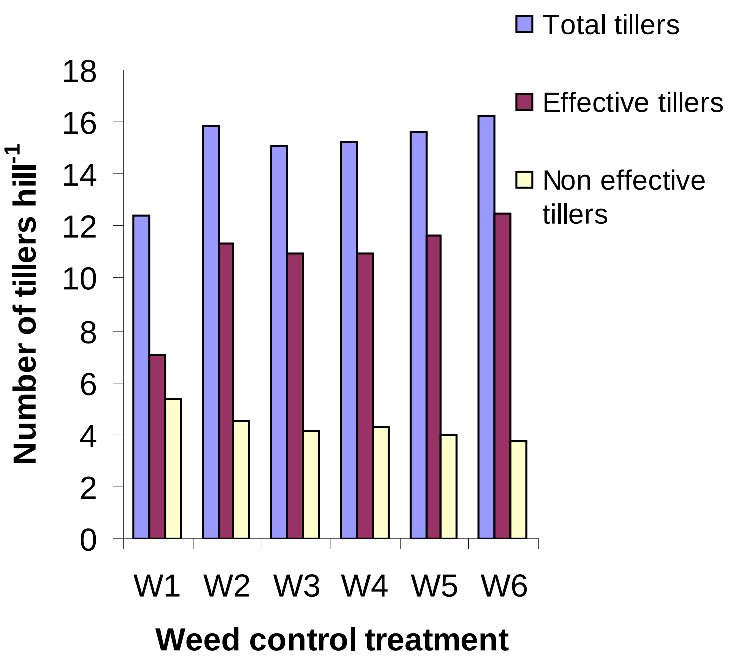
Interaction effect of different weed control and plant spacing treatments had significant effect on number of tillers hill^{-1}(Table 6). It was found that widest plant spacing 30cm x 20cm produced the highest number of effective tillers hill^{-1} than the other two spacing treatments along with all the integrated weed management. The highest number of effective tillers hill^{-1}(14.98) was observed in the treatment combination of W_3S_3 which was statistically similar to 14.97, 14.00, 13.00, 13.00 and 12.98 number of effective tillers hill^{-1} obtained in W_2S_2, W_6S_3, W_6S_2, W_5S_3 and W_4S_3 treatment combinations respectively but was significantly higher than the rest treatment combinations.

4.6.4 Non effective tillers hill^{-1}

The number of non effective tillers hill^{-1} was not significantly influenced by weed control treatments (Fig. 21). Numerically the highest number of non effective tillers (5.39) was obtained by the unweeded treatment and the lowest number of non effective tillers (3.77) was obtained by the W_6 treatment.

Different spacing did not show any statistical difference on non effective tillers hill^{-1} (Fig. 22). However, there was small numerical variation (4.65 to 3.85) observed among them.

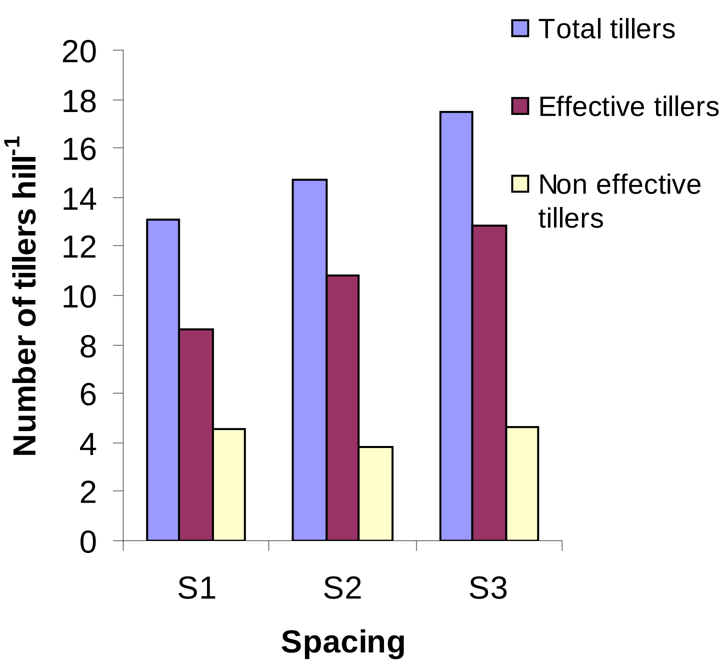
There was significant variation on the number of non effective tillers hill^{-1} due to different weed control treatments and spacings. The treatment combination of W_1S_1 gave the highest non effective tillers hill^{-1} (5.82) and W_5S_2 gave the lowest non effective tillers hill^{-1} (2.82). The rest treatment combinations were statistically similar with each other (Table 6).



Here, W_1= No weeding, W_2= Two hand weeding (HW), W_3= BRRI push weeder + 1 HW,

W_4=Butachlor + 1 HW, W_5= Oxadiazon + 1 HW, W_6= Pretilachlor + 1 HW

Fig.21. Effect of weed control treatment on the formation of total, effective and non-effective tillers hill^{-1} (LSD 0.05 of total, effective and non effective tillers hill^{-1} were 0.72, 1.60 and 1.71, respectively)



Here, S_1 = 20 cm x 10 cm, S_2 = 25 cm x 15 cm, S_3 = 30 cm x 20 cm

Fig.22. Effect of spacing on the formation of total, effective and non-effective tillers hill^{-1} (LSD value of total, effective and non effective tillers hill^{-1} were 0.51, 1.13 and 1.21, respectively)

4.6.5 Total grains panicle^{-1}

The weed control treatments significantly affected the total number of grains panicle^{-1} (Fig. 23). The total number of grains panicle^{-1} was highest in W_2 treatment (121.10) which was statistically superior to other integrated weed managements while the lowest number of grains panicle^{-1} was observed in the W_1 (unweeded) treatment (102.80).

There was a significant difference for total grains panicle^{-1} among the spacings (Fig. 24). Widest spacing (30 cm x 20 cm) gave the highest number of total grains panicle^{-1} (112.40) which was statistically similar to 25 cm x 15 cm spacing (112.20) but superior than 20 cm x 10 cm spacing (107.40).

The interaction effect of different weed control treatment with different spacing had highly significant interaction on total number of grains panicle^{-1}. It was evident from Table 6 that treatment combination W_2S_3 (two hand weeding at 30cm x 20cm spacing) produced the highest grains panicle^{-1} (124.80) which was statistically similar to the treatment combinations of W_2S_2, W_2S_1, W_3S_2 and W_4S_2 producing 119.30, 119.10, 114.40 and 114.30 total grains panicle^{-1} respectively. The W_6 (Pretilachlor) in all spacings produced comparatively lower number of total grains panicle^{-1} compared to other weed control treatments. The lowest grains panicle^{-1} was obtained from the unweeded treatment with closer spacing of 20cm x10cm (96.76).

4.6.6 Filled grains panicle^{-1}

The influence of different weed control treatments was significant on the number of filled grains panicle^{-1} (Fig. 23). The highest number of grains panicle^{-1} (92.06) was obtained from W_2 treatment which was statistically similar to W_3 and W_4 treatments (86.06 and 85.82, respectively). It might be due to least crop weed competition that ensured sufficient nutrients and other growth resources, which enhanced higher filled grain production. The lowest number of grains panicle^{-1} (67.05) was observed in the no weeding treatment which was inferior to others. This might be due to higher crop weed competition in the no weeding treatment where weeds shared with the crop for their nutrients, water, light or other necessary growth factors and consequently reduced grains panicle^{-1}. Similar findings were also reported by Polthanee *et al.* (1996) and Sanjoy *et al.* (1999) where the number of filled grains panicle^{-1} were increased due to weed control over no weeding.

Production of filled grains panicle^{-1} was significantly affected by plant spacing. From Fig. 24 it was revealed that widest spacing of 30cm x 20cm produced the highest number of grains panicle^{-1} (89.94) which was statistically similar to 25 cm x 15 cm spacing (83.77). The lowest filled spikelets panicle^{-1} (72.89) was produced by the closest spacing 20cm x 10cm. Rao *et al.* (1990) and Khalil (2001) found the similar observation who stated that wider spacing produced higher number of filled grains panicle^{-1}. Since fertility and development of grains depend on environmental factors such as nutrition, moisture and light, wider spacing possibly facilitated supply of more food materials and light for the plant and ultimately for development of grains compared to narrower spacing.

Interaction between different weed control treatments and spacing had significant effect on filled grains panicle^{-1} (Table 6). The highest number of grains panicle^{-1} (100.80) was obtained in W_2S_3 treatment combination that followed by W_3S_3 (95.85). The lowest number of grains panicle^{-1} (58.71) was recorded in W_1S_1. It was evident from the findings that the wider spacings produced more filled grains panicle^{-1} with the different integrated management than the closer spacing with no weeding treatment.

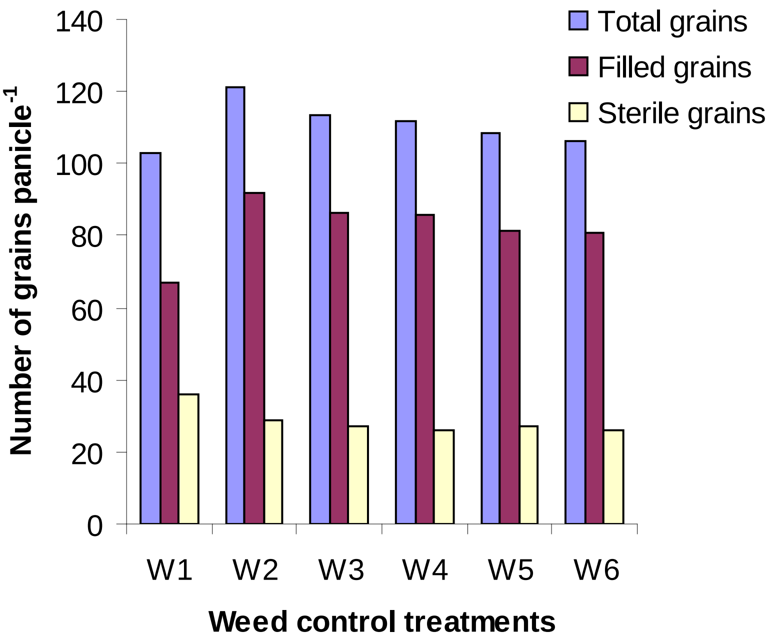
4.6.7 Sterile grains panicle^{-1}

The number of sterile grains panicle^{-1} varied significantly due to the effect of weed control treatments (Fig. 23). The highest number of sterile grains panicle^{-1} (35.71) was observed in the no weeding treatment which was significantly higher than all the integrated weed control treatments. The lowest number of sterile grains panicle^{-1} (25.80) was produced by W_6 (Pretailachlor + one hand weeding) treatment which was statistically similar to other integrated weed management.

Spacing had a significant effect on sterile grains panicle^{-1}. A gradual increase in sterile grains was observed as the spacing became closer between the lines and hills (Fig. 24). The closest spacing 20cm x 10cm produced the highest sterile grains panicle^{-1} (34.54) and the lowest sterile grains panicle^{-1} (22.48) was produced by the widest spacing of 30cm x 20 cm.

The reason of highest sterile grains panicle^{-1} in the closest spacing might be attributed to the keen competition for nutrients, light and space among the plants.

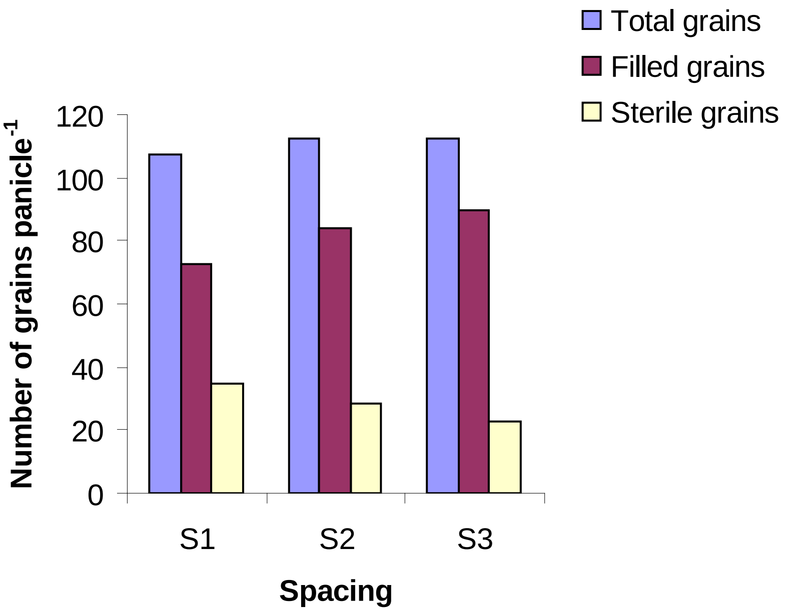
The interaction effect between the weed control treatments and spacing was highly significant on the number of sterile grains panicle^{-1} (Table 6). It was observed that 20cm x 10



Here, W_1= No weeding, W_2= Two hand weeding (HW), W_3= BRRI push weeder + 1 HW,

W_4=Butachlor + 1 HW, W_5= Oxadiazon + 1 HW, W_6= Pretilachlor + 1 HW

Fig.23. Effect of weed control treatment on the production of total grains, filled grains and sterile grains panicle^{-1} (LSD 0.05 of total spikelets, grains and sterile spikelets panicle^{-1} were 6.63, 8.88 and 4.71, respectively)



Here, S_1 = 20 cm x 10 cm, S_2 = 25 cm x 15 cm, S_3 = 30 cm x 20 cm

Fig.24. Effect of spacing on the production of total grains, filled grains and sterile grains panicle^{-1} (LSD 0.05 of total spikelets, grains and sterile spikelets panicle^{-1} were 4.69, 6.28 and 3.33, respectively)

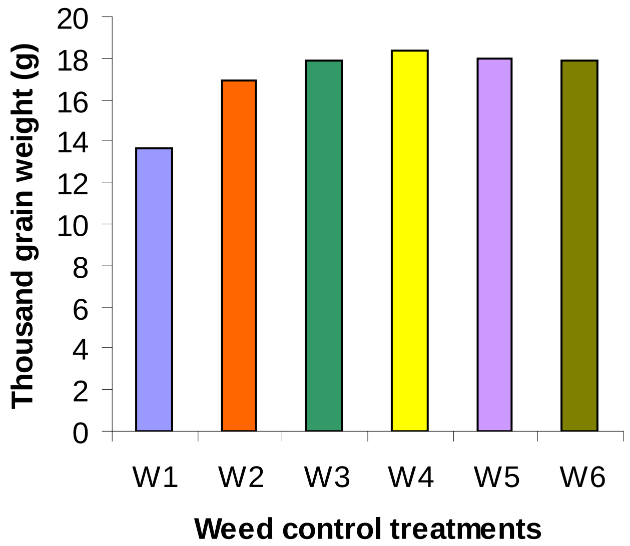
cm spacing and unweeded plot produced the highest number of sterile grains panicle^{-1} (38.05). The lowest number of sterile grains panicle^{-1} (15.93) was obtained from the treatment combination of W_3S_3. From the results it was observed that the unweeded plot with spacing of 25cm x 15cm produced the lowest number of sterile grains panicle^{-1} but in the other integrated weed management plots spacing of 30cm x 20cm produced the lowest sterile grains panicle^{-1}. This might be due to the severe infestation of weeds in the wider spaced crops and plant to plant competition in the closer spaced crops. But in the integrated weeded plot in wider spacing of 30cm x 20cm, the weeds were effectively controlled than the other two spacings. Hence, the sterile grains panicle^{-1} was reduced in the wider spaced crops.

4.6.8 Weight of 1000 grain

Thousand grain weight was significantly influenced by weed control treatments (Fig. 25). The thousand grain weight was highest in W_4 treatment (18.32 g) which was statistically similar to other integrated weed management except W_2 treatment (16.95 g). The thousand grain weight was lowest (13.66 g) in the unweeded plot. Similar finding were also observed by Yuan *et al.* (1991).

Different spacing had a significant effect on thousand grain weight (Fig. 26). The highest thousand grain weight was observed in wider spacing of 30cm x 20cm (18.30 g) which was statistically similar to 25 cm x 15 cm spacing (18.08 g) whereas closest spacing of 20cm x 10cm produced the lowest thousand grain weight (14.93 g).

The interaction between the different weed control treatments and spacings was significant for thousand grain weight (Table 6). The highest thousand grain weight was observed in the treatment combination of W_6S_3 (20.32 g) and the lowest thousand grain weight was observed in the treatment combination of W_1S_1 (13.37 g).

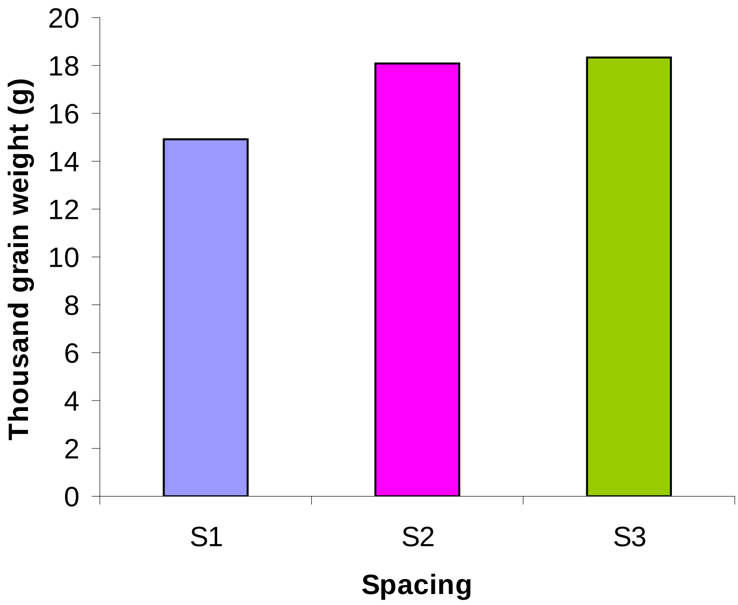


Here, W_1= No weeding, W_2= Two hand weeding (HW), W_3= BRRI push weeder + 1 HW,

W_4=Butachlor + 1 HW, W_5= Oxadiazon + 1 HW, W_6= Pretilachlor + 1 HW

Fig.25. Effect of weed control treatment on 1000-grain weight

(LSD 0.05 is 1.26)



Here, S_1 = 20 cm x 10 cm, S_2 = 25 cm x 15 cm, S_3 = 30 cm x 20 cm

Fig.26. Effect of spacing on 1000-grain weight
(LSD 0.05 is 0.89)

4.6.9 Grain yield

Crop management practices are among the factors responsible to get higher yield. Proper weed management in transplanted aman rice field ensures higher yield. Grain yield was considerably affected by weed control treatments (Fig.27). The highest grain yield (3.60 t ha^{-1}) was obtained from W_6 treatment which was statistically similar to other integrated weed management treatments. The lowest grain yield (1.44 t ha^{-1}) was obtained from W_1 treatment. This happened due to severe weed infestation with various species of weeds and competition for moisture, space, air, light and nutrients between weeds and rice plants which had adverse effect on all the yield components and finally on grain yield. Similar findings were also reported by Polthanee *et al.* (1996), Thomas *et al.* (1997), Sanjoy *et al.* (1999), Gogoi *et al.* (2000) and Atalla and Kholosy (2002).

Different spacing had a significant effect on grain yield (Fig. 28). The highest grain yield (3.27 t ha^{-1}) was found in the spacing of 25 cm x 15 cm which was statistically similar to 30 cm x 20 cm spacing (3.14 t ha^{-1}). The closest spacing 20 cm x 10 cm produced the lowest grain yield (2.97 t ha^{-1}).

Interaction effect between different weed control treatments and spacings significantly influenced grain yield (Table 6). The highest grain yield (3.87 t ha^{-1}) was obtained from the treatment combination of W_6S_2 followed by the W_3S_3 producing 3.82 t ha^{-1} which was statistically similar with the yields obtained from W_5S_2, W_4S_2, W_2S_3, W_2S_2 and W_6S_3 respectively. The lowest yield (1.24 t ha^{-1}) was obtained from the unweeded plot with 30 cm x 20 cm spacing which was statistically similar to unweeded treatment with 25cm x 15cm and 30cm x 20cm spacings. This happened due to the more number of hills m^{-2} was present in 25cm x 15cm spacing than in 30cm x 20cm spacing.

4.6.10 Straw yield

Straw yield of rice was significantly influenced by different weed control treatments (Fig.27). The highest straw yield (4.80 t ha^{-1}) was obtained from the treatment W_2 which was statistically similar with the treatment W_6 (4.73 t ha^{-1}). Significantly the lowest straw yield (4.20 t ha^{-1}) was obtained from the unweeded treatment. Similar observations were found by Islam (1995) and Toufiq (2003).

Spacing had significant effect on straw yield (Fig. 28).The narrowest spacing (20cm x 10cm) produced the highest straw yield (4.68 t ha^{-1}) and the lowest straw yield(4.44 t ha^{-1}) was produced by the widest spacing (30cm x 20cm). Similar observations were given by Hegazy *et al.* (1995), Khalil (2001) and Nurujjaman (2001).

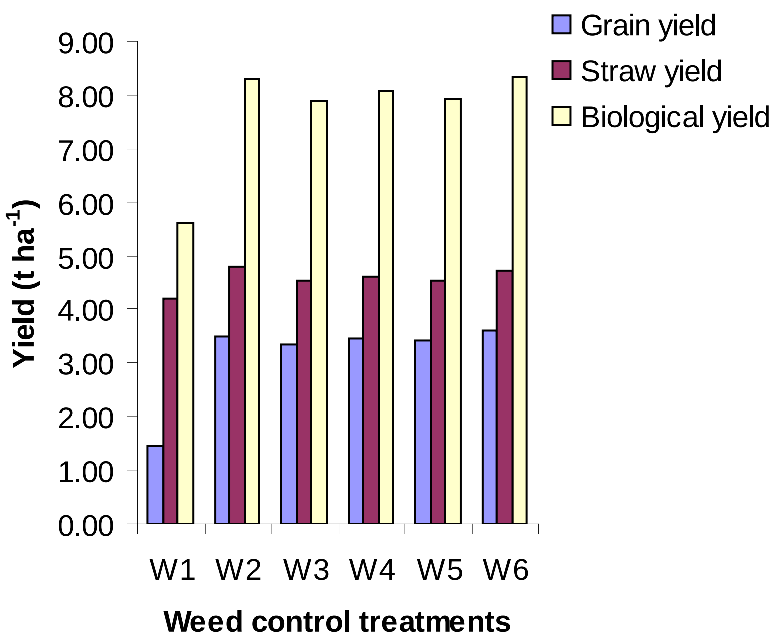
Straw yield was significantly affected due to interaction between different weed control treatments and plant spacings (Table 6). The highest straw yield (5.09 t ha^{-1}) was obtained from the interaction between 20cm x10cm spacing and Rifit 500EC (Pretilachlor) + one hand weeding treatment. The lowest straw yield (3.98 t ha^{-1}) was observed from the interaction between 30cm x 20cm spacing and unweeded treatment. Similar observation was found by Nurujjaman (2001).

4.6.11 Biological yield

Biological yield was significantly influenced by different weed control treatments (Fig. 27). The highest biological yield (8.33 t ha^{-1}) was observed in the W_6 treatment which was statistically similar with the treatment W_2 (8.29 t ha^{-1}). The unweeded plot (W_1) gave the lowest biological yield (5.63 t ha^{-1}) among the treatments.

Spacing had significant effect on biological yield (Fig. 28). It was observed that spacing of 25cm x 15cm produced the highest biological yield (7.85 t ha^{-1}) which was significantly different from the widest spacing of 30cm x 20cm and closest spacing of 20cm x 10cm.

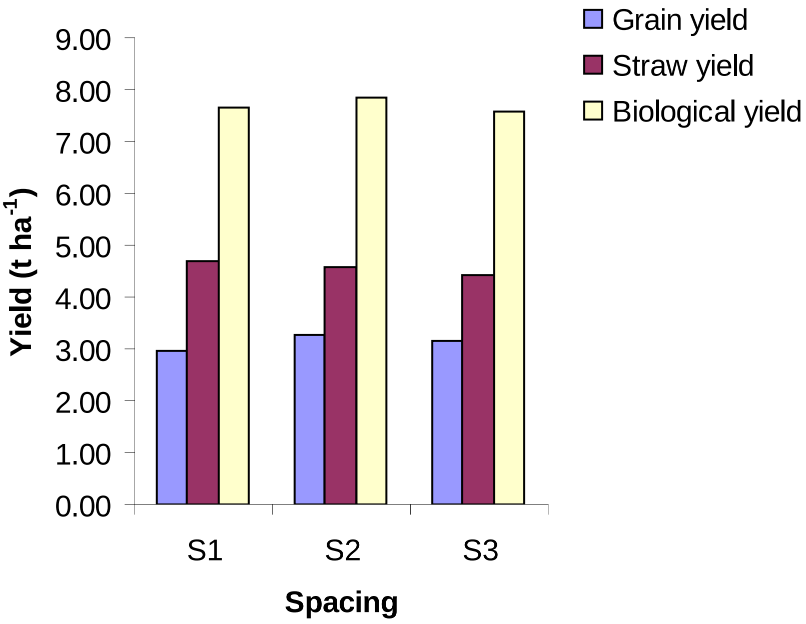
The interaction between different weed control treatments and spacing had significant influence on biological yield (Table 6). The highest biological yield (8.49 t ha^{-1}) was obtained from the treatment combination of W_6S_2 which was statistically similar with the W_6S_1, W_4S_2, W_2S_3 and W_2S_2. The lowest biological yield (7.58 t ha^{-1}) was observed in the W_1S_3. Higher weed infestation not only reduced the grain yield but also hampered the plant growth and tillering capacity and ultimately reduced straw yield and also biological yield.



Here, W_1= No weeding, W_2= Two hand weeding (HW), W_3= BRRI push weeder + 1 HW,

W_4=Butachlor + 1 HW, W_5= Oxadiazon + 1 HW, W_6= Pretilachlor + 1 HW

Fig. 27. Effect of weed control treatment on grain, straw and biological yield
(LSD 0.05 of grain, straw and biological yield were 0.28, 0.11 and 0.12, respectively)



Here, S_1 = 20 cm x 10 cm, S_2 = 25 cm x 15 cm, S_3 = 30 cm x 20 cm

Fig.28. Effect of spacing on grain, straw and biological yield
(LSD 0.05 of grain, straw and biological yield were 0.20, 0.08 and 0.08, respectively)

4.6.12 Harvest index

Harvest index was significantly affected by the different weed control treatments (Fig. 29) .The highest harvest index (43.20%) was observed in the W_6 treatment which was statistically similar to W_4 and W_5 treatments. The lowest harvest index (24.47%) was observed in the treatment W_1 (unweeded).

Spacing had a significant effect on harvest index (Fig. 30). The highest harvest index (40.95%) was observed in the spacing of 25cm x 15cm which was significantly different from the other two spacings. The lowest harvest index was observed in the spacing of 20cm x 10cm (37.69%).

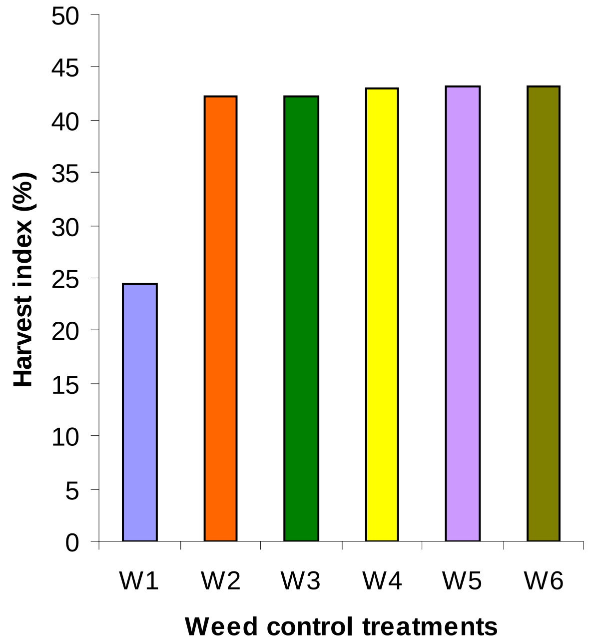
The interaction between different weed control treatments and spacing had significant effect on harvest index (Table 6). The highest harvest index (46.35%) was observed in the treatment combination of W_3S_3 which was statistically similar with the W_6S_2 (45.65%). The lowest harvest index (22.23%) was found in the W_1S_1 (unweeded at 20cm x 10cm spacing). It was observed that the unweeded plot along with all the spacings gave the minimum harvest index than the integrated weed management with different spacings.

4.7. Economic performance of different weed control treatments under different spacing

The cost of production and return of unit plot of transplanted aman rice (cv. BRRI dhan 37) converted into hectare and discussed below:

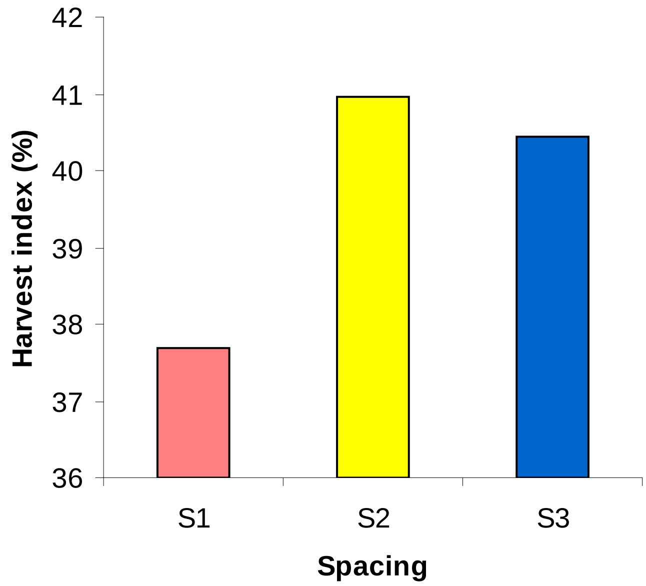
Economic performance of transplanted aman rice (cv. BRRI dhan 37) was varied for different weed control treatments and different spacings used in the present experiment. The cost of production was varied mainly for the weeding cost and for raising of seedlings under different spacings. The weeding cost was varied mainly for labourers and material required under different weed control treatments. For the narrower spacing of 20cm x 10cm, much seeds were required for raising of seedlings as in that spacing more hills m^{-2} were needed. So, for the wider spacing less seeds were required for raising of seedlings to cover the field.

In case of no weeding, there was no involvement of cost for weed control. In the treatment W_2 (two hand weeding) required 53, 53 and 60 labourers for 20cm x10cm, 25cm x 15cm and 30 cm x 20 cm spacings respectively. In the treatment W_3 (one weeding with BRRI



Here, W_1= No weeding, W_2= Two hand weeding (HW), W_3= BRRI push weeder + 1 HW,
W_4=Butachlor + 1 HW, W_5= Oxadiazon + 1 HW, W_6= Pretilachlor + 1 HW

Fig. 29. Effect of weed control treatment on harvest index
(LSD 0.05 is 0.41)



Here, S_1 = 20 cm x 10 cm, S_2 = 25 cm x 15 cm, S_3 = 30 cm x 20 cm

Fig. 30. Effect of spacing on harvest index

(LSD 0.05 is 0.29)

push weeder + one hand weeding) 35, 35 and 40 labourers were required for 20cm x 10cm, 25cm x 15cm and 30cm x 20cm spacings respectively. In case of herbicidal treatments fewer labourers were required for weeding than the treatment W_2 and W_3 but the labourer numbers were varied according to spacing. The weeding cost was Tk. 1620.00, 1620.00, 1830.00, 2315.00, 2455.00, 2665.00,1740.00, 1810.00 and 2020.00 for the treatment combination of W_4S_1, W_4S_2, W_4S_3, W_5S_1, W_5S_2, W_5S_3, W_6S_1, W_6S_2 and W_6S_3 respectively (Appendix XIII).

Excluding weeding cost, cost of production of BRRI dhan 37 rice ha^{-1} was Tk. 29023.00, 28395.00, 28032.00 for 20cm x 10cm, 25cm x 15cm and 30cm x 20cm spacings respectively (Appendix IX to XIII). Including weeding cost, the cost of production of BRRI dhan 37 rice was the highest (Tk.32733.00 ha^{-1}) for the treatment W_2S_1 (two hand weeding at 20cm x 10cm spacing) and the lowest (Tk.30052.00 ha^{-1}) at W_6S_3 (Pretilachlor + one hand weeding) at 30cm x 20cm spacing treatment (Table 7).

4.7.1. Gross return

Gross return was influenced by different weed control treatments and spacing (Table 7). The highest gross return (Tk 54052.00 ha^{-1}) was obtained from Pretilachlor + one hand weeding at 25cm x 15cm spacing and the lowest gross return (Tk. 19317.00 ha^{-1}) was obtained from no weeding at 30cm x 20cm spacing. The second highest gross return (Tk. 53211.00 ha^{-1}) was obtained from one weeding with BRRI rice weeder + one hand weeding at 30cm x20cm spacing.

4.7.2. Net return

Net return varied in different weed control treatments and spacings (Table 7). The highest net return (Tk. 23847.00 ha^{-1}) was obtained from the treatment Pretailachlor + one hand weeding at 25cm x 15cm spacing. In the unweeded plots at all spacings no profit was achieved.

Table 7: Cost of production, return and Benefit cost Ratio (BCR) of transplanted aman rice cv. BRRI Dhan 37 under different treatments.

Treatments	Cost of production (Tk./ha)			Gross return (Tk./ha)			Net Profit (Tk./ha)	BCR
	Variable fixed cost	Weeding cost	Total cost	Grain	Straw	Total		
$W_1 S_1$	29023.00	0.00	29023.00	19019.00	3486.00	22505.00	-6518.00	0.78
$W_1 S_2$	28395.00	0.00	28395.00	20891.00	3402.00	24293.00	-4102.00	0.86
$W_1 S_3$	28032.00	0.00	28032.00	16133.00	3184.00	19317.00	-8715.00	0.69
$W_2 S_1$	29023.00	3710.00	32733.00	42471.00	3870.00	46341.00	13608.00	1.42
$W_2 S_2$	28395.00	3710.00	32105.00	46358.00	3850.00	50208.00	18103.00	1.56
$W_2 S_3$	28032.00	4200.00	32232.00	47411.00	3810.00	51221.00	18989.00	1.59
$W_3 S_1$	29023.00	2450.00	31473.00	38870.00	3774.00	42644.00	11171.00	1.35
$W_3 S_2$	28395.00	2450.00	30845.00	41535.00	3618.00	45153.00	14308.00	1.46
$W_3 S_3$	28032.00	2800.00	30832.00	49673.00	3538.00	53211.00	22379.00	1.73
$W_4 S_1$	29023.00	1620.00	30643.00	43693.00	3734.00	47427.00	16784.00	1.55
$W_4 S_2$	28395.00	1620.00	30015.00	47957.00	3714.00	51671.00	21656.00	1.72
$W_4 S_3$	28032.00	1830.00	29862.00	43498.00	3594.00	47092.00	17230.00	1.58
$W_5 S_1$	29023.00	2315.00	31338.00	43485.00	3544.00	47029.00	15691.00	1.50
$W_5 S_2$	28395.00	2455.00	30850.00	48100.00	3744.00	51844.00	20994.00	1.68
$W_5 S_3$	28032.00	2665.00	30697.00	42081.00	3574.00	45655.00	14958.00	1.49
$W_6 S_1$	29023.00	1740.00	30763.00	43810.00	4072.00	47882.00	17119.00	1.56
$W_6 S_2$	28395.00	1810.00	30205.00	50362.00	3690.00	54052.00	23847.00	1.79
$W_6 S_3$	28032.00	2020.00	30052.00	46202.00	3600.00	49802.00	19750.00	1.66

Here, W_1= No weeding, W_2= Two hand weeding (HW), W_3= BRRI push weeder + 1 HW, W_4=Butachlor + 1 HW, W_5= Oxadiazon + 1 HW, W_6= Pretilachlor + 1 HW and S_1 = 20 cm x 10 cm, S_2 = 25 cm x 15 cm, S_3 = 30 cm x 20 cm

4.7.3. Benefit cost ratio (BCR)

Benefit cost ratio varied in different weed control treatments and spacings (Table 7). It was evident that the herbicidal plots along with one hand weeding each at the spacing of 25cm x 15cm gave the higher BCR than the other two spacings (20cm x 10cm and 30cm x20cm). Among all the treatment combinations, Pretailachlor + one hand weeding at 25cm x 15cm spacing gave the highest BCR (1.79). The second highest BCR (1.73) was given by the treatment combination of W_3S_3 (BRRI rice weeder + one hand weeding at 30cm x 20cm spacing) and the third highest BCR (1.72) was given by the W_4S_1 (Oxadiazon + one hand weeding at 25cm x 15cm spacing). All the unweeded treatments at different spacings showed the negative BCR. This might be because less production due to higher weeds competition. One weeding with BRRI rice weeder + one hand weeding at 30cm x 20cm was also profitable because the weeder could easily operated at that spacing and controlled the weeds more effectively in lines and rows of the crop field and labourers requirement were also less than the hand weeding treatment. The weeds that were controlled by the weeder get rotten in the soil at the initial stages of the crop and contributed to the vigorous growth that ultimately produced higher effective tillers m^{-2} and grain yield. It can be concluded from economic point of view that when labour is a limiting factor, herbicide may serve as an alternative means of weed control.

CHAPTER 5

SUMMARY AND CONCLUSION

The present piece of work was done at the Agronomy field, Sher-e-Bangla Agricultural University, Dhaka during the period from July to December, 2006 to find out the influence of integrated weed management and plant spacing on the growth and yield of transplanted aman rice cv BRRI dhan 37.

The experiment was laid out in a randomized complete block design (factorial) with three replications. The size of the unit plot was 4m x 2.5m. The weeding treatments were no weeding (W_1), hand weeding at 15 and 40 DAT(W_2), one weeding with BRRI rice weeder at 15 DAT and one hand weeding at 40 DAT (W_3), M. Chlor 5G (Butachlor)@ 13 kg ha^{-1} at 5 DAT and one hand weeding at 40 DAT (W_4), Oxastar 25EC (Oxadiazon) @ 1.9 l ha^{-1} at 5 DAT and one hand weeding at 40 DAT (W_5) and Rifit 500EC (Pretilachlor)@ 0.97 l ha^{-1} at 5 DAT and one hand weeding at 40 DAT (W_6). M.Chlor 5G, Oxastar 25EC and Rifit 500EC were the preemergence herbicides applied in 4-5 cm standing water. Twenty five days old seedlings of rice variety BRRI dhan 37 were transplanted on August 5, 2006 using two seedlings per hill.

The data of weed parameters were collected at 30 DAT and 60 DAT. Weed parameters such as total weed population (no. m^{-2}), weed biomass (g m^{-2}), weed control efficiency (%) were examined. The data on growth parameters viz. plant height, total number of tillers hill^{-1}, total dry matter hill^{-1}, leaf area index, crop growth rate and relative growth rate were recorded during the period from 15 to 75 DAT. At harvest, characters like plant height, total tillers hill^{-1}, effective tillers hill^{-1}, non effective tillers hill^{-1}, total grains panicle^{-1}, filled grains panicle^{-1}, sterile grains panile^{-1}, 1000 grain weight, grain yield, straw yield, biological yield and harvest index were recorded.

Twelve weed species infested the experimental plots belonging to seven families. The most important weed species in the experimental plots throughout the growing period were *Sphenoclea zeylanica, Eclipta alba, Ludwigia octovalvis, Echinochloa colona and Fimbristylis miliacea* respectively. Weed density, weed biomass and weed control efficiency were significantly influenced by the weed control treatments. The highest weed density and weed biomass were observed in the no weeding treatment at 30cm x 20cm spacing at 30 DAT and 60 DAT. The lowest weed density and weed biomass were found in the Rifit 500EC (Pretilachlor) + one hand weeding treatment at 20cm x 10cm spacing at 30 DAT. At 60 DAT, the lowest weed density and weed biomass were observed in the two hand weeding treatment at 20cm x 10cm spacing. At 30 DAT, weed control efficiency was highest by Rifit 500EC (Pretilachlor) + one hand weeding treatment at 25cm x 15cm spacing. At 60 DAT, weed control efficiency was not significant among the treatments.

Different weed control treatments and plant spacings had significant effect on crop growth parameters viz. tiller no. hill^{-1}, plant height, plant dry weight, crop growth rate (CGR), relative growth rate (RGR) and leaf area index (LAI) at different DAT. The highest plant height was observed in Rifit 500EC (Pretilachlor) + one hand weeding treatment at 25cm x 15cm spacing at 60 DAT. The highest tillers no. hill^{-1} was observed in Rifit 500EC (Pretilachlor) + one hand weeding treatment at 30cm x 20cm spacing. The leaf area index (LAI) was highest in one weeding with BRRI rice weeder + one hand weeding at 30cm x 20cm spacing at 60DAT. Plant dry weight hill^{-1} was highest in two hand weeding treatment at 30cm x 20cm spacing at 60 DAT . Crop growth rate (CGR) and relative growth rate (RGR) was highest in two hand weeding treatment at 30cm x 20cm spacing at 45-60 DAT.

Interaction between different weed control treatments and plant spacings significantly influenced yield and yield contributing characters. Total tillers hill^{-1}, effective tillers hill^{-1}, harvest index was highest and sterile grains panicle^{-1} was lowest in the BRRI rice weeder + one hand weeding treatment at 30cm x 20cm spacing . The lowest non effective tillers hill^{-1} was found in Oxastar 25 EC (Oxadiazon) + one hand weeding at 25cm x 15cm spacing. The total grains panicle^{-1} and filled grains panicle^{-1} was highest in two hand weeding at 30cm x 20cm spacing. Thousand grain weight was highest in Rifit 500EC (Pretilachlor) + one hand weeding at 30cm x 20cm spacing and straw yield was highest in Rifit 500EC (Pretilachlor) + one hand weeding at 20cm x 10cm spacing . The grain yield and biological yield were highest in the treatment Rifit 500EC (Pretilachlor) + one hand weeding at 25cm x 15cm spacing.

From the economic point of view, it was observed that the benefit cost ratio was the highest (1.79) from Rifit 500EC (Pretilachlor) at the rate of 0.97 L ha^{-1} with one hand weeding at 40 DAT at 25cm x 15cm spacing which was followed by BRRI rice weeder at 15

DAT with one hand weeding at 40 DAT at 30 cm x 20cm spacing (1.73), M.Chlor 5G (Butachlor) at the rate of 13 kg ha^{-1} with one hand weeding at 40 DAT at 25cm x 15cm spacing (1.72).

Based on the results of the present experiment, the following conclusion can be drawn:

1. Weed infestation was identified as one of the major constraints of transplanted aman rice cultivation in the study area.
2. Plant spacing played a vital role for the growth and yield of transplanted aman rice.
3. At closer spacing (20cm x 10cm) weed population and density were lower compared to the wider spacing (30cm x 20cm).
4. Almost all agronomic characters decreased at closer spacing except sterile grains $panicle^{-1}$ and grain yield, straw yield and biological yield increased with plant spacing of 25cm x 15cm.
5. Two times weeding, one with Pretilachlor (preemergence herbicide) application along with one hand weeding at 25cm x 15cm plant spacing or where labourers were available, weeding once with BRRI rice weeder along with one hand weeding at 30cm x 20cm plant spacing might be the best practice to keep weed infestation at minimum level, to ensure higher yield as well as profitable rice production.

REFERENCES

Abedin, M. Z. and Chowdhury, M. K. (1982). Procedures for data collection in major field crops. Extension and Research Project, BARI. Ishurdi, Pabna, Bangladesh. pp. 5-12.

Agazzani, C., Campagana, G. and Rapparini, G. (1999). Weed control in dry sown rice. *Informatore Agrario.* **55** (22): 85-87.

Ahissou, A. and Akobundu, I. O. (1983). Weed interference in hydromorphic rice. In: Proceedings of the Second Biannual Conf., Abidjan, Ivory Coast. West Afr. Weed Sci. Soc. pp. 34-39.

Ahmed, N. U. (1981). Effect of time of nitrogen application on weed growth and yield of dry seeded rice. *Intl. Rice. Res. Newl.* **6** (2): 12-13.

Ahmed, G. J.U., Hossain, S. T., Rahman M. B. and Kabir M. S. (1999). Chemical weed control in wet seeded rice. Brighton Crop Protec. Conf. Weeds Proc. Intl. Conf. Brighton, UK. pp. 243-248.

Ahmed, G. J. U., Mamun, A. A., Hossain, S. M. A., Siddique, S. B. and Mirdha, A. J. (1997). Effect of Bosagran and raking combined with hand weeding to control weeds in aus rice . *Bangladesh Agron. J.* **7** (1&2): 31-32.

Ahmed, G. J. U., Mridha, A. J., Bhuiyan, M. K. A., Riches, C. R. and Mortimer, M. (2003). Effect of different weed management systems on weed control, plant growth and grain yield of lowland rice. In: Proceedings of Nineteenth Asian Pacific Weed Sci. Soc. Conf. 17-21 March, 2003. Philippines. No.1: 84-92.

Akobundu, I. O. and Ahissou, A. (1985). Effect of inter row spacing and weeding frequency on the performance of selected rice cultuvars on hydromorphic soils of West Africa. *Crop Protec.* **4** (1): 71-76.

Alam, M. S., Islam, M. N., Zaman, A. K. M., Biswas, B. K. and Saha, M. K. (1996). Relative efficiency and economics of different cultural methods and herbicides for weed control in transplanted aus rice. *Bangladesh J. Agril. Sci.* **23**(1): 67-73.

Angiras, N. N. and Rana, S. S. (1998). Integrated weed management in direct seeded puddled sprouted rice. *Indian J. Agron.* **43** (4): 644-649.

Ashraf, M. M., Awan, T. H., Manzoor, Z., Ahmad, M. and Safdar, M. E. (2006). Screening of herbicides for weed management in transplanted rice. *J. Animal Plant Sci.* **16** (3/4): 89-92.

Attalla, S. I. and Kholosy, A. S. (2002). Effect of weed control treatment on transplanted rice. Bull. Fac. Agric., Cairo Univ. 53 (4): 525-530.

Ayub, M., Sharma, M. S. and Nazir, M. S. (1987). The yield and yield component of fine rice as influenced by different spacing. *Pakistan J. Sci, Ind. Res.* **30** (7): 523-525.

Azad, A. K., Gaffer, M. A., Samanta, S. C., Kashem, M. A. and Islam, M. T. (1995). Response of BR 10 rice variety to different levels of nitrogen and spacing. *Bangladesh J. Sci. Ind. Res.* **30** (1): 31-38.

Aziz, M. B. and Hasan, R. (2000). Evaluation of System of Rice Intensification (SRI) in Bangladesh. Locally Intensified Farming Enterprised Project, CARE, Dhaka, Bangladesh. pp. 4-9.

Balasubramiyan, P. (1983). Effect of planting system, herbicide application and nitrogen on weed growth and yield of rice. *Madras Agric. J.* **70** (20): 125-127.

Balaswamy, K. (1999). Effect of urea and herbicides on weed composition and density in transplanted rice. *J. Res. ANGRAU.* **27** (3): 5-11.

Bali, A. S. (2006). Response of scented rice 'mushk budgi' to various planting geometry and fertility levels under temperate agro-climatic conditions of Jammu and Kashmir. *Environ. Ecology.* **24** (Special 3): 638-641.

Baloch, M. S., Awan, I. U., Gul H. and Khakwani, A. A. (2006). Effect of establishment methods and weed management practices on some growth attributes of rice. *Rice Sci.***13** (2): 131-140

Bari, M. N., Mamun, A. A. and Anwar, S. M. S. (1995). Weed infestation in transplanted aman rice as affected by land topography and time of transplanting. *Bangladesh J. Agril. Sci.* **22** (2): 227-235.

BBS (Bangladesh Bureau of Statistics). (2002). Yearbook of Agricultural Statistics of Bangladesh. Bangladesh Bureau of Statistics, Stat. Div., Min. Plan., Govt. of the People’s Repub. Bangladesh. p.36.

BBS (Bangladesh Bureau of Statistics). (2003). Yearbook of Agricultural Statistics of Bangladesh. Bangladesh Bureau of Statistics. Stat. Div., Min. Plan. Govt. of the People’s Repub. of Bangladesh. p.123.

Belz, R. G. (2007). Allelopathy in crop-weed interactions - an update. *Pest Management Sci.* **63** (4): 308-326.

Bhab, K. L., Dhama, A. K. and Azad, B. S. (1987). Effect of Plant spacing and number of seedlings hill^{-1} on the growth and yield of Basmati rice. *Anl. Agril. Res.* **12** (3): 249-254.

Bhattacharya, S. P., Gash, R. P., Brahmachari, K., Pal, T. K. and Kumar, T. K. K. (1996). Efficiency of some new generation herbicides in controlling weed of transplanted boro paddy. *Environ. Ecol.* **14** (2): 657-661.

Bhowmick, M. K. (2002). Optimization of Pretilachlor dose for weed management in transplanted rice . *Annals Plant Protec. Sci.* **10** (1): 131-133.

Bhowmick, M. K., Nayar, R. L. and Ray, D. (2002). Herbicide studies on weed management, crop phytotoxicity, growth and yield of dry season rice. *Annals Agril. Res.* **23** (1): 116-122.

Bijon, K. M. (2004). Effect of variety and weed control on weed seed bank, weed dynamics and the performance of transplanted aman rice. M. S. Thesis. Dept. Agron., Bangabandu Sheikh Mujibar Rahman Agril. Univ.,Salna, Gazipur.,Bangladesh.

Biswas, J. C., Satter, S. A. and Siddique, S. B. (1991). Evaluation of herbicides in direct seeded rice. *Bangladesh Rice J.* **2** (1-2): 40-46.

Brar, L. S., Walia, U. and Dhaliwal, B. K. (1997). Time of application of herbicides against *Echinochloa crus-galli* in transplanted rice. *J. Res. Punjab. Agril. Univ.* **34** (2): 131-135.

BRRI (Bangladesh Rice Research Institute). (1990). Annual Report for 1987. Bangladesh Rice Res. Inst., Joydebpur, Gazipur,Bangladesh. pp. 16, 40-42.

BRRI (Bangladesh Rice Research Institule). (1991). Anual Report for 1988. BRRI, Joydebpur, Gazipur. pp.10-33.

BRRI (Bangladesh Rice Research Institule). (1992). Anual Report for 1990. BRRI, Joydebpur, Gazipur. pp.8, 320.

BRRI (Bangladesh Rice Research Institute). (1997). Internal Review for 1996. Bangladesh Rice Res. Inst., Joydebpur, Gazipur, Bangladesh. pp. 7-8.

BRRI (Bangladesh Rice Research Institule). (1998 a). Anual Report for 1995. Bangladesh Rice Res. Inst., Joydebpur, Gazipur,Bangladesh. pp.7-8.

BRRI (Bangladesh Rice Research Institute). (1998 b). Annual Report for 1995. Bangladesh Rice Res. Inst., Joydebpur, Gazipur,Bangladesh. pp. 12-14.

BRRI (Bangladesh Rice Research Institute). (2000 a). Adhunic Dhaner Chash (in Bangla). Bangladesh Rice Res. Inst., Joydebpur, Gazipur, Bangladesh. pp. 8-18.

BRRI (Bangladesh Rice Research Institute). (2000 b). Adhunic Dhaner Chash (in Bangla). Bangladesh Rice Res. Inst., Joydebpur, Gazipur, Bangladesh. p.27.

Burhan, H. D., Sozzi and Zosehke. (1989). Set-off for weed control in rice. Practical experience for Indonesia. Proc. 12th Asian Pacific Weed Sci. Soc. Conf. 1989. Taipei, Tainwan. No.1: 127-131.

Carbonell, P. U. and Moody, K. (1983). Weed control practices in irrigated and rainfed rice farms in Nueva, Ecija, Philippines. Philippines Agric. 66: 458-469.

Chandra, D. and Mama, G. B. (1990). Weed management in transplanted rice grown under shallow submerged condition. *Indian J. Agron.* **27** (4): 465-467.

Chandra, S. and Pandey, J. (2001). Effect of rice culture, nitrogen and weed control on nitrogen competition between scented rice and weeds . *Indian J. Agron.* **46** (1): 68-74.

Chandra, S. and Solanki, O. S. (2003). Herbicidal effect on yield attributing characters of rice in direct seeded puddled rice . *Agril. Sci. Digest Karnal.* **23** (1): 75-76.

Chandra, S., Tiwari, A. N. and Singh, R. (1998). Efficiency of herbicides in direct seeded puddled rice. *Agril. Sci. Digest Karnal.* **18** (2): 71-72.

Chavan, S. A., Kanade, V. M. and Khanvilkar, S. A. (1989). Effect of graded N and spacing on performance on Mashuri variety of rice. *J. Maharashtra Agril. Univ.* **14** (2): 196-197.

Chon, S., Youh, J. O. and Kim, U. J. (1994). Difference in morphological and anatomical response to Butachlor. *Korean J. Weed Sci.* **14** (3): 199-211.

Chowdhury, H. A. H., Talukder, N. M., Chowdhury, A. K. and Hossain, M. Z. (1995). Effect of Ronstar on weed management, yield and nutrient uptake by rice. *Bangladesh J. Agril. Sci.* **22** (1): 93-98.

Chris, E. (2002). Experience with the System on Rice Intensification in Nepal. In: Assessments of the System of Rice Intensification Prof. Int. Conf., Sanya, Chaina. April 1-4, 2002. pp. 64-66.

Dhiman M., Singh,R. P. and Singh, R. K. (2006). Studies on weed management in transplanted rice (*Oryza sativa* L.). *Res. Crops.* **7** (3): 630-632.

Dhiman, M. (2005). Weed control in transplanted rice (*Oryza sativa* L.). *Haryana J. Agron.* **21** (1): 28-30.

Dongarwar, U. R., Pawar, W.S. and Shinde, V. S. (2005). Scented rice varieties as influenced by different spacing in Vidarbha zone of Maharashtra. *Oryza.* **42** (1): 73-74.

Dunand, R. and Dilly, R. (1982) . Rice growth analysis. In 74th Ann. Prog. Rep. Rice Exp. Sta. pp.159-172.

Dutta, R. And Gogi, A. K. (1994). Integrated weed control in direct seeded upland rice (*Oryza sativa*). *Indian J. Agron.* **39** (4): 639-641.

Elliot, P. C., Navarez, D. C. and Moody, K. (1984). Yield of rainfed transplanted rice as affected by cultivar, fertilizer level and weeding regime. Rice Farming Systems Program. Intl. Rice Res. Inst., Los Banos, Philippines. pp.1-6.

FAO (Food and Agriculture Organization). (1998). Production Yearbook for 1998. FAO, UN. Rome , Italy. p.118.

Gardner, F. P., Pearce, R. B. and Mistechell, R. L. (1985). Physiology of crop plants. Iowa State Univ. Press. Iowa, 500010. p.66.

Gautam, A. K., Mishra, B. N., Sarkar, N. C. and Mishra, P. K. (2005). Effect of graded levels of nitrogen and plant spacing on grain yield and quality of aromatic rice. *Annals Agril. Res.* **26** (3): 402-405.

Geethadevi, T., Andani, G., Krishanappa, M., Babu, B. T. R. and Gowda, A. (2000). Effect of nitrogen and spacing on the growth and yield of hybrid rice. *Current Res. Univ. Agril. Sci. Bangalore.* **29** (5-6): 73-75.

Ghosh, B. C., Reddy, M, D. and Reddy, B. B. (1998). Effect of seedling density on the growth and yield of transplanted aman rice in an intermediate deep water situation. *Thai. J. Agric. Sci.* **21** (1): 13-21.

Gnanasambandan, S. and Murthy, P. B. (2001). Effect of tillage practices and pre-emergence herbicides application for weed control in wet seeded rice. *Madras Agril. J.* **88** (10-12): 590-593.

Gogoi, A. K. (1998). Weed control in late transplanted low land rice. *Indian J. Agron.* **43** (2): 298-301.

Gogoi, A. K., Rajkhowa, D. J. and Kandali, R. (2000). Effect of varieties and weed control practices on rice productivity and weed growth. *Indian J. Agron.* **45** (3): 580-585.

Gogoi, A. K., Rajkhowa, D. J. and Kandali, R. (2001). Integrated weed control in rainy season rice under medium land situation. *Indian J. Agron.* **33** (1-2): 10-21.

Hakkansson, S. (1984). R spacing, seed distribution in the row, amount of weeds influence on production in stands of cereals. In: Weeds and Weed control 25th Swedish Weed Conf. Upasala, 2nd Feb., 1984. Vol.1. pp. 17-34.

Han H. D., Chen M. J. and Lin, Y. H. (2006). Effects of different spacings and N application levels on yield of rice Jinliangyou 36. *Fujian Agril. Sci. Tech.* **3** (1): 50-51.

Haque, D. E. (2002). Effect of Madagascar Technique of younger seedling and wider spacing on the growth and yield of Boro rice. M. S. Thesis. Dept. Agro., Bangladesh Agril. Univ., Mymensingh. pp.28-71.

Haque, M. S. and Nasiruddin, M. (1988). Effect of population density on yield and agronomic traits of deep water rice. In Proc. 1987. Intl. Deep Water Rice Workshop. Manila, Phillppines: IRRI. pp. 449-453.

Haque, M.E. (1993). Rostar as weedicide in transplanted aman rice ,M.S. Thesis, Dept. Agron., Bangladesh Agril. Univ., Mymenshngh, pp. 29-31.

Hegazy, M. H., Abd-el Fattah, K. and Abadi, D. (1995). Effect of algalization. nitrogen fertilization and plant density on rice yield and it's compenents. *Ann. Agri. Sci. Cairo*. **40** (2): 547-577.

Hossain, M. (2000). Auto-ecology of *Echinochloa crus-galli* and its control in direct seeded aus rice. M. S. Thesis. Dept. Agron., Bangladesh Agril. Univ., Mymensingh. pp. 57-62.

Hossain, M. Z. (2002). Performance of BRRI dhan 32 in the SRI and Conventional Methods and Their Technology Mixes. M. S. Thesis, Dept. Agron., Bangladesh Agril. Univ., Mymensingh. pp. 28-71.

Hu, W. H., Wu, C. S., Deng, S. H. and He, S. H. (1997). A study of the growth characteristics of rice at different populations. *J. Jilin. Agril. Univ.* **19** (1): 21-27.

Hunt, R. (1978). The field curve in plant growth studies. Math and plant physiology (Eds. Rise, D. A. and Edwas, DAC). Aca, Press. London. pp. 283-298.

Hwu, K. and Thseng, F. S. (1982). Environmental effects on agronomic characters and their development stabilities in rice (*Oryza sativa* L). The differences in mean values variations within plants and between plants of agronomic characters in different plant densities and crop seasons. *J. Agric. Assoc. China.* **118** (3): 48-61.

IRRI (International Rice Research Institute). (1985). International Rice Research 25 years of Partnership. Los Banos, Philippines. pp. 40-46.

IRRI (International Rice Research Intitute). (1975). Annual Report for 1974. Intl. Rice Res. Inst., Los Benos, Philippines. pp. 141-233.

Islam , M. S. (1995). Effect of cultivar and weeding regime on growth and performance of boro rice. M. Sc. (Ag.) Thesis, Dept. Agron., Bangladesh Agril. Univ., Mymensingh. pp. 40-43.

Islam, M. S., and Haq, K. A, (1987). Development of a low cost weeder for low-land paddy. *Bangladesh J. Agric.* **12** (4): 255-262.

Islam, M. S., Sarker, M. A. R., Rahman, M. S., Musa, A. M. and Dhan, S. C. (1994). Effect of plant population density on transplanted aus rice under tidally flooded conditions. *Bangladesh J. Agril. Sci.* **21** (2): 349-353.

Islam, T., Bhowmick, M. K., Ghosh, R. K. and Sounda, G. (2001). Effect of Pretilachlor on weed control and yield of transplanted rice. *Environ. Ecol.* **19** (2): 265-268.

Jacob, D. and Syriac, E. K. (2005 a). Performance of transplanted scented rice (*Oryza sativa* L.) under different spacing and weed management regimes in southern Kerala. *J. Tropical Agric.* **43** (1/2): 71-73.

Jacob, D. and Syriac, E. K. (2005 b). Relative efficacy of different spacings and weed control methods in scented rice. *Oryza.* **42** (1): 75-77

Janardhan, G., Muniyappa, T. V. and Gowda, J. V. N. (1993). Effect of pre-emergence herbicides on weed control in transplanted rice. *Crop Res. Hisar.* **6** (1): 155-158.

Jena, S. N., Tripathy, S., Sarangi, S. K. and Biswal, S. (2002). Integrated weed management in direct seeded rainfed lowland rice. *Indian J. Weed. Sci.* **34** (1-2): 32-35.

Kalhirvelan, P. and Vaiyapuri. V. (2003). Relative efficacy of herbicides in transplanted rice. *Indian J. Weed Sci.* **35** (3-4): 257-258.

Kalyanasundaram, D., Kumar, S. R.V. and Kumar, K. P. S. (2006). Studies on integrated weed management in direct-seeded lowland rice (*Oryza sativa* L.). *Res. Crops.* **7** (3): 627-629.

Kamalam, J. and Bridgit, T. K. (1993). Effect of chemical and integrated weed management in upland rice. *J. Tropic. Agric.* **31**: 77-80.

Karim, M., Rahman, M., Aziz, M. and Gonsalves, C. (2002). Effect of spacing and seedling age on rice yields in farmers fields in Rajshahi and Kishoregonj District, Bangladesh-Two components in the System of Rice Intensification. LIFE-NOPEST-II Project. CARE . Bangladesh. pp.1-6.

Kathiresan, G. and Veerabadran, V. (1991). Effect of integrated weed management on nutrient uptake in semi dry rice and associated weeds. *Mysore J. Agril. Sci.* **25**: 414-417.

Khalil, M. E. (2001). Effect of planting density on the growth and yield of some fine rice varieties. M. S. Thesis. Dept. Agron., Bangladesh Agril. Univ., Mymensingh, Bangladesh.

Khan, M. A. H., Jensen, H. E. and Jensen, S. E. (1981). Barley crop development, yield and light energy utilization under field condition. *Cereal Res. Comm.* **9** (2): 191-195.

Kim, S. C. and Moody, K. (1980). Effect of plant spacing on the competitive ability of rice growth in association with various weed communities at different nitrogen levels. *J. Korean Soc. Crop. Sci.* **25** (4): 17-27.

Kulmi, G. S. (1990). Cultural and chemical weed control in transplanted rice (*Oryza sativa*). *Crop Res. Hisar.* **3** (2): 151-154.

Kurmi, S. and Das, N. (1993). Effect of herbicides on weed control in transplanted rice. Integrated weed management for sustainable agriculture. Proceedings of an Ind. Soc. of India. Vol. III. pp. 27-29.

Madhu, M., Najappa, H. V. and Naik, H. R. (1996). Economics of weed control treatment in puddled seeded rice. *Crop Res. Hisar.* **12** (2): 133-137.

Mahajan, G., Boparai, B. S., Bra, L. S. and Sardana, V. (2003). Effect of Pretilachlor on weeds in direct seeded puddled rice . *Indian J. Weed Sci.* **35** (1-2): 128-130.

Mahbub, A. M. M., Hossain , M. and Janaich, A. (2001). Hyrid rice adoption in Bangladesh. A socioeconomic assessment of farmers experience: Research

Monograph, Series no. 18. Social Sciences Division, 2001. Los Banos, Philippines. p.38.

Mamun, A. A. (1990). Weeds and their control: A Review of Weed Research in Bangladesh. JSARD, Japan Intl. Co-operation Agency. Dhaka, Bangladesh. pp. 45-72.

Mamun, A. A., Karim, S. M. R., Begum, M., Uddin, M. I. and Rahman, M. A. (1993). Weed survey in different crops under three Agroecological Zones of Bangladesh. BAURES Prog. 8: 41-51.

Mandal, M. A. H., Rahman M. A. and Gaffer, M. A. (1995). Field efficiency of Rilof H and Rifit herbicides for weed control in transplanted rice. *Bangladesh J. Agril. Sci.* **20**: 7-12.

Manish C., Khajanji, S. N., Savu, R.M. and Dewangan, Y. K. (2006). Effect of halosulfuron-methyl on weed control in direct seeded drilled rice under puddled condition of Chhattisgarh plains. *Plant Archives.* **6** (2): 685-687.

Mannan, M. A. and Siddique, J. B. (1991). Effect of seedling age and date of planting on the growth and yield of photoperiod sensitive rice. *Bangladesh Rice J.* **2** (1-2): 104-106.

Mia, M. A. B. (2001). Effect of variety and spacing on the growth, yield and yield contributing characters of aromatic rice. M. S. Thesis, Dept. Agron., Bangladesh Agril. Univ., Mymensingh. pp. 22-65.

Miah, M. H. N., Karim, M. A., Rahman, M. S. and Islam, M. S. (1990). Performance of Nizersail mutants under different spacing. *Bangladesh J. Train. and Dev.* **3** (2): 31-34.

Mian, A. L. and Bhuiya, M. S. U. (1977). Cost, output and return in crop production. *Bangladesh J. Agron.* **1** (1-2): 8.

Mobasser, H. R., Tari, D. B., Vojdani, M., Abadi, R. S. and Eftekhari, A. (2007). Effect of seedling age and planting space on yield and yield components of rice (cv. Neda). *Asian J. Plant Sci.* **6** (2): 438-440.

Moorthy, B. T. S. and Das, F. C. (1992). Performance evaluation of tow manuallly operated weeders in upland rice. *Orissa J. Agril. Res.* **5** (1-2): 36-41.

Moorthy, B. T. S., Saha, S. and Saha, S. (2002). Evaluation of pre and post emergence herbicides for their effects on weeds and upland direct seeded rice. *Indian J. Weed Sci.* **34** (3-4): 197-200.

Moorthy, B. T. S., Sanjay, S. and Sanjoy, S. (1999). Relative efficacy of different herbicides for weed control in direct seeded rice on puddled soil. *Indian J. Weed Sci.* **31**: 3-4, 210-213.

Murty, P. S. S. and Murty, M. S. (1981). Influence of LAI at flowering on rice. *Oryza.***18** (10):35-38.

Mustapha, C. (2000). Experiments with the System of Rice Intensification in the Gambia. In: Assessments of the System of Rice Intensification. Proc. Intl. Conf., Sanya, China. April 1-4, 2000. p.56.

Nair, A. K., Pramic, S. C., Ravisankar, N. and Dinesh, R. (2002). Effect of vareties and weed control practices on productivity of rice and weed growth in lowland of the South Andamans. *Indian J. Agril. Sci.* **72** (8): 477-479.

Nandal, D. P., Hari, O.M. and Om, H. (1998). Weed control in direct seeded puddled rice. *Indian J. Weed Sci.* **30** (1-2): 18-20.

Navarez, D. E., Estano, D. B. and Moody, K. (1982). Preliminary evaluation of farmers weed control practices in Cagayan in Philippines. *Philippines J. Weed Sci.* **8** (2): 49-55.

Nurujjaman, M. (2001). Effect of plant spacing and herbicides on the weed control and yield of transplanted aman rice (cv. BR 22). M. S. Thesis. Dept. Agron., Bangladesh Agril. Univ., Mymensingh, Bangladesh.

Otsuka, H., Nemoto, M. and Masuda, S. (2006). The floristic composition of paddy fields and their levees under different weed management techniques. *J. Weed Sci. Tech.* **51** (4): 229-238.

Ottis, B. V. and Talbert, R. E. (2007). Barnyardgrass (*Echinochloa crus-galli*) control and rice density effects on rice yield components. *Weed Tech.* **21** (1): 110-118.

Padmajarao, S. (1995). Yield and high density grain as influenced by crop density and N level in scented rice. *Madras Agric. J.* **82** (2):108-112.

Patil, S. J., Natarayan, S. P. and Pattanshetti, H. V. (1986). Herbicides for weed control in transplanted rice. *Intl. Rice Res. Newl* . **11** (2): 28.

Polthanee, A., Ta-Oun, M., Panchapan, S., Lasirkul, M., Pramojchani, P., Yamazaki, K., Nakano, M., Fukami, M. and Ushikubo, A. (1996). Effective weed management on growth and yield of rainfed direct seeded rice. *Kaen-Kaset Khon Kaen Agril. J. Thailand.* **24** (2): 76-80.

Prasad, K. and Rafey, A. (1995). Effect of integrated weed management on weed growth, nutrient uptake, economics and energetics in rainfed upland rice (*Oryza sativa*). *Indian J. Agri. Sci.* **65** (4): 260-264.

Purushotham, S., Munegowda, M. K. Dwarakanath, N. and Mohan, S. L. (1990). Evaluation of new herbicides in transplanted rice. *Current Res. Univ. Agril. Sci. Bangalore.* **19**: 73-75.

Radford, P. J. (1967).Growth analysis formulae. Their use and abuse. *Crop Sci.* **7**: 171-175.

Rafiq, K., Maqsood, M., Akbar, N. and Iqbal, M. S. (1998). Effect of different spatial arrangements on yield and yield components of fine rice (Basmati-385). *Pakistan J. Agril. Sci.* **35** (1-5): 59-61.

Rajendran, R. and Kempuchetty, N. (1998). Efficiency of herbicides in direct seeded puddled rice. *Agril. Sci. Digest. Karnal.* **18** (2): 71-72.

Rajkhowa, D. J., Gogoi, A. K. and Kandali, R. (2001). Effect of weed control and nutrient management practices in rice. *Indian J. Weed Sci.* **33** (1&2): 41-55.

Raju, A., Pandian, B. J., Thukkaiyannan, P. and Thavaprakash, N. (2003). Effect of weed management practices on the yield attributes and yield of wet seeded rice. *Acta. Agron. Hungarica.* **51** (4): 461-464.

Ramakrishna, T. A, Shivraj, B. and Gowda, A. (1992). Effect of planting date, seedling age and spacing on yield of rice. *Current Res. Univ. Agril. Sci. Bangalore.* **21** (4): 63-64.

Rangaraju, G. (2002). Weed flora and weed dynamics of pre-monsoon dry seeded rainfed rice as influenced by herbicide and it's time of application. *Indian J. Weed Sci.* **34** (1-2):123-125.

Ranjit, J. D., Suwanketnikom, R. (2005). Response of weeds and yield of dry direct seeded rice to tillage and weed management. *Natural Sci.* **39** (2): 165-173.

Rao, K. S., Moorthy, B. T. S. and Manna G. B. (1990). Plant population for higher productivity in Basmati type scented rice. *Intl. Rice Res. Newsl.* **15** (1): 26.

Rashid, M. H. and Khan, M. A. H. (2006). Tillering dynamics and productivity of BRRI dhan 44 as influenced by spacing and nitrogen management technique. *J. Agric. Rural Develop.* **4** (1/2): 47-52.

Razzaque, A. H. M., Enamul, M. and Gaffer, M. A. (1998). Performance of Ronstar as a herbicide in transplanted aman rice. *Bangladesh J. Sci. Ind. Res.* **33** (4): 503-507.

Reddy, B. G. M., Patter, P. S. and Itnal, C. Z. (2001). Agronomic management of transplanted rice under late planted conditions. *Karnataka J. Agril. Sci.* **14** (3): 760-761.

Rekha, K. B., Razu, M. S. and Reddy, M. D. (2002). Effect of herbicides in transplanted rice. *Indian J. Weed Sci.* **34** (1-2): 123-125.

Rekhashri, K., Borthakur, M. P., Sarmah, B. N. and Kalita, R. (1997). Effect of planting geometry and levels of fertilizer on yield parameters, yield and uptake of late planted sail rice. *J. Agril. Sci. Soc. North-East India.* **10** (2): 256-258.

Samanta, S. C., Gaffer, M. A., Kashem, M. A., Sultan, A. and Ahmed, S. (1995). Ronstar for weed control in transplanted aman rice culture. *Bangladesh J. Sci. Ind. Res.* **30** (2-3): 225-233.

Samar S., Ladha, J. K., Gupta, R.K., Lav, B., Rao, A. N., Sivaprasad, B. and Singh,P. P. (2007). Evaluation of mulching, intercropping with *Sesbania* and herbicide use for weed management in dry-seeded rice (*Oryza sativa* L.). *Crop Protec.* **26** (4): 518-524.

Sanjoy, S., Morthy, B. T. S. and Jha. K. P. (1999). Influence of different production factors on the performance of rainfed upland rice . *Indian J. Agril. Sci.* **69** (6): 449-450.

Sarkar, M. A. R., Sarkar, A. U. and Islam, M. S. (1988). Effect of seedling age, planting density and number of seedling hill^{-1} on the yield and yield component of transplanted aman rice. *Bangladesh J. Extn. Edn.* **3** (2): 71-76.

Sarker, M. A. I. (2001). Effect of row sowing and number of seedling hill^{-1} on the performance of hybrid rice, Sonar Bangla-1. M. S. Thesis. Dept. Agron., Bangladesh Agril. Univ., Mymensingh. p. 52.

Savithri, K. E., Chidandra, M. R. and Tomy, P. J. (1994). Efficiency of pre-emergence herbicides in transplanted rice. *J. Trop. Agril.* **32**: 27-29.

Sawant, A. C. and Jadav, S. N. (1985). Efficiency of different herbicides for weed control in transplanted rice in Konkan. *Indian J. Weed Sci.* **17** (3): 35-39.

Selvam, V., Boopathi, S. N. M. R., Poonguzhalan, R., Narayan, A. (2001). Effect of time of sowing and weed management practices in some dry rice. *Madras Agril. J.* **88** (1-2): 12-16.

Shah, M. H., Khusu, M. K., Khandays, B. A. and Bali. (1991). Effect of spacing and seedling hill^{-1} on transplanted rice under late sown condition. *Indian J. Agron.* **36** (2): 247-276.

Shah, M. H., Singh, K. N., Khanday, B.A., Zutshi, S. N., Koul , R. N., Siddiqe, M. and Bali, A. S. (1990). Relative efficiency of different formulations of butachlor in controlling weeds of transplanted rice. *Indian J. Weed Sci.* **22** (3-4): 70-73.

Sharma, A. and Gogoi, A. K. (1995). Mechanical weed control in upland rice. *World Weed.* **2** (2): 137-143.

Sharma, S. K. and Bhunia, S. R. (1999). Weed management in transplanted rice under Ghaggar floodplains of northwest Rajasthan. *Indian J. Agron.* **44** (3): 543-547.

Shivamdiah, N. C., Ramegowda, S. and Bommegowda, A. (1987). Studies on integrated weed management in drill sown rice. *Current Res. Univ. Agril. Sci. Bangalore.* **16** (4): 51-52.

Siddique, M. R., Lakapale, R. and Tripathi, R. S. (1999). Effect of spacing and fertilizer on medium duration rice (*Oryza sativa*) varieties. *Indian J. Agron.* **44** (2): 310-312.

Singh, C. M., Moody, K. and Cho, S. C. (1985). Weed control through inter-row cultivation in upland rice. *Sarhad J. Agric.* **16** (3): 35-40.

Singh, G. and Singh, O.P. (1994). Herbicidal control of weed in transplanted rice in rainfed low land condition. *Indian J. Agron.* **39**(3): 463-465.

Singh, G., Mehta, R. K. and Singh, G. (1998). Relative efficacy of mechanical and chemical weed control measures in rainfed lowland rice. *Ann. Agril. Res.* **19** (1): 112-113.

Singh, G., Singh, R. K., Singh, V. P., Nayak, R. and Singh, R. S. (1999). Weed management in transplanted rice (*Oryza sativa*) under rainfed lowland situation. *Indian J. Agron.* **44** (4): 728-732.

Singh, O. P. and Bhan, V. M. (1992). Effect of herbicides and water submergence levels on control of weeds in transplanted rice. *Indian J. Weed Sci.* **24** (4): 226-230.

Singh, R. P. Reddy, B. G. and Rao, A. S. (1994). Comparative performance of mechanical weeder alone and in combination with herbicides. *J. Soils and Crops.* **25** (3): 41-43.

Singh, R. S. (2005). Study of Beushening in controlling weeds under rainfed lowland rice in Chotanagpur Region. *J. Applied Biology*. **15** (1): 22-24.

Singh, S. P. and Kumar, R. M. (1999). Efficacy of single and sequential application of herbicides on weed control in transplanted rice. *Indian J. Weed Sci.* **31** (3-4): 222-224.

Singh, V. P., Govindra S., Singh, R. K., Singh, S. P., Kumar, A., Sharma, G., Singh, M. K., Mortimer, M. and Johnson, D. E. (2005). Effect of weed management and crop establishment methods on weed dynamics and grain yield of rice. *Indian J. Weed Sci.* **37** (3/4): 188-192.

Srinivasan, K. and Purushothaman, S. (1990). Effect of plant spacing on ratoon rice performance. *Intl. Rice. Newsl.* **15** (4): 21.

Subramanian, E., Martin, G. J. and Balasubramanian, R. (2006). Effect of integrated weed-management practices on growth and yield of wet-seeded rice (*Oryza sativa*) and their residual effect on succeeding pulse crop. *Indian J. Agron.* **51** (2): 93-96.

Tamilselvan, N. and Budhar, M. N. (2001). Weed control in direct seeded puddled rice. *Madras. Agril. J.* **88** (10-12): 745-746.

Thangamuthu, G. S. and Subramanian, S. (1983). Effect of plant population and urea super granule deep placement on rice yield. *Intl. Rice Res. Newsl.* **8** (5): 23-24.

Thomas, C. G., Abraham, C. T. and Sreedevi, P. (1997). Weed flora and their relative dominance in semi dry rice culture. *J. Tropic. Agric.* **35**: 51-53.

Tosh, G. C., Reddy, B. S. and Nonda, K. C. (1981). Integrated weed management in dryland rice . *Int. Rice Res. Newsl.* **6** (5): 20.

Toufiq, A. (2003). Integrated weed management in transplanted aman rice cv. BRRI dhan 37. M. S. Thesis. Dept. Agron., Bangladesh Agril. Univ., Mymensingh, Bangladesh.

Trivedi, K. K., Tiwari, J. P. and Bisen, C. R. (1986). Integrated weed control in upland drilled rice. *Pesticides.* **20** (11): 29-33.

Tsai, J. C. (1987). Effect of cultural method on the yield and some physiological characters of rice cultivars different in grain weight. *J. Agril Res. Chiana* **36** (1): 63-64.

Venkataraman, N. S. and Gopalan, M. (1995). Current status of weed problems in rice production in Tamil Nadu, India. In. Papusas, H. R. and Heong, K. L. (ed.) Weed Management in Rice Production. Intl. Rice. Res. Inst., Los. Banos. Laguna, Philippines. pp. 113-126.

Verma, A. K., Pandey, N. and Tripathi, S. (2002) . Effect of plant spacing and number of seedlings on productive tillers, spikelet sterility, grain yield and harvest index of hybrid rice. *Intl. Rice Res. Notes.* **27** (10): 51.

Verma, O. P. S., Katyal, S. K. and Sharma, H. C. (1988). Effect of planting density, fertilizers and weed control of transplanted rice. *Indian J. Agron.* **33** (4): 372-375.

Virida, A. M., Patel, H. S. and Patel, M. P. (1993). Spacing and nitrogen requirements of rice varieties. *Gujarat Agril. Univ. Res. J.* **19** (1): 133-135.

Wang, S., Cao, W., Jiang, D., Dai, T. and Zbu, Y. (2002). Physiological characteristics and high yield techniques with SRI rice. In: Assessments of the System of Rice Intensification. Proc. Intl. Conf., Sanya, China. April 1-4, 2002. pp.117-121.

Yan, Q. (2002). The system of rice intensification and its use with hybrid rice varieties in china. In: Assessments of the System of Rice Intensification. Proc. Intl. Conf., Sanya, Chian. April 1-4, 2002. p.110.

Yang, F., Guo, L., Xu, C. and Shao, X. (1999). Study on yield performance of rice “Jinongda-3’ under different density. *J. Jilin. Agril. Univ.* **21** (3): 16-18.

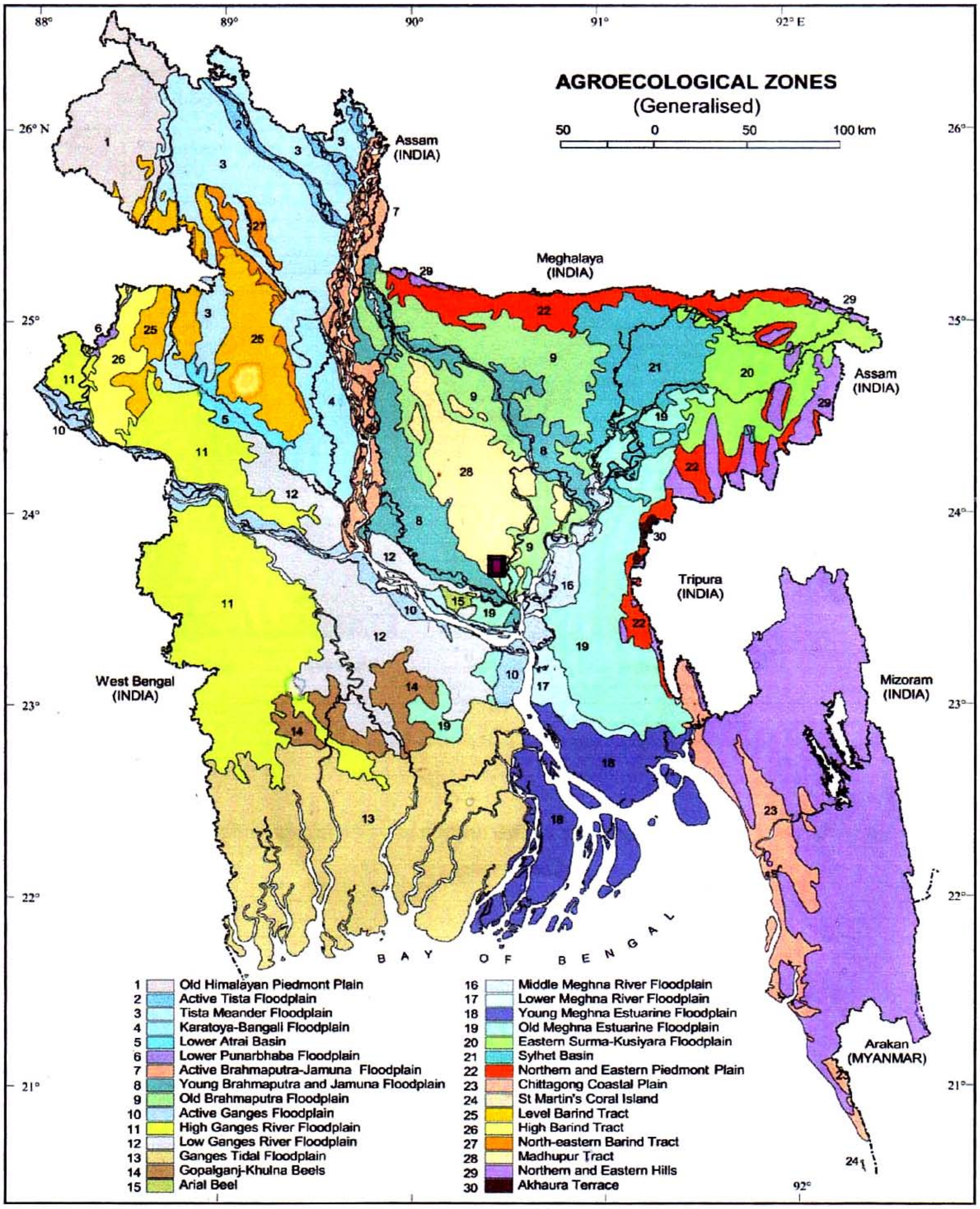
Yoshida, S. (1981). Fundamentals of Rice Crop Science, IRRI, Philippines: 1- 41.

Yuan, H. G., Xu, H. Z. ,Gias, J. and Yin, X. C. (1991). Preliminary report of weed control experiments with various new herbicides in direct sowing and seedling transplanting rice fields. *J. Weed Sci.* **5**(1): 17-23.

Zhao, G. P., Chen, Z. Y. and Zhang, G. P. (1998). Effect of plant density on population structure and light utilization by seedlings of rice raised in dry nursery. *J. Zhejiang Agril. Univ.* **24** (4): 349-353.

APPENDICES

Appendix I. Map showing the experimental site under study



The experimental site under study

Appendix II: Characteristics of experimental soil was analyzed at Soi Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	***Characteristics***
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

Source: SRDI (Soil Resources Development Institute), Farmgate, Dhaka

B. Physical and chemical properties of the initial soil

Characteristics	*Value*
Partical size analysis	
% Sand	27
%Silt	43
% Clay	30
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Source: SRDI (Soil Resources Development Institute), Farmgate, Dhaka

Appendix III: Monthly record of air temperature, rainfall, and relative humidity during the period from July – December, 2006

Month	***RH (%)***	***Air temperature (^oC)***			***Rainfall (mm)***
		Max.	***Min.***	***Mean***	
July	81	31.4	25.8	28.6	542
August	82	32.0	26.6	29.3	361
September	81	32.7	26.0	29.35	514
October	80	30.5	24.3	27.4	417
November	72	29.0	19.8	24.4	3
December	66	27.0	15.6	21.3	0

Source: Bangladesh Meterological Department (Climatic Division), Agargaon, Dhaka-1207

Appendix IV: Analysis of variance (Mean squares) for weed density, weed biomass and weed control efficiency as influenced by integrated weed management and spacing in transplanted aman rice cv. BRRI Dhan 37 at different DAT.

Sources of variation	Degrees of freedom	Weed density (no. m $^{-2}$)		Weed biomass (g m^{-2})		Weed control efficiency (%)	
		30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT
Replication	2	2271.722	342.574	93.748	46.602	1629.508**	674.305
Weeding (A)	5	14244.122**	21521.619**	706.525**	1122.345**	8932.350	8591.934
Spacing (B)	2	1246.722*	364.130	199.014**	103.843*	11.690*	18.549
Interaction (A x B)	10	243.078**	131.685*	34.735**	10.196*	187.249	4.683
Error	34	441.977	208.437	20.249	25.811	212.188	36.481

Note: ** = Significant at 1 % level of probability and * = Significant at 5 % level of probability

Appendix V: Analysis of variance (Mean squares) for plant height and total number of tillers hill^{-1} as influenced by integrated weed management and spacing in transplanted aman rice cv. BRRI Dhan 37 at different DAT.

Sources of variation	Degrees of freedom	Plant height (cm)					Total number of tillers hill^{-1}				
		15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT
Replication	2	8.229	21.810	303.951	97.195	58.820	0.498	1.282	3.886	8.241	7.167
Weeding (A)	5	4.919**	60.144**	160.680	296.949**	135.139**	1.294**	4.677**	10.478**	26.371**	17.871**
Spacing (B)	2	12.328**	73.203**	1.611	1036.231**	470.634**	42.545**	301.876**	414.629**	160.491**	110.042**
Interaction (A x B)	10	2.585**	9.994*	275.132*	62.387*	37.050*	0.512**	2.359**	3.489*	4.179*	4.134**
Error	34	0.867	12.231	188.913	29.781	16.643	0.310	0.459	1.580	2.520	0.976

Note: ** = Significant at 1 % level of probability and * = Significant at 5 % level of probability

Appendix VI: Analysis of variance (Mean squares) for LAI and total dry matter as influenced by integrated weed management and spacing in transplanted aman rice cv. BRRI Dhan 37 at different DAT.

Sources of variation	Degrees of freedom	LAI					Total dry matter (g hill^{-1})				
		15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT
Replication	2	0.001	0.008	0.055	0.001	0.008	0.515	0.012	0.550	0.602	0.289
Weeding (A)	5	0.037**	0.372**	2.849**	5.428**	4.901**	0.858*	5.383**	32.773**	36.678**	31.384**
Spacing (B)	2	0.025**	0.195**	1.913**	2.520**	2.242**	0.188	5.829**	94.616**	115.892**	81.951**
Interaction (A x B)	10	0.004**	0.007*	0.109	0.227**	0.180**	0.205	1.172**	3.762**	1.641**	1.849**
Error	34	0.002	0.003	0.053	0.018	0.018	0.355	0.317	0.307	0.164	0.109

Note: ** = Significant at 1 % level of probability and * = Significant at 5 % level of probability

Appendix VII: Analysis of variance (Mean squares) for crop growth rate (CGR) and relative growth rate (RGR) as influenced by integrated weed management and spacing in transplanted aman rice cv. BRRI Dhan 37 at different DAT.

Sources of variation	Degrees of freedom	CGR (g hill^{-1} day^{-1})				RGR (mg g^{-1} day^{-1})			
		15-30 DAT	30-45 DAT	45-60 DAT	60 –75 DAT	15-30 DAT	30-45 DAT	45-60 DAT	60 –75 DAT
Replication	2	0.002	0.003	0.010	0.008	56.743	38.896	9.018	0.160
Weeding (A)	5	0.012**	0.059**	0.006*	0.003	38.705	25.732**	11.407*	0.409*
Spacing (B)	2	0.018**	0.298**	0.008*	0.011**	32.126	143.129**	97.480**	5.158**
Interaction (A x B)	10	0.008*	0.010**	0.010**	0.003**	64.947*	76.164*	8.328	0.299
Error	34	0.003	0.002	0.002	0.003	0.005	0.052	4.069	0.121

Note: ** = Significant at 1 % level of probability and * = Significant at 5 % level of probability

Appendix VIII: Analysis of variance (Mean squares) for the yield and yield contributing characters as influenced by integrated weed management and spacing in transplanted aman rice cv. BRRI Dhan 37 at different DAT.

Sources of variation	Degrees of freedom	Plant height (cm)	Total tillers hill^{-1}	Effective tillers hill^{-1}	Non effective tillers hill^{-1}	Total spikelets panicle^{-1}	Grains panicle^{-1}	Sterile spikelets panicle^{-1}	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Replication	2	5.121	1.638	34.128	21.036	175.007	19.516	82.722	2.926	0.422	0.005	0.399	27.619
Weeding (A)	5	77.761**	16.767**	32.308**	2.929	362.431**	643.821**	124.429**	27.535**	6.230**	0.348*	4.757**	632.396**
Spacing (B)	2	99.543**	86.790**	80.910**	3.361	143.209*	1341.776**	654.530**	63.867**	0.423*	0.278*	0.173*	51.872**
Interaction (A x B)	10	12.920*	3.248**	5.290	1.660	23.273	22.587	34.834	3.333	0.169	0.081	0.277	11.333
Error	34	4.787	0.559	2.801	3.187	47.914	85.896	24.175	1.731	0.083	0.195	0.320	7.705

Note: ** = Significant at 1 % level of probability and * = Significant at 5 % level of probability

Appendix IX: Wages and price of different items used in the experiment.

No.	Item of expenditure	Rate (TK)
A.	Labour: (i) Human labour (man-day 8 hours)	70.00
	(ii) Animal labour (animal-day of 8 hours of a pair of bullock)	60.00
	(iii) Mechanical labour (tractor-day of 8 hours)	1740.00
B.	Rice seed BRRI Dhan 37 per kg	15.00
C.	Fertilizer (i) Urea per kg	6.00
	(ii) TSP per kg	13.00
	(iii) MP per kg	10.00
	(iv) Gypsum per kg	4.00
	(v) Zinc sulphate per kg	40.00
D.	Irrigation (One irrigation per hectare)	650.00
E.	Pesticide (i) Herbicide	
	(a) M.Chlor 5G per kg	60.00
	(b) Oxastar 25 EC per 100 ml	85.00
	(c) Pretilachlor 500 EC per 100 ml	100.00
	(ii) Insecticide	
	(a) Basudin 10 G per kg	95.00
F.	Value of land (One hectare)	1,50,000.00
G.	Interest on inputs and value of land per year	12.50 %
H.	Miscellaneous overhead cost	5 %

Appendix X: Operation wise break up of labour required per hectare of transplanted aman rice

cv. BRRI Dhan 37 (excluding weeding cost)

Sl. no.	Operation	Man-day for 20 x 10 cm^2	Man-day for 25 x 15 cm^2	Man-day for 30 x 20 cm^2	Animal-day	Tractor-day
1.	Land preparation	35.00	35.00	35.00	20.00	0.5
2.	Fertilizer application	2.00	2.00	2.00	-	-
3.	Seedling transplantation	40.00	35.00	32.00	-	-
4.	Weeding	variable	variable	variable	-	-
5.	Irrigation	1	1	1	-	-
6.	Plant protection (spraying insecticides)	2	2	2	-	-
7.	Harvesting	27.00	25.00	24.00	-	-
8.	Carrying	15.00	15.00	15.00	-	-
9.	Threshing	20.50	20.50	15.00	-	-
10.	Cleaning drying, weight and bagging	13.50	13.50	13.50	--	-
	Total labour	156.00	149.00	145.00	20.00	0.5
	Total cost of labour	10920.00	10430.00	10150.00	1200.00	870.00

Appendix XI: Cost of production of raising rice seedlings for 500m^2 of land for transplanted aman rice.

Sl. no	Head of expenditure	Quantity			Total cost (Tk.)		
		20 x 10 cm^2	25 x 15 cm^2	30 x 20 cm^2	20 x 10 cm^2	25 x 15 cm^2	30 x 20 cm^2
1.	Input cost						
	A. Immaterial inputs						
	i. Human labour (man-day)	7	7	7	490	490	490
	ii. Animal labour (animal-day)	2	2	2	120	120	120
	Sub-Total (Immaterial input cost)				610	610	610
	B. Material input cost						
	i. Rice seed	30	25	22	450	375	330
	ii. Water	2 irrigation	2 irrigation	2 irrigation	65.00	65.00	65.00
	iii. Pesticides (Vitavex-200)	80g	80g	80g	46.00	46.00	46.00
	Sub-total (material input cost)				561.00	486.0	441.00
	Total input cost				1171.00	1096.00	1051.00
2.	Overhead cost						
	i. Interest on input cost	1171.00	1096.00	1051.00	24.00	22.00	21.00
	ii. Interest on value of land	7500	7500	7500	156.00	156.00	156.00
	iii. Miscellaneous overhead cost	1171.00	1096.00	1051.00	58.00	54.00	52.00
	Total overhead cost				228.00	228.00	228.00
3.	Total cost of seedlings				1409.00	1328.00	1280.00

Appendix XII: Cost of production per hectare of transplanted aman rice cv. BRRI Dhan 37

excluding weeding cost.

Sl. No	Head of cost of production	Cost (Tk.)	Cost (Tk.)	Cost (Tk.)
		20 x 10 cm^2	25 x 15 cm^2	30 x 20 cm^2
1	Input cost			
	A. Immaterial cost	12990.00	12500.00	12220.00
	B. Material cost			
	i. Seedling (for one hectare)	1409.00	1328.00	1280.00
	ii. Fertilizer			
	(a)Urea 150 kg	900.00	900.00	900.00
	(b) TSP 100 kg	1300.00	1300.00	1300.00
	(c) MP 70 kg	700.00	700.00	700.00
	(d) Gypsum 60 kg	240.00	240.00	240.00
	(e) Zinc sulphate 10 kg	400.00	400.00	400.00
	iii. Irrigation (2 times)	1300.00	1300.00	1300.00
	iv.Insecticides(Basudin 5G) 15 kg	1425.00	1425.00	1425.00
	Total input cost (Material + immaterial cost)	20664.00	20093.00	19765.00
2.	Overhead cost			
	i. Interest on input cost @ 12.5% for 5 months	1076.00	1047.00	1025.00
	ii. Interest on value of land @ 12.5% for 4 months	6250.00	6250.00	6250.00
	iii. Miscellaneous overhead cost @ 5% of input cost	1033.00	1005.00	988.00
	Total overhead cost	8359.00	8302.00	8267.00
	Total cost of production (excluding weeding cost)	29023.00	28395.00	28032.00

Appendix XIII: Weeding cost of different weed control treatments for one hectare of land of
transplanted aman rice cv. BRRI Dhan 37.

Treatments	Immaterial cost		Material cost		Total cost (Tk.)
	Number man-day^{-1}	Cost (Tk.)	Amount	Cost (Tk.)	Cost (Tk)
W_1 S_1	0.00	0.00	0.00	0.00	0.00
W_1 S_2	0.00	0.00	0.00	0.00	0.00
W_1 S_3	0.00	0.00	0.00	0.00	0.00
W_2 S_1	53.00	3710.00	0.00	0.00	3710
W_2 S_2	53.00	3710.00	0.00	0.00	3710
W_2 S_3	60.00	4200.00	0.00	0.00	4200
W_3 S_1	35.00	2450.00	0.00	0.00	2450
W_3 S_2	35.00	2450.00	0.00	0.00	2450
W_3 S_3	40.00	2800.00	0.00	0.00	2800
W_4 S_1	12.00	840.00	13kg	780.00	1620
W_4 S_2	12.00	840.00	13kg	780.00	1620
W_4 S_3	15.00	1050.00	13kg	780.00	1830
W_5 S_1	10.00	700.00	1.9L	1615.00	2315
W_5 S_2	12.00	840.00	1.9L	1615.00	2455
W_5 S_3	15.00	1050.00	1.9L	1615.00	2665
W_6 S_1	11.00	770.00	970ml	970.00	1740
W_6 S_2	12.00	840.00	970ml	970.00	1810
W_6 S_3	15.00	1050.00	970ml	970.00	2020