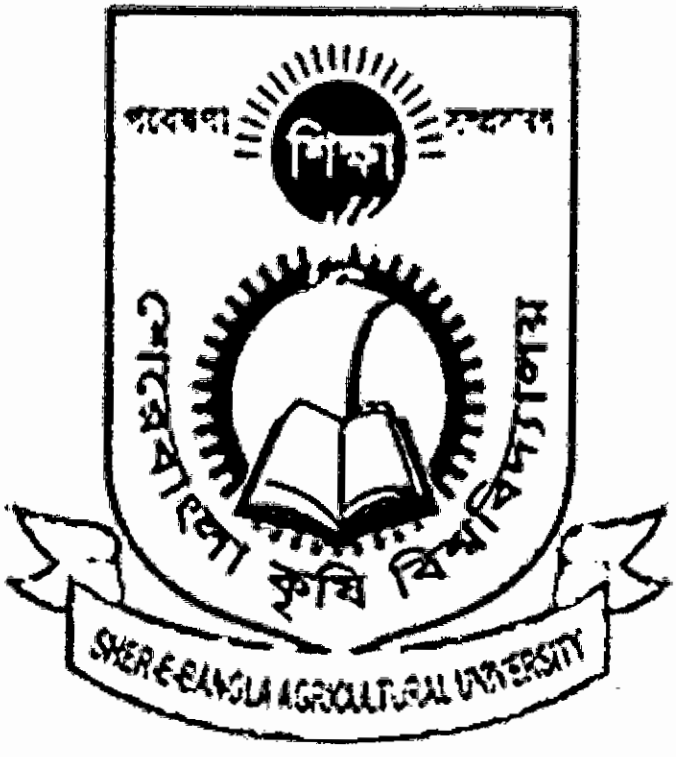
EFFECT OF DIFFERENT RATES AND DATES OF MUSTARD OIL CAKE APPLICATION ON GROWTH AND YIELD OF RICE

AFRIN AKHTER

Registration No.: 18-09039



DEPARTMENT OF SOIL SCIENCE

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA-1207

JUNE, 2020

EFFECT OF DIFFERENT RATES AND DATES OF MUSTARD OIL CAKE APPLICATION ON GROWTH AND YIELD OF RICE

BY

AFRIN AKHTER

Registration No.: **18-09039**

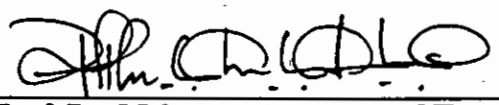
A Thesis

Submitted to the Department of Soil Science, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirement for the degree of

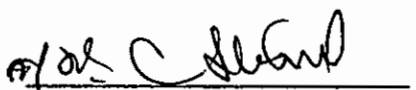
MASTER OF SCIENCE (MS)
IN
SOIL SCIENCE

SEMESTER: JANUARY-JUNE, 2020

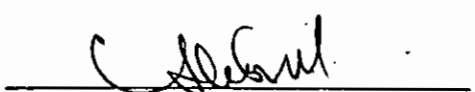
Approved By:



Prof. Dr. Mohammad Mosharraf Hossain
Supervisor
Department of Soil Science
Sher-e-Bangla Agricultural University
Dhaka-1207



Prof. Dr. Saikat Chowdhury
Co-supervisor
Department of Soil Science
Sher-e-Bangla Agricultural University
Dhaka-1207



Prof. Dr. Alok Kumar Paul
Chairman
Examination Committee
Department of Soil Science
Sher-e-Bangla Agricultural University
Dhaka-1207

JUNE, 2020

Department Of Soil Science
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

Ref: SAU/Soil Science/

CERTIFICATE

This is to certify that the thesis entitled, **"Effect of different rates and dates of mustard oil cake application on growth and yield of rice"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirement for the degree of **Master of Science in Soil Science,** embodies the result of a piece of *bona fide* research work carried out by **Afrin Akhter,** Registration No.:**18-09039,** under my supervision and my guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged by her.

Date:
Dhaka, Bangladesh

Prof. Dr. Mohammad Mosharraf Hossain
Supervisor
Department of Soil Science
Sher-e-Bangla Agricultural University
Dhaka-1207

Dedication

I dedicate my thesis to my parents whose efforts and ever willing support have made this dream come true

ACKNOWLEDGEMENT

The author expresses the endless gratitude to the supreme ruler Almighty Allah Who enabled her to complete the thesis successfully.

The author expresses her deepest sense of gratitude, immense indebtedness and profound appreciation to her reverend research supervisor **Professor Dr. Mohammad Mosharraf Hossain**, Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka-1207 for planning the research work, vigilant supervision, constructive suggestions, sympathetic encouragement to conduct the research work as well as preparation and for going through the manuscript of the thesis.

She also expresses her grateful appreciation and deep sense of respect to her research co-supervisor **Professor Dr. Saikat Chowdhury**, Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka-1207 for proper guidance, continuous advice, constructive criticism, painstaking suggestions, kind help and encouragement during the course of research work and preparation of this manuscript.

She is immensely indebted to **Professor Dr. Alok Kumar Paul**, Chairman of the Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka-1207 for providing her the facilities to conduct the experiment.

She expresses her gratitude and profound respect to all of her respective teachers of the Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka-1207 for their valuable teaching and co-operations in completing the research study.

She also expresses her sincere gratitude and thanks to all other staff of the Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka-1207 for their kind and untiring help and sincere cooperation during the research period.

It is beyond words to express her appreciation, gratitude and esteemed respect for her parents for their unconditional love, ever willing help, patience, constant encouragement and their faith in her which always kept her focused on her objectives and helped to achieve her goals.

At last but not the least, the author wishes to express his profound gratitude and deepest appreciation to her all other relatives for their ever-ending prayer, encouragement, sacrifice and dedicated efforts to educate her to this level.

Dhaka, Bangladesh
June, 2018

The author

ABSTRACT

The experiment was carried out at the Soil Science Farm at Sher-e-Bangla Agricultural University, Dhaka during the period of November, 2018 to May 2019 to study the effect of different rates and dates of mustard oil cake application on growth and yield of rice (BRRI dhan67). The experiment was laid out on Randomized Completely Block Design (RCBD) with three replications. There were four mustard oil cake (MOC) fertilizer levels viz., M_1=no mustard oil cake, M_2=25 kg ha^{-1}, M_3=50 kg ha-1, M_4=75 kg ha^{-1} and three time of application viz., T_1=Basal dose, T_2=20 DAT, and T_3=35 DAT. Mustard oil cake was top dressed in three equal splits at 10, 35 and 55 DAT. Results indicated that the effect of mustard oil cake showed significant variation in respect of all growth, yield contributing characters and yield. At harvest, highest plant height (81.66cm), tillers $hill^{-1}$ (21.55), effective tillers $hill^{-1}$ (14.22), panicle length (21.87cm), filled grains $panicle^{-1}$ (132.1), 1000 grain weight (29.35 g), grain yield (8.2 t ha^{-1}), straw yield (5.16 t ha^{-1}) was obtained from the application of MOC. On the other hand, highest plant height (81.67cm), tillers $hill^{-1}$ (21.42), effective tillers $hill^{-1}$ (14.58), panicle length (22.84cm), filled grains $panicle^{-1}$ (132.24), 1000 grain weight (29.35 g), grain yield (7.6 t ha^{-1}), straw yield (5.15t ha^{-1}) was obtained from the time of application. Mustard oil cake @ 75 kg gave the highest grain yield (7.6 t ha^{-1}). Interaction effect showed that application of MOC @75 kg application in 75 days after application gave the highest (9.9 t ha^{-1}) grain yield. Therefore, application of MOC @ 75 kg ha^{-1} at 35 DAT appears to be the best package for BRRI dhan67 produced higher yield.

CONTENT

Chapter I

INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food for more than half of the world's population, making it the most important cereal crop. With the increase of world's population, the global rise in rice consumption portends an increased pressure on our dwindling agricultural land. It has been reported that to feed the fast growing world's population, annual cereal production will need to rise to about 3.0 billion tons by 2050 (FAO, 2009) from around 2.6 billion tons today (FAO, 2017). Rice is grown in more than a hundred countries with a total harvested area of nearly 160 million hectares, producing more than 700 million tons every year (IRRI, 2010). Rice grain is rich in nutrients and contains a number of vitamins and minerals. Rice provides 21% of global human per capita energy and 15% of per capita protein (IRRI, 2010). To meet this demand, high-yielding varieties are being developed, which require extensive application of fertilizers such as mustard oil cake (N) and phosphorus (P) (Hazell, 2010). As currently practiced, an additional 40 and 20 million metric tons of chemical N and P fertilizers, respectively, will be required for food production by 2040 (Gregory *et al.*, 2010). The alarming increase in synthetic chemical fertilizer has led to degradation in soil, deterioration in air and water quality, which threatens the environmental sustainability (Tilman *et al.*, 2001). Clearly, there is an urgent need to develop efficient, sustainable and green crop production systems for future use.

The population of Bangladesh is still growing by two million every year and may increase by another 30 million over the next 20 years. Thus, Bangladesh will require about 27.26 million tons of rice for the year 2020. But the average yield of rice is poor (4.34 t ha^{-1}) in Bangladesh (BRRI, 2011). On the other hand, rice production area is decreasing day by day due to high population pressure. The possibility of horizontal expansion of rice

production area has come to stand still (Hamid, 1991). Therefore, attempts should be taken to increase the yield per unit area through use of comparatively high yielding varieties along with judicial fertilizer management. Introduction of hybrid rice is an important step towards augmentation of rice yields. Hybrid rice yield potential of the rice plant by 15-20% or more with the application of almost same amount of agricultural inputs (Husain *et al.*, 2000). Hybrid rice out yielded the existing conventional high yielding varieties (HYVs) by 15-20% in India, Bangladesh and Vietnam (Janaiah *et. al.*, 2002).

Proper fertilization is an important management practice which can increase the yield of hybrid rice. Judicious and proper use of fertilizers can markedly increase the yield and improve the quality of rice (Youshida, 1981). Mustard oil cake (MOC) is one of the most important plant nutrients and plays a crucial role in increasing crop production and farm income. Mustard oil cake consumption is increasing along with world crop production. However, more than 50 % of applied N is not assimilated by the rice plant, particularly when N fertilizer is applied using conventional broadcast methods. Most of the N not assimilated by the plant is lost through different mechanisms including ammonia (NH_3) volatilization, surface runoff, nitrification–denitrification and leaching (Dong *et al.* 2012; Rochette *et al.* 2013; Savant and Stangel 1990). Among these loss mechanisms, the most significant amount of loss occurs through NH_3 volatilization which reaches up to 50 % of applied N (Sommer *et al.* 2004). These losses decrease N use efficiency (NUE) of conventional split broadcast prilled urea (PU) (Savant and Stangel 1990; Sommer *et al.* 2004).

Mustard oil cake is the top most important nutrient and it is a key input for rice production in the rice growing countries as well in Bangladesh (Hasan, 2002). Mustard oil cake is required in adequate amount at early, at mid tillering, and panicle initiation stage for better grain development (Ahmed *et al.* 2005).Among potential of three primary elements

(NPK), phosphorus is relatively absorbed by the plants in small amount than other two, but plays an equally important role. Phosphorus deficiency results in decreased leaf number, leaf blade, reduced panicles plant^{-1}, grain panicle^{-1}, and reduced filled grain panicle^{-1} (Aide and picker,1996). Phosphorus status in Bangladesh soil is quite low. So application of phosphatic fertilizer is essential to obtain higher yield. However, the major plant nutrient element mustard oil cake and phosphorus, plays a vital role in rice production.

The present status of organic matter in Bangladesh is very low and below the critical level (1.5%) (BARC,1997). Bangladesh has a great constraint to maintain soil organic matter under high temperature and high rainfall condition. The organic manure is traditionally is an important source for supplying nutrients for rice in Bangladesh and recognized as a substitute of inorganic fertilizers (Sharma and Mitra, 1991). In past 25 years, use of inorganic fertilizers has been increased rapidly, whereas utilization of organic manures decreased due to various reasons including the unavailability of organic manures. Among the different organic manures available in Bangladesh, mustard oil cake (MOC) is a highly valued one. MOC contains high amount of macro and micro nutrients. Mustard oil cake supplies 5.1-5.2%, 1.8-1.9%, 1.1-1.3% N, P and K, respectively (BARC, 1997). It also supplies sufficient amount of S, Zn and B for the growth and yield of rice. But in Bangladesh, its use is very much limited to some vegetable and ornamental plants only. It has not been used so far in rice by the farmers. But, very recently research work aimed to explore the possibility of application of MOC in rice has just been initiated. The highest grain yield of rice (7.06 t ha-1) was obtained from the application of mustard oil cake @ 75 kg ha-1 along with recommended chemical fertilizers (BRRI, 2004). Ali et al. (2001) recorded the highest rice grain yield from the combination of 50% N as MOC with 50% N as urea, and they also opined that like plant height, total tillers hill-1, LAI, dry matter production and straw yield were influenced by MOC application. But for maximum

utilization of applied MOC, what is important that to standardize its level and time of application for a particular variety and growing season as well, otherwise it may not be economically viable. So, it is necessary to know the optimum levels of mustard oil cake and time of application for maximum growth, development and expected yield of hybrid rice. Keeping all the points in mind mentioned above, the present piece of research work was under taken with the following objective.

1. To investigate the effect of different levels of mustard oil cake and time of application on the growth and yield of rice.

CHAPTER II

REVIEW OF LITERATURE

The continuous and unbalanced use of the chemical fertilizers under intensive cropping systems has been considered to be the main cause for declining crop yield and environmental degradation. All essential elements must be present in optimum amounts and in forms usable by plants. Urea and TSP are chemical fertilizers most commonly applied by rice farmers. Mustard oil cake is a major component of proteins, hormones, chlorophyll, vitamins and enzymes, essential for rice. Rice plants require a large amount of mustard oil cake at the early and mid-tillering stage to maximize the number of panicles (Datta, 1988). The recommended doses of other nutrients are also necessary for potential rice yield. Considering the above point, available literatures were reviewed under mustard oil cake and phosphorus application for hybrid and inbreed rice.

2.1 Effect of mustard oil cake on growth and yield of rice

Mustard oil cake absorbed by rice during the vegetative growth stages contributed in growth during reproduction and grain-filling through translocation (Bufogle *et al.* 1997; Norman *et al.*, 1992). Mustard oil cake is very essential for the growth and development of crops. It enhances biomass and seed yield subject to the efficient water supply. Lack of mustard oil cake results stunted growth, pale yellow color, small grain size and poor vegetative as well as reproductive performance. Mustard oil cake is an essential component of amino acid and related protein of the plant structure. An increase in yield of cereals with increasing rate of mustard oil cake has been reported earlier (Khan *et al.*, 1994).

2.1.1 Effect of mustard oil cake on growth character of rice

2.1.1.1 Plant height

Salem (2006) reported that the mustard oil cake levels had a positive and significant effect on growth parameters of rice plants. Increasing mustard oil cake levels up to 70 kg ha^{-1} significantly increased plant height. The highest plant height was recorded about 92.81 cm with 70 kg mustard oil cake ha^{-1}.

Ahmed *et al.* (2005) reported that among 5 levels, 80 kg mustard oil cake ha^{-1} gave the highest plant height (155.86 cm) and the height decreased gradually with decreased levels of mustard oil cake fertilizer application.

Meena *et al.* (2003) reported that application of 200 kg mustard oil cake ha^{-1} significantly increased the plant height (127.9 cm) of rice while they applied another dose, 100 kg mustard oil cake ha^{-1}.

Pot experiments were conducted by Wang *et al.* (2002) to determine the effect of mustard oil cake levels no mustard oil cake, low mustard oil cake, medium mustard oil cake, high mustard oil cake and super high mustard oil cake on the growth of plants and leaves in hybrid rice Shanyou 64 and conventional rice Kinmaze. They found that the plant height increased with increasing mustard oil cake levels.

Kumar and Subbaiah (2001) conducted an experiment in Andhra Pradesh, India to identyfy the response of the rice hybrid PAC-803 and cv. Ajaya to various mustard oil cake sources, i.e. urea, calcium ammonium nitrate, ammonium sulfate and diammonium phosphate (DAP) + mustard oil cake. They reported that tallest Ajaya (101.03 cm) and PAC-803 (85.18 cm) plants were obtained with calcium ammonium nitrate and ammonium sulfate, respectively.

A field experiment was conducted by Geethadevi *et al.* (2000) in India to determine the effect of different mustard oil cake rates (0, 50, 100 and 150 kg ha^{-1}) and spacing (15 x 10

or 20 x 10 cm) on the growth and yield of hybrid rice. Among mustard oil cake rates, treatment with 150 kg mustard oil cake ha^{-1} recorded the highest values for plant height (87.20 cm).

Mishra *et al.* (2000) conducted a field experiment in Bhubaneswar, Orissa, India, and reported that rice cv. Lalate was given 76 kg mustard oil cake ha^{-1} at 0, 7, 14 for 21 days after transplanting (DAT), and reported that mustard oil cake application increased plant height.

Experiments were conducted by Rajendran and Veeraputhiran (1999) to study the effects of 4 mustard oil cake levels (0, 75, 150 and 225 kg ha^{-1}) and 3 sowing rates in the nursery (10, 20 and 30 g m-2) on hybrid rice ADTRH1. Mustard oil cake was applied at 3 equal splits namely: 7 days after transplanting, active tillering and panicle initiation stages. Observation upon harvest revealed that plant height was found with 225 kg mustard oil cake ha^{-1}.

Vijaya and Subbaiah (1997) showed that plant height of rice increased with the application of mustard oil cake and were greater with the deep placement method of application both mustard oil cake and P compared with broadcasting.

2.1.1.2 Tillering pattern

BRRI (2008a) conducted an experiment to study the comparetive study of some promising lines with BRRI modern rice varieties to different mustard oil cake levels *viz.* 0, 30, 60, 90, 120 and 150 kg mustard oil cake ha-1. It was reported that tiller production with mustard oil cake @ 120 kg ha^{-1} produced significantly higher tiller than those of lower mustard oil cake levels.

BRRI (2006) reported that the maximum tillers hill-1 (10.2) was produced with 120 kg mustard oil cake ha^{-1} compared to 90 and 0 kg mustard oil cake ha^{-1} application.

A field experiment was conducted by Lang *et al.* (2003) to study the effect of different fertilizer application rates on seedling of Jinyou 207, Guihuanian and Teyou 524 were sown in no-tillage plots situated in 3 different counties in Guangxi, China. At an early stage of growth, the seedlings were subjected to one of three mustard oil cake fertilizer treatments. Treatment A used a conventional application rate (CAR) of 157-5-172.5 kg ha-1N, treatments B and C used CAR + 10% and CAR + 20%, respectively. They found that the increase in mustard oil cake fertilizer application rate increased the speed of seedling establishment and tillering peak.

Wang *et al.* (2002) reported that the tiller number increased with increasing mustard oil cake levels.

Kumar and Subbaiah (2001) noted that application of DAP + mustard oil cake resulted in the highest number of tillers m^{-2}.

Rajendran and Veeraputhiran (1999) observed that productive tillers m^{-2} increased as the mustard oil cake rate increased.

2.1.1.3 Leaf area index

Masum *et al.* (2008) conducted an experiment to study the effect of four levels of seedling $hill^{-1}$ *viz*; 1, 2, 3 and 4 and two forms of mustard oil cake – prilled urea (PU) and urea supergranules (USG) on yield and yield components of modern (BRRI dhan44) and traditional (Nizershail) transplant *aman* rice. They reported that leaf area index significantly higher in USG receiving plant than prilled urea.

Hamidullah *et al.* (2006) conducted an experiment on growth and yield performance of BINA dhan 5 in *boro* season as affected by mustard oil cake levels *viz.* 80, 120 and 160 kg mustard oil cake ha^{-1}. They reported that leaf area index was peak at 60 DAT and decline thereafter, highest 5.53 obtained with 160 kg mustard oil cake ha^{-1} at 60 DAT.

Miah *et al.* (2004) found that LAI was significantly higher in mustard oil cake receiving plots than urea at heading.

A field test with the super hybrid rice (SHR) combination Liangyoupeijiu was conducted by Tang *et al.* (2003) in Changsha, Hunan, China. Nine treatments were used, including 0, 60, 120, 180, 240, 180, 130, 225 and 160 kg mustard oil cake ha^{-1}. They reported that higher mustard oil cake fertilizer application amount ensured a higher leaf area index.

2.1.1.4. Total dry matter production

Xie *et al.* (2007) reported that increased split application of N from control to 140 kg mustard oil cake ha^{-1} increased dry matter accumulation (DMA) of different growth stages of Jinzao22 and Shanyou63 rice varieties and after that dose the DMA reduced due to the losses of mustard oil cake by volatilization.

Sing and Modgal (2005) noted that dry matter accumulation (DMA) and concentration and uptake of mustard oil cake increased with increasing level of mustard oil cake at all the stages of crop growth.

Miah *et al.* (2004) noted that mustard oil cake applied plots gave higher TDM compared to urea irrespective of number of seedling transplanted hill-1.

Fu *et al.* (2000) conducted a field experiment in Zhejiang Province, China to evaluate the mustard oil cake fertilizers (0, 100, 150, 180, 225, 270, and 300 kg N ha-1 as urea, two-thirds top-dressed as basal and one third top dressed 7 days after transplanting, on dry

matter and N partitioning in hybrid rice 518. They reported that higher N applications significantly increased dry matter partitioning of leaf at the vegetative stage. Partitioning of dry matter to leaves decreased as the N concentration in the leaves decreased. Leaf partitioning of absorbed N, compared to dry matter, was higher and varied little during early vegetative growth, but varied greatly from panicle initiation onwards, probably due to competition for N among leaves, stem and the developing panicle.

A field experiment was conducted by Geethadevi *et al.* (2000) in Karnataka, India to determine the effect of different mustard oil cake rates (0, 50, 100 and 150 kg N ha^{-1}) and spacing (15 cm x 10 cm or 20 cm x 10 cm) on the growth and yield of hybrid rice. Among mustard oil cake rates, treatment with 150 kg mustard oil cake ha-1 recorded the highest values for total dry matter per plant (57.08 g).

Das (1989) reported that the dry matter yield of rice were higher with application of mustard oil cake of various forms and methods of application of mustard oil cake fertilizers to rice grown under flooded conditions, placement of mustard oil cake (1 and 2 g size) in the root zone at transplanting was the most effective in increasing dry matter production and were the lowest with urea applied as a basal drilling.

2.1.1.5 Crop growth rate:

A field experiment was conducted by Das and Panda (2004) in Bhubaneswar, Orissa, India, to study the effects of mustard oil cake (0, 60, 120 or 180 kg ha^{-1}) and K (0, 40, 80 or 120 kg ha^{-1}) on the growth rate of hybrid rice 6102. mustard oil cake was applied as a basal dressing (25%), and as a top dressing at 18 days after transplanting (DAT; 50%) and at the panicle initiation stage (25%). K (K2O) was applied during transplanting. Irrespective of treatment difference, Crop growth rate (CGR) was greater at 40-60 DAT

and lower at 20-40 DAT. The increase in the N rate increased CGR. The highest CGR (22.52 g day-1 m-2) was obtained with 80 kg K2O ha^{-1}.

2.1.2 Effect on yield contributing character

2.1.2.1 Effective tillers $hill^{-1}$

Awan *et al.* (2011) conducted an experiment to study the effect of different mustard oil cake levels (110, 133 and 156 kg mustard oil cake ha^{-1}) in combination with different row spacing (15 cm, 22.5 cm and 30 cm). They noted that maximum level of mustard oil cake (156 kg mustard oil cake ha^{-1}) produced maximum effective tillers irrespective of spacing.

A field experiment was conducted by Singh and Shivay (2003) at the Research Farm of the Indian Agricultural Research Institute, New Delhi, India to study the effect of coating prilled urea with eco-friendly neem formulations in improving the efficiency of mustard oil cake use in hybrid rice. Two rice cultivars, hybrid rice (NDHR-3) and Pusa Basmati-1, formed the main plots, with the levels of mustard oil cake (0, 60, 120 and 180 kg N ha^{-1}) and various forms of urea at 120 kg N ha-1in the subplots. They found that increasing levels of mustard oil cake significantly increased the number of effective tillers $hill^{-1}$.

Meena *et al.* (2002) studied the response of hybrid rice to mustard oil cake (0, 100 and 200 kg ha^{-1}) and potassium application (0, 75 and 150 kg ha^{-1}) at the research farm of the IARI, New Delhi. They observed that application of mustard oil cake significantly increased the effective tillers.

Jee and Mahapatra (1989) observed that number of effective tillers m^{-2} were significantly higher with 90 kg mustard oil cake ha^{-1}as split application of mustard oil cake.

Rama *et al.* (1989) mentioned that effective tiller increased significantly when mustard oil cake level increased from 40 to 120 kg mustard oil cake ha^{-1} as different modified urea

materials and mustard oil cake produced significantly higher effective tiller than split application of mustard oil cake.

2.1.2.2 Panicle length

Hasanuzzaman *et al.* (2009) conducted an experiment to study the economic and effective method of mustard oil cake application in rice crop. They noted that mustard oil cake produced longest panicle (22.3 cm).

Islam *et al.* (2008) conducted an experiment to study the effect of mustard oil cake and number of seedlings per hill on the yield and yield components of T. *aman* rice (BRRI dhan 33). They noted that panicle length, number of grain panicle^{-1} increased with the application rate of N up to 100 kg ha-1 and then declined. Singh and Shivay (2003) found that increasing levels of mustard oil cake significantly increased the panicle length.

Meena *et al.* (2002) observed that increase in mustard oil cake fertilizer application rate enhanced length and weight of panicles of hybrid rice.

Patel and Mishra (1994) carried out an experiment with rice cv. IR36 and were given 0, 30, 60 or 90 kg N ha^{-1} as Muossorie rock phosphate-coated urea, *neem* cake-coated urea and gypsum coated urea, USG or PU. The coated materials as incorporated before transplanting and USG as placed 5-10 cm deep a week after transplanting and urea as applied in 3 split doses. They showed that N management practices had no significant effect on panicle length and percent sterility.

Sen and Pandey (1990) carried out a field trial to study the effects of placement of USG (5, 10 or 15 cm deep) or broadcast PU @ 38.32 kg N ha^{-1} on rice. They revealed that all depths of USG placement resulted in higher yield characters than broadcast PU; however, differences except for panicle lengths were not significant.

2.1.2.3 Filled grains panicle^{-1} and unfilled grains panicle^{-1}

Masum *et al.* (2010) reported that placement of mustard oil cake fertilizer in the form of @ 58 kg mustard oil cake ha^{-1} produced the highest number of effective tillers hill^{-1}, filled grains panicle^{-1} which ultimately gave the higher grain yield than split application of urea.

A field experiment was conducted by Edwin and Krishnarajan (2005) to study the effects of irrigation and mustard oil cake fertilizer treatments on the yield of rice hybrid variety CoRH2 in Coimbatore, Tamil Nadu, India. They suggested that mustard oil cake supplied at 7 DAT, 21 DAT, panicle initiation stage and first flowering stage gave the highest filled grains.

Lang *et al.* (2003) found that the increase in mustard oil cake fertilizer application rate enhanced grains per panicle, effective panicles per plant, and total florets per plant.

Meena *et al.* (2002) noted that increase in mustard oil cake fertilizer application rate enhanced number of grains and filled grains of hybrid rice.

2.1.2.4 1000 grain weight

Maitti *et al.* (2003) conducted an experiment to study the effects of mustard oil cake fertilizer rate (0, 120, and 140 kg ha^{-1}) on the performance of 1 cultivar (IET-4786) and 4 hybrid varieties (ProAgro 6Y213, ProAgro 6Y3024, ProAgro 6111N, and ProAgro 6201) of rice in Mohanpur, West Bengal, India. The mustard oil cake fertilizer was applied during transplanting (50%) and at the tillering and panicle initiation stages (50%). They reported that the application of 140 kg N ha^{-1} resulted in the highest increase in grain yield (by 76.2%), number of panicles (by 109.00%), number of filled grains per panicle (by 26.2%), and 1000-grain weight (5.80%) over the control, and the highest mustard oil cake (136.701 kg ha^{-1}), phosphorus (132.029 kg ha^{-1}), and potassium (135.167 kg ha^{-1}) uptake.

Meena *et al.* (2002) reported that increase in mustard oil cake fertilizer application rate increased 1000-grain weight of hybrid rice.

Hasan *et al.* (2002) determined the response of hybrid (Sonar Bangla-1 and Alok 6201) and inbred (BRRI Dhan 34) rice varieties to the application methods of urea supergranules (USG) and prilled urea (PU), mustard oil cake and reported that the effect of application method of USG and PU was not significant in respect of panicle length, number of unfilled grains panicle^{-1} and 1000-grains weight.

Ahmed *et al.* (2000) conducted a field experiment to study the effect of point placement of urea supergranules (USG) and broadcasting prilled urea (PU) as sources of N in T. *aman* rice. USG and PU were applied @ 40, 80, 120 or 160 Kg N ha^{-1}. They suggested that USG was more efficient than PU in producing panicle length, filled grains panicle^{-1} and 1000-grain weight.

Roy *et al.* (1991) compared deep placement of urea supergranules (USG) by hand and machine and prilled urea (PU) by 2 to 3 split applications in rainfed rice. They obtained highest 1000-grain weight from USG treated plots.

Thakur (1991) observed that yield attributes differed significantly due to levels and sources of mustard oil cake at 60 kg mustard oil cake ha^{-1} produced the highest panicle weight, number of grains panicle-1, 1000- grain weight.

2.1.2.5 Effect on grain yield and straw yield

BRRI (2009) conducted an experiment on study of N release pattern from mustard oil cake and prilled urea under field condition and its effect on grain yield and N nutrition of rice with three doses of mustard oil cake namely 50, 100 and 150 kg mustard oil cake ha-1.

Result showed that the highest grain yield was recorded when N applied @ 100 kg N ha^{-1} both from USG and PU and the highest straw yield was obtained in PU @ 150 kg N ha^{-1}.

BRRI (2008b) conducted an experiment on the title of response of MVs and hybrid entries to added mustard oil cake in a rice rice cropping pattern. Six mustard oil cake doses 0, 40, 80, 120, 160 and 120 kg mustard oil cake ha^{-1} were tested and resulted that grain yield of hybrid responded up to 120 kg mustard oil cake ha^{-1}.

Kabir *et al.* (2009) conducted an experiment to find out the effect of urea super granules (USG), prilled urea (PU) and poultry manure (PM) on the yield and yield contributes of transplant *aman* rice. They observed that the highest grain yield (5.17 t ha^{-1}), straw yield (6.13 t ha^{-1}) and harvest index (46.78%) were found from full dose of USG.

Lin *et al.* (2008) conducted an experiment to find out the effect of plant density and mustard oil cake fertilizer rates (120, 150, 180 and 210156 kg mustard oil cake ha^{-1}) on grain yield and mustard oil cake uptake of hybrid rice. They observed that there was a better response to mustard oil cake fertilization, as increasing mustard oil cake application from 120 to 180 kg mustard oil cake ha^{-1} (by 50%) raised yield by 17%. Raising the application rate to 210 kg mustard oil cake ha^{-1} (by 75%) boosted yield by 24.1%.

Field experiments were conducted by Wan *et al.* (2007) in China to study the effects of different mustard oil cake fertilizer application regimes (basal and panicle applications) on the yield, quality and N use efficiency of super japonica hybrid rice cv. Changyou 1. They indicated that yield was significantly influenced by the different mustard oil cake fertilizer application regimes. The regime with the highest yield was at the basal to panicle application ratio of 58.34:41.66 and equal split panicle applications at the fourth and second leaf age from the top.

A study was conducted by Mubarak and Bhattacharya (2006) under the Gangetic alluvial soil of West Bengal, India, to investigate the response of hybrid rice cultivars to various levels of mustard oil cake and potassium. Significantly higher values for growth and grain yield were obtained with the application of 150:60:80 kg NPK ha^{-1}, which was at par with 150:60:40 kg NPK ha^{-1}.

A study was conducted by Ingale *et al.* (2005) to determine the effects of seedling ages at transplanting (25, 40 and 55 days), number of seedlings per hill (one or two) and mustard oil cake rates (50, 100 and 150 kg ha^{-1}) on the yields of Sahyadri rice hybrid. They found that the application of 150 and 100 kg mustard oil cake ha^{-1} resulted in significantly higher yields than treatment with 50 kg mustard oil cake ha^{-1}.

Edwin and Krishnarajan (2005) reported that mustard oil cake supplied at 7 DAT, 21 DAT, panicle initiation stage and first flowering stage gave the highest grain yield and straw yield and lowest level of spikelet sterility (25.30%).

Saiti *et al.* (2005) conducted an experiment to evaluate three traditional and three improved cultivars which were grown under four fertilizer treatments: no added fertilizer, mustard oil cake only, phosphate only (P; 50 kg P ha^{-1}), and mustard oil cake and P (NP) at three locations. The two improved cultivars, IR55423-01 and B6144-MR-6-0-0 out-yielded traditional cultivars in all locations and fertilizer treatments. N fertilizer application increased grain yields of the two improved cultivars from 3.1 to 4.0 t ha-1 while increasing those of traditional cultivars from 1.6 to 1.9 t ha-1.

A field experiment was conducted by Rakesh *et al.* (2005) at Research farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India, to determine the response of hybrid rice cv. MPH-501 to different mustard oil cake (40, 80, 120 and 160 kg N ha^{-1}) and potassium levels (30, 60, and 90 kg K2O ha^{-1}). The application

of 160 kg N and 60 kg K2O ha^{-1} significantly influenced the growth and yield attributes of hybrid rice and produced higher grain and straw yield.

Mustard oil cake fertilizer when applied as mustard oil cake was reported to have increased grain yield by around 18% and saved around 32% mustard oil cake in wetland rice and appeared to be a good alternative mustard oil cake fertilizer management for rice production (Annon., 2004).

A field experiment was conducted by Upendra *et al.* (2004) at Pusa, Bihar, India to evaluate two newly developed rice hybrids (KHR2 and DRRH1) and one local control (Boro 5) growth under 10 different mustard oil cake-potassium (NK) fertilizer levels. Data were recorded for plant height, effective tillers m-2, panicle length, test weight, grain yield, straw yield, harvest index and benefit:cost ratio. Both rice hybrids performed better than the local cultivar. Yield and related characters increased with increasing fertilizer levels up to 150 kg N ha^{-1} and 80 kg K ha^{-1}.

A study was conducted by Verma *et al.* (2004) in Madhya Pradesh, India to investigate the effect of planting date (20 July; and 5 and 20 August) and mustard oil cake rates (50, 100 and 150 kg ha^{-1}). They reveled that mustard oil cake at 100 and 150 kg ha^{-1} resulted in the highest yield.

Singh and Shivay (2003) found that increasing levels of mustard oil cake significantly increased the grain and straw yields.

Maitti *et al.* (2003) reported that the application of 140 kg mustard oil cake ha^{-1} resulted in the highest increase in grain yield.

A field experiment was conducted by Balasubramanian (2002) in Madurai, Tamil Nadu, India to study the effect of levels (0, 150, 200 and STCR-based N) and time of application

(3 or 4 splits) of mustard oil cake on 'CoRH 1' hybrid rice. Hybrid rice recorded good response to N up to 256.7 kg ha-1 (STCR-based N). Higher levels of mustard oil cake improved the growth and yield of rice. The STCR-based mustard oil cake applied in 4 splits (basal, active tillering, panicle initiation and panicle emergence) registered the maximum grain yield, followed by 200 kg mustard oil cake ha^{-1} applied in 4 splits.

Meena *et al.* (2002) resulted that application of mustard oil cake significantly increased grain and straw yields of hybrid rice up to the level of 200 kg mustard oil cake ha^{-1}.

A field experiment was conducted by Devasenamma *et al.* (2001) in Andhra Pradesh, India to study the performance of rice hybrids (APHR-2, DRRH-1, MGR-1, TNRH-16 and NLR-33358) at various mustard oil cake fertilizer rates (0, 60, 120 and 180 kg ha^{-1}). The highest values for yield and yield components were obtained with 180 kg mustard oil cake ha^{-1}.

Ahmed *et al.* (2000) revealed that mustard oil cake was more efficient than PU at all respective levels of mustard oil cake in producing grain and straw yields. Placement of USG @ 160 Kg mustard oil cake ha^{-1} produced the highest grain yield (4.32 t ha^{-1}) which was statistically identical to that obtained from 120 kg mustard oil cake ha^{-1} as USG and significantly superior to that obtained from any other level and source of mustard oil cake. Rajendran and Veeraputhiran (1999) suggested that grain yield increased as the N rate increased. The highest straw yield (13.1 t ha^{-1}) was found with 225 kg mustard oil cake ha^{-1}.Balaswamy (1999) found that in an experiment deep placement of mustard oil cake as urea supergranules reduced the dry weight of weeds resulting in more panicles and filled grains and increased the grain yield of rice over the split application of prilled urea by 0.43 and 0.3 t ha^{-1} and basal application of large granular urea by 0.73 and 0.64 t ha^{-1} respectively. Department of Agricultural Extension conducted 432 demonstrations in 72

Upazilla as of 31 districts in Bangladesh of *boro* rice. It was reported that USG plots, on an average, produced nearly 5 percent higher yields than the PU treated plots while applying 30-40% less urea in the form of mustard oil cake (Islam and Black, 1998).

Singh and Singh (1997) conducted a field experiment in 1987 in Uttar Pradesh, India, dwarf rice cv. Jaya was given 90 or 120 kg N ha^{-1} as urea super granules, large granular urea or neem cake coated urea. mustard oil cake was applied basally, or in 2 equal splits (basally and panicle initiation). They found that grain yield was highest with 120 kg mustard oil cake (4.65 t ha^{-1}), was not affected by N source and was higher with split application.

Kumar *et al.* (1996) reported that application of mustard oil cake in the sub soil gave 22% higher grain yield than control.

Rashid *et al.* (1996) conducted field experiments in two locations of Gazipur district to determine the mustard oil cake use efficiency of mustard oil cake and prilled urea (PU) in irrigated rice cultivation. It was observed that 87 kg mustard oil cake ha^{-1} from USG produced the highest grain yield. However, 58 kg mustard oil cake ha^{-1} from mustard oil cake and 87 kg N ha^{-1} from PU produced statistically similar grain yield to that of 87 kg ha^{-1} from mustard oil cake.

2.2 Effect of time of application

The amount of P absorbed by hybrid rice during the middle growth stage was over half of the total P absorbed during the whole growth period. However, less P was supplied by soil at the middle growth stage. Phosphorus application resulted in normal growth, early ripening and increased yield. The contents of protein and mustard oil cake in rice leaves decreased when insufficient P was applied. P enhanced the photosynthetic efficiency of

leaves, increased the grain yield and shortened the growth period of rice. It is suggested that P application could enhance the absorption and use of mustard oil cake and potassium by hybrid rice (Liu, 1996)

2.2.1Effect on growth character

2.2.1.1 Plant height

A field experiment was conducted by Alam *et al.* (2009a) at the Agronomic field of the Sher-e-Bangla Agricultural University to study the relative performance of inbreed and hybrid rice varieties at different levels of P. Three varieties of inbreed and hybrid (BRRI dhan 48, Aloron and Hira 2) and five levels of P (0, 24, 48, 72 and 96 kg P ha-1) were used as treatment. They reported that plant height and growth rate varied significantly due to variation of P and tallest plant was obtained with 96 kg P ha-1.

A field experiment was conducted by Alvi *et al.* (2004) to evaluate how much P should be applied to the rice and wheat crops under rice-wheat cropping system. Mustard oil cake and potassium were applied uniformly to all the plots at the rate of 120 and 60 kg ha-1 respectively. They reported that plant height was influenced significantly by the application of P.

Fageria and Baligar (1997) carried out an experiment to evaluate on the growth and P use efficiency of 20 upland rice cultivars at low (0 mg P kg-1), medium (75 mg P kg-1) and high (150 mg P kg-1) levels of applied P on an Oxisol. Plant height was influenced significantly by the application of P.

2.2.1.2 Tillering pattern

Alam *et al.* (2009b) reported that tiller production differed significantly with the application of P fetrilizer and 72 kg P ha-1 showed to produce better tiller production and fertility.

2.2.1.3 Leaf area index and total dry matter production

Alam *et al.* (2009c) found that dry matter partitioning in different part plants varied significantly due to variation of P.

The agronomic efficiency of four phosphate sources (tripol superphate, ordinary Yoorin thermophosp hate, coarse of yoorin thermophosphate and North Carolina phosphate rock) were evaluated by Brasil *et al.* (2002). The soils received three rates of phosphorus (40, 80 and 120 mg P kg-1 of soil) plus the control treatment. The results showed the highest dry matter was obtained in soils fertilized with triple superphote.

2.2.2 Yield contributing character

Alam *et al.* (2009d) suggested that filled grain panicle-1, unfilled grain panicle-1, spikelet sterility, 1000 grain weight had a significant effect with the application of P fertilizer.

Shar and Burbey (2003) conducted a field experiment at farmer fields in dry season, from June to September 2001 with six NPK compound dosages (0, 50, 100, 150, 200 and 250 kg NPK ha-1). Results showed that increasing rate of NPK compound significantly affected the grain number panicle-1, unfilled grain percentages, 1000 grain weight and grain yield. The highest grain yield was found by appling 100 kg Urea + 250 kg NPK compound, following by 82.5 kg N + 37.5 kg P2O5 ha-1+ 37.5 kg K2O ha-1.

Mondal *et al.* (2003) conducted a field experiment to investigate the effect of P application on rice cv. IET-5656- lathyrus cv. The treatments comprised 4 fertilizer management levels, i.e. fertilizer application as per farmers practice (40:20:20 kg N: P2O5:K2O ha-1) to rice and no fertilizer application to lathyrus (T1); 100% of recommended dose of fertilizer (RDF) both rice and lathyrus (T2); 100% of RDF to rice + recommended dose of P for lathyrus to rice (T3) and RDF for lathyrus + recommended dose of P for rice to lathyrus at sowing (T4). The RDF for rice was 80,:40:40: kg mustard oil cake: P2O5:K2O ha-1 and that for lathyrus was 10:20:20 kg N: P2O5:K2O ha-1. They reported that highest number of effective tiller m-2 (425.0), number grains panicle-1 (92.8) of rice were obtained from T3 treatment.

In pot trials by Jiang *et al.* (1999) on whitish lacustrine soil, rice was given 0, 2, 4, 6 and 8 kg P2O5 mu-1. The total number of panicles and 1 grain number panicle-1 increased with up to 6 kg P2O5 mu-1.

2.2.3 Spikelet sterility

Shah (2002) examined the P deficiency in control plots caused stunted growth with limited tillers and decreased filled spikelet percentage panicle-1.

Ortega and Rojas (1999) reported that the P application decreased floret sterility.

2.2.4 Grain and straw yield

A field experiment was conducted by Dwivedi *et al.* (2006) in Uttar Pradesh, India in a silt loam soil to evaluate the effect of mustard oil cake, phosphorous and potassium levels on growth yield and quality (protein) of hybrid rice (*Oryza sativa*). Optimum mustard oil cake level was found to be 184.07 kg ha-1. In case of phosphorus and potassium, higher doses each of 80 kg ha-1 P2O5 and K2O were found to be better to obtain higher production and

good quality (protein) of hybrid rice. The maximum grain yield was recorded with 200 kg N ha-1, 80 kg P2O5 ha^{-1} and 80 kg K2O ha^{-1}.

A field experiment was carried out with rice cv. Jia-9312 by Iqbal (2004) in China, involving P at 0, 40 and 60 kg ha-1 under irrigated conditions. He stated that a positive effect on rice biomass and grain yield for P application was observed which varied from 5.8 to 7.8 t ha-1.

Saiti *et al.* (2005) conducted an experiment to evaluate three traditional and three improved cultivars which were grown under four fertilizer treatments: no added fertilizer, mustard oil cake only (90 kg N ha-1), phosphate only (50 kg P ha-1), and N and P (NP) at three locations. Applying only P gave no effect on grain yield, and applying P with N increased grain yield only by 0.5 t ha-1 over N application alone on average over all cultivars at all locations.

Alvi *et al.* (2004) reported that paddy grain and straw yields were influenced significantly by the application of P. Application of 50 kg P_2O_5 gave the higher yield following by 100 kg P_2O_5 ha^{-1}.

Ravi *et al.* (2000) conducted an experiment to study on the effects of single superphosphate (SSP), monammonium phosphate (MAP), Maton rock phosphate (MRP), Gapsaphos, North Carolina rock phosphate, Jordan phosphate rock (JPR) A and B, and compactions of JPR A or B with SSP, MAP or MAP + S on the yield of rice and cowpea in rice-cowpea and rice-rice cropping systems. Grain (5921.02 kg ha-1) and pod yield (1638.88 kg ha-1) for the rice-cowpea cropping system and the respective values for the rice-rice cropping system (4216.67 and 4308.77 kg ha-1) were highest with application of JPR (A) + MAP + S (compacted).

Kendaragama *et al.* (2003) conducted an experiment to investigate the seasonal and long-term influence of rice crop on the availability of soil P in relation to five rates of triple super phosphate application (0, 25, 75 and 100 kg P2O5 ha-1) in well drained, imperfectly drained and poorly drained soil. This study indicates that practice of correct P supply is needed for sustaining available P status in soil and crop yield although rice does not immediately respond for irregularities phosphate fertilizer application.

Field experiment was conducted by Rao (2003) in India to determine the utilization pattern of phosphorus rates (30, 60 and 90 kg ha-1) and sources (ammonium polyphosphate, urea nitric phosphate and diammonium phosphate) in rice crop in terms of apparent recovery factor, physiological and agronomic efficiency. He stated that 60 kg P ha-1 gave the highest agronomic efficiency when P was applied in the form of ammonium polyphosphate following by urea nitric phosphate and diammonium phosphate and the lowest term P rates.

Sing (2003) conducted a field experiment under rainfed condition in Jharkhand, India during to establish the relationships between plant P and grain yield of upland rice cv.. Kalinga III grown on red upland soils. He reported that rice yield varied significantly due to P fertilizer.

Nadeem and Ibrahim (2002) carried out a study to determine the P requirement of rice crop grown after wheat, under submearsed condition. Rice crop was 100 kg P2O5 and 120 kg N ha-1 and highest paddy yield was obtained from the treatment where 37.5 kg (50%) P was applied. It showed that when wheat received its recommended dose of P then for rice only 50% of the recommended rate (75%) is enough to achieve the optimum yield of rice.

Zubaida and Munir (2002) conducted an experiment on phosphorus fertilizer on rice. They found that phosphorus application by P-starter (20 kg SP36 ha-1) is more economical

and more benefit over phosphorus application of 100 kg SP36 ha-1 and reduce fertilizer application 80 kg SP36 ha-1 and gave yield of paddy rice 4.236 and 4.320 t ha-1 respectively. Lal *et al.* (2002) conducted a field experiment to study the individual and interactive effects of P (0, 11, 22, and 33 kg ha-1) and Zn (0, 6 and 12 kg ha-1) on the yield and P uptake of lowland rice. They reported that maximum grain yield (33.35 q ha-1) and P uptake (10.06 kg ha-1) were observed with the combined application of 33 kg P and 12 kg Zn ha-1. Available P in soil samples after harvest increased considerably with increasing rates of P and Zn application.

Annadurai and Palaniappan (1998) in afield trial India in monsoon season, rice was given 0, 9.5, 19 or 38 kg P2O5 ha-1 with or without spraying 2% diammonium phosphate(DAP) at 2-3 growth stages. Grain yield increased significantly with up to 19 kg P2O5 ha-1 and was increased by DAP application with no significantly difference between treatment schedule.

Rao and Shukla (1997) conducted a field trial with rice cv. Sarjoo 52 grown with given 13, 26 or 39 kg P ha-1 as ammonium polyphosphate, urea nitric phosphate or diammonium phosphate, in combination with 15, 30 or 45 kg ZnSO4 ha-1. They stated that grain yield in both years increased with increasing P rate also with 30 kg ZnSO4 ha-1. Yield was highest when P was applied as applied as ammonium polyphasphate.

Chen *et al.* (1997) conducted a field experiment at the Rice Research Institute of Yunnan Agricultural University, on soils low in P and Zn and rice cultivers-Xunza 29, hexi 35 and Yungeng 34 were given 0 or 5 kg Zn ha^{-1} and 60, 150 or 200 kg P ha^{-1}. Application of Zn and P significantly increased yield.

2.3 Interaction effect of mustard oil cake and time of application

2.3.1 Effect on growth characters

2.3.1.1 Plant height

Amin *et al.* (2004) conducted an experiment to evaluate the effect of increased plant density and fertilizer dose on yield of rice variety IR-6. He found that increased fertilizer dose of mustard oil cake and PK increase Plant height.

Saha *et al.* (2004) conducted a field experiment on *boro* season and found that plant height significantly increased with the increased level of different mustard oil cake and PK fertilizer model.

Singh *et al.* (2003) reported that crop growth rate, such as plant height, dry mater production averaged across treatments, was highest at 45-60 days after transplanting of rice and significantly influence by mustard oil cake and PK fertilizers.

2.3.1.2 Tillering pattern

Ndaeyo *et al.* (2008) conducted an experiment in Nigeria with five rice varieties (WAB340- 8-8-2HI, WAB881-10-37-18-8-2-HI, WAB99-1-1, WAB224-8-HB, WAB189-B-B-B-8-HB) and four rates of NPK (15:15:15) fertilizer (0, 200, 400 and 600 kg ha-1). The results showed that 600 kg ha-1 NPK (15:15:15) fertilizer rate significantly increased tillers per plant.

2.3.1.3 Total dry matter production

Hasanuzzaman *et al.* (2010) noted that total dry weight of plant increased with the increased different level of fertilizer and poultry manure @ 4 t ha-1 + mustard oil cake - 40, P-6, K-36, S-10 kg ha-1 i.e. 50% NPK gave the higher dry matter production. Singh *et*

al. (2003) also reported that crop growth rate and relative growth rate such as total dry matter production was significantly influenced by mustard oil cake and PK.

2.3.2 Effect on yield contributing characters

2.3.2.1 Effective tillers hill^{-1}

Venkateswarlu and Singh (1980) observed higher grain yield with 120 kg mustard oil cake + 60 kg P2O5 + 45 kg K2O ha-1 followed by 80 kg mustard oil cake + 40 kg P2O5 + 30 kg K2O ha-1. Yield attributes like number of effective tillers m^{-2}, panicle weight, grains panicle^{-1} and test weight were increased with increase in the fertilizer level.

Halder *et al.* (2000) reported that the number of panicles per plant increased with increase in mustard oil cake and PK rates.

2.3.2.2 Panicle length

Islam *et al.* (2008) found that panicle length, filled grains panicle^{-1}, unfilled grains panicle^{-1}, filled grain percentage, influenced significantly due to application of different rates of mustard oil cake and PK nutrients.

Asif *et al.* (2000) reported that mustard oil cake and PK levels significantly increase the panicle length, number of primary and secondary branches panicle^{-1} when mustard oil cake and PK fertilizer applied in 180-90-90 kg ha^{-1} this might be attributed to the adequate supply of mustard oil cake and PK.

2.3.2.3 Filled grains panicle^{-1} and unfilled grains panicle^{-1}

Saha *et al.* (2004) conducted an experiment to create and compare a suitable fertilizer recommendation model for lowland rice. Five different fertilizer recommendation models

were tested and compared with one check plot. Results show that the application of different packages estimated by different fertilizer models significantly influence panicle length, panicle numbers, spikelet number per panicle, total grains panicle^{-1}, number of filled grain and unfilled grain per panicle. The combination of mustard oil cake and PK that gives the height result was 120-13-70-20 kg ha^{-1} mustard oil cake and PKS.

2.3.2.4 1000 grain weight

Ndaeyo *et al.* (2008) also reported that number of spikelet per plant was significantly influenced by increase in mustard oil cake and PK fertilizer rates. The number of panicles per plant across the rice cultivars showed that it ranged from 15.26 - 17.04 in the 600 kg ha^{-1} plots in 2005 and 15.27 - 16.79 in 2006.

Chandrashekarappa (1985) reported that application of 100 kg mustard oil cake, 100 kg P_2O_5 and 50 kg K_2O ha^{-1} gave the highest grain yield. This was on par with 100 kg mustard oil cake, 50 kg P_2O_5 and 50 kg K_2O ha^{-1}. The increase in yield was due to increased dry matter production, plant height, leaf area index, leaf area duration, number of tillers hill-1 and to some extent panicle length and 1000 grain weight.

Sikdar and Gupta (1979) observed that spikelet sterility was higher at 100 kg mustard oil cake + 50 kg P_2O_5 + 50 kg K2O ha^{-1} as compared to 50 kg mustard oil cake + 25 kg P_2O_5 + 25 kg K_2O ha^{-1}. But, the spikelets panicle^{-1}, grain yield and to some extent 1000 grain weight were higher with higher dose of fertilizers.

2.3.3 Effect on grain yield and straw yield

Ali *et al.* (2010) conducted an experiment and found that integrated plant nutrition system that is 116-33-5-22-0.40-5000 kg ha^{-1} N-P-K-S-Zn-Cow dung for *boro* and 87-16-15-7-0.15 kg ha^{-1} N-P-K-S-Zn for T. *aman* gives the higher yield. The grain yield of *boro* and

T. *aman* rice increased 18% and 14% respectively than the absolute control and total grain yield of rice was increased by about 16%.

Mollah *et al.* (2008) conducted an experiment to determine the optimum fertilizer dose for Mustard - *boro* - T. *aman* rice cropping pattern which enhancing total production and profit. Six different doses of fertilizer were estimated from soil test value, BARC Fertilizer Recommendation Guide' 97 and Farmers practice. They reported that the highest grain yield and gross margin were obtained from soil test base (STB) fertilizer dose that is 122-25-111-19 kg ha^{-1} mustard oil cake and PK for *boro* rice and 82-15-70-11 kg ha^{-1} mustard oil cake and PK for T. *aman* rice.

Islam *et al.* (2008) conducted an experiment to determine the response and the optimum rate of nutrients (NPK) for Chili- Fallow-T. *aman* cropping pattern. He found that grain yield influenced significantly due to application of different rates of nutrients and 60-19-36 kg ha-1 mustard oil cake and PK maximized the yield of T. *aman* rice varieties in respect of yield and economics.

Howlader *et al.* (2007) conducted an experiment at farmers' field of Farming System Research and Development (FSRD) site to determine the response and to find out the optimum rate of nutrients (NPK) for Mungbean-T. *aus*-T. *aman* cropping pattern under AEZ-13. The results indicated that fertilizer nutrient dose that maximized yield of T. *aus* and T. *aman* rice were 78-24-15 kg ha^{-1} and 48-13-13 kg ha^{-1} mustard oil cake and PK, respectively while 70-19-14 kg ha^{-1} mustard oil cake and PK was profitable for T. *aus* rice and 45-11-13 kg ha^{-1} mustard oil cake and PK for T. *aman* rice in respect of yield and economics.

Oikeh *et al.* (2006) combination of 60 kg mustard oil cake, 13 kg P and 25 kg K ha^{-1} (low to moderate input) has proved sufficient to double grain yield to 4 t ha^{-1} as compared to

zero fertilizer application. He recommended 120 kg mustard oil cake, 26 kg P and 25 kg K ha^{-1} appropriate for high input farmers which generates 145% more grain yield compared to no mustard oil cake and PK fertilizer application.

Yadav and Tripathi (2006) conducted an experiment in India to find out the best fertility levels for different hybrid rice varieties. Three hybrid rice varieties (Pant Shankar Dhan -1, Pro-Agro 6201 and Pro-Agro 6444) and one inbred variety (NDR-359) were tested at four levels of fertility i.e. control 80: 40: 40, 160: 80:80 and 240:120:120 kg mustard oil cake and PK ha^{-1}. Paddy varieties (Pro-Agro 6201 and Pro-Agro 6444) being statistically at par with application of 160:80:80 kg mustard oil cake and PK ha^{-1}.

Saito *et al.* (2005) conducted an experiment with three traditional and three improved cultivars were grown under four fertilizer treatments *viz.* 0 kg N ha^{-1}, 90 kg N ha^{-1}, 50 kg P2O5 ha^{-1} and NP. They reported applying P with mustard oil cake increased grain yield over mustard oil cake application alone.

Field experiments conducted by Natarajan and Arivazhagan (2005) at an Annamalai University experimental farm (Tamil Nadu, India) on hybrid rice ADTRH-1 revealed that the application of chemical fertilizer at recommended dose (100:50:50 kg NPK) increased the grain yield to 5.98 t ha^{-1}.

Amin *et al.* (2004) conducted an experiment to evaluate the effect of increased plant density and fertilizer dose on yield of rice variety IR-6. He found that increased fertilizer dose of mustard oil cake and PK increase grain and straw yield.

A field experiment was carried out by Surajit *et al.* (2004) at West Bengal, India to study the effect of different levels of fertilizers on the growth and yield of hybrid rice. The experiment was laid out with eight treatment combinations consisting of two cultivars,

namely, ProAgro 6444 (hybrid) and IET 4786 (HYV); four levels of fertility (0:0:0, 50:25:25, 100:50:50, 150:75:75 kg N, P_2O_5 and K_2O ha^{-1}) in three replicates. They noted that application of 150:75:75 kg N, P_2O_5 and K_2O ha^{-1}gave the highest grain yield of rice compared with other levels of fertility.

A field experiment was conducted by Pawar *et al.* (2003) at different locations in eastern Vidarbha Zone of Maharashtra, India, to work out the fertilizer requirement of hybrid rice in comparison with high yielding varieties. The fertilizer dose of 150:75:75 kg NPK ha^{-1} gave significantly higher grain yield.

Sudha and Chandini (2002) found that when the recommended dose of NPK that is 70:35:35 kg ha^{-1} was applied then the grain and straw yield was 4.269 and 4.652 t ha^{-1} but when the fertilizer dose is increased 25% and 50% then the grain yield and straw yield increased. For 25% increase of fertilizer the grain and straw yield was 4.363 and 4.877 t ha^{-1} and for 50% increase of fertilizer the grain and straw yield was 4.90 and 5.390 t ha^{-1}, respectively.

Haq *et al.* (2002) conducted an experiment with twelve treatments combination of N, P, K, S, Zn and Diazinon. He found all the treatments significantly increase the grain and straw yield of BRRI dhan 30 rice over control. 90 kg N + 50 kg P_2O_5 + 40 kg K_2O + 10 kg S + 4 kg Zn ha^{-1} + diazinon give the height grain and straw yield.

A field experiment was conducted by Bhowmick and Nayak (2000) to study the performance of hybrids (CNHR 2 and CNHR 3) and high-yielding cultivars (IR 36 and IR 64) of rice (Oryza sativa) at 5 levels of NPK fertilizer (0:0:0, 120:60:60, 150:75:75, 180:90:90) + 30 ZnSO4 kg ha^{-1}. Grain and straw yields increased with increasing level of nutrition for hybrids up to a rate of 180:90:90 + 30 ZnSO4 kg ha^{-1}, and for high-yielding cultivars up to 120:60:60.

The experiment was carried out by Brohi *et al.* (1997) to identify the effect of mustard oil cake and phosphorus on rice. Mustard oil cake at the rates of 0, 60, 120, 180 and 240 kg ha^{-1} as urea and phosphorus at the rates of 0, 50, 100 and 150 kg P_2O_5 ha^{-1} as triple superphosphate were applied to the soil before sowing. Additionally potassium was applied at 40 kg K_2O ha^{-1} level as K_2SO_4 per pot for normal plant growth. Both mustard oil cake and phoshorus fertilization have increased the straw and grain yields of rice plant significantly.

Brohi *et al.* (1997) also conducted an experiment to identify the effect of mustard oil cake and P fertilization on the yield and nutrient status of rice crop. They found that interaction effect of mustard oil cake and P for grain and straw was highest with 240 kg mustard oil cake ha^{-1} and 150 kg P_2O_5 ha^{-1}.

From the reviews cited and discussed above, it can be concluded that mustard oil cake, phosphorus and their interaction play a remarkable role for growth, yield and yield components of hybrid rice when urea supergranule was proved to be superior to prilled urea in rice cultivation.

CHAPTER III

MATERIALS AND METHODS

The pot experiment was conducted at the Sher-e-Bangla Agricultural University Soil Science Farm, Dhaka, Bangladesh during the period from December 2017 to April 2019 to study the effect of different doses of mustard oil cake application in different times on growth and yield of rice. The details of the materials and methods have been presented below:

3.1 Description of the experimental site

3.1.1 Location

The present piece of research work was conducted in the experimental area of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is 23^0 74′ N latitude and 90^0 35′ E longitude with an elevation of 8.2 meter from sea level.

3.1.2 Soil

The soil of the experimental area that used in the pot for rice grown belongs to "The Modhupur Tract", AEZ 28. Soil was silty clay in texture. Soil pH was 5.6 and has organic carbon 0.45%. The experimental area was flat having available irrigation and drainage system. The physico -chemical properties of initial soil sample have been presented in Appendix I.

3.1.3 Climate

The geographical location of the experimental site was under the subtropical climate, characterized by three distinct seasons, winter season from November to 2 February and the pre-monsoon period or hot season from March to April and

monsoon period from May to October (Edris*et al.*, 1979). Details of the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Weather Station, Sher-e Bangla Nagar, Dhaka and has been presented in Appendix II.

3.2 Experimental details

3.2.1 Treatments

The experiment comprised of two factors.

Factor A: Application Time (3 levels):

i. T_1: Basal Dose

ii. T_2: 20 days after transplanting

iii. T_3: 35 days after transplanting

Factor B: MOC (4 levels)

i. M_1: 0 Kg MOC /ha

ii. M_2: 25 Kg MOC /ha

iii. M_3: 50 Kg MOC /ha

iv. M_4: 75 Kg MOC /ha

There were 12 treatments combinations. The treatment combinations were T_1M_1, T_1M_2, T_1M_3, T_1M_4, T_2M_1, T_2M_2, T_2M_3, T_2M_4, T_3M_1, T_3M_2, T_3M_3 and T_3M_4.

3.2.2 Experimental design and layout

The experiment was laid out in Randomized Completely Block Design (RCBD) with three replications. There were 36 plots for 12 treatment combinations in each of 3 replications. The 12 treatment combinations of the experiment were assigned at random in 36 plots of each replication.

3.3 Growing of crops

3.3.1 Raising seedlings

3.3.1.1 Seed collection

The seeds of the test crop i.e. BRRI dhan67 was collected from Bangladesh Rice Research Institute (BRRI), Joydevpur, Gazipur.

3.3.1.2 Seed sprouting

Healthy seeds were selected by specific gravity method and then immersed in water bucket for 24 hours and then they were kept tightly in gunny bags. The seeds started sprouting after 48 hours and were sown after 72 hours.

3.3.1.3. Preparation of seedling nursery bed and seed sowing

According to BRRI recommendation seed bed was prepared with 1 m wide seed bed adding nutrients as per the requirements of soil. Seeds were sown in the seed bed on December 20, 2018, in order to transplant the seedlings in the plot as per experimental treatment.

3.3.2 Preparation of the plot

The land for the experiment was prepared at 25 January, 2019. Weeds and stubble were removed from the soil and finally obtained a desirable tilth of soil for transplanting of seedlings.

3.3.3 Fertilizers and manure application

The fertilizers N,P K, S, Zn and B in the form of MoP, gypsum, zinc sulphate and boric acid, respectively were applied as basal doses. The entire amount of MoP, gypsum, zinc sulphate and boric acid, TSP (as per treatment) and100% of urea were applied during the final preparation of land. Different levels of MOC (Mustard

oil cake) fertilizers were mixed with the soil as per treatment. The rest of urea fertilizer were applied at two equal instalments after 25 and 45 DAT (day after transplanting). The dose and method of application of fertilizers are shown in Table 1.

Table 01. Dose of fertilizer and method of application of fertilizers

Fertilizers	Dose (kg/ha)	Application (%)		
		Basal	1st installment	2nd installment
Urea	RFD	1/3	1/3	1/3
MP	100	100	-	-
Gypsum	60	100	-	-
Borax	10	100	-	-

Source: Anon., 2010, BRRI, Joydevpur, Gazipur

3.3.4 Uprooting of seedlings

The nursery bed was made wet by application of water one day before uprooting of the seedlings. The seedlings were uprooted on January 27, 2019 without causing much mechanical injury to the roots.

3.3.5 Transplanting of seedlings in the plots

The rice seedlings were transplanted in the plot at 28 January, 2019 and 2 healthy seedlings were transplanted in the plot in a hill.

3.3.6 After care

After establishment of seedlings, various intercultural operations were accomplished for better growth and development of the rice seedlings.

3.3.6.1 Irrigation and drainage

Irrigation was provided to maintain a constant level of standing water up to 6 cm in the early stages to enhance tillering and 10-12 cm in the later stage to discourage late tillering. The plot was finally dried out at 15 days before harvesting.

3.3.6.2 Gap filling

First gap filling was done for all of the plots at 10 days after transplanting (DAT) by planting same aged seedlings.

3.3.6.3 Weeding

Weeding were done to keep the plots free from weeds, which ultimately ensured better growth and development. The newly emerged weeds were uprooted carefully at tillering stage and at panicle initiation stage by manual means.

3.3.6.4 Plant protection

Furadan 57 EC was applied at the time of final land preparation and later on other insecticides were applied as and when necessary.

3.4 Harvesting, threshing and cleaning

The rice plants were harvested depending upon the maturity of plant and harvesting was done manually from each plot. The harvested crop of each pot was bundled separately, properly tagged and brought to threshing floor. Enough care was taken during harvesting, threshing and also cleaning of rice seed. Fresh weight of grain and straw were recorded plot wise. The grains were cleaned and finally the weight was adjusted to a moisture content of 12%. The straw was sun dried and the yields of grain and straw $plot^{-1}$ were recorded and converted to t/ha.

3.5 Data recording

3.5.1 Plant height

The height of plant was recorded in centimeter (cm) at the time of harvest. The height was measured from the ground level to the tip of the tiller.

3.5.2 Number of tillers hill^{-1}

The number of tillers hill^{-1} was recorded at the time of harvest by counting total tillers in a hill.

3.5.3 Total tillers hill^{-1} (at harvest)

The total number of total tillers hill^{-1} was counted as the number of panicle bearing and non-bearing tillers hill^{-1}. Data on total tillers hill^{-1} were counted at harvest and value was recorded.

3.5.4 Effective tillers hill^{-1}

The total number of effective tillers hill^{-1} was counted as the number of panicle bearing tillers plant^{-1}. Data on effective tiller hill^{-1} were counted and value was recorded.

3.5.5 Length of panicle

The length of panicle was measured with a meter scale from five (05) selected panicles and the average value was recorded.

3.5.6 Number of panicle

The number of total panicle per hill were counted.

3.5.7 Filled grain hill^{-1}

The total number of filled grain per hill were counted manually.

3.5.8 Un-filled grain hill^{-1}

The total number of unfilled grain per hill were counted manually.

3.5.9 Filled grains panicle^{-1}

The total number of filled grains were collected randomly from selected 5 panicles of a plot on the basis of grain in the spikelet and then average number of filled grains panicle^{-1} was recorded.

3.5.10 Unfilled grains panicle^{-1}

The total number of unfilled grains was collected randomly from the same 5 panicles where filled grains were counted of a plot on the basis of number of grains in the spikelet and then average number of unfilled grains panicle^{-1} were recorded.

3.5.11 1000-seed weight

One thousand healthy seeds were counted randomly from the total cleaned harvested seeds of each individual plot and then weighed in grams and recorded.

3.5.12 Grain yield

Grains obtained from each unit plot were sun-dried and weighted carefully. The dry weight of grains of each plot was measured in yield plot^{-1}.

3.5.13 Straw yield

Straw obtained from each unit plot were sun-dried and weighted carefully. The dry weight of the straw of each plot was measured.

3.6 Statistical analysis

The data obtained for different characters were statistically analyzed using Statistix10 software to observe the significant difference among the treatments. The mean values of all the characters were calculated and factorial analysis of variance was performed. The significance of the difference among the treatment means was estimated by the Least Significant Difference Test (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER VI

RESULTS AND DISCUSSION

The experiment was conducted to investigate the influence of mustard oil cake and phosphorus levels on the growth and yield of BRRI dhan67. This chapter comprised with presentation and discussion of the results obtained from the study. Treatments effect of mustard oil cake and date of application in all the studied parameters have been presented in Figure 1 to Figure 4 and interaction effect of mustard oil cake and phosphors in Table 1 to Table 3.

4.1 Crop growth characters

4.1.1 Plant height

4.1.1.1 Effect of MOC

Effect of application time showed insignificant variation on plant height of BRRI dhan67 at harvesting stage (Table). Regardless of treatment differences, plant height increased progressively up to maturity and found insignificant variation. The highest plant height (81.75 cm) was found on M_4 treated plot and lowest (69.11cm) plant height was found from M_1 (control) treated plot.

4.1.1.2 Effect of time of application

Effect of time of application levels showed insignificant variation on plant height of BRRI dhan67 at harvesting stage (Table, Fig). Plant height increased progressively up to maturity and found insignificant variation. The highest plant height (81.67cm) was found on T_3 treated plot and lowest (69.6 cm) plant height was found from T_1 (Control) treated plot.

4.1.1.3 Interaction effect of mustard oil cake and time of application

The interaction effect of mustard oil cake and time of application showed significant variation on plant height of BRRI dhan67 (Table, Fig). On the one hand, the highest plant height (86.63 cm) was found from T_3M_4 treated plot. Likewise, T_2M_2, T_2M_4 and T_3M_3 were also found identical with T_2M_3 treatment. On the other hand, the lowest plant height (58.1cm) was observed from T_1M_1 (control) treatment. However, T_3M_4 were found identical with T_1M_1 (control) treated plot.

4.1.2 Total tiller

4.1.2.1 Effect of MOC

Data presented in Table1 in response of different application time showed statistically significant variation on total tiller numbers of BRRI dhan67 at harvesting stage (Table, Fig). Unrelated of treatment differences, total tiller increased up to maturity and found statistically significant variation. One the one hand, the highest total tiller (21.56) was found on M_4 treated plot and lowest total tiller was found from M_1 (control) treated plot.

4.1.2.2 Effect of time of application

Effect of time of application showed statistically significant variation on total tiller of BRRI dhan67 at harvesting stage (Table, Fig). Nevertheless, of treatment differences, total tiller increased up to maturity and found significant variation. The highest total tiller (21.42) was found on T_2 treated plot and lowest (16.58) total tiller was found from T_1 (control) treated plot.

4.1.2.3 Interaction effect of mustard oil cake and time of application

The interaction effect of mustard oil cake and time of application showed significant variation on

total tiller of BRRI dhan67 (Table, Fig). On the one hand, the highest total tiller (27.67) was found from T_3M_4 treated plot. On the other hand, the lowest total tiller (12.33) was observed from T_1M_1 (control) treatment. However, T_3M_4, T_3M_1 were found similar with T_1M_1 (control) treated plot. This finding was found in agreement with the findings of different researchers. Likewise, Salem (2006) reported that the mustard oil cake levels had a positive and significant effect on growth parameters of rice plants. He also found that increasing mustard oil cake levels up to 70 kg ha^{-1} significantly increased plant height. The highest plant height was recorded about 92.81 cm with 70 kg N ha^{-1}.

4.1.3 Effective tiller

4.1.3.1 Effect of MOC

The effect of MOC showed significant variation on effective tiller of BRRI dhan67 at harvesting stage (Table, Fig). In the treatment differences, effective tiller increased up to maturity and found significant variation. The highest effective tiller (14.22) was found on M4 treated plot and lowest (9.89) effective tiller was found from M_1 (control) treated plot.

4.1.3.2 Effect of time of application

Different time of application showed significant variation on effective tiller of BRRI dhan67 at harvesting stage (Table, Fig). The highest effective tiller (14.58) was found on T_3 treated plot and lowest (10.83) effective tiller was found from T_1 (control) treated plot

4.1.3.3 Interaction effect of mustard oil cake and phosphorus

The interaction effect of mustard oil cake and time of application showed significant variation on effective tiller of BRRI dhan67 (Table, Fig). On the one hand, the highest effective tiller (18.00) was found from T_2M_3 treated plot. Similarly, T_2M_2 and T_2M_4 were also found similar with T_2M_3 treatment. On the other hand, the lowest effective tiller (7.67) was observed from T_1M_1 (control) treatment. However, T_3M_4, T_3M_1 were found similar with P_1N_1 (control) treated plot. Similarly, Wang *et al.* (2002) found that the tiller number increased with increasing mustard oil cake levels.

4.1.4 Non effective tiller

4.1.4.1 Effect of MOC

Effect of MOC showed insignificant variation on non-effective tiller of BRRI dhan49 at harvesting stage (Table, Fig). Irrespective of treatment differences, non-effective tiller increased up to maturity and found insignificant variation. The highest non effective tiller (7.33) was found on M_4 treated plot and lowest (5.44) non effective tiller was found from M_1 (control) treated plot.

4.1.4.2 Effect of time of application

Effect of time of application showed significant variation on non-effective tiller of BRRI dhan67 at harvesting stage (Table, Fig). Notwithstanding of treatment differences, non-effective tiller increased up to maturity and found insignificant variation. The highest non effective tiller (6.83) was found on T_2 treated plot and lowest (5.75) non effective tiller was found from T_1 (control) treated plot.

4.1.4.3 Interaction effect of mustard oil cake and time of application

The interaction effect of mustard oil cake and time of application showed significant variation on non-effective tiller of BRRI dhan67 (Table, Fig). On the one hand, the highest non effective tiller (9.67) was found from T_2M_3 treated plot. Likewise, T_3M_2, T_2M_4 and

T_1M_4 were also found similar with T_2M_3 treatment. On the other hand, the lowest non effective tiller (4.67) was observed from T_1M_1 (control) treatment.

Table 01. Effect of mustard oil cake and time of application on growth and yield contributing parameters of BRRI dhan67

Treatments	Plant Height (cm)	Total tiller	Effective tiller	Non-effective tiller
Date of Application				
T_1	69.6c	16.58b	10.83b	5.75a
T_2	73.67b	17.42b	10.92b	6.583a
T_3	81.67a	21.42a	14.58a	6.833a
LSD(0.05)	3.4722	1.2482	1.7142	1.4526
CV%	5.50	8.02	16.80	26.98

Table 02. Effect of mustard oil cake and time of application on growth and yield contributing parameters of BRRI dhan67

Mustard oil cake (N)	Plant height (cm)	Total tiller	Effective tiller	Non-effective tiller
M_1	69.11c	15.22d	9.89c	5.44b
M_2	76.23b	19.33b	12.78ab	6.56ab
M_3	72.81bc	17.78c	11.56bc	6.22ab
M4	81.76a	21.56a	14.22a	7.33a
LSD(0.05)	4.0094	1.4413	1.9794	1.6773
CV%	5.50	8.02	16.80	26.98

Table 03. Effect of mustard oil cake and time of application on growth and yield contributing parameters of BRRI dhan67

T x M	Plant height (cm)	Total tiller	Effective tiller	Non-effective tiller
T1 M1	58.10g	12.33g	7.66f	4.67b
T1 M2	68.76ef	17.33de	10.67cdef	6.67b
T1 M3	76.60bcd	18.00cde	12.67bcd	5.33b
T1 M4	74.93cde	18.67bcd	12.33bcde	6.33b
T2 M1	78.56bc	17.33de	12.33bcde	5.00b
T2 M2	80.96abc	20.667b	14.67ab	6.00b
T2 M3	63.00 fg	14.67ef	9.00ef	5.67b
T2 M4	80.50abc	20.00bc	13.33bc	6.67b
T3 M1	70.66de	16.00ef	9.67def	6.67b
T3 M2	78.96bc	20.00bc	13.00bcd	7.00ab
T3 M3	82.03 ab	19.00bcd	12.00bcde	7.00ab
T3 M4	86.63a	27.667a	18.00a	9.67a
LSD(0.05)	6.9445	2.4963	3.4283	2.9052
CV%	5.50	8.02	16.80	26.98

4.1.5 length of Flag leaf

4.1.5.1 Effect of Mustard oil cake

Application of different mustard oil cake levels were found statistically significant variation on the length of flag leaf of BRRI dhan67 (Table, Fig). The flag leaf of BRRI dhan67 increased progressively up to maturity and found significant variation. The highest flag leaf length (29.88 cm) was found on M_4 treated plot and lowest (24.96 cm) flag leaf length was found from M_1 (control) treated plot.

4.1.5.2 Effect of time of application

Effect of time of application showed statistically significant variation on flag leaf length of BRRI dhan67 (Table, Fig). The highest flag leaf (30.07cm) was found on T_3 treated plot and lowest (24.04 cm) flag leaf was found from T_1 (control) treated plot

4.1.5.3 Interaction effect of mustard oil cake and time of application

The interaction effect of mustard oil cake and time of application showed statistically significant variation on flag leaf length of BRRI dhan67 (Table, Fig). On the one hand, the highest flag leaf length (35.97cm) was found from T_3M_4 (33g,150g) treated plot. On the other hand, the lowest flag leaf length (20.83cm) was observed from T_1M_2 treatment.

4.1.6 Panicle length

4.1.6.1 Effect of mustard oil cake

Effect of mustard oil cake levels showed statistically significant variation on panicle length of BRRI dhan67 at harvesting stage (Table, Fig). Regardless of treatment differences, panicle length increased progressively up to maturity and found significant variation. The highest panicle length (21.87cm) was found on M_4 (150g) treated plot and lowest (16.88cm) panicle length was found from M_1 (control) treated plot.

4.1.6.2 Effect of time of application

Effect of time of application showed statistically significant variation on panicle length of BRRI dhan67 at harvesting stage (Table, Fig). Nonetheless of treatment differences, panicle length increased progressively up to maturity and found insignificant variation. The highest panicle length (22.84cm) was found on P_2 (33g) treated plot and lowest (17.33cm) panicle length was found from P_1 (control) treated plot.

4.1.6.3 Interaction effect of mustard oil cake and time of application

The interaction effect of mustard oil cake and time of application showed statistically significant variation on panicle length of BRRI dhan67 (Table, Fig). On the one hand, the highest panicle length (28.73cm) was found from T_3M_4 treated plot. On the other hand, the lowest panicle length (13.60cm) was observed from T_1M_1 (control, control) treatment. This finding was in agreement with the findings of different researchers. Likewise, Islam *et al.* (2008) conducted an experiment to study the effect of mustard oil cake and number of seedlings per hill on the yield and yield components of T. *aman* rice (BRRI dhan 33). They noted that panicle length, number of grain panicle^{-1} increased with the application rate of N up to 100 kg ha-1 and then declined

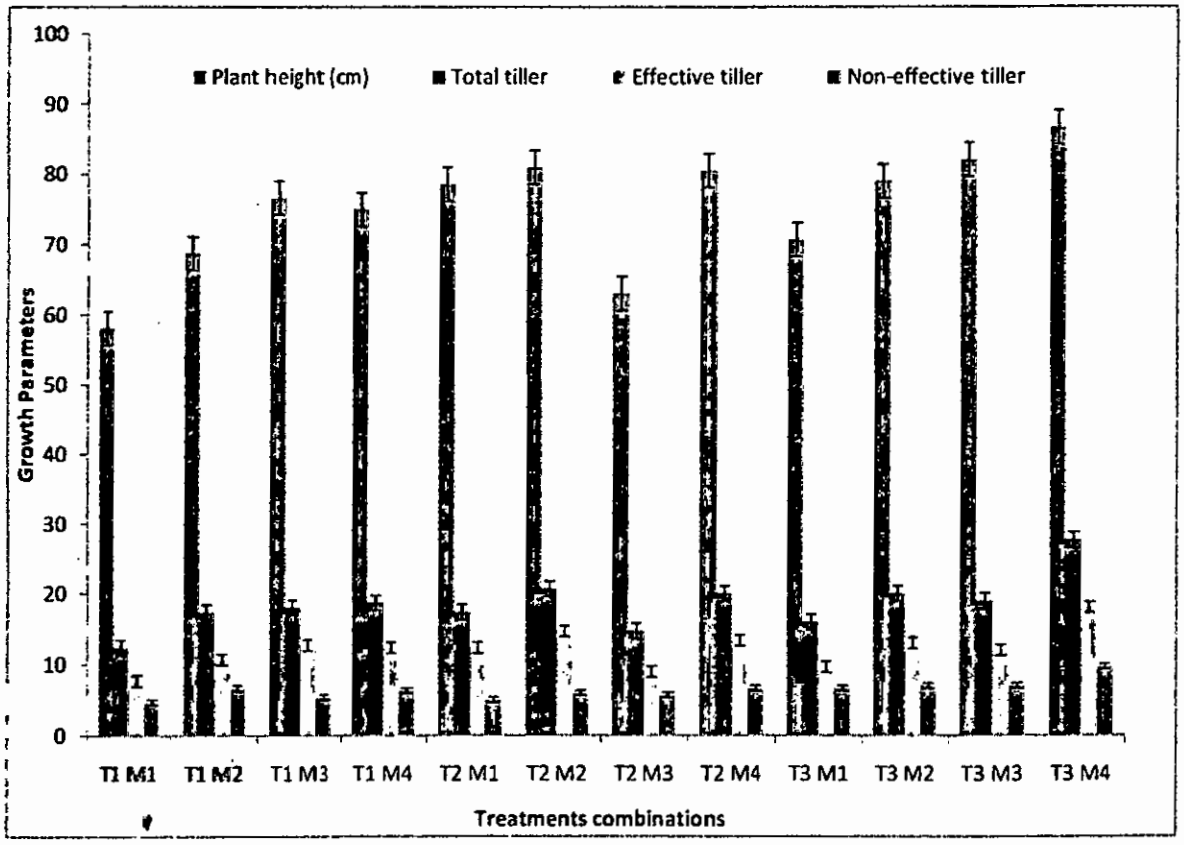


Fig2: Interaction effect of mustard oil cake and time of application on growth and yield parameters of rice

Table 04. Effect of mustard oil cake and time of application on growth and yield contributing parameters of BRRI dhan67

Treatments	Flag leaf(cm)	Panicle length(cm)
Time of application		
T1	24.04c	17.33c
T2	26.55b	18.36b
T3	30.07a	22.84a
LSD(0.05)	2.2192	0.8149
CV%	9.80	4.96

Mustard oil cake (M)	Flag leaf(cm)	Panicle length(cm)
M1	24.97b	16.88c
M2	27.38ab	19.82b
M3	25.32b	19.48b
M4	29.88a	21.87a
LSD(0.05)	2.5625	0.9409
CV%	9.80	4.96

T x M	Flag leaf(cm)	Panicle length
T1 M1	22.30def	13.60h
T1 M2	20.83f	16.83fg
T1 M3	25.53cde	18.63e
T1 M4	27.50bc	20.27cd
T2 M1	27.40bc	18.73de
T2 M2	30.33b	22.37b

T2 M3	21.90ef	16.63g
T2 M4	26.57bcd	21.53bc
T3 M1	25.20cdef	18.30ef
T3 M2	30.97b	20.27cd
T3 M3	28.13bc	18.23efg
T3 M4	35.97a	28.73a
LSD	4.4384	1.6297
CV%	9.80	4.96

4.2 Crop yield character

4.2.1 Filled grain

4.2.1.1 Effect of Mustard oil cake

Effect of mustard oil cake levels showed statistically significant variation on filled grain of BRRI dhan67 at harvesting stage (Table, Fig). Regardless of treatment differences, filled grain increased progressively up to maturity and found significant variation. The highest filled grain (132.14) was found on M_4 treated plot and lowest (112.69) filled grain was found from M_3 treated plot.

4.2.1.2 Effect of time of application

Application of time of application showed significant variation on filled grain of BRRI dhan67 at harvesting stage (Table, Fig). Regardless of treatment differences, filled grain increased progressively up to maturity and found insignificant variation. The highest filled grain (132.24) was found on T_3 treated plot and lowest (110.08) filled grain was found from T_1 (control) treated plot.

4.2.1.3 Interaction effect of mustard oil cake and time of application

The combined effects of mustard oil cake and time of application showed significant variation on filled grain of BRRI dhan67 (Table, Fig). On the one hand, the highest filled grain (91.56cm) was found from T_3M_4 treated plot. On the other hand, the lowest filled grain (99.67) was observed from T_1M_1 (control) treatment. Similarly, Masum *et al.* (2010) said that placement of N fertilizer in the form of USG @ 58 kg N ha^{-1} produced the highest number of effective tillers $hill^{-1}$, filled grains $panicle^{-1}$ which ultimately gave the higher grain yield than split application of urea.

4.2.2 Unfilled grain

4.2.2.1 Effect of Mustard oil cake

Effect of mustard oil cake levels showed significant variation on unfilled grain of BRRI dhan67 at harvesting stage (Table, Fig). Unfilled grain increased progressively up to maturity and found significant variation. The highest unfilled grain (41.03) was found on M_1 (control) treated plot and lowest (26.82) unfilled grain was found from M_3 (150g) treated plot.

4.2.2.1 Effect of time of application

Effect of time of application showed significant variation on unfilled grain of BRRI dhan67 at harvesting stage (Table, Fig). The highest unfilled grain (39.89) was found on T_1 (control) treated plot and lowest (25.33) unfilled grain was found from T_3 treated plot.

4.2.2.3 Interaction effect of mustard oil cake and time of application

The interaction effect of mustard oil cake and time of application showed statistically significant variation on unfilled grain of BRRI dhan67 (Table, Fig). On the one hand, the highest unfilled grain (52.03) was found from T_1M_1 (control, control) treated plot. On the other hand, the lowest unfilled grain (17.40) was observed from T_2M_3 treatment. However, T_2M_4 were found similar with T_2M_3 treated plot.

4.2.3 Grain yield

4.2.3.1 Effect of Mustard oil cake

Effect of mustard oil cake levels showed statistically significant variation on grain yield of BRRI dhan67 at harvesting stage (Table, Fig). The highest grain yield (38.99) was found on M_4 treated plot and lowest (26.28) grain yield was found from M_1 (control) treated plot.

4.2.3.2 Effect of time of application

Effect of time of application showed statistically significant variation on grain yield of BRRI dhan67 at harvesting stage (Table, Fig). The highest grain yield (36.24) was found on T_4 treated plot and lowest grain yield was found from T_1(control) treated plot.

4.2.3.3 Interaction effect of mustard oil cake and time of application

The interaction effect of mustard oil cake and time of application showed statistically significant variation on grain yield of BRRI dhan67 (Table, Fig). On the one hand, the highest grain yield (51.79) was found from T_3M_4 treated plot. On the other hand, the lowest grain yield (22.34) was observed from T_1M_1 (control, control) treatment. Thakur (1991) observed that yield attributes differed significantly due to levels and sources of mustard oil cake at 60 kg N ha^{-1} through USG produced the highest panicle weight, number of grains $panicle^{-1}$, 1000- grain weight.

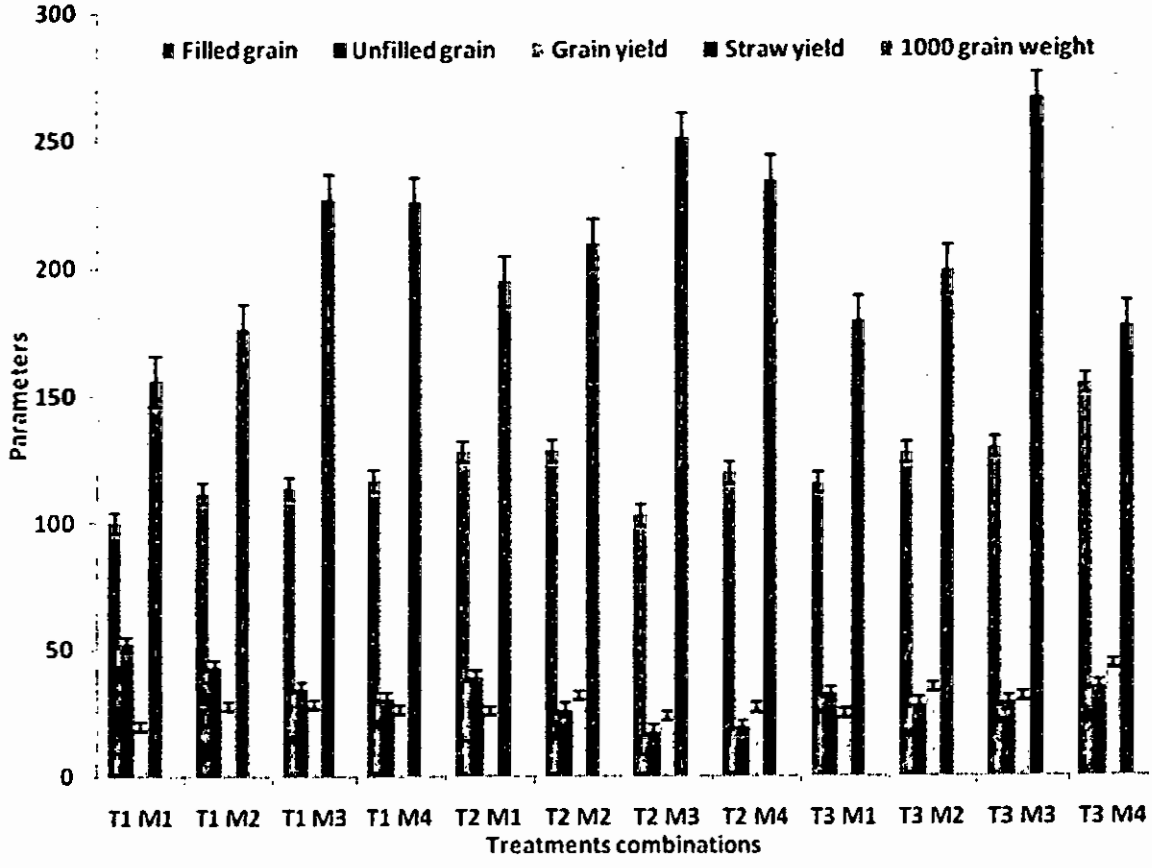


Fig3: Interaction effect of mustard oil cake and time of application on yield parameters of rice

4.2.4 Straw yield

4.2.4.1 Effect of Mustard oil cake on straw yield

Effect of mustard oil cake levels showed statistically significant variation on straw yield of BRRI dhan67 at harvesting stage (Table, Fig.). The highest straw yield (248.11 gm) was found on M_4 treated plot and lowest (176.56 gm) straw yield was found from M_1 (control) treated plot. The findings of this research were also in agreement with the findings of several researchers. Also, Alvi *et al.* (2004) found the similar result and he reported that paddy grain and straw yields were influenced significantly by the application of P. Application of 50 kg P_2O_5 gave the higher yield following by 100 kg P_2O_5 ha^{-1}.

4.2.4.2 Effect of time of application on straw yield

Effect of time of application showed insignificant variation on straw yield of BRRI dhan67 at harvesting stage (Table, Fig). The highest straw yield (226.17) was found on T_3 treated plot and lowest (196.00) straw yield was found from T_1 (control) treated plot.

4.2.4.3 Interaction effect of mustard oil cake and time of application on straw yield

The interaction effect of mustard oil cake and time of application showed statistically significant variation on straw yield of BRRI dhan67 (Table, Fig). On the one hand, the highest straw yield (266.67g) was found from T_3M_4 treated plot. Likewise, T_3M_3 was also found similar with T_2M_3 treatment. On the other hand, the lowest straw yield (155.67) was observed from T_1M_1 (control, control) treatment. Singh and Shivay (2003) found that increasing levels of mustard oil cake significantly increased the grain and straw yields.

4.2.5 1000-grain weight

4.2.5.1Effect of Mustard oil cake on 1000 grain weight

Effect of mustard oil cake levels showed significant variation on thousand grain wt of BRRI dhan67 at harvesting stage (Table, Fig). The highest thousand grain wt (0.0267kg) was found on M_4 treated plot and lowest (0.0248kg) thousand grain wt was found from M_1 (control) treated plot.

4.2.5.2 Effect of time of application on 1000-grain weight

Effect of time of application showed insignificant variation on thousand grain wt of BRRI dhan67 at harvesting stage (Table, Fig). The highest thousand grain wt (0.0261kg) was found on T_3 treated plot and lowest (0.0253kg) thousand grain wt was found from T_1(control) treated plot.

4.2.5.3 Interaction effect of mustard oil cake and time of application on 1000-grain weight

The interaction effect of mustard oil cake and time of application showed statistically significant variation on thousand grain weight of BRRI dhan67 (Table, Fig). On the one hand, the highest thousand grain wt (0.0273kg) was found from T_3M_4 treated plot. On the other hand, the lowest thousand grain wt (0.0243kg) was observed from T_1M_1 (control, control) treatment.

Table 03. Effect of mustard oil cake and time of application on growth and yield contributing parameters of BRRI dhan67

Treatments	Filled grain	Unfilled grain	Grain yield(kgha^{-1})	Straw yield(kgha^{-1})	T_grain wt(kgha^{-1})
Time of application					
T_1	110.08c	39.89a	25.40c	196.00b	0.025b
T_2	118.49b	25.33c	28.57b	201.58b	0.026ab
T_3	132.24a	30.94b	33.24a	226.17a	0.026a
LSD(0.05)	4.9950	3.5889	2.5824	8.3883	4.4414
CV%	4.93	13.29	9.56	4.79	2.05

Mustard oil cake (N)	Filled grain	Unfilled grain	Grain yield(kgha^{-1})	Straw yield(kgha^{-1})	T_grain wt(kgha^{-1})
M_1	114.21c	41.03a	23.278c	176.56d	0.0248d
M_2	122.04b	32.23b	31.44b	194.78c	0.026b
M_3	112.69c	26.82c	25.57c	212.22b	0.0254c
M_4	132.14a	28.13bc	35.99a	248.11a	0.0267a

LSD(0.05)	5.7678	4.1441	2.9819	9.6860	5.1284
CV%	4.93	13.29	9.56	4.79	2.05

T x M	Filled grain	Unfilled grain	Grain yield	Straw yield	T _grain wt
T1 M1	99.67e	52.03a	19.34f	155.67g	0.024d
T1 M2	111.33cd	42.93b	27.80cde	176.00f	0.025c
T1 M3	113.13c	34.27cd	28.18cde	226.67b	0.026b
T1 M4	116.20c	30.33de	26.29de	225.67bc	0.025c
T2 M1	127.53b	38.90bc	25.72e	194.67de	0.025cd
T2 M2	127.83b	25.90ef	31.61bc	209.33cd	0.026b
T2 M3	102.57de	17.40g	23.60ef	251.00a	0.025c
T2 M4	119.30bc	19.13fg	26.83cde	234.00b	0.025bc
T3 M1	115.43c	32.17cde	24.77e	179.33ef	0.025cd
T3 M2	126.97b	27.87de	34.91b	199.00d	0.026b
T3 M3	129.00b	28.80de	31.00bcd	266.67a	0.026b
T3 M4	154.30a	34.93cd	43.79a	177.00f	0.027a
LSD(0.05)	9.9901	7.1777	5.1648	16.777	8.882E-04
CV%	4.93	13.29	9.56	4.79	2.05

CHAPTER V

SUMMARY AND CONCLUSIONS

A field experiment was conducted at the Soil Science field of Sher-e-Bangla Agricultural University (SAU), during December, 2017 to May, 2018 with a view to finding out the influence of mustard oil cake and time of application on growth and yield of BRRI dhan67. The experiment comprised with four levels of mustard oil cake (M_1 = 0 kg ha^{-1}, M_2 = 60 kg ha^{-1}, M_3 = 90kg ha^{-1}, M_4 = 120 kg ha^{-1}) and three time of application (T_1 = Basal application, T_2 = 20 days after of application, T_3 = 30 days after application). The experiment was laid out in a Randomize Complete Block Design with three replications. There were 12 treatments combinations. The total numbers of unit plots were 36. The size of plot was 1.75 m x 2.5 m = 4.38 m^2.Seedlings were transplanted with 25 cm spacing between lines and 15 cm spacing between hills. Intercultural operations such as gap filling, weeding, water management and pest management were done as and when necessary. Maturity of crop was determined when 90% of the grains become golden yellow in color. An area of 1 m^2 was harvested from centre of each plot avoiding the border effect. The harvested crop of each plot was separately bundled, properly tagged and then brought to the threshing floor. Threshing was done by pedal thresher. The grains were cleaned and sun dried to moisture content of 12 %. Straw was also sun dried properly.

The data on crop growth characters like plant height and number of tillers $hill^{-1}$ were recorded at 15, 30, 45, 60, 75. 90, 105DAT and at harvest and dry mater were recorded at 30 DAT, 60 DAT, 90 DAT and at harvest in the field and yield as well as yield contributing characters like number of effective tillers $hill^{-1}$, panicle length, number of grains $panicle^{-1}$, percent filled and unfilled grains,1000-grain weight, grain and straw yield were recorded after harvest.

A significant variation in plant height at different plant ages was observed due to mustard oil cake level variation. Plant height increased progressively up to maturity. At harvest, the tallest plant (81.76 cm) was observed with M_4 and shortest (69.11 cm) with control treatment. And the tallest plant height (81.66 cm) was observed with T_2 and shortest (69.60 cm) with control treatment. The treatment combination T_3M4_3 produced highest plant height (86.63 cm) at harvest.

Tillers $hill^{-1}$ increased up to 75 DAT and then decline irrespective of treatment variables. In all the growth stages, maximum tillers $hill^{-1}$ were observed with M_4Application of 75 kg

MOC ha^{-1} produced the highest effective tiller $hill^{-1}$ (14.22) and lowest (9.89) by control. Application at 35 DAT produced the highest effective tillers (14.58) and lowest by T_1. Treatment combination T2M3 produced highest number of effective tillers (18.00) and lowest by T_1M_1.Mustard oil cake and time of application had positive role in increasing the panicle length. Application of 75 kg MOC produced longest panicle (21.87cm) and shortest with control.

Application of 75 kg MOC produced highest (132.24) filled grains. Among the treatment combination T_2M_3 produced highest filled grains. Maximum unfilled grain was observed with control treatment of MOC and time whereas T_1M_1 produced maximum unfilled grain. Significantly highest 1000 grain weight (0.0267Kg) was observed with T_3 and lowest (0.0248Kg) with T_1.

The highest 1000 grain weight (0.0273Kg) was obtained with combination treatment of T_3M_4 and lowest (0.0243Kg) with T_1M_1. 75 kg MOC ha^{-1} produced the highest grain yield (8.2 t ha^{-1}). The lowest grain yield was observed with T_1. In case of time, (T3) produced the highest grain yield (7.6t ha^{-1}). Among the different treatment combination T_3M_4 produced the highest grain yield (9.9t ha^{-1}). Significant variation in straw yield was observed when MOC was applied but there was no significant variation among the time levels. The highest straw yield (5.16 t ha^{-1}) was observed with T_3. Among the treatment combination, T_3M_4 produced the highest straw yield (9.9 t ha^{-1}). It could be concluded that application of mustard oil cake and time of application is necessary for raising yield of BRRI dhan67.

Results indicated that the effect of mustard oil cake showed significant variation in respect of all growth, yield contributing characters and yield. At harvest, highest plant height (81.66cm), tillers $hill^{-1}$ (21.55), effective tillers $hill^{-1}$ (14.22), panicle length (21.87cm), filled grains $panicle^{-1}$ (132.1), 1000 grain weight (29.35 g), grain yield (8.2 t ha^{-1}), straw yield (5.16 t ha^{-1}) was obtained from the application of MOC. On the other hand, highest plant height (81.67cm), tillers $hill^{-1}$ (21.42), effective tillers $hill^{-1}$ (14.58), panicle length (22.84cm), filled grains $panicle^{-1}$ (132.24), 1000 grain weight (29.35 g), grain yield (7.6 t ha^{-1}), straw yield (5.15t ha^{-1}) was obtained from the time of application. Mustard oil cake @ 75 kg gave the highest grain yield (7.6 t ha^{-1}). Interaction effect showed that application of MOC @75 kg application in 75 days after application gave the highest (9.9 t ha^{-1}) grain yield. Therefore, application of MOC @ 75 kg ha^{-1} at 35 DAT appears to be the best package for BRRI dhan67 produced higher yield.

REFERENCES

A A, Mohanty S, Rozell S, Hardy B B. Rice in the Global Economy: Strategic Research and Policy Issues for Food Security. Los Banos, the Philippine: International Rice Research Institute: 61–92.

Ahmed, M. H., Islam, M. A., Kader, M. A. and Anwar, M. P. (2000). Evaluation of urea supergranules as a source of mustard oil cake in T. *aman* rice. *Pakistan J. Biol. Sci.* **2**(5): 735-737.

Ahmed, M., Islam, M. and Paul, S. K. (2005). Effect of mustard oil cake on yield and other plant characters of Local T. Aman Rice, Var. Jatai. *Res. J. Agric. Biol. Sci.* **1**(2): 158-161.

Aide, M. and Picker, J. (1996). Potassium and Phosphorus Nutrition in Rice. Information from 1996 Missouri Rice research Update.

Alam, M. M., Ali, M. H., Amin, A.K.H.R. (2009d). Yield attributes, yield and harvest index of three irrigated rice varieties under different levels of phosphorus. *Advances in Biol. Res.* **3** (3-4): 132-139.

Alam, M. M., Ali, M. H., Hasanuzzaman, M. H. and Nahar, K. and Islam M. R. (2009c). Dry matter partitioning in hybrid and inbreed rice varieties under variable dose of phosphorus. *Intl. J. sustain. Agric.* **1**(1): 10-19.

Alam, M.M., Hasanuzzaman, M.H. and Nahar, K. (2009a). Growth pattern of three high yielding rice varieties under different phosphorus levels. *Advances in Biol. Res.* **3**(3-4): 110-116.

Alam, M.M., Hasanuzzaman, M.H. and Nahar, K. (2009b). Tiller dynamies of three irrigated rice varieties under varing phosphorus levels. *American- Eurasia J. Agron.* **2**(2): 89-94.

Ali, A. M., Alam, R. M. and Molla, M.S.H. (2005). Crop productivity as affected by fertilizer management options in boro-T. aman cropping pattern at farmers' field. *Bangladesh J. Agril. Res.* **35**(2): 287-296.

Alvi, A., Yaseen, M., Khalid, J., Ghafoor, A. and Ali, M. A. (2000). Determination of optimum phosphorus rate in rice-wheat system cropping: Growth and yield parameters. *Pakistan J. Soil Sci.* **23** (1-2): 28-33.

Amin, M., Khan, M. A., Khan, E. A. and Ramzan, M. (2004). Effect of increased plant density and fertilizer dose on the yield of rice variety Ir-6. *J. res. Sci.* **15**(1):9-16

Annaduria, K. and Palaniappan, S. (1998). Phosphorus management with diammonium phosphate spray on productivity of lowland transplanted rice (*Oryza sativa*). *Indian J. Agron.* **43**(2): 278-283.

Anonymous. (2004). Adaption and adoption USG technology for resource poor farmers in the tidal submergence area. Annual Internal Review Report for 2003-2004.

Asif, M., Aslam, M., Jabbar, A., Rafique, K., Babar, M.R. and Ehsanullah. (2000). Panicle structure, kernel quality and yield of fine rice as influenced by NPK rates and split mustard oil cake application. *Intl. J. Agri. Biol.* **2**(4): 306-308.

Awan, T.H., Ali, R.I., Manzoor, Z., Ahmed, M. and Akhtar, M. (2011). Effect of different mustard oil cake levels and row spacing on the performance of newly evolted medium grain rice variety, KSK-133. *J. Animal and Plant Sci.* **21**(2): 231-234.

Balasubramanian, R. (2002). Response of hybrid rice (Oryza sativa) to levels and time of application of mustard oil cake. *Indian J. Agron.* **47**(2): 203-206.

Balaswamy, K. (1999). Influence of different pre-emergence herbicides in relation to forms of urea on weed control and crop performance in transplanted rice. *J. Res. ANGRAU.* **27**(4): 1-6.

BBS (Bangladesh Bureau of Statistics). (2010). Agriculture crop cutting. Estimation of boro rice 2009-2010. Government of the People's Republic of Bangladesh. Web site: http://www. bbs. gov.bd.

Bhowmick, N. and Nayak, R. L. (2000). Response of hybrid rice (*Oryza sativa*) varieties to mustard oil cake, phosphorus and potassium fertilizers during dry (boro) season in West Bengal. *Indian J. Agron.* **45**(2): 323-326.

Brasil, E.S., Muraoka, T., boaretto, A. E. and Scivittaro, W. B. (2002). Phosphate fertilizers with varying water-solubility are applied to Amazonian soils: Agronomic efficiency of P sources. International Atomic Energy Agency Technical Documents *IAEA-TECDOCs.* **5**(12): 143-149.

Brohi, A., Karaman, M., Aktas, A. and Savasli, E. (1998). Effect of mustard oil cake and phosphorus fertilization on the yield and nutrient status of rice grown on artificial siltation soil from the Kelkit river. *J. Agric. and Forest.* **22**: 585-592.

BRRI (Bangladesh Rice Research Institute). (2000). Annual Report for 1999-2000. Bangladesh Rice Research Institute, Joydebpur, Gazipur. P. 138.

BRRI (Bangladesh Rice Research Institute). (2006). Web site: http://www. Knowledge-brri.org. BRRI (Bangladesh Rice Research Institute). (2006a). Annual Report for 2005-2006. Bangladesh Rice Res. Inst., Joydebpur, Gazipur-1701.

BRRI (Bangladesh Rice Research Institute). (2006b). Annual Report for 2005-2006. Bangladesh Rice Res. Inst., Joydebpur, Gazipur-1701.

BRRI (Bangladesh Rice Research Institute). (2008a). BRRI Annual Internal Review 2006-2007. Soil Science Devision. Bangladesh Rice Research Institute, Gazipur-1701.

BRRI (Bangladesh Rice Research Institute). (2008b). Annual Report for 2007-2008. Bangladesh Rice Research Institute, Gazipur-1701.

BRRI (Bangladesh Rice Research Institute). (2009). BRRI Annual Internal Review 2007-2008. Soil Science Division. Bangladesh Rice Research Institute, Gazipur-1701.

BRRI (Bangladesh Rice Research Institute). (2011). Adhunik Dhaner Chash (in bengali). Bangladesh Rice Research Institute, Joydebpur, Gazipur. pp. 5.

Bufogle, A., Bollich, P.K., Norman, R.J., Kovar, J. L., Lindau, C. W. and Macchiavelli, R. E. (1997). Rice plant growth-and mustard oil cake accumulation in drillseeded and water-seeded culture. *Soil Sci. Soc. America J.* **61**: 832-839.

Chandrashekarappa, K. N. (1985). Efficiency of mustard oil cake, phosphorus and potassium and their split applications of rice (*Oryza sativa* L.). *M. Sc. (Agri.) Thesis, Univ. Agric. Sci.* Bangalore.

Chen, L. J., Fan, X. M. (1997). Response to grain quality phosphous and zinc fertilizer in rice genotype. CRRN, *Chinese Rice Res. Newsl.*

Craswell, E. T. and De Datta, S. K. (1980). Recent developments in research on mustard oil cake fertilizers for rice. *Indian J. Agron.* **31**(4): 387-389.

Das, D. K. (1989). Efficiency of different urea materials for rainy season rice (*Oryza sativa*). *Indian J. Agril. Sci.* **59**(8): 534-536.

Das, L. K. and Panda, S. C. (2004). Effect of varied doses of mustard oil cake and potassium on crop growth rate of hybrid rice at different growth stages. *Environ. Ecol.* **22**(Spl-3): 540-542.

De Datta, S. K. (1981). Principles and practices of rice production. John Wiley and Sons, New York. Pp. 618.

De Datta, S.K., 1988. Principles and practices of rice production. International Rice Research Institute. Los Banos, Philippines. Pp. 349.

Devasenamma,V. Reddy, M. R.and Soundararajan, M. S. (2001). Effect of varying levels of mustard oil cake on yield and yield components of hybrid rice. *J.Res. ANGRAU.* **29**(1): 1-3.

Dweivedi, R. K. and Bajpai, R. P. (1995). Effect of different sources of urea and mustard oil cake levels on low land rice. *J. Res. Birsa Agril. Univ.* 7(2): 161-162.

Dwivedi, A. P., Dixit, R.S. and Singh, G. R. (2006). Effect of mustard oil cake, phosphorus and potassium levels on growth, yield and quality of hybrid rice (*Oryza sativa* L.). *Oryza.* **43**(1): 64-66.

Edwin, L. and Krishnarajan, J. (2005). Influence of irrigation and mustard oil cake management practices on yield of hybrid rice. *Agric. Sci. Digest.* **25**(4): 309-310.

Fageria, N. K. and Baligar, V. C. (1997). Upland rice genotypes evaluation for phosphorus use efficiency. *J. Plant Nutr.* **20**(4):499-509.

Fageria, N. K. and Barabosa-Filho, M. P. (1982). Screening rice cultivars for tolerance to low levels of available soil phosphorus. *Revista-Brasileira-de-ciencia-do-solo.* 6(2):146-151.

Food and Agriculture Organizations of the United Nations (FAO). 2009. The State of Food and Agriculture. Rome: United Nations.

Food and Agriculture Organizations of the United Nations (FAO). 2017. The State of Food and Agriculture. Rome: United Nations.

Fu, Q. L., Yu, J. Y.and Chen, Y. X. (2000). Effect of mustard oil cake applications on dry matter and mustard oil cake partitioning in rice and mustard oil cake fertilizer requirements for rice production. *J. Zhejiang Univ. Agril. Life Sci.* **26**(4): 399-403.

Geethadevi, T., Andani, G., Krishnappa, M. and Babu, B. T. R. (2000). Effect of mustard oil cake and spacing on growth and yield of hybrid rice. *Current Res. Univ. Agril. Sci. Bangalore.* **29**(5& 6): 73-75.

Gorgy, R. N., Zayed, B. A., Abou, A.A.B. (2009). Effect of split application of mustard oil cake and potassium to SK2047 hybrid rice. *J. Agric. Sci. Mansoura Univ.* **34**(11):10631-10642.

Gosh, B.C., Raghavian, C.V. and Jana, M. K. (1991). Effect of seed rate and mustard oil cake on growth and yield of direct sown sown rice (*Oryza sativa*) under intermediate deep water condition. *Indian J. Agron.* **36**: 227-228.

Gregory D I, Haefele S M, Buresh R J, Singh U. 2010. Fertilizer use, markets, and management. *In*: Pandey S, Byerlee D, Dawe D, Doberman A A, Mohanty S, Rozell S, Hardy B B. Rice in the Global Economy: Strategic Research and Policy Issues for Food Security. Los Banos, the Philippine: International Rice Research Institute: 231–263.

Gupta, M. L., and Bhandra, D. (1980). Manganese phosphate relationship in rice in alluvial soil. *J. Indian Soc. Soil Sci.* **28**: 485-490.

Halder, K.P. Chowdhury, M. J. U. and Ahmed, N. (2000). Effect of planting methods and mustard oil cake rates on the yield and yield components of Aus rice grown under rainfed condition at the coastal area of Bangladesh. *Bangladesh J. Agric. Sci.*, **27**:59-64.

Hamid, M. A. (1991). A data base on agricultural and food grains in Bangladesh. Ayesha Akhtar, 606 North Shahjahanpur, Dhaka, Bangladesh. Pp. 30-35.

Hamidullah, A. T. M., Rahman, M. S., Miah, M. N. M. and Miah, M. A. K. (2006). Growth and yield performance of BINA Dhan 5 in *boro* season as affected by mustard oil cake rate. *Bangladesh J. Nuclear Agric.* **22**: 93-98.

Haq, M. T., Sattar, M. A. Hossain, M. M. and Hasan, M. M. (2002). Effects of fertilizers and pesticides on growth and yield of rice. *On Line J. Biolo. Sci.* **2**(2): 84-88.

Hasan, M. S., Hossain, S. M. A., Salim, M., Anwar, M. P. and Azad, A. K. M. (2002). Response of hybrid and inbred rice varieties to the application methods of urea supergranules and prilled urea. *Pakistan J. Bio. Sci.* **5** (7): 746-748.

Hasanuzzaman, M. Nahar, K. Alam, M.M., Hossain, M.Z. and Islam, M.R. (2009). Response of transplanted rice to different application methods of urea fertilizer. *Intl. J. Sustain. Agric.* **1**(1):1-5.

Hasanuzzaman, M., Ahamed, K.U., Nahar, K. and Akhter, N. (2010). Plant growth pattern, tiller dynamics and dry matter accumulation of wetland rice (*Oryza sativa* L.) as influenced by application of different manures. *Nature and Science.* **8**(4):1-10.

Hazell P B R. 2010. Asia's green revolution: Past achievement, and future challenges. *In*: Pandey S, Byerlee D, Dawe D, Doberman

Howlader, M. I. A., Islam, M. S., Rafiquzzaman, S., Chowdhury, M. M. A. A. and Rashid, M. M. (2007). Yield response of mungbean, T. *aus* and T. *aman* rice to NPK fertilizers in Ganges Tidal Floodplain. *J. Soil. Nature.* **1**(3): 11-19.

Husain, A., Muazzam, M., Hossain, M. and Janaiah, A. (2000). Hybrid Rice Adoption in Bangladesh: A Socio-economic Assessment of Farmers' Experiences. A

collaborative research report of research & evaluation division, BRAC, Dhaka and Social Sciences Division, International Rice Research Institute, Philippines.

Ibrahiem, A. A., El-Khawaga, A. A., Sharabash, M. T. M. and Iman, A. A. (2004). The use of mineral and biofertilizer mustard oil cake source in rice. *Zagazig J. Agric. Res.* **31**: 509-521.

Indira, C. (2005). Effect of mustard oil cake fertilizers on growth, yield and quality of hybrid rice (*Oryza sativa*). *J. Central-European-Agric.* **6**(4): 611-618.

Ingale, B.V., Jadhav, S. N.; Waghmode, B. D. and Kadam, S. R.(2005). Effect of age of seedling, number of seedling hill-1 and level of mustard oil cake on performance of rice hybrid, Sahyadri. *J. Maharashtra Agril.Univ.* **30**(2): 172-174.

Iqbal, M. T. (2004). Yield and biomass in rice interactions of mustard oil cake, phosphorus and water application. *Pakistan J. Agril. Sci.* **7**(12):2115-2120.

IRRI (International Rice Research Institute). (2010). http:// www.irri.org/about rice/ rice facts/what is rice?

Islam M T, Hossain M M. 2012. Plant probiotics in phosphorus nutrition in crops, with special reference to rice. *In*: Maheshwari D K. Bacteria in Agrobiology: Plant Probiotics. Berlin Heidelberg: Springer: 325–363.

Islam M. S., Howlader M. I. A., Rafiquzzaman S., Bashar H. M. K. and Al-Mamun M. H. (2008). Yield Response of Chili and T. Aman Rice to NPK Fertilizers in Ganges Tidal Floodplain. *J. Soil. Nature.* **2**(1): 07-13

Islam, M. M. and Black, R. P. (1998). Urea supergranules technology impact and action plan for 1988-89. Proc. National Workshop on Urea supergranules (USG) Technology, held at BARC, Dhaka, Bangladesh, 25 June, 1998.

Islam, M. S., Akhter, M. M., Rahman, M. S. Q., Banu, M. B. and Khalequzzaman, K. M. (2008). Effect of mustard oil cake and number of seedlings per hill on the yield and yield components of T. *aman* rice (BRRI dhan 33). *Intl. J. Sustain. Crop Prod.* **3**(3): 61-65.

Janaiah, A., Hossain, M. and Husain, M. (2002). Hybrid Rice for Tomorrow's Food Decurity: Can the Chinese Miracle be Replicated in other Countries? *Outlook on Agriculture*, **31** (1): 23-33.

Jee, R. C. and Mahapatra, A. K. (1989). Effect of time of planting of some slow release mustard oil cake fertilizers on low land rice. *Intl. Rice Res. Newsl.* **12(4)**: 52-53. 123

Jiang, Y. F., Chu, Y. F., Jing, D. A., Jiang, Y. F., Chu, Y. F. and Jing, D. A. (1999). A study of the proper amount of phosphorus fertilizer for high yielding cultivation of rice in whitish lake soil. *Jiangsu Agril. Sci.* **2**: 46-48.

Kabir, M. H., Sarkar, M. A. R., and Chowdhury, A. K. M. S. H. (2009). Effect of urea super granules, prilled urea and poultry manure on the yield of transplant aman rice varieties. *J. Bangladesh Agril. Univ.* 7(2): 259-263.

Katyal, J. C. (1978). Management of P in lowland rice. *Phosphorus in Agric.* 73:21-34.

Kendaragama, K. M. A., Banda, K. M. S. and Bandara, P.T. (2003). Influence of rice crop on soil phosphorus availability in relation to phosphate fertilizer application. *Ann. Srilanka Dept. Agric.* **5**: 129-139.

Khan, A., Sarfaraz, M., Ahmad, N., and Ahmad, B. (1994). Effect of N dose and irrigation depth on nitrate movement in soil and N uptake by maize. *Agric. Res.* **32**:47-54.

Kumar, R. M. and Subbaiah, S. V. (2001). Influence of different sources of mustard oil cake on growth and grain yield of rice hybrid vs. HYV (high yielding variety) of rice. *J. Res. ANGRAU.* **29**(1): 4-8.

Kumar, V. J. F., Balasubramanian, M. and Jesudas, D. M. (1995). Application of different forms of urea for rice. *J. Indian Soc. Soil Sci.* **44**(2): 267-270.

Lal, B., Majumder, B. and Venkatesh, M. S. (2000). Indivisual and interactive effects of phosphorus and zinc in lowland rice. *Indian J. Hill Frmg.* **13**(1-2): 44-46.

Lang, N., Xu, S. H., Liang, R. J.and Chen, G. S. (2003). Effect of different fertilizer application rates on no-tillage and seedling-throwing rice. *Hybrid-Rice.* **18**(2): 52.

Li, G. X., Shi, Q. H., Li, Z. L. and Li, G. H. (2003). Characteristics of mustard oil cake uptake and mustard oil cake application technique of two-line early maturing hybrid Tianliangyou 402. *Hybrid-Rice.* **18**(3): 37-39.

Lin, X. Q., Zhu, D. F., Chen, H. Z., Cheng, S. H and Uphoff, N. (2008). Effect of plant density and mustard oil cake rates on grain yield and nitrogrh uptake of hybrid rice (*Oryza sativa* L.). *J. Agric. Biote. and Sustain. Develop.* **1**(2): 44-53.

Liu, Y. W. (1996). Effect of phosphorus on growth and physiology of hybrid rice. *Acta Pedologica Sinica.* **33**(3): 308-316.

Maiti, S., Naleshwar, N. and Pal, S. (2003). Response of high yielding and hybrid rice to varied levels of mustard oil cake nutrition. *Environ. Ecol.* **21**(2): 296-300.

Maity, S. K. and Mishra, B. N. (2001). Effect of levels and time of mustard oil cake application on productivity of hybrid rice. *Ann. Agril. Res.* **22**(1): 160-161.

Masum, S. M., Ali, M. H., and Ullah, M. J. (2008). Growth and yield of two T. aman rice varieties as affected by seedling number hill-1 and urea supergranules. *J. agric. Educ. Technol.* 11(1 & 2): 51-58.

Masum, S. M., Ali, M. H., and Ullah, M. J. (2010). Performance of seedling rate and urea supergranules on the yield of T. *aman* rice varieties. *J. Sher-e- Bangla Agric. Univ.* 4(1):1-5.

Matsua, T., **Kumaza**wa, K., Ishii, R., Ishihara, K. and Hirata, H. (1995). Science of the **plant**. Volume Two phyliosophy. Food and Agriculture Policy Research **Centre**, Tokyo. Japan. pp. 1240.

Meena, S. L., Sundera, S., and Shivay, Y. S. (2003). Response to hybrid rice to mustard oil cake and potassium application in sandy clay- loam soils. *Indian J. Agric. Sci.* 73(1): 8-11.

Meena, S. L., Surendra, S.and Shivay, Y. S. (2002). Response of hybrid rice (Oryza sativa) to mustard oil cake and potassium application. *Indian J. Agron.* 47(2): 207-211.

Merbach W, Deubel A, Gransee A, Ruppel S, Klamroth A K. 2010. Phosphorus solubilization in the rhizosphere and its possible importance to determine phosphate plant availability in soil: A review with main emphasis on German results. *Arch Agron Sol Sci*, 56: 119–138.

Miah, M. A. M. and Ahmed, Z. U. (2002). Comparative efficiency of the chlorophyll meter technique, urea supergranules and prilled urea for hybrid rice in Bangladesh. **In**: Hybrid Rice in Bangladesh: Progress and Future Strategies. *Bangladesh Rice Res. Inst.* Pub. No.138. pp. 43-50.

Miah, M. N. H., Talukder, S., Sarkar, M. A. R. and Ansari, T. H. (2004). Effect of number of seedling hill-1 and urea supergranules on growth and yield of the rice cv. BINA Dhan 4. *J. Biol. Sci.* **4** (2): 122-129.

Mirzeo, W. A. and Reddy, S. N. (1989). Performance of modified urea materials at graded levels of mustard oil cake under experimental and farmer's management conditions in low land rice (*Oryza sativa*). *Indian J. Agril. Sci.* **59**: 154-160.

Mishra, B. K., Mishra, S., Dash, A. k. and Jena, D. (2000). Effect of time for urea supergranules (USG) placement on low land rice. *Ann. Agril. Res.* **20**(4): 443-447.

Mollah M. R. A., Khalequzzaman K. M., Hossain M .M. and Rahman S. M. L. (2008). Cropping Pattern Based Fertilizer Recommendation for Mustard -Boro-T. Aman Rice Cropping Pattern under AEZ-25 at Nandigram, Bogra. *J. Soil. Nature.* **2**(2): 31-34.

Mondal, S. S., Arup, G. and Acharya, D. (2003). Studies on the effect of phosphorus on the productivity of crops in rice-lathyrus (as utera) cropping system under rainfed situation. *J. Interacademicia.* **7**(4):426-429.

Morgan, M. A. (1997). The behavior of soil and fertilizer phosphorus. In: Tunny, H., O.T. Carton, P.C. Brookes and A.E. Johnston (eds.). Phosphorus loss from soil to water. Cab International, Wallingford, U.K. pp. 137-149.

Mubarak, T. and Bhattacharya, B. (2006). Response of hybrid rice cultivars to various levels of mustard oil cake and potassium grown on gangetic alluvial soil in summer season. *Environ. Ecol.* **24** (3): 515-517.

Nadeem, M. Y. and Ibrahim, M. (2003). Phosphorus management in wheat-rice cropping system. *Pakistan J. Soil Sci.* **21**(4): 21-23.

Naik, B. B. and Yakadri, M. (2004). Effect of integrated nutrient management on yield of hybrid rice (*Oryza sativa* L.). *J. Res. ANGRAU.* **32**(2): 85-89

Natarajan, S. and Arivazhagan, K. (2005). Mustard oil cake management in hybrid rice. *J. Ecobiology.* **17**(4): 317-320

Ndaeyo, N. U., Iboko, K.U., Harry, G. I. and Edem, S. O. (2008). Growth and yield performances of some upland rice (*oryza sativa* l.) Cultivars as influenced by varied rates of NPK (15:15:15) fertilizer on an ultisol. *J. Trop. Agric. Food. Env. Ext.* 7 (3): 249 – 255.

Norman, R. J., Guindo, D., Wells, B. R. and Wilson, C.E. (1992). Seasonal accumulation and partitioning of mustard oil cake-15 in rice. *Soil Sci. Soc. America J.* **56**:1521-1527.

Oikeh, S. O., Nwilene, F., Diatta, S., Osiname, O., Toure, A. and Okhidievbie, O. (2006). Agrophysiological responses of upland NERICA rice to mustard oil cake and phosphorus fertilization in the forest agroecology of West Africa. Paper presented at the ASA-CSSA-SSSA 2006 International Meetighs, Indianopolis, USA. 12-16 November 2006.

Ortega, B. R. and Rojas, W. C. (1999). Agronomic assessment of the effects of phosphorus sources on flooded rice. *Agric. Tecnica Santiago.* **58**(1):23-31.

Patel, S. R. and Mishra, V. N. (1994). Effect of different forms of urea and levels of mustard oil cake on the yield and mustard oil cake uptake of rice. *Advn. Pl. Sci.* 7(2): 297-401. Pawar, W.S., Ommala, K., Usha, D.and Farkade, B.K. (2003). Effect of varying levels of fertilization on yield of hybrid rice (KJTRH1). *J. Soils Crops.* **13**(2): 357-360.

Peng, S., Garcia, F. V., Gines, H. C., Laza, R. C., Samson, M. L, Sanico, A. L., Visperas, R. M. and Cassman, K. G. (1996). Mustard oil cake use efficiency of irrigated tropical rice established by broadcast wet-seeding and transplanting. *Fert. Res.* **45**: 29-96.

Rafique, A. K. M. A., Rahman, K. M. M., Ali, M. A., Pramanik, M. Y. A. and Chowdhury, A.K. (2005). Effect of applied zinc and phosphorus on yield and zinc and phosphorus contents of rice cv. BR 11. *Bangladesh J. Agril. Sci.* **32**(1):81-86.

Rajendran, K. and Veeraputhiran, R. (1999). Effect of seed rate and mustard oil cake levels on hybrid rice (Oryza sativa). *Madras Agril. J.* **86**(7/9): 459-460.

Raju, R. A., Hossain, M. M. and Nageeswariq, R. M. (1987). Relative efficiency of modified urea materials for low land rice. *Indian J. Agron.* **32**(4): 460-462.

Rakesh, K., Rajesh, K. and Sanjeev, K. (2005). Effect of mustard oil cake and potassium levels on growth and yield of hybrid rice. *J. Applied Biol.* **15**(1): 31-34.

Rama, S., Reddy, G. and Reddy, K. (1989). Effect of levels and sources of mustard oil cake on rice. *Indian J. Agron.* **34**(3): 364-366.

Rambabu, P., Pillai, K. G. and Reddy, S. N. (1983). Effect of modified ureas materials and their methods of application on dry matter production, grain yield and mustard oil cake uptake in rice. *Oryza.* **20**: 86-90.

Rao, C. M., Ramaish, N. V., Reddy, S. N. and Reddy, G. V. (1986). Effect of urea and urea supergranules on dry matter accumulation yield and nutrient uptake in rice (*Oryza sativa*). *J. Res.* **14**:1-3.

Rao, C.P. and Shulla, D.N. (1997). Physiological parameters and yield of transplanted rice (*Oryza sativa*) as affected by level and sources of phosphorus in combination with zinc. *Indian J. Agric. Sci.* 67(5): 215-217.

Rashid, M. A., Billah, K. A., Mazid, M. A. and Jameel, F. (1996). Mustard oil cake use efficiency of urea supergranules and prilled urea in irrigated rice cultivation. *Bangladesh Rice J.* **7**(1&2): 41-44.

Ravi, M. V., Thippeshappa, G. N., Viswanatha, D. P. and Siddaramappa, R. (2000). *Current Res. Univ. Agril. Sci. Bangalore.* **29**(9&10): 139-141.

Richardson A E, Simpson R J. 2011. Soil microorganisms mediating phosphorus availability update on microbial phosphorus. *Plant Physiol*, **156**(3): 989–996.

Roy, B. C., Mazid, M. A. and Siddique, S. B. (1991). Efficiency of different forms and application methods of N fertilizer on rainfed low land rice. *Bangladesh Rice J.* **2**(1&2): 75-78.

Saha, P. K., Saleque, M. A., Panaullah, G. M. and Mazid Miah, M. A. (2004). Comparison of the fertilizer recommendation models for low land rice. *Bangladesh J. Soil Sci.* **30** (1-2): 31-37.

Sahar, A. and Burbey, N. (2003). Effect of mustard oil cake, phosphorus and potassium (NPK) compound dosages on the growth and yield of lowland rice. *J. Stigma (Indonasia).* **11**(1):26-29.

Sahrawat, M. L., Abekoe, M. K., Diatta, S., Tian, G., Ishida, F., Keatings, D., Carsky, R. and Wendt, J. (2001). Application of inorganic phosphorus fertilizer. In: Proc. Symp. Sponsored by the American Soc. Agron. USA. 5-9 November 2000. pp. 225-246.

Saito, K., Linquist, B., Atlin, G.N., Planthaboon, K., Shiraiwa, T. and Horie, T. (2005). Response of traditional and improved upland rice cultivars to N and P fertilizer in northern Laos. *Field Crops Res.* **30**: 30-35.

Salem, A. K. M. (2006). Effect of mustard oil cake levels, plant spacing and time of farmyard manure application on the productivity of rice. *J. Appl. Sci. Res.* **2**(11): 980-987.

Savant, N. K., Crasewar, E. T. and Diamond, R. B. (1991). Use of urea supergranules for wetland rice: a review Fert. News. **28**(8): 27-35.

Sen, A. and Pandey, B. K. (1990). Effect on rice of placement depth of urea supergranules. *Intl. Rice Res. Newsl.* **15**(4): 18, 51

Shah, M. A. L. (2002). Phosphorus nutrition of rice varieties in relation to phosphorus sources and rates on a phosphorus deficit soil. Ph.D. Thesis Dept. Soil Sci., Banghabandhu Sheikh Mujibur Rahman Agric. Univ. Gazipur.

Sharkar, A. K. and Choudhary, K. (1988). Relative efficiency of different methods of phosphoric fertilizer application on yield and P nutrition of rice. J. Indian Soc. Soil Sci. **36**: 466-470.

Sikdar, H. P. and Gupta, D. K. D., (1979), Physiology of grain filing rice. *Indian. Agriculturist*, **23**(1): 11-23.

Singh, B. K. and Singh, R. P. (1986). Effect of modified urea materials on rainfed low land transplanted rice and their residual effect on successding wheat crop. *Indian J. Agron.* **31**: 198-200.

Singh, B. K., and Modgal, S.C. (2005). Pattern of dry mattern accumulation and mustard oil cake concentration and uptake as influenced by levels and methods of mustard oil cake application in rainfed upland rice. *J. Plant Sci.* **52**(1): 9-17.

Singh, R. K. (2003). Phosphorus and drought effect on the productivity of upland rice in plateau of Jharkhand. *New Agriculturist.* **14**(1&2): 13-18.

Singh, S.and Shivay, Y. S. (2003). Coating of prilled urea with eco-friendly neem (Azadirachta indica A. Juss.) formulations for efficient mustard oil cake use in hybrid rice. *Acta Agronomica Hungarica.* **51**(1): 53-59.

Singh, V. K., Dwivedi, B. S., Shukla, A. K. and Yadav, R. L. (2003). Effects of mustard oil cake and phosphorus fertilization on the growth and yield of rice (*Oryza sativa*) and wheat (*Triticum aestivum*) as influenced by the inclusion of forage cowpea (*Vigna unguiculata*) in rice-wheat system. *Indian J. Agril. Sci.* **73** (9): 482-489.

Stevenson F J. 1999. Cycles of Soil: Carbon, Mustard oil cake, Phosphorus, Sulfur, Micronutrients. *Soil Sci*, **144**(5): 238.

Sudha, B. and Chandini, S. (2002). Nutrient management in rice *(Oryza Sativa* L.) *J. Trop. Agric.* **40**: 63-64.

Surajit, K., Mandal, B. K., Mandal, B. B. and Partha, H. (2004). Effect of different levels of fertility on growth and yield of hybrid rice during summer. *Indian Agriculturist.* **48**(1&2): 9-14.

Tang, Q. Y., Zou,Y. B., Mi, X. C., Wang, H. and Zhou, M. L. (2003). Grain yield formation and N fertilizer efficiency of super hybrid rice under different N applications. *Hybrid Rice.* **18**(1): 44-48.

Thakur, R. B. (1991a). Relative efficiency of prilled urea and modified urea fertilizer on rainfed low land rice under late transplanting. *Indian J. Agron.* **36**(1): 87-90. 132 Thakur, R. B. (1991b). Effect of levels and forms of urea on low land rice under late transplanting. *Indian J. Agron.* **36**: 281-282.

Tilman D, Reich P B, Knops J, Wedin D, Mielke T, Lehman C. 2001. Diversity and productivity in a long-term grassland experiment. *Science*, **294**: 843–845.

Upendra, R., Dayanand, P.and Choudhary, S. K. (2004).Evaluation of newly developed hybrid rice under different levels of mustard oil cake and potassium on calcitharants of North Bihar. *J. Applied Biol.* **14**(1): 42-43

Venkateswarlu and Singh, M., (1980), Response of rice varieties to different spacings and fertility levels on yield attributes and yield. *Indian J. Agron.*, **25**(2): 263-272.

Verma, A. K., Pandey, N. and Tripathi, R. S. (2004).Leaf growth, chlorophyll, mustard oil cake content and grain yield of hybrid rice as influenced by planting times and N levels. *Ann. Agril. Res.* **25**(3): 456-458.

Vijaya, D. and Subbaiah, S. V. (1997). Effect of methods of application of granular forms of fertilizers on growth, nutrient uptake and yield of paddy. *Ann. Agril. Res.* **18**(3): 361-364.

Wan, L. J., Zhang, H. C., Huo, Z.Y., Lin, Z. C.; Dai, Q. G., Xu, K. and Zhang, J. (2007). Effects of mustard oil cake application regimes on yield, quality, and mustard oil cake use efficiency of super japonica hybrid rice. *Acta-Agronomica-Sinica.* **33**(2): 175-182.

Wang, R. L. Hua, C. and Wei, J. C. (2002). Effect of mustard oil cake levels on photosynthetic characteristics of rice variety (combination) Shanyou 64 and Kinmaze. *Chinese J. Rice Sci.* **16**(4): 331-334.

Xia, W., Wang, W. and Zhang, Q. (2007). Potential production simulation and optimal nutrient management of two hybrid rice varieties in Jinhua, Zhejiang Proviance. *J. Zhejiang Univ. Sci.* **8**(7): 486-492.

Yadav, R. T. and Tripathi, H. N. (2006). Studies on comparative performance of rice hybrids in relation to varying fertility levels. Directory of Ph. D. Dissertations on Agriculture in SAARC countries. **2**:23.

Yoshida, S. (1981). Physiological analysis of rice yield. **In**: Fundamental of Rice Crop Science. IRRI, Los Banos, Philippines. pp. 91-98, 269.

Zubaidah, Y. and Munir, R. (2002). Phosphorus (P) fertilization on paddy rice. *J. Stigma (Indonasia)*. **10**(2):106-108.