EFFECT OF PUDDLING INTENSITY, IRRIGATION SCHEDULING AND NUTRIENT SOURCES ON GROWTH AND YIELD OF RICE (*Oryza sativa* L.) IN RICE-WHEAT CROPPING SYSTEM

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DIVISION OF AGRONOMY

THESIS

SUBMITTED TO FACULTY OF POST-GRADUATE STUDIES SHER-E-KASHMIR UNIVERSITY OF AGRICULTURAL SCIENCES AND TECHNOLOGY OF JAMMU (J&K) IN PARTIAL FULFILMENT OF REQUIREMENTS FOR THE AWARD OF THE DEGREE OF

DOCTOR OF PHILOSOPHY IN AGRICULTURE

(AGRONOMY)

Regd. No. J-04-D-22 **Submitted on 03 day of March 2008**

RICE

AGRONOMY

To
Almighty

Certificate - I

This is to certify that the thesis entitled **"Effect of puddling intensity, irrigation scheduling and nutrient sources on growth and yield of rice (*Oryza sativa* L.) in rice-wheat cropping system"** submitted in partial fulfillment of the requirements for the degree of **Doctor of Philosophy in Agriculture (Agronomy)** is a record of bonafide research carried out by Mr. **Rohit Sharma** Registration No. **J-04-D-22** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma. It is further certified that help and assistance received during the course of thesis investigation have been duly acknowledged.

03.03.08

Place : Jammu

Date : 03-03-2008

Major Advisor

(Prof. Dileep Kachroo)

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Certificate – II

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Certificate-IV

It is certified that all the necessary correction as suggested by the external examiner/evaluator and the advisory committee have been duly incorporated in the thesis entitled "**Effect of puddling intensity, irrigation scheduling and nutrient sources on growth and yield of rice (*Oryza sativa* L.) in rice-wheat cropping system**" submitted by Mr. **Rohit Sharma** Registration number : **J-04-D-22.**

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Abstract

An experiment entitled "Effect of puddling intensity, irrigation scheduling and nutrient sources on growth and yield of rice (*Oryza sativa* L.) in rice-wheat cropping system" was conducted at the research farm, FOA, Main campus, Chatha of SKUAST-Jammu during *kharif* and *rabi* seasons of 2005-06 and 2006-07, respectively. The soil of the experimental field was sandy loam in texture, slightly alkaline in reaction (pH-7.4), low in organic carbon (0.46 percent), low in available nitrogen and medium in available phosphorous and potassium. Rice variety PC-19 sown in nursery @ 40 Kg/ha was transplanted, where as wheat variety PBW-343 was sown after the harvest of rice, using 100 Kg seed ha^{-1}. The experiment comprises of 36 treatment combinations was laid out in split plot design consisting of three puddling intensity (Normal practice, 2 times puddling and 3 times puddling), three levels of irrigation scheduling (2 DADPW, 4DADPW and SMP at 150 cm suction) in main plots and four nutrient sources (Vermicompost 3t/ha+inorganic fertilizer, Vermicompost @ 6t/ha, FYM+inorganic fertilizer (50% each) and N, P and K recommend through inorganic fertilizer) in sub plots. The treatments were randomized and replicated thrice. During *rabi* season the wheat crop was sown as blanket crop for studying the residual effect of the treatments applied in rice Recommended dose of fertilizer i.e. N, P_2O_5 and K_2O were applied as per the treatments in rice, where as in succeeding wheat crop100 kg N/ha, 60 kg P_2O_5/ha and 60 kg K_2O/ha were applied. The N in case of inorganic fertilizer was applied in three splits, while P_2O_5 and K_2O and N through organic source were applied as basal.

Application of three times puddling intensity produced significant increase in yield attributes of rice (No. of tillers/m^2, No. of panicles/m^2, No. of grains/panicles and grain weight/panicles, profile soil moisture and water expense efficiency), which concomitantly increased the grain and straw yield of rice during both the year of experimentation significantly over normal practice and 2 times puddling. However, the plots received 3 times puddling, percolation rate of water was found to be decreased significantly than normal practice and 2 times puddling.

Among the irrigation scheduling SMP at 150 cm suction significantly increased the plant height (g), dry matter (g/m^2), No. of tillers/m^2, No. of panicles/m^2, No. of grains/panicles, grain weight/panicles, grain yield, straw yield, N,P,K uptake and water expense efficiency of rice over 4 DADPW and 2 DADPW.

However, under nutrient sources the N, P and K at recommended dose applied through inorganic fertilizer produced significantly taller plant, increased dry matter (g/m^2), No. of tillers/m^2, No. of panicles/m^2, No. of grains/panicles, grain weight/panicles, grain yield, straw yield, N,P,K uptake and water expense efficiency of rice over the application of vermicompost @ 3t/ha+inorganic fertilizer, vermicompost @ 6t/ha and FYM+inorganic fertilizer during 2005-06, where as during 2006-07 alone application of vermicompost @ 6t/ha was found to produced significant influence on growth, yield attributes, grain yield and N, P, K uptake of rice. Apart from this alone application of vermicompost @

6t/ha not only decreased the percolation rate of water but also showed increasing trend towards water expense efficiency and profile soil moisture.

The positive significant correlation were observed between grain yield and No. of tillers/m^2, 1000-grain weight, N, P and K uptake, where as negative correlation was obtained with the percolation rate of water (cm/day).

Residual effect of nutrient sources noticed on of succeeding wheat crop, revealed that the application of vermicompost @ 6t/ha gave significant increase in grain and straw yield of wheat over vermicompost applied @ 3t/ha+inorganic fertilizer, FYM+inorganic fertilizer and recommended application of N, P and K through inorganic fertilizers.

The interaction effect between puddling intensity (3 times puddling) irrigation scheduling (SMP at 150 cm suction), puddling intensity (3 times puddling) and nutrient sources (vermicompost @ 6 t/ha) was found to be significant in realizing the grain yield of rice.

It is therefore, concluded that the application of three times puddling, irrigation SMP at 150 cm suction and vermicompost @ 6t/ha not only increased the yield and yield attributes of rice but also produced the highest water expense efficiency, besides decreased the percolation losses. The residual effect of nutrient sources with application of vermicompost @ 6 t/ha improved the yield of wheat significantly.

03.03.08

Signature of Major Advisor

Rohit Sharma

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INTRODUCTION

CHAPTER - I

INTRODUCTION

Cereals are important food grain crops and play a pivotal role in ensuring food and livelihood security of the nation. Among the cereals, rice-wheat is the major cropping system that plays a significant role in food security by contributing 76 per cent of the total foodgrain production of the country. This system occupied an area of about 9.7 million hectares in India (Jhoshi and Tripathi, 2006). Rice and wheat are widely grown in sequence in Indo-Gangetic plains.

Jammu and Kashmir state, known for rice cultivation, constitutes an area of 2.59 lakh hectares under rice and 2.53 lakh hectares under wheat. However, under Jammu province alone, rice and wheat cover an area of about 1.16 and 2.47 lakh hectares, respectively with an average yield of 16.02 q/ha for rice and 18.27 q/ha for wheat, respectively (Anonymous, 2006), which is far less as compared to national average of rice, i.e 20.17 and wheat, 25.67 q/ha (Anonymous, 2006).Therefore, it becomes imperative to increase its productivity vertically rather than horizontal expansions through exploration of agronomic manipulations which still have the vast potential to be explored.

Land preparatory tillage is done prior to every crop with the objectives to provide a favorable soil environment for better crop growth and yield. Among the various agronomic practices puddling has been most commonly used practice under transplanted rice cultivation. Puddling or working soil saturation moisture during rice cultivation eliminates most macropores which transmit water. The remaining macropores are partially filled by dispersed fine particles (Sharma and Datta., 1985., Adachi., 1990) resulting in drastic reduction in percolation losses of water, which also helps to control weeds and creates a softer medium for easy transplantation of rice seedlings (Datta *et al.*, 1979). The extent of percolation losses of water depends on puddling intensity because higher puddling alters the soil physical environment for holding the water over the surface for longer periods. Therefore, the requirement of optimum puddling intensity is the need of an hour, as it is having further scope to minimize weed infestation, water and nutrient losses.

Apart from these, both rice and wheat are nutrient exhaustive crops as they are the heavy feeders of nutrients. In order to restore the soil fertility under the rice-wheat cropping system, the eco-friendly means viz. integrated plant nutrient system (IPNS) or organic nutrient management is regarded as the need of hour as it not only enhances the nutrient flow but also maintains the soil physical condition more particularly after puddling and thereby, may check the adverse affects on the growth and yield of succeeding wheat. Integrating chemical fertilizers with organic manure has been found to be giving quite promising results not only in maintaining higher productivity but also improving greater stability in crop production (Nambiar and Abrol., 1992). Farmyard manure is being used as a major nutrient source in field crops. Limited availability of this manure however, necessitates the search for alternative sources. Vermicompost has been advocated as good organic manure for use in integrated management practice in field crops (Shroff and Devasthali., 1992). Present trend of growing crops organically is gaining prominence among the farmers of the west, as the foods grown organically are not only addressing the environmental concerns, but also fetch good economic return for the farmers besides increasing the overall productivity of system and sustain the soil health over a longer period of time.

Water being another limited resource and scarce needs careful management as both over and under use of water had negative impact on the growth and yield of crops. Rice alone consumes major share of irrigation, as 50-80 per cent of the total water applied is lost as deep percolation (Parihar and Sandhu, 1987; Hira *et al.*, 2002). With the advent of new concepts, the emphasis is now given more on yield per drop of water rather than yield/ha. Optimum water management in rice on the basis of appropriate scheduling indices is of practical relevance and need of the hour. Among the scheduling practices, application of water to rice have been carried out mainly on the basis of disappearance of ponded water and irrigation water applied to rice at an interval of 2-6 days after complete infiltration of water, depending upon different soil and climatic conditions. A saving of 34 per cent irrigation water was observed without any loss in yield by applying irrigation to rice 2 days after the infiltration of ponded water (Sandhu *et. al.*, 1980., Hira *et al.*, 2002). Recently the application of irrigation water on the basis of soil matric potential as criteria for scheduling irrigation to rice at 150 $\pm$ 20 cm suction had gained importance and acceptability. Measurement of soil matric with locally fabricated tensiometer seems a reasonable proportion for best and easy method for irrigating rice and needs investigation under the evaporative demand of water and soil texture of Jammu region.

Hence, keeping in view of these arguments, an experiment has been conducted to integrate the puddling intensity, nutrient resources, and irrigation scheduling in rice under rice-wheat cropping system for optimum resource utilization and sustained production with the following objectives.

1. To work out the optimum puddling intensity and its effect on yield and soil characteristics.
2. To find out the impact of nutrient sources on the productivity in rice-wheat cropping system.
3. To work out the water- expense efficiency.

REVIEW OF LITERATURE

CHAPTER-II

REVIEW OF LITERATURE

The research work conducted so far in India and abroad and the available information relevant to the research investigation entitled **"Effect of puddling intensity, nutrient sources and irrigation scheduling on growth and yield of rice (*Oryza sativa* L.) in rice-wheat cropping system."** have been compiled in this chapter under various heads:-

2.1 Effect of puddling intensity on

2.1.1 Growth and yield of rice

2.1.2 Soil characteristics

2.1.3 On succeeding wheat crop

2.2 Effect of nutrient sources on

2.2.1 Growth and yield of rice.

2.2.2 Soil characteristics and nutrient uptake.

2.2.3 On succeeding wheat

2.3 Effect of Irrigation scheduling on

2.3.1 Growth and yield of rice

2.3.2 Water use efficiency and nutrient uptake.

2.3.3 On succeeding wheat

2.4 Interaction effect

2.1 Effect of puddling intensity

2.1.1. Growth and yield of rice

Datta and Kerim (1974) conducted a field experiment to study the water and nitrogen economy of rainfed rice (*Oryza sativa* L.) grown on monmorillonitic clay and reported that significantly lower grain yields were obtained from non puddled soil than from puddled soils. However, under rainfed conditions, the rice underwent longer growth duration on non puddled soil than on puddled treatments. The grain yield was 1.2 t/ha higher in puddled than in non puddled soils.

Sharma and Datta (1985) in a field experiment carried out at IRRI, Phillippines to evaluate the effect of puddling (no puddling ; puddling comprising of one wet ploughing with animal drawn moldboard plough, followed by three harrowing) on grain yield of rice (variety IR 36) on clay and clay loam soil condition and revealed that under both soil types, puddling significantly increased grain yield (5.9 Mg ha^{-1} in clay soil and 5.5 Mg ha^{-1} in clay loam soil) as compared to non puddled soil (4.9 Mg ha^{-1} in clay soil and 3.6 Mg ha^{-1} in clay loam soil). The increase was attributed to more filled spikelets per panicle and plant height in puddled soil.

Purushothaman *et al.* (1987) evaluated a field study on the effect of puddling methods on low land rice (variety Paiyur 1) at Tamilnadu and reported that puddling twice with an iron plough followed by one puddling with a helical blade puddler produced significantly higher grain yield of rice (6.4 t/ha) than the plot puddled 3 times with iron plough (6.0 t/ha); plot puddled once with an iron plough followed by one puddling with a helical blade (5.7 t/ha) and plot puddled twice with an country plough followed by one puddling with a helical blade puddler (5.4 t/ha).

In a field experiment conducted in Ludhiana, Punjab, Singh *et al.* (1995) evaluated the effect of three levels of puddling (No puddling, Puddling with two runs of a tractor drawn cultivator each followed by planking and puddling with four runs of cultivator followed by four planking) in sandy loam soil and opinioned that puddling with four runs of cultivator followed by four planking significantly increased grain yield (3.26 t/ha) of rice compared with no puddling (2.22 t/ha) and two runs of tractor drawn cultivator in standing water followed by 2 planking (2.54 t/ha).

Garg *et al.* (1996) conducted field experiment on sandy clay loam soil at IARI, New Delhi to compare the effect of puddling on rice growth and yield and reported that rice yield under puddled condition were significantly higher (42.60 q ha^{-1}) than under non puddled conditions (33.50 q ha^{-1}).

Singh *et al.* (2001) from Ludhiana evaluated the effects of puddling intensity (no puddling, two discing followed by one planking, four discing followed by one planking) on performance of rice on sandy loam and clay loam soils and observed that increasing puddling intensities enhanced grain yield of rice with mean values of 4.8, 5.6 and 5.9 Mg/ha under no puddling; two disking + planking and 4 disking + planking, respectively.

Kukal (2002) from Ludhiana conducted a three year field study on sandy loam soil to analyze the effect of puddling intensity [unpuddled, 2 wet cultivations followed by one planking (medium), 4 wet cultivations followed by one planking (high)] on the performance of rice and concluded that 1000 grain weight (20.36 g and 21.76 g), grain yield (60.00 q/ha and 62.66 q/ha) was significantly higher in medium (2 wet cultivations followed by one planking) and high (4 wet cultivations followed by one planking) puddled plots, respectively as compared to unpuddled plots (1000 grain weight, 27.70g and grain yield, 50.00 q/ha).

In a three year field experiment conducted at Ludhiana, Punjab on sandy loam soil Kukal and Aggarwal (2003) evaluated the effect of puddling intensity [no puddling, medium puddling (2 passes of tractor drawn cultivator followed by leveling with wooden plank) and high puddling (4 passes of tractor drawn cultivator followed by leveling with a wooden plank)] on performance of rice (*Oryza sativa* L.) and observed that puddling treatments did not affect total dry matter and grain yield of rice significantly. The average rice yield under medium and intensive puddling was 5.96 and 6.09 tha^{-1}.

Mohanty and Painuli (2003) at Bhopal on clay soil evaluated the effect of three land preparatory tillage treatments (no puddling, puddling by four and puddling by eight passes of a 5 hp power tiller) on growth and yield of rice on vertisol and revealed that number of effective tillers, 1000-grain weight and grain yield were higher under puddling by 8 passes of power tiller (235 m^{-2}, 25.8g and 5462 kg ha^{-1}, respectively) than under soils puddled by 4 passes of power tiller (182 m^{-2}, 24.8g, 5143 kg ha^{-1}, respectively) and un-puddled soil (115 m^{-2}, 23.3g , 2625 kg ha^{-1}, respectively).

Mohanty *et al.* (2004) from Bhopal evaluated the effect of puddling intensity on clay soil (no puddling, puddling by four and eight passes of a 5 hp power tiller) on yield of rice and observed that grain yield of puddled soils (puddling by eight passes of a 5 hp power tiller) was slightly higher (5462 Kg ha^{-1}) than soil puddling by four passes of a 5 hp power tiller (5143 Kg ha^{-1}) but were significantly higher over no-puddled soil (2625 Kg ha^{-1}).

Sidhu *et al.* (2003) conducted three year field experiment on sandy loam soil at Ludhiana to study the effect of puddling intensity (one cultivation in flooded water followed by planking; two cultivations in flooded water followed by planking; and four cultivations in flooded water followed by planking) on rice yield and reported that yield of rice increased significantly with increase in puddling intensity during all the three years, the increase being more pronounced during the third year. The yield of rice recorded an significant increase in soil puddled by four cultivations in flooded water followed by planking (6.38 t ha^{-1}) followed by puddling through two cultivations in flooded water with planking (5.96 t ha^{-1}) and one cultivation in flooded water with planking (5.78 t ha^{-1}).

Tripathi *et al.* (2003) conducted a field experiment on rice *(Oryza sativa. L.)* at Pantnagar, on clay loam soil to study the effect of puddling (non puddled fallow, direct seeded rice, puddled transplanted rice and puddled fallow) on performance of rice and concluded that grain yield under unpuddled direct seeded condition (4695 kg/ha) was lower than under puddled transplanted condition (5082 Kg ha^{-1}) but the straw yield was higher under former (7500 Kg ha^{-1}) than latter (6890 Kg ha^{-1}).

Parihar (2004.a) conducted field study on a clay loam soil at Bilaspur, Chattisgarh, to evaluate the effects of puddling (conventional puddling, cultivator 3 passes + 2 planking, reduced puddling through puddler) to rice in rice-wheat cropping system and found that reduced puddling through puddler and conventional puddling did not produce any significant influence on the growth, yield attributes and yield of rice during three years of experimentation.

Sidhu *et al.* (2006) evaluated the effects of puddling operation (a wet cultivation followed by planking, two wet cultivations followed by a planking and four wet cultivations followed by a planking) in sandy loam soils of Ludhiana (Punjab), Modipuram (Uttar Pardesh) and silty clay loam soil of Kaul (Haryana) and reported that the rice grain yield increased significantly with increase in puddling intensity in sandy loam soils at Ludhiana, the average rice grain yield over different years increased from 5.79 t/ha in wet cultivation followed by planking to 5.96 and 6.44t/ha in 2 and 4 wet cultivation followed by planking. Whereas in sandy loam soil at Modipuram, the grain yield of rice increased by 18.6 per cent with increase in puddling intensity from one pudding to two puddling with further increase in puddling intensity to four puddling. The grain yield of rice increased by 19.3 per cent. However in silty clay loam soil of Himachal Pradesh, there was no significant effect of increased puddling intensity on grain yield of rice.

2.1.2 Soil characteristics

Datta and Kerim (1974) conducted a field experiment to study the water and nitrogen economy of rainfed rice (*Oryza sativa* L.) grown on montmorillonitic clay and reported that much more water was lost from non puddled soil than from puddled soil. Water use efficiency of rice in irrigated control was 2.5 times higher in the puddled soil than in the non puddled soil.

Sinha *et al.* (1981) conducted a field study on puddling effects on water flow through soils and reported that puddling reduces water losses in coarse textured soil only; the second puddling was less effective in reducing the specific discharge except in sandy loam soil where second puddling might have resulted in more uniform sealing of pores.

Virmani *et al.* (1982) conducted a field study on physical and chemical properties of vertisols and their management and revealed that bulk density may increase with time even when soil is submerged because of setting of particles. In swelling clays even submergence with out puddling, subsequently decreases bulk density.

Sawhney (1989) conducted an experiment to study the effect of rice-wheat and maize wheat crop rotations on aggregation, bulk density and infiltration characteristics of some alluvium derived soil and found that puddled traditional rice soils of Punjab contained higher organic matter as compared to adjoining non puddled soils. Sur *et al.* (1981) reported similar observations. The main reason for increase of organic matter was attributed to reduced conditions occurred in paddy soils. The higher amount of organic carbon in puddled rice soils was mainly owing to anaerobic decomposition.

Sharma and Datta (1985) in a field experiment carried on clay loam soil at IRRI, Phillippines and evaluated the effect of puddling (no puddling and puddling consisted of one wet ploughing with animal drawn moldboard plough, followed by three harrowing) in rice crop (variety IR 36) under clay and clay loam soil condition and revealed that puddling decrease bulk densities of both soils in the top 0.1 m layer by about 30 per cent, but the difference in the bulk density between puddled and non puddled soil narrowed with time. Puddling decreased percolation rate by more than 70 per cent in the clay loam soil but its effect on percolation was negligible in the clay soil, besides seasonal water loss by percolation was decreased by about 0.03 m in the clay soil and by 0.48 m in the sandy loam soil.

Aggarwal *et al.* (1995) concluded that bulk density of 0-30 cm soil layer increased with increasing level of puddling. They reported that bulk density was 1.76 Mg/m^{-3}, 1.78 Mg/m^{-3} and 1.83 Mg/m^{-3} with low medium and high puddling intensities respectively. However, they reported that increased bulk density can be counterbalanced by organic manure.

In a laboratory study, Sandhu (1995) investigated that puddling resulted in accumulation of organic matter in top 2.5 cm soil layer of all soils i.e. sandy loam, silt loam, and clay, highest being in clay (0.78%) and least in silt loam.

Singh *et al.* (1995) from Ludhiana evaluated the effect of three levels of puddling (no puddling, puddling with two runs of a tractor drawn cultivator each followed by planking and puddling with four runs of cultivator and four planking) in sandy loam soil and observed that puddling with two runs of a tractor drawn cultivator each followed by planking (2.3 mm hr^{-1}) and four runs of cultivator and four planking decreased the penetration resistance (2.5 mm hr^{-1}) as compared with no puddling (6.0 mm hr^{-1}), respectively. The increased in intensity of puddling increased the bulk density; the increase was uniform up to 20 cm soil depth.

Garg *et al.* (1996) conducted a field experiment on sandy clay loam soil at IARI, New Delhi to compare the effect of puddling on rice growth and yield and reported that average bulk densities of 0-15 and 15-30 cm of sandy clay loam at flowering of rice increased significantly by puddling (1.60-1.63 Mg m^{-3}) and compaction (1.62-1.65 Mg m^{-3}) over the bulk densities of 1.47-1.52 Mg m^{-3} for control. The percolation rate at 30 days after transplanting under compaction was significantly lower than under puddled treatment but as the crop growth progressed, the effect of compaction and puddling on percolation rate became less prominent and non significant.

Hafele *et al.* (1999) evaluated four puddling levels and revealed that puddling destroyed the soil structure, bringing large quantities of salt in to soil solution. Each puddling activated deeper salt deposits because tillage depth could not be maintained. Plant establishment was poor in puddled plots, presumably because puddling established a lower but homogenous salt distribution in the root zone.

Singh *et al.* (2001) from Ludhiana evaluated the effects of puddling intensity (no puddling, two discing + one planking, four discing + one planking) on performance of rice on sandy loam and clay loam soils and reported that increase in puddling intensity tended to increase in bulk density of 14-20 cm layer due to sealing of pores by dispersed clay particles and by compaction. Saturated hydraulic conductivity was also found increased significantly increased with increase in puddling intensity.

Kukal (2002) from Ludhiana conducted a three year field study on sandy loam soil to analyze the effect of puddling intensity [unpuddled, two wet cultivations followed by one planking (medium puddling), four wet cultivations followed by one planking (high puddling) each at shallow 5-6cm and 10-12 cm depth] on the performance of rice and reported that average percolation rate decreased to the extent of 54-58 per cent with medium puddling and the difference were significant over no puddling, but were at par with high puddling intensities.

Mohanty and Painuli (2003) from Bhopal on clay soil evaluated the effect of three land preparatory tillage treatments (no puddling, puddling by four and puddling by eight passes of a 5 hp power tiller) in rice and observed that at harvest maximum bulk density was observed in puddling by eight passes of a 5 hp power tiller (1.83 Mg m^{-3}) followed by four passes of a 5 hp power tiller (1.74 Mg m^{-3}) and no puddling (1.60 Mg m^{-3}). Soil penetration resistance was zero in puddled layers and below this layer; it was lowest with increased intensity of puddling. Puddling reduced seepage plus percolation to 5.6 mm h^{-1} in no puddling, 2.8 mm h^{-1} in puddling by four passes of a 5 hp power tiller and 2.4 mm h^{-1}puddling by eight passes of a 5 hp power tiller.

Mohanty *et al.* (2004) from Bhopal on clay soil evaluated three puddling intensities i.e. no puddling, puddling by four and eight passes of a 5 hp power tiller and observed that soil bulk density and penetration resistance increased significantly from transplanting to harvest in puddled soils but in non puddled soils significantly increase of penetration resistance only occurred at surface 0-7 cm layer. Crack dimension were larger under higher intensity of puddling. Water loss through seepage plus percolation was significantly higher for non puddled soil as compared to puddled soil, whereas, high intensity of puddling resulted in further reduction of water losses.

Kukal and Aggarwal (2003) evaluated the effect of puddling intensity [no puddling, medium puddling (2 passes of tractor drawn cultivator followed by leveling with wooden plank) and high puddling (4 passes of tractor drawn cultivator followed by leveling with a wooden plank)] on performance of rice (*Oryza sativa* L.) and concluded that medium puddling resulted in decreases in percolation losses by 53-56% from that of un puddled plots. Increase puddling from medium to high did not decrease the percolation rate of water significantly during all the period. The differential setting of soil particles results in sealing of the puddled surface with clay particles, there by reducing the percolation losses of water.

Tripathi *et al.* (2003) conducted a field experiment with rice (*Oryza sativa*) at Pantnagar, on clay loam soil to study the effect of puddling (non puddled fallow, direct seeded rice, puddled transplanted rice and puddled fallow) on performance of rice and concluded that puddling reduced water stable aggregates of diameter 8 to 1 mm from 21.1 to 3.2 percent and increased water stable aggregates of diameter > 0.211 mm from 28.2 to 59.8 percent. Puddling caused a significant increase in bulk density of the soil. Puddling reduced hydraulic conductivity of 0.15 to 0.225 m layer by 96.1 percent. Similarly infiltration rate was reduced by 95.2 per cent and air filled porosity by 30. 9 percent. Soil moisture in 0 to 0.075 m layer was always above field capacity

Sidhu *et al.* (2003) conducted three year field experiment at Ludhiana to study the effect of puddling intensity (1 cultivation in flooded water followed by planking, 2 cultivations in flooded water followed by planking and 4 cultivations in flooded water followed by planking) on rice yield in sandy loam soil and revealed that with increased puddling intensity, the mineral N content in soil profile increased. The respective increase in mineral N with 2 and 4 puddling over 1 puddling was 19 and 22.5 per cent, respectively, there by reduced the N loss through leaching.

Parihar (2004. a) conducted field study on a clay loam soil on an experimental farm at Bilaspur, Chattisgarh to evaluate the effects of puddling [conventional (cultivator 3 passes + 2 planking) and reduced (puddling through reduced puddler)] to rice in rice-wheat cropping system and reported that the bulk density decreased with increasing the level of puddling but the infiltration rate was maximum (2.05 cm/hr) under reduced puddling as compared to conventional method (1.87 cm/hr). However, available N, P and K were maximum under reduced puddling.

Sidhu *et al.* (2006) evaluated the effects of puddling operation (1 wet cultivation followed by planking, 2 wet cultivations followed by a planking and 4 wet cultivations followed by a planking) in sandy loam soils of Ludhiana (Punjab) and Modipuram (Uttar Pardesh) and silty clay loam soil of Kaul (Haryana) and reported that increasing puddling intensity helped in retaining more mineral N in the soil profile by reducing N leaching losses. The available K and Zn content of soil decreased with increase in puddling intensity under sandy loam soil conditions but increased the amount of Fe and Mn.

2.1.3 Succeeding wheat crop

Parihar (2004. a) in his field study at Bilaspur (M.P) reported that wheat yield was significantly low in plots (29.80 q/ha) where rice was grown in puddled condition compared to puddling and line sowing of sprouted seeds (30.34 kg/ha) and line sowing of sprouted seed without puddling (32.36 kg/ha).

2.2 Effect of nutrient sources on

2.2.1 Growth and yield of rice

Hegde (1996) from Khargpur carried out field study on sandy loam to study the effect of integrated nutrient supply on crop productivity and soil fertility in rice-rice system and observed that 25- 50 per cent N need of rice in rainy season could be substituted by organic source like farmyard manure. Use of FYM to substitute 25-50 per cent N needs increased the total rice production by 10.5 per cent over that which received all the recommended nutrients through inorganic fertilizers only. Integration of FYM with chemical fertilizers had more favourable effect on nutrient balance than with green manures.

In a three year field experiment conducted at Kharagpur on sandy clay loam soil Jana and Ghosh (1996) studied the integrated nutrient management through organic and inorganic sources of fertilizers in puddled rice (IR-36)-rice crop sequence and reported that grain yield of rainy season rice was higher under 100 per cent recommended dose of NPK fertilizer (4.31 t/ha) which was statistically at par with the application of 75 per cent of recommended NPK + 25 per cent of FYM (4.03 t/ha). Application of NPK at sub optimal dose i.e. 75% and 50% of recommended dose, or following farmers practice reduced grain yield significantly

Jadhav *et al.* (1997) from Dapoli conducted greenhouse experiment to assess the effect of the conjunctive use of FYM, Vermicompost and urea on growth of rice (RTN-1) in Alfisol soil and reported that at 30 and 60 DAT, maximum dry matter production of rice was recorded in the treatment where application of Urea 100 per cent recommmded while at harvest maximum dry matter accumulation was recorded in the treatment Urea 75 % of recommended + Vermicompost 25 per cent (42.59 q/ha).followed by Urea 75 % of recommended + farmyard manure 25 per cent (39.80 q/ha).

Hegde (1998) reviewed the data of four locations (Ludhiana, Kanpur, Navasari and Kalyani which was being carried out 6-10 years to study the effect of integrated nutrient supply and revealed that the possibility of substituting 50 percent N needs of rice through green manure in semi-arid ecosystem at Ludhiana, Kanpur and Navasari with a slide depression in productivity, where as under humid ecosystem (Kalyani) all the organic sources (FYM, crop residues and green manures) substitute 25-50 percent N needs of rice with significant increase in grain yield. Continuous rice-wheat cropping lead to decline in available phosphorous was found improved under integration of nutrient sources

Kumar *et al.* (1998) from Ranchi on sandy loam soil reported that fertilizer and farmyard manure application in soil significantly increase the yield of rice over the control. Grain yield of rice varied from 3.54 t/ha (control) to 3.77 t/ha (FYM).

Gupta *et al.* (1999) from R.S. Pura, Jammu under clay loam soils, reported that increased application of phosphorous up to 75 kg P_2O_5 ha^{-1} coupled with 10t ha^{-1} of FYM increased the grain and straw yield of rice significantly. The optimum dose of P_2O_5 with FYM application for rice was worked out to be 38 kg P_2O_5 ha^{-1}, where as without FYM application the optimum P_2O_5 dose was worked out to be 44 kg ha^{-1}.

Jeyabal *et al.* (1999) from Secunderabad conducted a three year field study to evaluate the integrated nutrient management techniques in rice and reported that application of farmyard manure gave 17.2 to 23.4 per cent higher yield over control. Farmyard manure integrated with 100 per cent inorganic produced the tallest plant, increased number of panicles by 4.7 to 13.5 per cent, produced longest panicles, which was 11.0 to 14.5 per cent and recorded on yield of 5.28 to 5.72t/ha, respectively which was 18.1 and 17.2 per cent higher than that obtained with application of 100% NPK through inorganic fertilizer alone.

Sharma (1999) conducted field experiment at Cuttack to study the effect of combined use of farmyard manure (0 and 10 t/ha) and nitrogenous fertilizer (0, 20 and 40 kg N /ha) on performance of direct sown rice (cv. Gayatri) and reported that significantly higher plant height (113.00 cm), number of panicle per m^2 (194), panicle weight (2.17 g), grain yield (3.86 t/ha) and straw yield (6.51 t/ha) was obtained with the application of 10t/ha FYM over no FYM. The application of 10t/ha FYM resulted in either same or significantly higher grain yield than that with 40kg/ha N applied basally through urea fertilizer. Top dressing of 20-40 kg/ha N through urea super granule resulted in no additional advantage in the farm yard manure treated plots.

Singh *et al.* (1999) from Pantagar studied the effect of decade long fertilizer and manure application in silty loam soil on soil fertility and productivity of rice-wheat system and observed that the recommended fertilizer treatments (NPK + FYM) resulted in highest production of rice and wheat (7.1 t/ha), which were significantly higher than all other treatments. After 10 years of continuous cropping under rice-wheat rotation all the fertility treatments resulted in significant reduction in yield but the reduction in yield was least in treatment where NPK was integrated with FYM.

Thakur and Patel (1999) from Raigarh studied the effect of split application of nitrogen with and without farmyard manure on growth and yield of rice and concluded that application of nitrogen either 60 or 80 Kg/ha in three or four split doses with and without FYM 5t ha^{-1} though being at par with each other, significantly increased the growth parameters viz. dry mater production, leaf area index, leaf area duration, crop growth rate and relative growth rate with concomitant significant increase in grain yield of rice over control. However the higher grain yield (3.73 t/ha) was recorded with the application of 80 kg N/ha in three splits with 5t farmyard manure per hectare compared with application of 60 kg N/ha in three splits (3.0 t/ha).

Vasanthi and Kumaraswamy (1999) conducted field experiment on red sandy clay loam soil at Madurai to evaluate the effect of Vermicompost prepared from different organic material to increase the yield of rice and soil fertility status and reported significantly higher grain yields were recorded in the treatments that received vermicompost prepared from any of the organic materials plus N, P and K (inorganic fertilizer) than the treatment that received N, P and K (inorganic fertilizer) alone. Grain yield increased by over 20 per cent due to application of Vermicompost at 5 t/ha over the N, P and K (inorganic fertilizer) alone.

Sengar *et al.* (2000) in a field experiment on wet season transplanted rainfed rice conducted in lowland areas of Vertic Ustochrept on clay soil at Jagdalpur (M.P.) revealed that application of N fertilizer and manures significantly increased the yield. The higher grain and straw yields of rice were obtained in the treatment receiving ½ FYM+N, P (2.58 and 4.90 t/ha.) followed by N, P, K+FYM (2.49 and 5.71 t/ha).

Subbaiah *et al.* (2000) carried out field experiment to study the influence of organic manures in conjunction with granulated fertilizers on rice (cv. Ajaya) at Hydrabad on a clayey soil and revealed that grain yield were higher with FYM+NPK than with GM+NPK. Significantly higher grain (5.85 t/ha) and straw (6.33 t/ha) yield was obtained with FYM application over no manure control (grain yield, 4.01 and straw yield, 4.53 t/ha). The per cent increase in yield due to application of farmyard manure over no manure was 45.8 during kharif season. Similarly, improved grain yields due to combined use of organic manures and inorganic fertilizer was also reported by (Singh *et al.,* 1990) and (Matriwade and Sheelavantar, 1994)

Murali and Setty (2000) in a field experiment at Raichur studied the effect of different levels of NPK and vermicompost on growth and yield of fine rice on deep black soil and revealed that application of 150-75-75 kg/ha NPK recorded significantly higher plant height (109.00 cm), number of tillers per hill (13.71), leaf area index (4.71) and total dry matter production per plant (10.40 g/hill), number of panicle per hill (12.00), number of grain per panicle (194.36), 1000-seed weight (22.83 g), grain yield (5261 (kg/ha) and straw yield (7416 kg/ha) at all the stages of crop growth as compared to lower levels of NPK (100-50-50 and 125-62.5-62.5 kg/ha). However, scented rice responded significantly to nutrients applied through organic sources as well and application of vermicompost @ 5t/ha produced significantly higher plant height (104.98 cm), number of tillers per hill (12.58), leaf area index (4.30) and total dry matter production per plant (9.57 g/hill), number of panicle per hill (10.92), number of grain per panicle (184.00), 1000-seed weight (22.19 g), grain yield (4889 (kg/ha) and straw yield

(7141 kg/ha) than no vermicompost application. The increased grain yield with vermicompost may be attributed to the significantly higher yield attributes due to increased availability of nutrients from vermicompost, presence of beneficial microflora such as nitrogen fixers (Lee, 1992., Kale, 1998), phosphate solublizers, VAM fungi etc. (Harinikumar *et al.,* 1991) and due to presence of biologically active metabolites like gibberlins, cytokinins, auxins and group B vitamins (Tomati *et al.,* 1991). Similar results were also obtained by Ravi and Srivastava (1997).

Sudhakar *et al.* (2002) from Coimbatore (Tamilnadu) reported that integrated application of organic N through vermicompost resulted in significantly better growth and yield of rice. Similarly, integrated application of organic N (vermicompost), and biofertilizer enhanced the growth, yield attributes and yield of rice Ravi and Srivastava (1997) tested vermicompost for its availability to replace a proportion of the urea fertilizer in rice and observed that N through vermicompost supplying one third or one fourth of N nutrient increased plant height, yield attributes and grain yield of rice significantly over alone application of N through urea.

Kumar and Parsad (2002) on silt loam soil of Jharkhand (Ranchi) conducted experiment on rice forage cropping system (rice-oat and rice-berseem) under integrated nutrient application. Rice-berseem cropping sequence when applied with 75 percent recommended NPK coupled with 10t FYM/ha not only produced the higher productivity but improved the N and P status in the soil significantly over 100 percent recommended NPK/ha in both seasons, 75 percent NPK/ha + 10t FYM/ha in *rabi* only and 75 percent NPK/ha + 10t/ha in *kharif* only.

Banik and Bejbaruah (2004) carried out field experiment at Jharkhand to evaluate the performance of vermicompost on rice (cv. Pankaj) yield in sandy loam soil and reported that organic manure and inorganic fertilizer alone and in combination influenced the growth and yield of rice. The significantly higher productive tiller per plant (6.47), filled grains per panicle (78.65),1000-grain weight (23.11 g) and grain yield (4.68 t/ha) was obtained in the treatment receiving 15 Kg/ha N through vermicompost + 45, 13 and 25 Kg/ha N, P and K, respectively followed by application of 15 Kg/ha N through FYM + 45, 13 and 25 Kg/ha N, P and K, respectively (productive tiller per plant, 6.27., filled grains per panicle, 78.65., 1000-grain weight, 22.79 g and grain yield , 4.61 t/ha). In a similar study

Singh *et al.* (2006) conducted a field experiment Bahraich (U.P.) to study the effect of integrated nutrient management on yield and yield attributes of rice (cv. Mahsuri) rice-wheat cropping system on sandy loam soil and reported that integrated use of in organic fertilizer either 25 per cent of recommended N through farmyard manure and rest RDF through inorganic fertilizer gave significantly higher grain (34.50 q/ha) and straw (48.64 q/ha) yield of rice over 50 per cent of recommended N though organic source and 50 per cent RDF through inorganic fertilizer (grain yield, 33.72 q/ha and straw yield, 47.54)

Singh (2006) conducted a field experiment at Agra (U.P.) to study the productivity of rice in rice-wheat cropping system under integrated nutrient supply system in recently reclaimed sodic soils and revealed that application of 100 per cent NPK with 10t/ha farmyard manure significantly increased the grain yield (40.32 q/ha) of rice as compared to application of recommended 100 per cent NPK (34.67 q/ha), 50 per cent NPK+10t/ha farmyard manure (33.83 q/ha), 50 per cent NPK (29.38 q/ha) and 10 t/ha FYM (25.17 q/ha).

2.2.2 Soil characteristics and nutrient uptake

Gill (1979) in a field experiment at Ludhiana under loamy sand soil condition studied the economy of N and P through FYM in rice-wheat rotation and revealed that application of 12t FYM/ha coupled with recommended chemical fertilizer (NPK) over a long period of time increased the DTPA extractable Zn, Cu, and Mn (2.2 to 3.4, 0.29 to 1.49, 6.5 to 24.3 and 14.5 to 30.2 ppm, respectively) in soil over application of chemical fertilizers.

Ganai and Singh (1988) in a field experiment studied the effect of farmyard manure applied in rice-wheat rotation on physico-chemical properties of soil and reported that application of farmyard manure either to rice or wheat resulted in significant increase in organic carbon content in soils i.e. 0.72 per cent to 0.93 per cent in case of rice and 0.94 per cent in case of wheat. However, no change in organic carbon was observed between rice and wheat during single cropping system.

Ekwue *et al.* (1993) conducted field experiment to evaluate the effect of incorporating two organic materials at varying levels on splash detachment and reported that organic materials are very much effective in soil compatibility by making stable aggregates. Organic materials reduced soil bulk density during compaction because of its less dense material dilutes the matrix.

Hegde (1996) carried out field study on sandy loam soil of Kolkota in rice–rice system and observed that application of 100 per cent NPK through inorganic fertilizers resulted in markedly higher available N in soil (198 kg/ha) followed by 50 per cent recommended dose of NPK through inorganic fertilizers + 50 percent through FYM (165 kg/ha) but P balance (8.9 kg/ha) and K (96 kg/ha) was positive in 50 per cent recommended dose of NPK through inorganic fertilizers + 50 percent through FYM followed by (8.8 kg/ha) in both P and K in 75 per cent recommended dose of NPK through inorganic fertilizers +25 percent through FYM.

In a three year field experiment conducted at Kharagpur in puddled rice-rice cropping sequence under sandy clay loam soil conditions Jana and Ghosh (1996) reported that uptake of the nutrients (112.5 kg/ha N, 19.20 kg/ha P , 115.80 kg/ha K) in rice was more when 75 per cent of the fertilizer were applied through inorganic and 25 per cent as organic source . The uptake (100.50 kg/ha N, 15.54 kg/ha P, 105.10 kg/ha K) of nutrients was less when 50 per cent N, P, K was supplied as inorganic and remaining 50 per cent as organic source.

Jadhav *et al.* (1997) conducted greenhouse experiment to assess the effect of the conjunctive use of FYM, Vermicompost and urea on nutrient uptake in rice (RTN-1) in Alfisol soil and observed a considerable increase in the uptake of major and secondary nutrients such as N, P, K, and Ca and Mg by rice under all the treatments. At harvest, maximum N uptake (417 mg/pot) was recorded in urea 75 per cent + vermicompost 25 per cent followed by urea 100 per cent (376 mg/pot), urea 75 per cent + 25 per cent FYM (357 mg/pot) and urea 50 per cent + 50 per cent vermicompost (353 mg/pot). Maximum

P uptake was observed in case of urea 75 per cent + 25 per cent FYM (87 mg/pot) followed by urea 50 per cent + 50 per cent vermicompost (81 mg/pot), urea 75 per cent + vermicompost 25 per cent (80 mg/pot) and urea 100 per cent (80 mg/pot). A significant increase in K uptake (557 mg/pot) by rice was observed in treatment receiving 75 kg N /ha through urea and 25 kg N/ha through vermicompost over the treatment urea 100 kg N /ha (476 mg/pot). Calcium and magnesium uptake at harvest was maximum in the treatment urea 75 per cent + vermicompost 25 per cent (124 and 93 mg/pot, respectively) followed by urea 25 per cent + 75 per cent FYM (116 and 91 mg/pot, respectively).

Hegde (1998) reported that under sandy loam soil conditions of Ludhiana in rice-wheat cropping system the soil fertility status after 10 years of crop cycle was maximum available N (132 kg/ha), P (35.5 kg/ha) and K (99 kg/ha) when applied with 50 per cent recommended dose NPK dose by fertilizers + 50 percent through FYM over control N (117 kg/ha), P (7.8 kg/ha) and K (92 kg/ha).

Gupta *et al.* (1999) from R.S. Pura, Jammu under clay loam soils, reported that in clay loam soil, with increase in levels of P from 25 to 100 kg/ha with or without FYM application, the uptake of P at all the stages of crop growth of rice increased significantly. The average removal of P by grain and straw at different levels of P with and without FYM varied from 0.647 to 0.787 kg ha^{-1} at tillering, 0.669 to 0.833 kg ha^{-1} at panicle initiation, 0.840 to1.001 kg ha^{-1} at flowering and 4.777 to 8.481 kg ha^{-1} at harvest. The uptake of P increased by 3.10 to21.64, 2.09 to 24.51, 4.29 to 19.17 and 6.64 to 77.54 per cent at these stages with the application of FYM over no FYM, respectively. The trend of P uptake values at different growth stages followed the order i.e. Harvest >Flowering >Panicle initiation >Tillering.

Vasanthi and Kumaraswamy (1999) conducted field experiment on red sandy clay loam soil at Madurai to evaluate the effect of Vermicompost prepared from different organic material alongwith N, P and K at recommended level and reported that O.C. content and available status of N, P, K and micro-nutrients were higher where as bulk density was lowest in treatments received vermicompost plus N, P and K through inorganic fertilizer than the treatment with N, P and K alone. Maximum values of 264 kg/ha N, 16.3 kg/ha P, 395 kg/ha K and O.C 13.4 g/kg were observed in *Ipomea* compost 10t/ha + NPK over control (192 kg/ha N, 11.4 kg/ha P, 223 kg/ha K and O.C 7.50 g/kg).

Jeyabal *et al.* (1999) from Secunderabad conducted a field study to evaluate the integrated nutrient management techniques in rice and reported that uptake of N, P and K was significantly influenced by the integrated application of nutrients. Integrated nutrient management with NPK and farmyard manure increased the N, P and K uptake by 17.5 to 3.20, 27.7 to 43.9 and 19.3 to 22.1 per cent, respectively over 100 per cent NPK alone.

Singh *et al.* (1999) from Panthnagar studied the effect of decade long fertilizer and manure application on silty loam soil in rice-wheat system and concluded that the status of organic matter went down drastically except in the plots receiving single super phosphate and farmyard manure. The maximum available P (18.9 kg/ha), K (220 kg/ha) and S (47.63 mg/ha) were observed in NPK + FYM where as minimum was found in control P (10.7 kg/ha), K (194 kg/ha) and S (20.66 mg/ha).

Subbaiah *et al.* (2000) carried out field experiment on clayey soil to study the influence of organic manures in conjunction with granulated fertilizers on rice (cv. Ajaya) at Hyderabad and revealed that conjunctive use of organic and inorganic fertilizer increased higher nutrient uptake of N and P in rice than alone application of inorganic fertilizer. Similarly, the application inorganic N, P and K alone decreased soil organic carbon as compared to conjunctive use of organic and inorganics (FYM + NPK).

Sengar *et al.* (2000) from Jagdalpur (M.P.) on clayey soil and revealed that nitrogen uptake under rainfed situations in grain and straw yield of rice was influenced significantly when farmyard manure was applied either alone or in combination with chemical fertilizers; the highest values of N (49.0 kg/ha), P (13.29 kg/ha) and K (129.2 kg/ha) uptake were observed in NPK + FYM treatment. However N, P and K treatment recorded lower uptake of N (38.8 kg/ha), P (9.28 kg/ha) and K (85.2 kg/ha).

Parihar (2004.a) conducted field study on a clay loam soil on an experimental farm at Bilaspur, Chattisgarh to evaluate the effects of puddling [conventional (cultivator 3 passes + 2 planking) and reduced (puddling through reduced puddler)] to rice in rice-wheat cropping system and reported that the soil physical properties like bulk density, infiltration rate and water holding capacity differed appreciably due to incorporation of organic material in the system. The application of 80 kg N/ha (50 per cent through FYM+50 per cent through urea) decreased the bulk density (1.42g/cc) vis-a-vis porosity and thus enhanced the infiltration (2.05 cm/ha) and water holding capacity (44.32) considerably over nutrient application through inorganics alone. Total N, P and K uptake (in grain and straw) by rice crop receiving FYM alongwith 50 kg N /ha through urea removed 108.81 kg N/ha, 19.04 kg P/ha and 113.83 kg K/ha, over control 102.09 kg N/ha, 8.89 kg P/ha and 108.92 kg K/ha respectively.

Singh *et al.* (2006) conducted a field experiment Bahraich (U.P.) to study the effect of integrated nutrient management on yield and yield attributes of rice (cv. Mahsuri) in rice-wheat cropping system on sandy loam soil and reported that application of organic manure and chemical fertilizer individually and in combination increased the available N by 7.1 – 94.5 kg/ha over control, available P increased by 1.3 – 5.9 kg/ha where as available K recorded as increasing from 18.0 – 66.0 kg /ha over control.

2.2.3 Succeeding wheat crop

Patidar and Mali (2002). from Udaipur conducted a field study on clay loam soil to study the residual effect of integrated nutrient management on succeeding wheat crop and revealed that residual effect of farm yard manure significantly increased the plant height, grains/ear of wheat by 6 percent with an constant increase in and grain (45.7 q/ha) & straw (102.6 q/ha) yields of wheat to the tune of 3.81 and 6.62 percent respectively over no farm yard manure application. The total uptake of N and P by wheat was also increased increases significantly due to the residual effect of FYM applied @ 10t/ha in rice over no farm yard manure application.

Singh and Singh (2006) from Pantnagar conducted a field study on sandy loam soil to study residual effects of organic and inorganic sources of nutrients on succeeding wheat followed by rice and revealed that yield attributes and harvest index in wheat were not influenced by the residual effect of farm yard manure & phosphorous applied to previous crop. Similarly grain and biological yield did not differed significantly due to residual effect of farm yard manure & Phosphorus applied in previous crop.

2.3 Effect of irrigation scheduling on

2.3.1 Growth and yield of rice

Narang and Singh (1988) in his water management studies in rice did not observe any significant variation in plant height, effective tillers per hill, test weight of grain and straw yield with reducing initial ponding duration of water from three weeks to one week in transplanted rice grown on loamy sand soil of Punjab. However, Yamaychi *et al.* (1988) in his studies on growth analysis of upland rice under different soil moisture conditions found reduction in leaf area index, stomata conductance and root length with water deficit during the vegetative phase of rice crop.

Misra *et al.* (1990) conducted field experiment to study the effect of intermittent irrigation on groundwater table contribution, irrigation requirement and yield of rice in mollisols of tarai region and reported no significant difference in rice grain yield owing to delay in application of irrigation 1 - 2 days after subsidence of ponded water as compared to maintaining continuous submergence through out the growth period. Similarly application of irrigation three days after subsidence of ponded water was not observed to reduce grain yield as compared to continuous submergence.

Prasad *et al.* (1990) from Bihar on sandy loam soil conducted 3 year study on early rice with five irrigation levels (continuous ponding of 5 ± 2 cm, irrigation to 7cm depth after 1, 3 and 5 days after disappearance of ponded water and rainfall only) in calcareous soil and reported no significant depression in grain yield up to 3 days drying of 7 cm ponded water (32.8 q/ha) as compared to common practice of continuous shallow submergence (34.8 q/ha) or one day drying of ponded water (34.6 q/ha). The yield attributing characters mainly leaf area index, panicle length and 1000 grain weight were significantly affected by varying irrigations schedules. The higher panicle length (18.86 cm), leaf area index (4.07), 1000-grain weight (21.33 g) was recorded in ponding of 7 cm water after 3 days after drying. The yield increase was substantial only up to 3 days after disappearance of ponded water and irrigation water more than this level could not bring significant increase in yield. However, 3 days drying saved around 30 percent irrigation water with higher water use efficiency as compared to continuous one.

Singandhupe and Rajput (1990) his field experiment on nitrogen uptake by rice as influenced by irrigation regimes and nitrogen in sodic soils recorded a significant depression in grain yield with further delay in irrigation application to four days after subsidence of ponded water. Application of irrigation two days after subsidence of ponded water at vegetative phase and four days after subsidence of ponded water at reproductive stage gave similar grain yield as that with applying irrigation two days after subsidence of ponded water through out the growth period.

Uppal *et al.* (1991) from Ludhiana conducted field experiment to study the irrigation need of PR-106 rice on a loamy sand soil at Ludhiana and concluded that the irrigation after 2 days of subsidence of ponded water at vegetative phase and 4 days of subsidence at reproductive phase gave high mean grain yield (6.11 tonnes/ha) as that obtained by standard practice of applying irrigation after 2 days of subsidence of ponded water though out the crop growth period and saved 12-22 cm irrigation water, but it reduced the grain yield by 3.6 -7.4 per cent. The treatments that gave higher grain yield also led to greater plant height, number of panicles/metre row length, panicle length, number of grains/panicle and 1000 grains weight.

Saikia and Dutta (1991) from Jorhat carried out field study on sandy loam soil to find out the suitable moisture regimes for transplanted rice and revealed that continuous submergence produced significantly highest number of panicle per hill (12.87), length of panicle (19.87cm), number of grain per panicle (78.03.), per cent filled grains (85.53), 1000-grain weight (21.05g) grain yield (29.44 q/ha) and straw yield (51.64 q/ha).

Saikia and Dutta (1992) from Jorhat on sandy loam soil evaluated three moisture regimes continuous shallow submergence 5$\pm$ 2cm, 7cm irrigation 1 day after disappearance of ponded water and 7cm irrigation 3 days after disappearance of ponded water and concluded that maintenance of continuous shallow submergence gave the highest grain yield (2944 kg/ha) which was 16.9 per cent more than that under 7cm irrigation 1 days after disappearance of ponded and 24.2 per cent more than that 7 cm irrigation 3 day after disappearance of ponded water.

Marazi *et al.* (1993) conducted field experiment evaluated the response of rice to different water regimes (four water regimes i.e. application of 5cm water at 0, 3, 6 and 9 days after disappearance of ponded water) at Wadura on clay loam soil and reported that application of water on the same day (continuous flooding) and 3 days after disappearance of ponded water significantly increased the panicle length (20.82 and 20.77 cm), spikelets/ panicle (97.75 and 95.75), filled grains / panicle (both 85.75) and 1000- grain weight (23.35 and 23.31 g) compared with application of water at 6 days (panicle length, 19.70cm., spikelets/ panicle, 88.00., filled grains / panicle, 77.50 and 1000- grain weight, 23.14 g) and 9 days (panicle length, 18.82cm., spikelets/ panicle, 78.00., filled grains / panicle, 68.00 and 1000- grain weight, 22.69 g) after disappearance of ponded water. Grain and straw yield increased significantly with the application of water on the same and 3 days after disappearance of ponded water. The grain and straw yields at irrigating the crop on the same day after disappearance of ponded water were respectively 15.6 and 15.6 percent more than that obtained with the application of water 9 days after, disappearance of ponded water, Jaggi (1986) reported that rice, instead of growing under continuous submergence could be grown with intermediate flooding and drying with out any reduction in yield provided that drying period did not exceed 2 - 3 days. Similar results were reported by Sandhu *et al.* (1980) and Jha *et al.* (1981).

Uppal and Bali (1994) conducted field trial at Ludhiana to study the effect of scheduling and cut off date of irrigation (2 irrigation levels viz., 5cm irrigation at 2 days and at 4 day after disappearance of ponded water) on yield and quality of rice in loamy sand soil and reported that the standard schedule of irrigation at 2 days resulted in significantly higher grain yield by 12.1 per cent compared with other schedule. Termination of irrigation at 21 days increased the grain yield by 19.8 and 7.7 per cent over 7 and 4 days, respectively. The irrigation at 2 days also significantly increased the straw yield (72.2 q/ha), panicle density/m^2 (204.6), grains/panicle (101.1) and 1000 grain weight (20.9 g) but it decreases the spikelet stability percentage but irrigation at 4 days after disappearance of ponded water had lower values of yield attributes and grain yield.

Panda *et al.* (1997) in their filed experiment conducted at Bhubaneswar (Orissa) studied the effect of different water management practices on rice (cv. Sarathi), taking six irrigation schedules on sandy loam soil reported that highest mean grain yield by 4.30 t/ha, were obtained by subjecting the crop to submergence of 5+2cm during tillering and reproductive stages with 7cm irrigation a day after disappearance of ponded water followed by submergence at 5±2cm (4.23 t/ha) during reproductive stages (panicle initiation to dough stage) and 7cm irrigation a day after disappearance of Ponded water (4.11 t/ha). Increased grain yield with land submergence was due to increase in panicle/m^2 (354), panicle length (22.8 cm), spikelets/ panicle (139), and 1000- grain weight (21.9 g).

Saikia and Balasubramaniam (1998) conducted field experiment at the wet land farm of Coimbtore to study the effect of two irrigation regimes (5 cm irrigation either on the day of disappearance or 3 days after disappearance of ponded water) on both wet seeded and transplanted rice systems in moderately drained deep clay soils and reported that higher yield could be obtained in wet seeded rice compared to transplanted rice. Irrigation applied at frequent intervals resulted in higher grain yield of wet seeded rice (4.78 t /ha) followed by transplanted rice (4.60 t/ha) over delayed irrigation (3 days after disappearance of ponded water).

Singh and Tripathi (1998) from Pantnagar on sandy loam soil studied five water regimes (continuous submergence of 5±2.5 cm, submergence 2 day after disappearance of ponded water, 7.5 cm, submergence 3 days after disappearance of ponded water, 7.5 cm, submergence 5 days after disappearance of ponded water and rainfed) and observed that grain yield was maximum under continuous submergence (5.05 t/ha) but there was no significant difference between yield of continuous submergence and 7.5 cm submergence 2 days after disappearance of ponded water (4.7 t/ha). Below in 7.5 cm submergence 3 days (4.1 t/ha) and 5 days (3.45 t/ha) after disappearance of ponded water and rain fed, as soil moisture stress increase, yield reduced significantly and minimum observed under rainfed conditions (2.7 t/ha). Irrigation in rice crop was necessary after where 7.5cm irrigation were made 2 days after disappearance of ponded water.

Dhiman *et al.* (1998) conducted a field experiment at Haryana with rice-wheat rotation to study the effect of irrigation (submergence up to 20 days after transplanting, then irrigation 1 days after disappearance of ponded water and submergence up to 20 days after transplanting or near hair cracking in rice, then 3-4 days after disappearance of ponded water) on clay loam soil and reported that submergence up to 20 days after transplanting, then irrigation 1 days after disappearance of ponded water resulted in maximum grain yield (67.00 q/ha) was significantly superior to submergence up to 20 days after transplanting or near hair cracking in rice, then 3-4 days after disappearance of ponded water (57.9 q/ha).

Bali and Uppal (1999) conducted field trial at Ludhiana to study the effect of irrigation schedule (2 irrigation levels viz., irrigation at 2 days and 4 days after infiltration of previously ponded water and 3 timings of withdrawal of irrigation water, viz., 7, 14 and 21 days after 50 per cent flowering) on yield and quality of rice (Basmati 370) in loamy sand soil and concluded that the schedule of irrigation application after 2 days of infiltration of ponded water (2.45 t/ha) produced significantly higher grain yield over that of 4 days infiltration of ponded water (2.07 t/ha). The decrease in time gap between the withdrawal of irrigation and 50 per cent flowering caused drastic reduction in the mean grain yield (1.85 t/ha). Withholding irrigation 7 days after 50 per cent flowering resulted in 28.0 and 22.3 per cent less yield than that of obtained under withholding irrigation 21 (2.57 t/ha) and 14 days (2.38 t/ha) after 50 per cent flowering, respectively.

Lakpale and Tripathi (1999) conducted field trial at Raipur (M.P) to study the effect of irrigation schedule on yield and water requirement of rice in silty loam soil and observed different water regimes had not affected grain yield and straw yield of rice significantly. However, continuous submergence of water (5 ± 2) recorded higher effective tillers ($379 m^{-2}$), panicle weight (4.7 g) and 1000-grain weight (30.2 g). where as irrigation at 5 days after disappearance of ponded water (7 cm depth) resulted in minimum effective tillers ($352 m^{-2}$), panicle weight (4.2 g) and 1000-grain weight (29.6 g) under continuous submergence water level of 5 ± 2 cm the irrigation was required worked out to be 85.29 cm than submergence of 7cm at 5 days after disappearance of ponded water (55.62 cm).

In an field experiment conducted at Tamilnadu Lourduraj and Rajagopal (1999) from Coimbatore on sandy loam soil evaluated the effect of irrigation regimes (irrigation one days and two days after disappearance of water) on grain yield of rice and reported that irrigation scheduled one day after disappearance of ponded water recorded higher grain yield (59.96 q/ha) compared to irrigation application at three days after disappearance of ponded water (57.99 q/ha). It is possible that enhanced nutrient availability under the higher irrigation regime promoted the supply of assimilates to sink, thus resulting in more number of spikelets leading increased yield.

Balasubramanian and Krishnarajan (2000) carried out field experiment at Coimbatore on clay loam soil to study the influence of irrigation regimes (irrigation to 5 cm depth one day after disappearance of ponded water, irrigation to 5 cm depth three days after disappearance of ponded water, continuous submergence of 2.5 cm depth one day after disappearance of ponded water, irrigation to 2.5 cm depth one day after disappearance of ponded water, irrigation to 2.5 cm depth three days after disappearance of ponded water, saturation throughout the crop period, maintaining 5 cm depth of water during critical stages and maintaining saturation during ordinary stages, maintaining 2.5 cm depth of water during critical stages and maintaining saturation during ordinary stages and transplanted rice-irrigation to 5 cm depth on day after disappearance of ponded water) during kharif season and concluded that highest yield was recorded in plots received with irrigation 5 cm depth one day after disappearance of ponded water (5505 kg/ha) followed by transplanted rice with applied at irrigation 5 cm depth one day after disappearance of ponded water (5428 kg/ha).

Ganesh (2000) in a field trial on red silty loam soil at Karnataka in transplanted Jaya rice compared 5 irrigation schedules (irrigation once in three days, once in 7 days, once in 3 days up to 48 days after transplanting, then once in 7 days to field saturation till crop maturity, maintaining 2.5 cm submergence up to 20 days after transplanting and 5.0 cm submergence later on till 15 days before harvest and farmers practice of continuous irrigation) and reported that maximum grain (46.9 q/ha) and straw (51.6 q/hq) yield was observed in giving irrigation once in 3 days up to 46 DAT later on once in 7 days and minimum grain (42.7q/ha) and straw (51.2q/ha) was noticed in irrigation as per UAS package i.e. maintaining submergence of 2.5 cm up to 20 days after transplanting, then 5.0 cm submergence till 15 days before harvest.

Das *et al.* (2000) from Jorhat on sandy loam soil to evaluated the effect of five irrigation regimes (rainfed, 7cm irrigation 3 days after disappearance of ponded water, 7cm irrigation 5 days after disappearance of ponded water, 5 cm irrigation 3 days after disappearance of ponded water, 5 cm irrigation 5 days after disappearance of ponded water) on direct seeded rice and concluded that different water regimes brought about conspicuous changes both in yield and yield attributes. Application of 7cm irrigation water after 3 days after disappearance of ponded water tended to show better effect on effective tillers/hill (12.4), grains/panicle (61.4) and 1000-grain weight (21.4 g) over those of 7cm irrigation water after 5 days after disappearance of ponded water (effective tillers/hill, 11.7 and grains/panicle, 59.1, 1000-grain weight, 20.8 g). Again with the wide interval of application of water from 3 days to 5 days showed some deterioration effects on both these yield attributes. The 1000-grain weight is expected to be least affected by the different water regimes and as such there was no significant variation. Frequent irrigations at 3 DAPDW either of 7 or 5 cm depth recorded higher grain ad straw yields over wider intervals. Similar type of observations was also recorded by (Dhiman *et al.*, 1998).

Balasubramanian and Krishnarajan (2001) in a field experiment conducted at Comibatore on clay loam soil to study the effect of post harvest status of soil available nutrients status of direct seeded rice (cv. ASD-18, IR 20) as influenced by water management practices (irrigation to 5 cm depth one day after disappearance of ponded water, irrigation to 5 cm depth three days after disappearance of ponded water, continuous submergence of 2.5 cm depth throughout the crop period, irrigation to 2.5 cm depth one day after disappearance of ponded water, irrigation to 2.5 cm depth three days after disappearance of ponded water, saturation throughout the crop period, maintaining 5 cm depth of water during critical stages and maintaining saturation during ordinary stages, maintaining 2.5 cm depth of water during critical stages and maintaining saturation during ordinary stages and transplanted rice-irrigation to 5 cm depth on day after disappearance of ponded water) on clay loam soil and concluded that highest plant height (86.3 cm), number of tillers per plant (442) and grain yield (5.50 t/ha) was recorded with irrigation 5cm depth one day after disappearance of ponded water followed by transplanted rice where irrigation to 5 cm depth one day after disappearance of ponded water produced plant height of 82.9 cm , 435 number of tillers per plant and 5.42 t/ha of grain yield, continuous submergence of 2.5 cm depth throughout the crop period

Singh *et al.* (2001) conducted a two year experiment at Ludhiana, Punjab to study the effect of soil (three puddling intensities- no puddling, two discing + one planking and four discing + one planking) and water management practices (two irrigation regimes- continuous submergence and intermittent submergence 2 days after drainage) on the water balance and performance of rice (cv PR 111) in deep sandy loam soil and opioned that continuous submerge of water significantly increased grain yield of rice over intermediate submergence 2 days after drainage which realized mean grain yield of 5.7

Mg ha^{-1} and 5.2 Mg ha^{-1} in intermittent submergence. The LAI and dry matter production of rice was not significantly affected by irrigation regimes.

Hira *et al.* (2002) conducted a field trial to schedule irrigation to rice (PR-108) crop on the basis of soil matric suction (80$\pm$20, 120$\pm$20 cm, 160$\pm$20 and irrigation at 2 day interval after infiltration of ponding water) at Ludhiana on sandy loam soil observed that grain yield was not significantly different among the irrigation treatments, though it was lowest in the plots receiving the recommended (irrigation at 2 day interval after infiltration of ponding water) irrigation schedule (4.84 t/ha).

Parihar (2004.a) conducted field study on a clay loam soil on an experimental farm at Bilaspur, Chattisgarh, to evaluate the effects of four irrigation schedules (irrigation at 0, 1, 3 and 5 days after infiltration of ponded water) to rice (cv. Mahamaya) in rice-wheat cropping system and revealed that the application of irrigation to rice after one day drainage period (after disappearance of 7 $\pm$ 2cm ponded water) recorded higher growth (effective tillers per m^2, 279.3., filled grain per panicle, 115.0., 1000-grain weight, 28.4g) and yield (grain yield, 54.55 q/ha and straw yield, 60.62 q/ha) significantly than 5 day drainage period (effective tillers per m^2, 265.0., filled grain per panicle, 100.8., 1000-grain weight, 29.0g) and yield (grain yield, 45.98 q/ha and straw yield, 58.36 q/ha) but was at par with 3 day drainage period (effective tillers per m^2, 278.3., filled grain per panicle, 110.7., 1000-grain weight, 28.5g) and yield (grain yield, 49.67 q/ha and straw yield, 59.16 q/ha).

2.3.2 Water use efficiency and nutrient uptake.

Subramaniam and Rajagopalan (1979) in a field experiment conducted at Madurai on the effect of water management practices of two irrigation regimes (5 cm submergence to saturation and saturation to field capacity 0.3 atm tension) along with continuous submergence on nutrient uptake in rice (cv. IR 20) and reported that N uptake was higher under the moisture regime of saturation to field capacity during the ripening phase `(133 kg/ha) compared to 5 cm submerge to saturation (118 kg/ha). P and Mn uptake in the neutral soil was not affected by the water management practices, where as K absorption was greater under field capacity. Fe uptake was more under higher moisture regime. N and P were equally distributed in grain and straw whereas the accumulation of K, Fe and Mn was phenomenally higher in straw than in grain.

Sandhu *et al.* (1980) conducted a field experiment on irrigation needs and yield of rice on sandy loam soil as affected by continuous and intermittent submergence and reported that as compared with continuous submergence, irrigation a days after infiltration of ponded water saved about 53 cm (25%) of irrigation water in low rainfall season and irrigation at 2 and 5 days after infiltration of ponded water saved 78 cm (40)% to 101 cm (52%) in high rainfall years. They further reported that the mean increase in irrigation water efficiency with 1 day, 2 day, 3 day and 5 day drainage was 30, 54, 57, and 88 per cent over the mean irrigation water efficiency of 28.9 kg ha^{-1} cm^{-1} with continuous submergence.

Jha *et al.* (1981) in a field study evaluated the irrigation requirement of higher yielding rice varieties growth on soils having shallow water table and reported a save in

37 to 44 per cent of irrigation water and increased water use efficiency by 49 to 77 per cent by applying irrigation 2-3 days after disappearance of ponded water than continuous flooding in rice field.

Aujla *et al.* (1984) conducted a field experiment to study the response of rice varieties to differential irrigation at different growth stages of crop on sandy loam soils in Punjab and found that irrigation at one day drainage saved 28 per cent of irrigation water and increased water use efficiency by 5.8 Kg paddy ha^{-1} cm^{-1} over continuous submergence.

Kumar *et al.* (1988) carried out a field experiment to study the effect of water regimes on the irrigation needs and yield of short duration rice grown on the soils of Kerela, and revealed that an economy of 11 to 32 per cent of irrigation water with applying irrigation water 2 days after disappearance of ponded water in rice field. However, Prasad and Prasad (1990) reported use of 30 to 50 per cent less water following irrigation at practice at 3 days drainage period before irrigation.

Narang and Singh (1988) in his water management studies under rice in transplanted rice grown on loamy sand soil of Punjab reported that 40 cm of irrigation water was save when the submergence duration of ponded water after transplanting of rice was reduced from three weeks to one week.

Singandhupe and Rajput (1990) in his field experiment on nitrogen uptake by rice as influenced by irrigation regimes and nitrogen in sodic soils reported a reduction in the uptake of N with increasing interval between irrigation. P uptake was influenced significantly during 1993. While K uptake was influenced in both the years, irrigation one day after disappearance of ponded water recorded significantly higher uptake than irrigation 2 days after disappearance of ponded water. Irrigation regimes did not affect the soil available N and K but only influenced soil available P and the P status was higher under 3 days after disappearance of ponded water.

Uppal *et al.* (1991) conducted field experiment to study the irrigation need of PR-106 rice on a loamy sand soil at Ludhiana and observed that irrigation after two days of subsidence of ponded water at vegetative phase and 4 days of subsidence at reproductive phase saved 10 cm depth of irrigation. Under water scarcity, irrigation after 4 days in reproductive phase and 2 days after subsidence of ponded water in reproductive phase saved 12-22 cm irrigation water, but iot reduced the grain yield by 3.6-7.4 per cent.

Saikia and Dutta (1991) from Assam on sandy loam evaluated three moisture regimes (continuous shallow submergence 5$\pm$2cm, 7cm irrigation 1 day after disappearance of ponded water and 7cm irrigation 3 days after disappearance of ponded water) and concluded that water requirement of the crop was maximum (1344 mm) under continuous submergence with the lowest water use efficiency was 21.90 kg/ha/cm. The water use efficiency under 7cm irrigation 1 day after disappearance of ponded water and 7cm irrigation 3 day after disappearance of ponded water was worked out to be 22.65 kg/ha/cm and 25.79 kg/ha/cm respectively.

Saikia and Dutta (1992) from Jorhat on sandy loam to evaluated three moisture regimes (continuous shallow submergence 5$\pm$2cm, 7cm irrigation 1 day after disappearance of ponded water and 7cm irrigation 3 days after disappearance of ponded water) and opined that total water use was maximum under continuous submergence due to higher irrigation requirement. The water use efficiency was highest under 7cm irrigation 3 days after disappearance of ponded water (5.79 kg/ha/cm), which was 26.45 per cent more than that under continuous shallow submergence 5$\pm$ 2cm with 4.79 per cent (1.05 kg/ha/cm). The continuous submergence recorded higher N uptake compared with intermittent irrigation under 7cm irrigation 1 day after disappearance of ponded water and 7cm irrigation 3 days after disappearance of ponded water.

Marazi *et al.* (1993) from Kashmir in clay loam soil conditions and reported that water application of water 3 days after disappearance of ponded water saved water 212.3mm (22.7%) as compared water applied at the same day after disappearance of ponded water. Water use efficiency increased from 8.05 to 10.81 kg grain/ha mm with the application of water 3 days after disappearance of ponded water compared to that of water applied at the same day of disappearance. Water use efficiency increased with decrease in number of irrigations..

Uppal and Bali (1994) in loamy sand soil of Ludhiana and reported that irrigation at 4 days after disappearance of ponded water produced (25.9 kg/ha/cm) water use efficiency values in rice which was only higher by 3.3 kg/ha/cm as compared to irrigation at 2 days after disappearance of ponded water (22.6 kg/ha/cm).

Panda *et al.* (1997) at Bhubaneswar (Orissa) in sandy loam soil and concluded that highest nutrient removal (19.16, 50.68 and 152.55 kg NPK/ha) by the crop was observed when submergence of 5$\pm$2cm during tillering and reproductive stages with 7cm irrigation a day after disappearance of ponded water was applied followed by that in submergence of 5$\pm$2 cm at reproductive stage (panicle initiation to dough stage). The lowest nutrient removal (72.41, 37.57 and 112.76 kg NPK/ha) observed in the plots which received 7cm irrigation four days after disappearance of ponded water. However, water use efficiency in the treatment with 7cm irrigation a day after disappearance of ponded water (33.7 kg/ha/cm) and 7cm irrigation four days after disappearance of ponded water (38.5 kg/ha/cm) was significantly higher than that in the continuous submergence of 5±2cm (28.5 kg/ha/cm) at tillering (20-45 days after transplanting) and submergence of 5±2cm at tillering and reproductive stages (27.8 kg/ha/cm).

Dhiman *et al.* (1998) from Haryana in clay loam soil reported that there was no distinct variation in pH, E.C., organic carbon and available P when rice crop was put under water submergence up to 20 days after transplanting or near hair cracking than 3-4 days after disappearance of ponded water.

Bali and Uppal (1999) from Ludhiana Punjab under loamy sand soil revealed that scheduling of irrigation application after 2 days of infiltration of ponded water in spite of having higher water expense (141.3 cm) had an edge in increasing water expense efficiency (17.4 kg grain/ha/cm) over the treatment of irrigation application after 4 days of infiltration (123.3 cm) of previously ponded water (WEE, 16.8 kg hrain/ha/cm). The irrigation schedules did not differently affect the bulk density.

In an field experiment conducted on sandy loam soil at Tamilnadu, Lourduraj and Rajagopal (1999) evaluated the effect of irrigation regimes (irrigation one days and two days after disappearance of water) on grain yield of rice and observed that irrigation one day after disappearance of ponded water recorded higher uptake (106.4, 25.5 and 122.3 kg NPK/ha) respectively than irrigation at three days after disappearance of ponded water

(102.1 N, 25.9 P and 117.6 K kg/ha). Soil available nutrients of N and K were not influenced by irrigation regimes. However, soil available P was higher at the irrigation regime of three days after disappearance of ponded water (12.7 kg/ha) than irrigation one day after disappearance of ponded water (12.20 kg/ha)

Balasubramanian and Krishnarajan (2000) carried out field experiment at Coimbatore on clay loam soil to study the influence of irrigation regimes during kharif season and reported that highest N, P and K uptake (104.4, 19.7 and 132.5 kg/ha, respectively)and water use(138 cm) with a lowest water use efficiency (39.2 kg/ha/cm) was realized when transplanted rice was irrigated to 5 cm depth on the day after disappearance of ponded water The highest water use efficiency (50.6 kg/ha/cm) was recorded with continuous submergence of 2.5 cm depth throughout the crop period.

Balasubramanian and Krishnarajan (2001) in a field experiment conducted at Comibatore (Tamilnadu) on clay loam soil concluded that (irrigation to 5 cm depth one day after disappearance of ponded water recorded the highest N (252.3 kg/ha), P (23.3 kg/ha) and K (438.7 kg/ha) availability, however this was on par with transplanted rice-irrigation to 5 cm depth on day after disappearance of ponded water (N, 248.1 kg/ha., P, 28.5 kg/ha and K, 418.6 kg/ha). The lowest levels of soil available nitrogen (222.1 kg/ha), phosphorus (19.0 kg/ha) and potassium (423.1 kg/ha) was recorded with maintaining irrigation 2.5 cm depth of water during critical stages and maintaining saturation during ordinary stages.

Hira *et al.* (2002) from Ludhiana on sandy loam soil observed that number of irrigations applied were maximum (29) under recommend practice of irrigation followed by 24 under 80$\pm$20 cm soil matric suction, 20 under 120 $\pm$ 20 cm soil matric and 18 under 160$\pm$20cm soil matric suction. This resulted in significant differences in irrigation water use efficiency among various treatments of irrigation. The irrigation water use efficiency under 160 $\pm$ 20 cm soil matric suction was the maximum (32.6 kg/ha cm). It was minimum (12.2 kg/ha cm) under recommend practice of irrigation.

Das *et al.* (2000) from Jorhat on sandy loam soil concluded that the higher water use was observed under 7cm irrigation 3 days after disappearance of ponded water (136.2 cm) which requires 7.12 number of irrigations. The treatments 5cm irrigation 3 days after disappearance of ponded water (118.2 cm) and 7cm irrigation 5 days after disappearance of ponded water (117.5 cm) showed almost similar water use requiring 7-12 and 5-8 numbers of irrigations, respectively.

2.3.3 Succeeding wheat crop

Parihar (2004.a) conducted field study on a clay loam soil at Bilaspur, Chattisgarh, to evaluate the effects irrigation levels (one day after disappearance of 7$\pm$2 ponded water, three and five days after disappearance of ponded water) to rice in rice-wheat cropping system and reported that maximum grain yield (3437kg/ha), spikes/m row length (77), grains/spike weight (36) and 1000-grain weight (42.0 g) was observed in three days after disappearance of ponded water over one day after disappearance of 7$\pm$2 ponded water, grain yield (3421 kg/ha), spikes/m row length (76), grains/spike weight (35) and 1000-grain weight (41.8 g).

2.4 Interaction Effect

Singh *et al.* (1995) from Ludhiana evaluated the effect of puddling intensity (3 puddling intensities- no puddling, 2 runs of a tractor drawn cultivator in standing water, each followed by planking ; and 4 runs of a cultivator and 4 planking) and nitrogen use efficiency (4 levels of nitrogen viz., 0, 80, 120 and 160 kg/ha) of rice on a sandy loam soil of Punjab and observed that increased levels nitrogen up to 120 kg N/ha coupled with increased puddling intensity at 4 runs of cultivator + 4 planking increased the growth and yield (3.37 t/ha) of rice significantly over other treatments in comparison.

Singh *et al.* (2001) conducted a two year experiment at Ludhiana, Punjab to study the effect of soil (three puddling intensities- no puddling, two discing + one planking and four discing + one planking) and water management practices (two irrigation regimes- continuous submergence and intermittent submergence 2 days after drainage) on the water balance and performance of rice (cultivar PR 111) the deep sandy loam soil and reported that intermittent irrigation and increased puddling intensity significant decreased percolation losses. Minimum percolation losses occurred in intermediate submergence 2 days after drainage and four disking + one planking puddling intensity and intermediate flooding in combination resulted in higher water use efficiency (55.6 kg/ha/cm). There was no interaction between puddling and irrigation. The increase in grain yield with puddling intensities and irrigation regimes may be due favourable soil environment for root proliferation, crop cover and dry matter accumulation.

Parihar (2004.b) in his field study from Bilaspur (M.P) on clay loam soil reported a significant interaction effect of crop establishment method and irrigation schedule. The highest grain yield of rice (54.55 q/ha) was recorded in puddling and transplanting alongwith irrigation scheduled at 1 day seepage period of ponded water (52.97 q/ha) followed by line sowing of sprouted seeds without puddling (47.64 q/ha). Rice grown under unpuddled condition recorded significantly less grain yield (47.64 q/ha) than rice grown under puddled condition, the irrigation scheduled after 5 and 7 days infiltration period of ponded water recorded significantly less yield (49.67 and 49.08 q/ha) than 1 (52.97 q/ha) or 3 days after seepage (54.55 q/ha)

MATERIALS AND METHODS

CHAPTER-III

MATERIALS AND METHODS

The present investigation entitled "Effect of puddling intensity, nutrient sources and irrigation scheduling on growth and yield of rice (*Oryza sativa* L.) in rice-wheat cropping system" was carried out during the years 2005-06 and 2006-07. The materials used, experimental procedures followed and techniques adopted during the course of experimentation have been described in this chapter.

3.1 Experimental site and location

The field experiment was conducted during both *Rabi* and *Kharif* seasons of 2005-2006 and 2006-2007 at the Research Farm, Division of Agronomy, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Main Campus Chatha, Jammu located at a latitude of 32^0-40' N and longitude of 74^0-58' E with an altitude of 332 m above mean sea level.

3.2 Climate

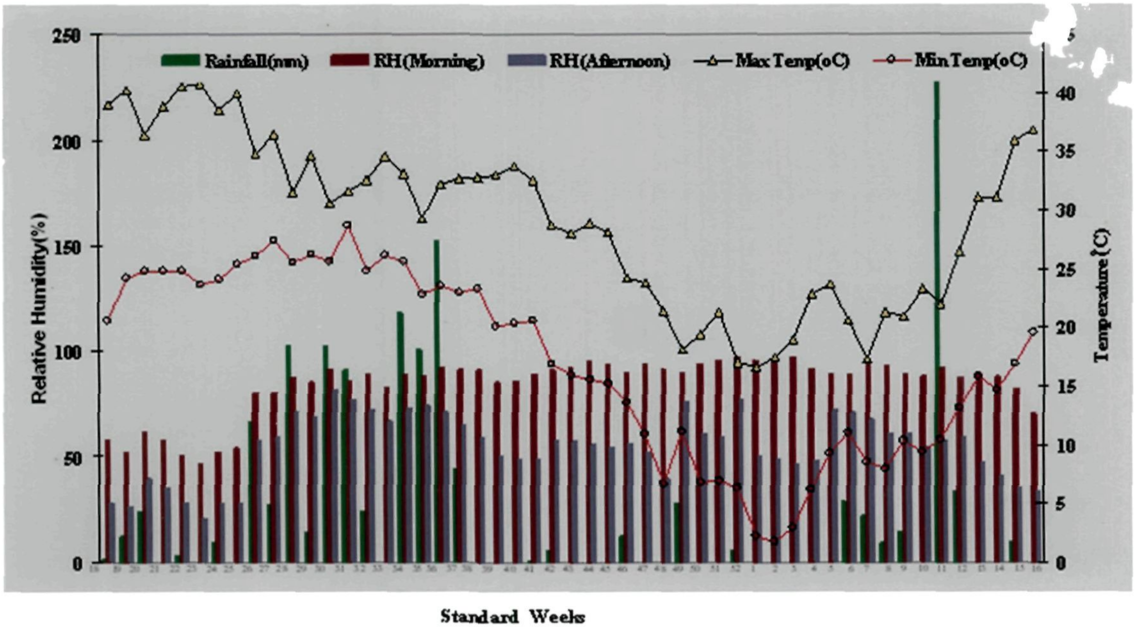
The climate of the experimental site is sub-tropical in nature and endowed with hot and dry early summer followed by hot and humid monsoon and cold winter. The mean annual rainfall varies from 1050- 1115 mm of which 70 per cent is received from south-west monsoon (June-September). However, the total rainfall and its distribution is subjected to large variation. Winter rains are scanty and a few showers of cyclonic rains are received during December to January or late spring. The mean maximum and minimum temperature shows considerable fluctuations during summer and winter. The temperature often rises to as high as 45 ^{0}C in the month of May-June, while the temperature touches to 0.14 ^{0}C during winter months especially in December-January.

The weather data for the crop season recorded at the Agrometeorological observatory located very close to the experimental site at the Research Farm, main campus, Chatha are depicted in Fig.3.1 and cited in Appendix:- I and II. The maximum and minimum temperature during the crop growing season (Fig 3.1) ranged from 13.9 to 42.9 ^{o}C and 2.8 to 27.1 ^{o}C, respectively in year 2005-06 and maximum and minimum temperature ranged from 16.6 to 40.8 ^{o}C and 1.7 to 28.7 ^{o}C, respectively in crop season 2006-07. The mean weekly relative humidity ranged from 35 to 82 per cent and 42 to 86.50 per cent in the year 2005-06 and 2006-07, respectively. The mean weekly rainfall ranged between 0 to 113.2 mm in 2005-06 and 0 to 242 mm during 2006-07. Total rainfall received during 2005-06 was 549.9 mm (*Rabi* 111.9 mm and *Kharif* 381.9 mm) whereas 1,304 mm (*Rabi* 396.8 mm and *Kharif* 852.9 mm) of rainfall was received during the succeeding year i.e. 2006-07, which was 754.1 mm more than the previous year.

3.3 Soil characteristics

The soil of the experimental field belongs to series II as classified by Despande *et al.* (1971). The samples were drawn by the core sampler from four depths (0-15, 15-30, 30-60 and 60-90 cm) from two locations. The samples of the respective depth were composited and analyzed for mechanical, physical and chemical properties.

2005-06



2006-07

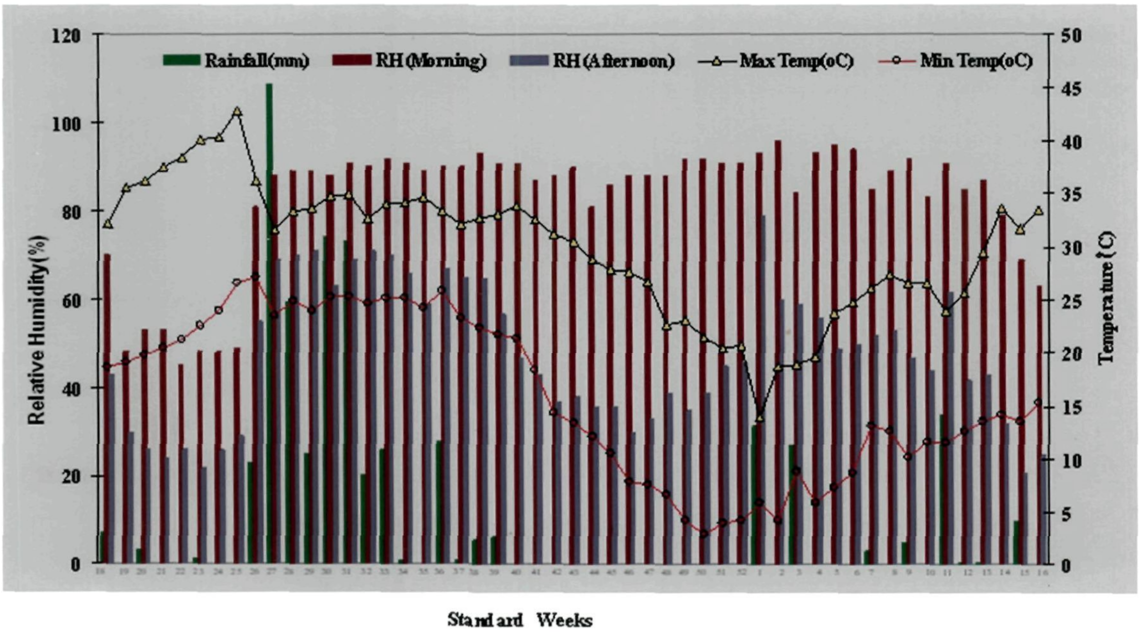


Figure 3.1 Weekly mean weather parameters prevailing during the crop season

3.3.1 Mechanical Properties

The soil is sandy loam in texture throughout the profile depth (Table 3.1). The sand fraction decreased with depth (63.9 to 44.1 percent) where silt and clay increased with depths (18.8 to 26.3 and 17.9 to 29.6 percent, respectively).

3.3.2 Physical characteristics

Physical characteristics of soil, viz. field capacity (FC), permanent wilting point (PWP) and bulk density (bd) were determined for different soil layers up to 90 cm soil profile (Table 3.2). The field capacity, permanent wilting point, bulk density and available water capacity of 90 cm soil was 16.64 cm, 6.86 cm, 1.50 Mg $m^{-3}$and 9.78 cm, respectively (available water capacity = FC-PWP).

3.3.3 Chemical properties

The soil was neutral in reaction (7.4) and medium in EC (0.16 dS m^{-1}). The soil tested medium in O.C (0.46), available N (212 Kg/ha), P (15.9 Kg/ha) and K (139 Kg/ha) [Table 3.3].

Table 3.1 Mechanical properties of soil

Soil depth (cm)	Soil parameters			Method employed
	Sand (%)	Silt (%)	Clay (%)	
0-15	63.9	18.8	17.3	International Pippette method (Piper, 1966)
15-30	54.4	21.8	23.8	
30-60	49.6	24.2	26.2	
60-90	44.1	26.3	29.6	

Table 3.2 Chemical properties of soil

S no.	Soil parameters		Method employed
1	pH	7.4	Suspension of soil & water (1:2.5) using glass-calomel electrode (Jackson, 1973)
2	EC (dS m^{-1})	0.16	Salt bridge measurements from the suspension used for pH determination (Jackson, 1973)
3	OC (%)	0.46	Dichromate oxidation of organic matter Walkley & Black (1934)
4	Available N (kg ha^{-1})	212	Alkaline permanganate method Subbiah and Asija (1956)
5	Available P (kg ha^{-1})	15.9	0.5 M Sodium bicarbonate (pH 8.5) Olsen *et al.* (1954)
6	Available K (kg ha^{-1})	139	1N Ammonium acetate extraction method using Flame photometer (Jackson, 1973)

Table 3.3 Physical characteristics of soil

Soil depth (cm)	Field capacity		Permanent wilting point		Available water content (cm)	Bulk density (Mg m^{-3})
	% w/w	cm	% w/w	cm		
0-15	13.05	2.84	5.30	1.15	1.69	1.45
15-30	12.70	2.74	5.20	1.12	1.62	1.44
30-60	12.30	5.42	5.11	2..25	3.17	1.47
60-90	12.55	5.64	5.21	2.34	3.30	1.50
		16.64		6.86	9.78	
Methods used	Field method (Coleman, 1944)		15 atm tension value (Richards and Weaver, 1943)		-	Core method (Bodman, 1942)

3.4 Cropping history of the experimental field

The cropping history for the last 7 years of the experimental site is given in table below:

Table 3.4 Cropping history of experimental site

Year	*Kharif*	*Rabi*
2001	Rice	Wheat
2002	Rice	Wheat
2003	Rice	Wheat
2004	Maize	Wheat
2005	Rice	Wheat
2006	Rice	Wheat
2007	Rice	Wheat

3.5. Experimental details

The experiment involving three puddling intensities, three irrigation schedules and four nutrient sources was laid out in split-plot design with Puddling and irrigation scheduling in main-plots and nutrient sources in sub-plots repeating each treatment replicated thrice as per the layout plan (Fig. 3.2)

A. Puddling intensity* — Symbol

1. Normal practice [x] — P_0
2. 2 times puddling. — P_1
3. 3 times puddling. — P_2

([x] Note : normal practice indicates ploughing followed by 1 Puddling)

B. Irrigation Scheduling *

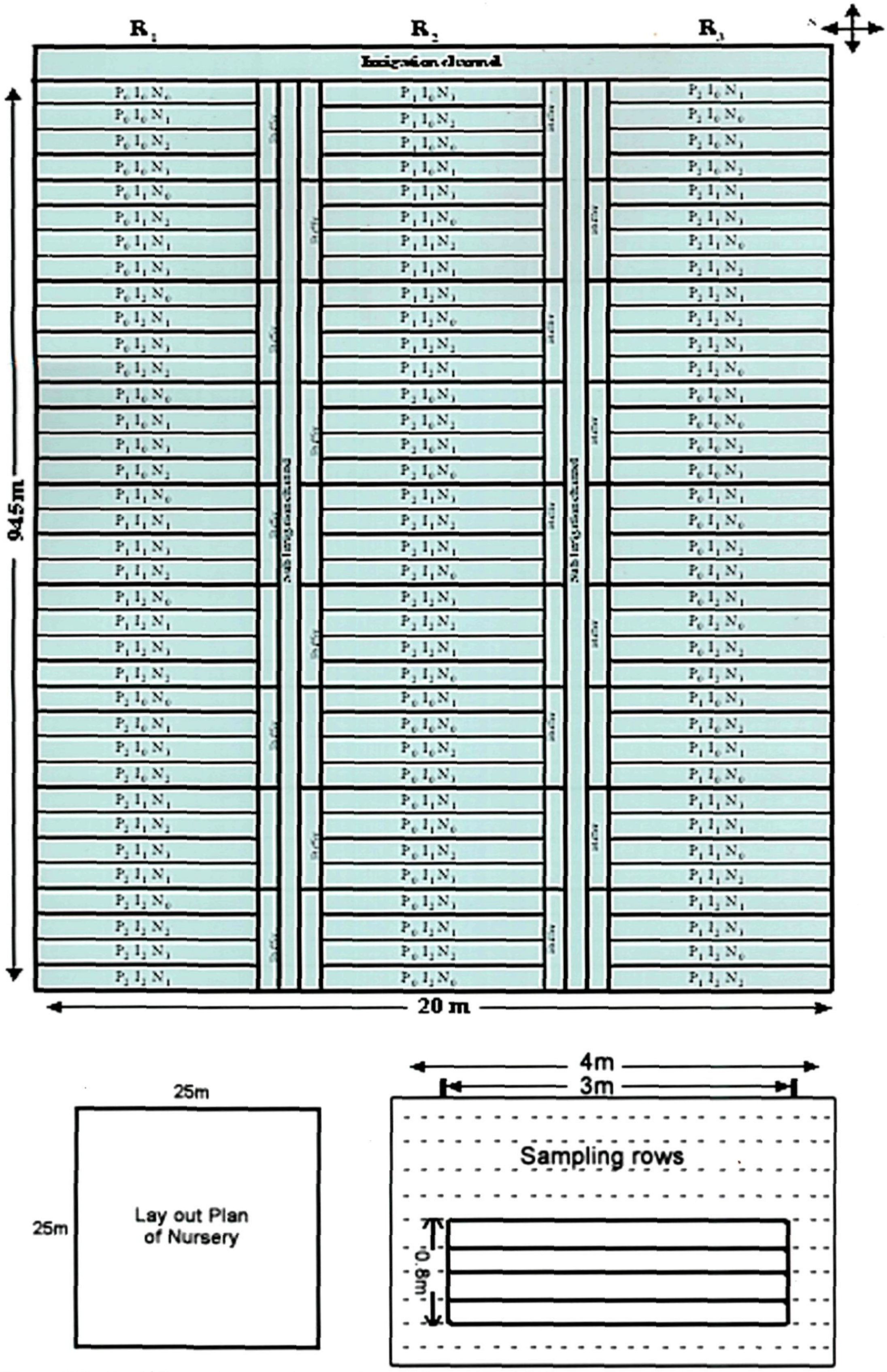
1. 2 Days after disappearance of ponded water (DADPW) I_0
2. 4 DADPW I_1
3. SMP 150 (soil matric potential based irrigation scheduling at 150 cm suction) I_2

C. Nutrient Sources**

1. Vermicompost 3t/ha+ inorganic fertilizer. N_0
2. Vermicompost 6t/ha. N_1
3. FYM + inorganic fertilizer (50% each) N_2
4. Control (Recommended N, P, K) N_3

* Puddling intensity and irrigation scheduling will be assigned to main plots and **nutrient sources to sub-plot.

Design	:	Split-plot design
Number of treatments	:	36
Number of replications	:	3
Total number of plots	:	108
Bund size	:	0.5 m
Main irrigation channel	:	1.0 m
Sub irrigation channel	:	0.5 m
Buffer	:	0.5 m
Gross plot size	:	2m × 4m = 8m2
Net plot size	:	3m × 0.8m = 2.4 m^2
Variety	:	PC-19 (Rice), PBW-343 (Wheat)



P_0, P_1 and P_2: Puddling at normal practice, 2 times and 3 times

I_0, I_1 and I_2: Irrigation at 2 and 4 Days after disapperance of ponded water and SMP at 150 cm suction

N_0, N_1, N_2 and N_3: Vermocompost at 3t/ha+inorganic fertilizer, Vermicompost @ 6t/ha, FYM+Inorganic fertilizer and N.P,K recomended (Control)

Fig :3.2 Lay out Plan of the Field Experiment

3.6. Details of cultural operations

Various cultural operations were done as per the details given in Table-3.5.

Table 3.5: Details of various field operations

S.No	Operation	Date of operation		Details of cultural operation
		2005-06	**2006-07**	
A	**Paddy**			
I	**Nursery raising**			
1	Pre sowing irrigation	4-6-2005	2-6-2006	One pre sowing irrigation was applied in the nursery plot
2	Preparation of field	9-6-2005	8-6-2006	Raised seed beds of 10-15 cm high each 1.25m wide and 7.5m length was prepared by dry method.
3	Date of nursery sowing	11-6-2005	10-6-2006	Sowing of rice seed done at 5 cm apart and 3cm deep in lines and covered with a thin layer of soil.
II	**Transplanting**			
4	Layout of experiment	6-7-005	-	Field was laid out as per the layout plan given in fig-3.3
5	Treatment imposed	9-07-05	09-07-06	w.r.t puddling and irrigation were imposed as per the technical programme. Plots receiving 6t/ha vermicompost on dry weight basis (N=2 %, P=0.6 % and K=1.3 %), were applied. Where as plots receiving 3t/ha vermicompost+inorganic fertilizer (N=2 %, P=0.6 % and K=1.3 %), FYM 50 % (N=0.61 %, P=0.22 % and K=0.72 %) + inorganic fertilizer (50 %) and N P and K (100% i.e. Recommended through inorganics). The half dose of inorganic N and full dose of P and K were applied as basal and remaining inorganic N top dressed in two splits.

Contd...

S.No	Operation	Date of operation		Details of cultural operation
		2005-06	2006-07	
6	Nursery uprooting and transplanting	10-07-005	10-07-06	Nursery uprooting and transplanting was done manually with a PP × RR distance of 15 × 20 cm.
7	Herbicide spray in rice	12-07-05	12-07-06	Herbicide Butachlor @ 1.5 Kg a.i. ha^{-1} was applied two days after transplanting of seedlings.
8	Irrigation	Dates and frequency as per treatment, Table-3.6	Dates and frequency as per treatment, Table-3.6	Pre sowing irrigation at field preparation. Each irrigation treatment amounted to 50mm as measured with partial flume. Soil matric potential was measured through vacuum gauge tensiometer installed at 15-20 cm depth.
9	Gap filling in rice	2-08-05	1-08-06	Gap filling was done manually.
10	Weeding of rice	3-09-05	8-09-06	The crop was kept weed free by manually uprooting the weeds
11	Harvesting of rice	17-10-05	24-10-06	Crop was harvested manually from net plot size of 2.4 m^2.
12	Threshing of rice	21-10-05	4-11-06	Threshing was done manually and grain yield was recorded plot wise
B	**Wheat (for residual studies)**			
13	Preparation of field	7-11-05	15-11-06	Field was prepared with power tiller without disturbing the bunds.
14	Fertilizer application	9-11-05	17-11-06	Uniform basal application of 50 kg N/ha, 60 Kg P/ha and 60kg K/ha through inorganic fertilizers were applied and remaining N was top dressed in two splits
15	Sowing of wheat	9-11-05	17-11-06	Sowing of wheat at 3cm depth by opening furrows in lines at a distance of 20 cm apart between the rows.
16	Irrigation			Applied irrigation by controlled flooding in the entire field.
	I	30-11-05	-	
	II	28-12-05	-	
	III	02-02-06	-	

Contd...

S.No	Operation	Date of operation		Details of cultural operation
		2005-06	2006-07	
17	Herbicide spray in wheat	2-12-05	10-12-06	Herbicide Isoproturon @ 0.75 kg a.i. + 2,4-D @ 500ml ethyl ester salt ha^{-1} was sprayed 30 days after sowing of wheat.
18	Harvesting of wheat	18-04-06	24-04-07	Crop was harvested manually from net plot size of 2.4 m^2.
19	Threshing of wheat	24-04-06	1-05-07	Threshing was done by using tractor- operated thresher and grain yield was recorded plot wise.

3.7 Observation recorded

3.7.1 Growth studies

3.7.1.1 Plant height

Five plants selected randomly from each plot were tagged (second row from east). The height of rice plant was measured with the help of metre scale from the base of the plant to the tip of the last fully opened leaf before panicle initiation and thereafter up to the tip of panicle at 30, 60 and 90 days after transplanting. Plant height values were presented in centimeters (cm) and average of all the five plants was taken for statistical analysis.

3.7.1.2 Dry matter accumulation

The samples for dry matter production (g m^{-1}) were taken from each plot by clipping two plants close to the soil surface from the second row from the west at different stages i.e. at 30, 60 and 90 days after transplanting and at harvest. The plants

Table: 3.6 Dates of irrigation applied to rice under various irrigation treatments.

Irrigation treatments	Dates of irrigation applied		Total number of irrigation		Total irrigation water applied (cm)	
	2005	**2006**	**2005**	**2006**	**2005**	**2006**
2 DADPW*	July 29, Aug. 03, 09, 13,17, 21, 25, 29 Sept. 02-, 06, 10, 14, 18, 22, 26, 29	July 17,26, 31, Aug. 4,10, 15, 26, 31 Sept. 08, 13, 18, 23, 28	16	13	80.00	65.00
4 DADPW	July 31, Aug. 11, 17, 23, 29, Sept. 04, 10, 16, 22, 28	July 26, Aug. 01, 12, 18, 27 Sept. 09, 15, 21, 27	10	9	50.00	45.00
SMP ** at 150 cm suction	Aug. 01, 13, 19, 24, 29, Sept. 03, 08, 17, 22, 27	July 27, Aug. 12, 17, 27 Sept. 10, 18, 23, 28	10	8	50.00	40.00

*** Days after disappearance of ponded water ** Soil matric potential**

samples taken were sun dried and then kept in hot air oven for drying at 70 $\pm$ 5 ^{0}C till attaining of constant weight.

3.7.2 Yield and yield attribute

3.7.2.1 Total Number of tillers per meter square

Number of tillers falling in a quadrate measuring 1m x 1m put randomly in each treatment plot were counted and expressed as tillers per meter square.

3.7.2.2 Number of panicles per meter square

Number of panicles falling in a quadrate measuring 1m x 1m put randomly in each treatment plot were counted and expressed as panicles per meter square.

3.7.2.3 Number of grains per panicles

Total numbers of grains from five randomly selected panicles mentioned above were counted and average number of grains per panicle was calculated treatment wise.

3.7.2.4 Grain weight per panicle

Grain weight of five randomly selected panicles mentioned above was taken and average grain weigh per panicle were calculated treatment wise and expressed in grams.

3.7.2.5 1000-grain weight

A random sample from bulk produce of each treatmental plot was taken, out of which 1000 grains were counted and weighed. The weight was expressed in grams as test weight (g).

3.7.2.6 Grain yield (q/ha)

From the individual plots, net plot area was harvested, sun dried for 3-4 days and was subsequently threshed and cleaned. The grains thus obtained, were weighed and expressed in q/ha.

3.7.2.7 Straw yield (q/ha)

The straw yield was computed by deducting the net plot grain yield from net plot bundle weight and expressed as q/ha.

3.7.2.8 Harvest index (%)

The ratio of economic yield and biological yield was computed by using the formula as give by Nichiporavich (1967).

$$\text{Harvest Index} = \frac{\text{Economic yield}}{\text{Total Biological Yield}} \times 100$$

3.7.3 Yield of succeeding wheat crop

3.7.3.1 Grain yield (q/ha)

From the individual plots, net plot area was harvested; sun dried for 3-4 days and was subsequently threshed and cleaned. The grains thus obtained, were weighed and expressed in q/ha.

3.7.3.2 Straw yield (q/ha)

The straw yield was computed by deducting the net plot grain yield from net plot bundle weight and expressed as q/ha.

3.7.4 Chemical analysis

3.7.4.1 Processing of samples

Treatment wise grain and straw samples taken at harvest were washed first with tap water and then with distilled water. These samples were dried in sun for 2-3 days and then in oven dried at 70°C for 24 hours, dried samples were ground in to 40 mesh size.

3.7.4.2 Estimation of total N

The ground samples of grain and straw weighing 0.5 gram were digested in the Kjeldhal's flask in concentrated sulphuric acid in presence of a digestion mixture consisting of K_2SO_4, $FeS0_4$ and $CuSO_4$ in the ratio of 20:2:1 and nitrogen was estimated by Kjeldhal's method (Jackson, 1973).

3.7.4.3 Estimation of P and K

0.5 gram of oven dried grain and straw samples from each treatment were put in conical flask followed by addition of about 10 ml tri-acid mixture (HNO_3, H_2SO_4 and HCL) in the ratio of 10:4:1 respectively and kept on the hot plate till digested. P and K from the extract were estimated by standard methods (Jackson, 1973).

3.7.4.4 N, P and K uptake by rice

Uniform representative samples were randomly selected from each plot, dried, processed and analyzed to determine the N, P and K content in plant samples (grains and straw) of rice at harvest. The uptake of the total plant (grain and straw) was calculated by multiplying their respective contents with plant dry matter (grain and straw).

3.7.5 Soil Studies

3.7.5.1 Nutrient status of soil

Before sowing of rice and after harvesting of wheat crop, the soil samples were taken for determination of available N, P and K. The soil samples were dried under shades ground and passed through 2 mm sieve and were analyzed for physico-chemical properties as per the standard procedure given in the Table-3.2.

3.7.5.2 Field capacity

Field capacity occurs when soil retains the maximum amount of water with little or no further loss of water by drainage or loss of gravitational water. Soil water content at matrix potential of -0.33 bars corresponding to the field capacity was determined layer wise up to 90 cm depth with the help of pressure plate apparatus.

$$FC = \frac{\text{Wet weight of soil at,-0.33 bar- dry weight of soil}}{\text{Dry weight of soil}} \times 100$$

3.7.5.3 Permanent wilting point

Soil water content at matrix potential of about - 15 bars corresponding to wilting point was also worked out layer wise up to 90 cm depth with the help of Pressure Plate apparatus.

$$PWP = \frac{\text{Wet Weight of Soil at, - 15 bar – dry weight of soil}}{\text{Dry weight of soil}} \times 100$$

3.7.5.4 Soil moisture status

Soil moisture content before pre irrigation for puddling, at harvest of rice and before sowing of wheat was calculated gravimetrically by drying the samples in oven at 105°C till constant weight. The moisture storage under different puddling and irrigation in different layers of 0-30, 30-60, 60-90, 90-120, 120- 150 and 150-180 cm of root zone was computed by following formula

$$M = \sum_{I=1}^{n} \frac{Mpi}{100} \times Dbi \times Di$$

Where,

M = Amount of moisture in 0 to 180 cm soil profile

$\sum_{I=1}^{n}$ = Summation of water content of n number of soil layers varied from 1 to nth layer

Mpi = Moisture percent of i^{th} layer

Dbi = Bulk density of i^{th} layer in Mg m^{-3}

Di = Depth of i^{th} layer of soil in cm

3.7.5.5 Bulk density

Soil samples for determination of bulk density of undisturbed soil was taken before sowing and after harvesting of wheat crop by using 1 m long core sampler having 4.5 cm internal diameter. The samples were taken from 0-15, 15-30. 30-60 and 60-90 cm depth from the plots receiving different puddling intensities, irrigation scheduling and nutrient sources. The samples were oven dried and bulk density was expressed as Mg m^{-3}.

3.7.5.7 Water expense

With the help of permanenly fixed scales, water depth before and after each irrigation was recorded and the difference was taken as the amount of applied irrigation. Irrigation was applied between 8:00 and 9:00 a.m. because loss of water during this period was assumed to be less.

The water use was calclulated by the formula

$$WE = IW + RF - SW$$

Where

WE	=	Water expense for the crop season (cm)
IW	=	Amount of irrigation water applied (cm)
RF	=	Effective rainfall during the crop season (cm)
SW	=	Amount of water left in the soil profile at the time of harvest (cm)

3.7.5.8 Water expense efficiency

The water expense efficiency of grains, straw and biological yield was calculated as the ratio of yield (grain, straw and biological yield) to the total amount of water expense and expressed as in Kg $ha^{-1}cm^{-1}$.

$$WEE = \frac{Y}{WE} \times 100$$

Where

WEE	=	Water expense efficiency (Kg ha^{-1} cm^{-1})
Y	=	Grain yield (Kg ha^{-1})
WE	=	Water expense (cm)

3.7.5.9 Percolation rate

The percolation rate of ponded water during the crop growth period was measured with the help of permanent scales fixed in the plots after each irrigation.

3.8 Statistical analysis

The data presented in the thesis are the mean values. All the observations are statistically analysed by using the analysis of variance. The results were tested for the treatments mean by applying F-test of significance on the basis of null hypothesis (Cochran and Cox, 1957). Wherever necessary, standard errors alongwith critical difference at 5 per cent level of significance were computed for discriminating the treatment effects for chance effects (Panse and Sukhamate, 1967).

EXPERIMENTAL RESULTS

CHAPTER-IV

EXPERIMENTAL RESULTS

The results obtained during the course of investigation entitled "Effect of puddling intensity, nutrient sources and irrigation scheduling on growth and yield of rice (*Oryza sativa* L.) in rice-wheat cropping system" conducted during 2005-06 and 2006-07 have been described in this chapter under following heads. The data recorded was analyzed and presented through tables and graphs.

4.1 Growth studies

4.1.1 Plant height (cm)

The plant height increased with the advancement of the crop age and conspicuous increase was observed between 30 and 60 days after transplanting (Table: 4.1). Different levels of nutrient sources and irrigation scheduling significantly increased the plant height from 60 DAT onwards up to 90 DAT, whereas puddling intensity did not affected the plant height significantly during both the crop seasons (Appendix -III).

The tallest plants were observed with application of N, P and K at recommended dose during the first year of experimentation whereas, during second year, application vermicompost @ 6t/ha brought significant increase in plant height than other treatments in comparison. Initial crop growth in terms of plant height was comparatively higher during second year of experimentation.

Table: 4.1. Effect of various treatments on plant height (cm) of rice in rice-wheat cropping system

Treatments	Plant height (cm)							
	2005-06			At harvest	2006-07			At harvest
	Days after transplanting				Days after transplanting			
	30	60	90		30	60	90	
Puddling intensity								
Normal practice	44.80	66.25	79.21	78.46	47.58	77.28	81.69	80.79
2-times puddling	45.19	67.15	79.87	79.09	47.94	78.32	82.14	81.25
3-times puddling	45.72	67.17	80.26	79.47	48.27	78.81	83.10	82.23
C.D. (p=0.05)	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
Irrigation scheduling								
2 DADPW*	44.74	66.66	79.63	78.85	47.51	78.55	82.00	81.10
4 DADPW	44.55	65.36	78.18	77.40	47.22	76.26	81.32	80.44
SMP ** at 150 cm suction	46.42	68.55	81.53	80.78	49.07	79.61	83.61	82.72
C.D. (p=0.05)	N.S	1.36	1.78	1.91	N.S	1.43	1.77	1.81
Nutrient sources								
Vermicompost 3t/ha+inorganic fertilizer	43.45	64.46	77.35	76.57	46.49	76.16	80.44	79.54
Vermicompost @ 6t/ha	44.69	65.77	78.92	78.13	49.39	80.77	84.37	83.51
FYM+In-organic fertilizer(50% each)	45.96	67.31	80.67	79.93	48.48	78.55	82.65	81.76
N.P.K Recommended	46.85	69.88	82.17	81.41	47.35	77.06	81.77	80.88
C.D. (p=0.05)	N.S	1.52	1.63	1.78	3.29	1.01	1.61	1.67

*** Days after disappearance of ponded water ** Soil matric potential**

Among different levels of irrigation, application of irrigation SMP at 150 cm suction increased the plant height significantly at 60 DAT onwards up to 90 DAT than irrigation applied at 2 and 4 days after disappearance of ponded water (DADPW), which were found at par with each other during first year of experimentation. However, irrigation applied at 2 DADPW though found at par with SMP at 150 cm suction during 2006-07, significantly increased the plant height of rice than the application of irrigation at 4 DADPW.

Among the different nutrient sources during, 2005-06, the application of N, P and K (inorganic fertilizer) at recommended levels brought significant increase in plant height compared with the vermicompost @ 3t/ha + inorganic fertilizers, 6t/ha vermicompost alone and FYM+inorganic fertilizers (50% each) at lateral stages of crop growth (60 and 90 DAT). However, during 2006-07, application of vermicompost @ 6t/ha increased the plant height significantly over vermicompost @ 3t/ha + inorganic fertilizer, FYM+inorganic fertilizers (50% each) and recommended levels of N, P and K applied through inorganic fertilizers.

4.1.2 Dry matter production (g/m^2)

The dry matter production (g/m^2) increased with the advancement of the crop age and conspicuous increase was observed between 60 and 90 DAT (Table: 4.2 and Fig:-4.1). Different nutrient sources increased the dry matter production of rice crop significantly from 30 DAT onwards of crop age, while irrigation at different stages significantly increased the dry matter production from 60 DAT onwards stage up to

Table :4.2. Effect of various treatments on dry matter (g/m^2) of rice in rice-wheat cropping system

Treatments	Dry matter (g)							
	2005-06				2006-07			
	Days after transplanting			At harvest	Days after transplanting			At harvest
	30	60	90		30	60	90	
Puddling intensity								
Normal practice	137.08	531.42	1010.00	1307.83	143.42	544.00	1027.83	1318.68
2-times puddling	137.50	532.25	1011.50	1308.42	143.83	544.83	1029.33	1319.25
3-times puddling	138.08	533.17	1012.25	1310.00	144.42	545.75	1030.08	1320.83
C.D. (p=0.05)	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
Irrigation scheduling								
2 DADPW*	137.83	531.33	1013.25	1309.50	144.68	543.92	1031.08	1320.33
4 DADPW	135.92	529.75	1006.50	1303.83	142.25	542.33	1024.33	1314.68
SMP** at 150 cm suction	138.92	535.75	1014.00	1312.92	145.25	548.33	1031.83	1323.75
C.D. (p=0.05)	N.S	3.96	2.67	2.97	N.S	3.28	2.94	2.77
Nutrient sources								
Vermicompost 3t/ha+inorganic fertilizer	135.44	528.90	1008.22	1303.68	138.78	537.22	1019.57	1311.00
Vermicompost @ 6t/ha	137.00	530.79	1010.22	1307.44	149.89	553.78	1039.67	1329.33
FYM+In-organic fertilizer(50% each)	138.22	533.00	1011.22	1309.89	145.57	546.33	1031.56	1321.22
N.P.K Recommended	139.57	536.44	1015.33	1314.00	141.33	542.11	1025.56	1316.79
C.D. (p=0.05)	3.15	3.16	3.74	3.45	3.16	3.46	3.31	3.51

*** Days after disappearance of ponded water ** Soil matric potential**

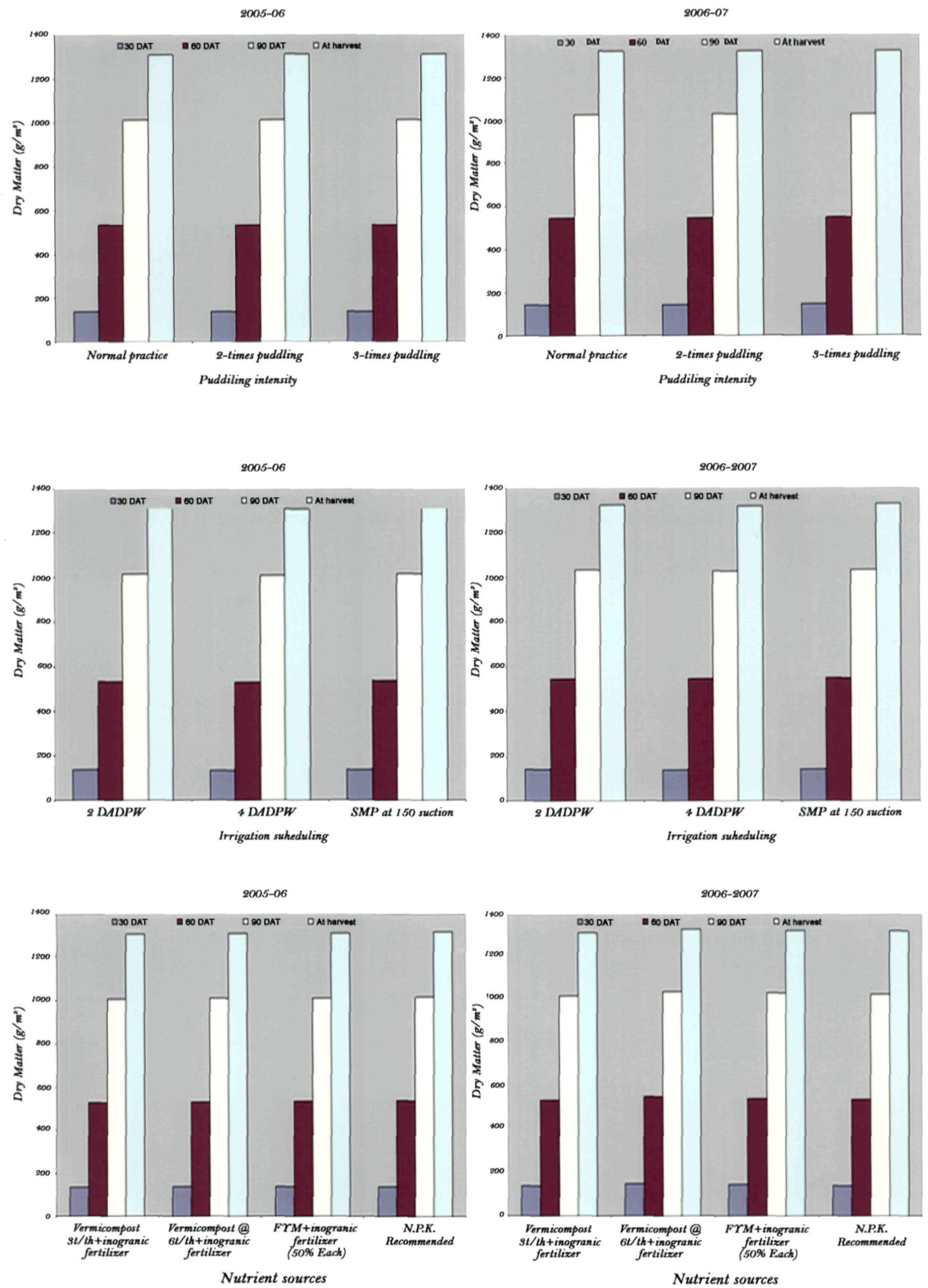


Fig: - 4.1. Effect of puddling intensity, irrigation scheduling and nutrient sources on dry matter (g/m²) of rice.

harvest. However, different levels of puddling intensity did not influence the dry matter production of rice significantly at any of the crop growth stage (Appendix-III).

Among the irrigation levels, application of irrigation at SMP 150 cm suction increased the dry matter production of rice significantly from 60 DAT onwards up to harvest than irrigation applied at 2 and 4 DADPW, expect at 90 DAT, where irrigation applied at 2 DADPW was found at par with SMP at 150 cm suction during both the years of experimentation.

Among the different nutrient sources, during 2005-06, application of N, P and K (inorganics) at recommended doses increased the dry matter production of rice crop significantly than the application of vermicompost @ 3t/ha+inorganic fertilizers. However, FYM+inorganic fertilizers (50% each) were found to be at par with N, P and K recommended at 30 DAT and at harvest. Where as, during 2006-07 vermicompost applied @ 6t/ha resulted in significant increase in dry matter production than the application of FYM+inorganic fertilizers (50% each), vermicompost @ 3t/ha + inorganic fertilizers and N, P, K (recommended through inorganics).

4.2 Yield attributes

4.2.1 Number of tillers per metre square

Number of tillers/m^2 increased significantly with different levels of puddling, irrigation scheduling and nutrient sources during both the years (Table: 4.3 and Appendix-IV).

Puddling intensity with 3 times puddling increased number of tillers/m^2 significantly as compared to normal practice of puddling and 2 times puddling. The latter being at par with each other during both years.

Irrigation scheduling SMP at 150 cm suction though being at par with irrigation applied at 2 DADPW increased the number of tillers/m^2 significantly than irrigation at 4 DADPW during 2005-06 and 2006-07.

Among the different nutrient sources, during 2005-06 application of N, P and K (inorganics) at recommended dose resulted in significant increase in number of tillers/m^2 than application of vermicompost @ 3t/ha+inorganic fertilizers and vermicompost alone @ 6t/ha but were at par when FYM + inorganic fertilizers (50% each) was applied. However, during 2006-07, significant increase in number of tillers/m^2 was observed when vermicompost @ 6t/ha was applied, which was at par with application of FYM + inorganic fertilizers (50% each) than the application of vermicompost @ 3t/ha + inorganic fertilizer and N, P and K at recommended dose (inorganic fertilizers).

4.2.2 Number of panicles per metre square

Different levels of puddling intensity, irrigation scheduling and nutrient sources resulted in significant increase in number of panicles/m^2 during both the years of experimentation. (Table: 4.3 and Appendix-IV). In general the number panicles per meter square were higher during second years of experimentation

Puddling intensity with 3 times puddling increased the number of panicles/m^2 significantly than 2 times puddling and normal practice during 2005-06 and 2006-07, respectively.

Application of irrigation SMP at 150 cm suction resulted in significant increase in number of panicles/m^2 than irrigation at 2 and 4 DADPW which were found at par with each other during 2005-06 and 2006-07, respectively.

Among the nutrient sources, application of N, P and K at recommended doses through inorganics during 2005-06 being at par with application of FYM+inorganic fertilizer (50% each) resulted in significant increase in number of panicles/m^2 than nutrients applied either through vermicompost @ 3t/ha+inorganic fertilizer or alone application of vermicompost @ 6t/ha. However during 2006-07, application of vermicompost @ 6t/ha was found to increase the number of panicles/m^2 than the FYM + inorganic fertilizers (50% each) vermicompost @ 3t/ha+inorganic fertilizer and recommended N, P, K through chemical fertilizer.

4.2.3 Number of grains per panicle

The number of grains per panicle increased significantly with different puddling intensity and nutrient sources (Table: 4. 3 and Appendix-IV).

Irrigation scheduling was found to bring non significant increase in number of grains /panicle. In general, the number of grains/panicle were lower during 2005-06 than during 2006-07.

Three times puddling increased the number of grains/panicles significantly than normal practice of puddling and other treatments during both the years of experimentation. The varying irrigation schedule did not produce any significant influence in increasing the number of grains/panicle in rice during both the crop seasons.

Table: 4.3. Effect of various treatments on tillers/m^2, panicles/m^2 and grains/panicle of rice in rice-wheat cropping system

Treatments	No. of tillers/m^2		No. of panicles/m^2		No of grains/panicle	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Puddling intensity						
Normal practice	314.72	324.97	223.33	228.58	95.58	98.08
2-times puddling	315.83	326.08	232.00	237.25	95.42	97.92
3-times puddling	322.50	334.39	237.00	243.36	99.17	101.08
C.D. (p=0.05)	2.53	2..82	4.21	3.93	2.12	0.83
Irrigation scheduling						
2 DADPW*	317.69	328.47	230.42	235.67	96.83	98.50
4 DADPW	314.97	325.78	227.08	232.33	96.25	98.75
SMP** at 150 cm suction	320.39	331.19	234.83	241.19	97.08	99.58
C.D. (p=0.05)	2.53	2.82	4.21	3.93	N.S	N.S
Nutrient sources						
Vermicompost 3t/ha+inorganic fertilizer	314.00	325.93	228.22	230.59	95.78	96.78
Vermicompost @ 6t/ha	311.04	336.41	225.57	246.37	94.11	103.44
FYM+In-organic fertilizer(50% each)	321.04	334.00	232.33	238.70	97.56	100.57
N.P.K Recommended	324..66	317.59	237.00	229.93	99.44	95.00
C.D. (p=0.05)	3.86	4.87	6.78	6.78	2.71	0.91

Interaction between Puddling vs Irrigation (Tillers/m^2, Panicles/m^2 and Grains/panicle) are significant

Interaction between Puddling vs Nutrients (Tillers/m^2) are Significant

*** Days after disappearance of ponded water ** Soil matric potential**

Among the different nutrient sources, during 2005-06, the application of N, P and K (inorganic fertilizer) at recommended levels resulted in significant increase in number of grains/panicle than application of vermicompost @ 3 t/ha + inorganic fertilizer and Vermicompost @ 6 t/ha were at par with application of FYM+inorganic fertilizers (50% each). However during 2006-07, application of vermicompost @ 6 t/ha increase the number of grains/panicle significantly than application of FYM+inorganic fertilizers (50% each), vermicompost @ 3t/ha+inorganic fertilizer and recommended N, P, K through chemical fertilizer.

4.2.4 Interaction effect

The interaction between different intensities of puddling and irrigation scheduling on number of tillers/m^2, number of panicles/m^2 and number of grains/panicle (Table: 4.4) at harvest was found to be significant during both the years.

Significantly more number of tillers/m^2 was recorded with 3 times puddling at different schedules of irrigation except SMP at 150 cm suction, where it was found to be at par with two times puddling intensity but significantly different than normal practice during both the year. Similarly irrigation schedule with SMP at 150 cm suction at varying puddling intensities resulted in significant increase in number of tillers/m^2 during both the years, when irrigation at 4 DADPW was applied.

Significantly more number of panicles/m^2 was observed at 3 times puddling intensity at varying irrigation schedule, 3 and 2 times puddling intensities (both being at par with each other). At different puddling intensities number of panicles was found to be

Table: 4.4. Interaction effect of puddling intensities and irrigation scheduling on number of tillers/m^2, number of panicles/m^2 and number of grains/panicle of rice during 2005-06 and 2006-07.

Treatments	2005-06			2006-07		
	Irrigation scheduling					
	2 DADPW*	4 DADPW	SMP** 150	2 DADPW	4 DADPW	SMP 150
Puddling intensity	Number of tillers/m^2					
Normal practice	316.25	312.00	315.92	326.50	322.25	326.17
2 times puddling	314.25	310.75	322.50	324.50	321.00	332.75
3 times puddling	322.58	322.17	322.75	334.42	334.08	334.67
CD at 0.05%		4.38			4.88	
	Number of panicles/m^2					
Normal practice	216.00	221.50	232.50	221.25	226.75	237.75
2 times puddling	228.75	230.00	237.25	234.00	235.25	242.50
3 times puddling	246.50	229.75	234.75	251.75	235.00	243.33
CD at 0.05%		7.29			6.81	
	Number of grains/panicle					
Normal practice	93.25	97.50	96.00	95.75	100.00	98.50
2 times puddling	96.75	93.00	96.50	99.25	95.50	99.00
3 times puddling	100.50	98.25	98.75	100.50	100.75	101.25
CD at 0.05%		1.66			1.44	

*** Days after disappearance of ponded water ** Soil matric potential**

more during 2005-06. However, during 2006-07 3 times puddling produced more number of panocles/m^2 when irrigation schedule SMP at 150 cm suction.

Number of grains/panicle during 2005-06 as well as 2006-07 puddling intensity at 3 times significantly more number of grains/panicle with irrigation schedule SMP at 150 cm suction 2 DADPW but at par with 4 DADPW, 2 times puddling at SMP at 150 cm suction and 2 DADPW was found to be at par but significantly superior than 4 DADPW but at normal practice of puddling SMP at 150 cm suction and 4 DADPW was found to be at par but significantly superior than 2 DADPW. Similarly irrigation schedule applied at 2 DADPW increased the number of grains/panicle significantly over normal practice and 2 times puddling intensity where as the irrigation schedule applied at 4 DADPW did not show any significant increase in number of grains/panicle over the normal practice, although the increase was significant over the 2 time puddling intensity. But the irrigation applied at SMP at 150 cm suction did not show any significant increase in number of grains/panicle at different puddling intensities.

The interaction between different intensities of puddling and nutrient sources on number of tillers/m^2 (Table: 4.5) at harvest was found to be significant during both the years. During both the years puddling intensity at 3 times puddling at varying levels of nutrient sources increased the number of tillers/m^2 of rice significantly than 2 times puddling and normal practice of puddling and were at par with each other. Similarly application of recommended dose of N, P and K (inorganic fertilizer) resulted in significant increase in number of tillers/m^2 of rice at normal practice and 2 times puddling but FYM + inorganic fertilizer (50%each) was found to be at par with N, P, and

Table: 4.5. Interaction effect of puddling intensities and nutrient sources on number of tillers/m^2 of rice during 2005-06 and 2006-07.

Treatments	Nutrient sources							
	2005-06				2006-07			
	Vermicompost 3t/ha+ inorganic fertilizer	Vermicompost @ 6t/ha	FYM+In-organic fertilizer(50 % each)	N.P.K Recommended	Vermicompost 3t/ha+ inorganic fertilizer	Vermicompost @ 6t/ha	FYM+In-organic fertilizer(50 % each)	N.P.K Recommended
Puddling intensity	Number of tillers/m^2							
Normal practice	310.00	302.89	321.00	325.00	327.00	332.00	333.00	307.89
2 times puddling	311.00	312.67	317.33	322.33	321.33	337.33	329.67	316.00
3 times puddling	321.00	317.56	324.78	326.68	329.44	339.89	339.33	328.89
CD at 0.05% fixed puddling and varying irrigation			3.42				3.81	
CD at 0.05% fixed irrigation and varying irrigation			4.78				6.03	

K at recommended dose and vermicompost @ 3t/ha+inorganic fertilizers at 3 times puddling and significantly superior than vermicompost @ 6t/ha during 2005-06. However, during 2006-07 vermicompost @ 6t/ha resulted in more number of tillers/m^2 at 2 and 3 times puddling over N, P and K at recommended dose and FYM + inorganic fertilizer (50%each) but at par with vermicompost @ 3t/ha + inorganic fertilizers, significant difference among the nutrient sources at normal practice of puddling.

4.2.5 Grain weight per panicle

Different levels of irrigation and nutrient sources increased the grain weight/ panicle significantly during 2005-06 and 2006-07 respectively where as different levels of puddling did not produce in increasing the grain weight/panicle of rice. (Table: 4.6 and Appendix-IV). In general the grain weight/ panicle was higher during 2006-07 than the year 2005-06.

Scheduling of irrigation through SMP at 150 cm suction increased the grain weight/panicle of rice crop significantly than irrigation at 4 DADPW but was found to at par with application at 2 DADPW during 2005-06 and 2006-07, respectively.

Among the nutrient sources, during 2005, application of N, P and K (inorganic fertilizer) at recommended dose resulted in significant increase in grain weight/panicles than application of vermicompost @ 6t/ha but was found to be at par with application of FYM+inorganic fertilizers (50% each) and vermicompost @ 3t/ha+inorganic fertilizer. However, during 2006-07, application of vermicompost @ 6t/ha was found to at par with application of FYM+inorganic fertilizers (50% each) increased the grain weight/panicle of rice crop significantly than vermicompost @ 3t/ha+inorganic fertilizers and N, P and K at recommended dose.

4.2.6 1000-grain weight

Irrigation scheduling and varying nutrient sources increased the 1000-grain weight of rice crop significantly whereas, non-significant difference was observed under different puddling intensity treatments (Table: 4.6 and Appendix-IV) 1000-grain weight was comparatively higher during 2006-07.

Among the different irrigation treatments, irrigation SMP at 150 cm suction increased the 1000-grain weight of rice crop significantly than irrigation at 2 and 4 DADPW during 2005-06. Though similar trend was observed in 2006-07.

Among different nutrient sources, during 2005-06, application of N, P and K (inorganic fertilizer) at recommended dose was at par with application of FYM+inorganic fertilizers (50% each) resulted in significant increase in 100-grain weight of rice crop than application of vermicompost @ 3t/ha+inorganic fertilizers and application of vermicompost @ 6t/ha. However, during second year of experimentation, application of FYM+inorganic fertilizers (50% each) though at par with application of vermicompost @ 3t/ha+inorganic fertilizers and application of vermicompost @ 6t/ha increased the 1000-grain weight of rice crop significantly than application of N, P and K at recommended dose.

4.2.7 Interaction effect

The interaction between different intensities of puddling and irrigation scheduling on grain weight/panicle (Table: 4.7) at harvest was found to be significant during both the

Table: 4.6. Effect of various treatments on grain weight /panicle and 1000-grain weight (g) of rice in rice-wheat cropping system

Treatments	Grain weight/panicle (g)		1000-grain weight (g)	
	2005-06	2006-07	2005-06	2006-07
Puddling intensity				
Normal practice	1.94	1.96	21.59	21.77
2-times puddling	1.95	1.97	21.69	21.87
3-times puddling	1.96	1.98	21.81	21.99
C.D. (p=0.05)	N.S	N.S	N.S	N.S
Irrigation scheduling				
2 DADPW*	1.95	1.97	21.37	21.96
4 DADPW	1.92	1.94	21.12	21.42
SMP** at 150 cm suction	1.99	2.00	22.61	22.25
C.D. (p=0.05)	0.05	0.05	0.63	0.63
Nutrient sources				
Vermicompost 3t/ha+inorganic fertilizer	1.94	1.94	21.52	21.83
Vermicompost @ 6t/ha	1.92	2.01	21.34	22.31
FYM + In-organic fertilizer(50% each)	1.97	1.99	21.90	21.85
N.P.K Recommended	1.98	1.93	22.02	21.54
C.D. (p=0.05)	0.04	0.04	0.62	0.63

Interaction between Puddling vs. Irrigation (Grain weight/panicle) are significant

*** Days after disappearance of ponded water, ** Soil matric potential**

Table: 4.7. Interaction effect of puddling intensities and irrigation scheduling on grain weight per panicle of rice during 2005-06 and 2006-07.

Treatments	2005-06			2006-07		
	Irrigation scheduling					
	2 DADPW*	4 DADPW	SMP** 150	2 DADPW	4 DADPW	SMP 150
Puddling intensity	Grain weight/panicle					
Normal practice	1.84	2.06	1.93	1.85	2.08	1.95
2 times puddling	1.91	1.87	2.08	1.93	1.88	2.09
3 times puddling	2.10	1.84	1.95	2.11	1.86	1.97
CD at 0.05%		0.081			0.086	

* Days after disappearance of ponded water, ** Soil matric potential

years. Significantly higher grain weight/ recorded with 3 times puddling at irrigation schedule 2 DADPW and SMP at 150 cm suction over 4 DADPW but at par with each other, 2 times puddling was significantly increase in grain weight/panicle with irrigation schedule SMP at 150 cm suction over 2 and 4 DAPDW but was found to be at par with each other but at normal practice of puddling significantly more grain weight/panicle was recorded over varying levels of irrigation. Similarly irrigation schedule applied at 2 DADPW increased the Grain weight/ panicle significantly at three times puddling over normal practice and 2 times puddling intensity. At 4 DADPW puddling intensity at normal practice increased the grain weight/ panicle over 2 times and 3 times puddling intensities which were at par with each other. The irrigation applied at SMP at 150 cm suction revealed a significant increase in grain weight/ panicle at 2 times puddling intensity over normal as well as 3 time puddling intensities.

4.2.8 Grain and Straw yield

The mean data on grain yield revealed that different levels of puddling, irrigation scheduling and nutrient sources significantly increased the grain and straw yield of rice during both the years of cropping seasons (Table: 4.8, Fig: 4.2 and Appendix-IV). However, higher total yield (grain and straw) was recorded during 2005-06 and 2006-07, respectively.

Three times of puddling was found to increase the grain and straw yield of rice significantly than with puddling two times and normal practice during 2005-06 and 2006-07. Irrigation scheduling at SMP at 150 cm suction brought significant increase in grain and straw yield than irrigation at 2 and 4 DADPW.

Among the different nutrient sources during 2005-06, grain and straw yield of rice were significantly higher with application of recommended dose of N, P and K (inorganic fertilizer) as compared to application of FYM+inorganic fertilizer (50%each), application of vermicompost @ 3t/ha+inorganic fertilizers and application of vermicompost @ 6t/ha. However, during 2006-07 maximum grain and straw yield were recorded in plots supplied with vermicompost @ 6t/ha but was found to be significantly higher than FYM + inorganic fertilizer (50%each), vermicompost @ 3t/ha + inorganic fertilizers and recommended dose of N, P and K (inorganic fertilizer).

4.2.9 Harvest Index.

The data on harvest index revealed that harvest index was affected significantly by puddling intensity, irrigation scheduling and different nutrient sources (Table: 4.8 and Appendix-VI).

Puddling intensity with three times puddling was found to be significantly increased in harvest index of rice than with puddling two times and normal practice during 2005-06 and 2006-07. Irrigation scheduling at SMP at 150 cm suction brought significant increase in harvest index of rice than irrigation at 2 and 4 DADPW.

Among the different nutrient sources during 2005-06, harvest index of rice were significantly higher with application of recommended dose of N, P and K (inorganic fertilizer) as compared to application of FYM+inorganic fertilizer (50%each), application of vermicompost @ 3t/ha+inorganic fertilizers and application of vermicompost @ 6t/ha. However during 2006-07 non significant difference in harvest index was observed among different nutrient sources but maximum harvest index were recorded in plots supplied

Table: 4.8. Effect of various treatments on grain yield (q/ha), straw yield (q/ha) and harvest index (%) of rice in rice-wheat cropping system

Treatments	Grain yield (q/ha)		Straw yield (q/ha)		Harvest Index (%)	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Puddling intensity						
Normal practice	41.94	43.60	60.76	62.83	59.12	59.01
2-times puddling	42.52	44.15	11.80	63.88	59.21	59.12
3-times puddling	43.72	45.34	64.01	66.09	59.38	59.29
C.D. (p=0.05)	0.41	0.41	0.67	0.60	0.17	0.15
Irrigation scheduling						
2 DADPW*	42.39	44.04	61.27	63.67	59.06	59.10
4 DADPW	42.07	43.69	61..21	62.96	59.23	59.01
SMP** at 150 cm suction	43.73	45.35	64.10	66.17	59.41	59.31
C.D. (p=0.05)	0.41	0.41	0.67	0.60	0.17	0.15
Nutrient sources						
Vermicompost 3t/ha+inorganic fertilizer	42.51	44.06	61.45	63.53	59.08	59.03
Vermicompost @ 6t/ha	41.75	45.56	59.91	66.57	58.89	59.36
FYM+In-organic fertilizer (50% each)	43.02	44.77	62.91	64.98	59.34	59.18
N.P.K Recommended	43.64	43.05	64.50	61.99	59.62	58.99
C.D. (p=0.05)	0.43	0.43	0.88	0.88	0.22	N.S

Interaction between Puddling vs Irrigation (Grain yield, straw yield) are significant

Interaction between Puddling vs Nutrients (Grain yield, straw yield) are Significant

*** Days after disappearance of ponded water ** Soil matric potential**

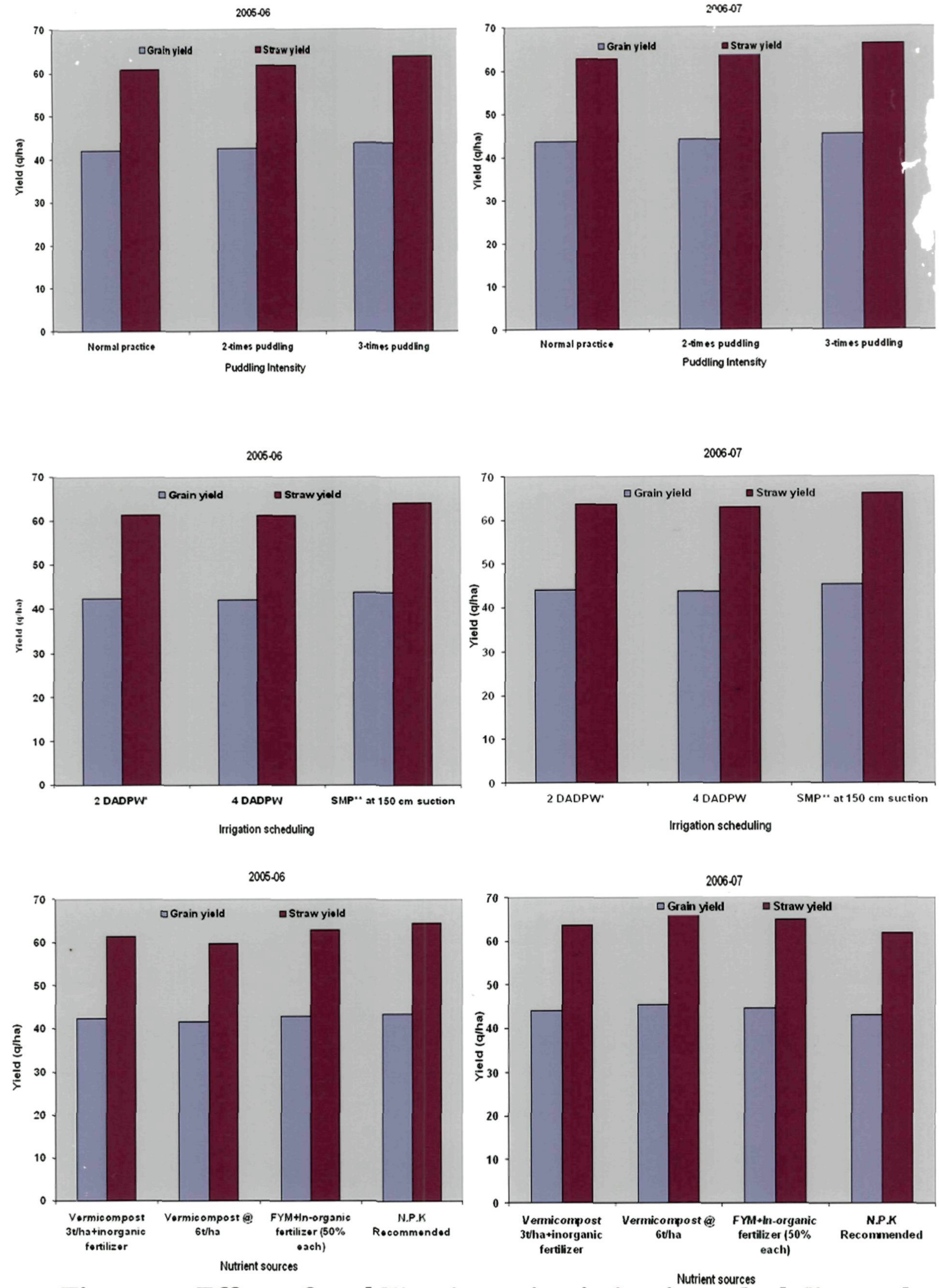


Fig:- 4.2. Effect of puddling intensity, irrigation scheduling and nutrient sources on grain and straw yield (q/ha) of rice

with vermicompost @ 6t/ha followed by FYM + inorganic fertilizer (50%each), vermicompost @ 3t/ha + inorganic fertilizers and recommended dose of N, P and K (inorganic fertilizer).

4.2.10 Interaction effect

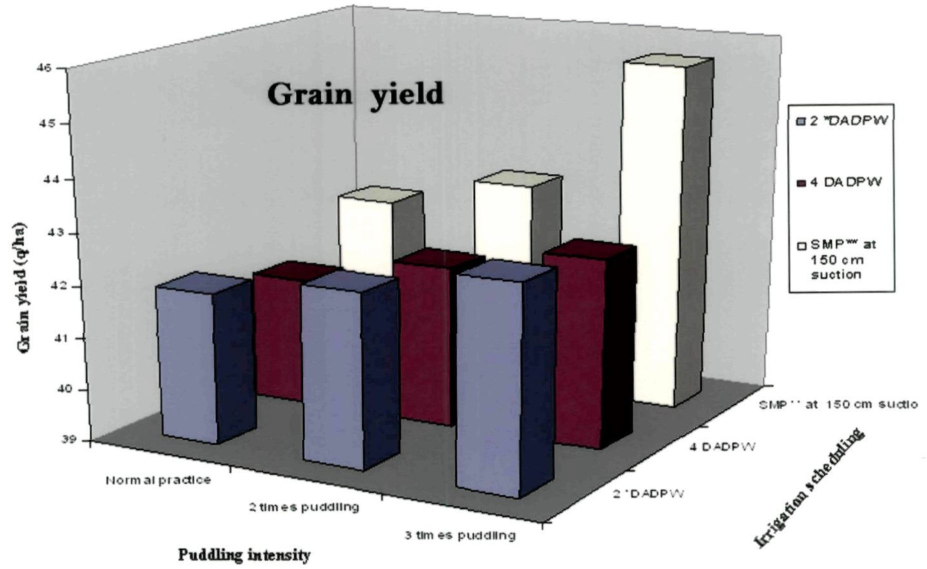
The interaction between different intensities of puddling and irrigation scheduling on grain and straw yield (Table: 4.9 and Fig - 4.3 and 4.3) at harvest was found to be significant during both the years. During 2005-06 puddling intensity at normal practice and at varying levels of irrigation scheduling increased the grain and straw yield of rice significantly. The irrigation applied at SMP at 150 cm suction resulted significant increase in grain and straw yield of rice at normal practice, 2 times puddling and 3 times puddling intensities over 2 and 4 DADPW. Similarly varying irrigation schedules applied at 2 DADPW, 4 DADPW and SMP applied at 150 cm suction also increased the grain and straw yield of rice significantly under varying puddling intensities. At 2 DADPW and 4 DADPW puddling intensity at 2 times and 3 times though at par with each other produced significantly higher grain and straw yield over normal practice. But at SMP at 150 cm suction and 3 times puddling intensity increased the grain and straw yield of rice significantly over normal practice and 2 times puddling intensity. Similar results were observed during 2006-07 also at irrigation schedules applied at 2 and 4 days after disappearance of ponded water with varying puddling intensities, but at SMP at 150cm suction three times puddling increased the grain and straw yield significantly over normal practice and 2 times puddling, which were at par with each other.

Table: 4.9. Interaction effect of puddling intensities and irrigation scheduling on number of grain and straw yield of rice during 2005-06 and 2006-07.

Treatments	2005-06			2006-07		
	Irrigation scheduling					
	2 DADPW*	4 DADPW	SMP** 150	2 DADPW	4 DADPW	SMP 150
Puddling intensity	Grain yield(q/ha)					
Normal practice	41.91	41.48	42.45	43.62	43.10	44.07
2 times puddling	42.33	42.10	43.10	43.99	43.72	44.73
3 times puddling	42.90	42.62	45.63	44.51	44.25	47.26
CD at 0.5%		0.71			0.71	
	Straw yield(q/ha)					
Normal practice	59.81	60.79	61.67	62.87	61.89	63.74
2 times puddling	61.50	61.00	62.91	63.58	63.08	64.99
3 times puddling	62.50	61.83	67.71	64.57	63.91	69.79
CD at 0.5%		1.17			1.05	

*** Days after disappearance of ponded water   ** Soil matric potential**

2005-06



2005-06

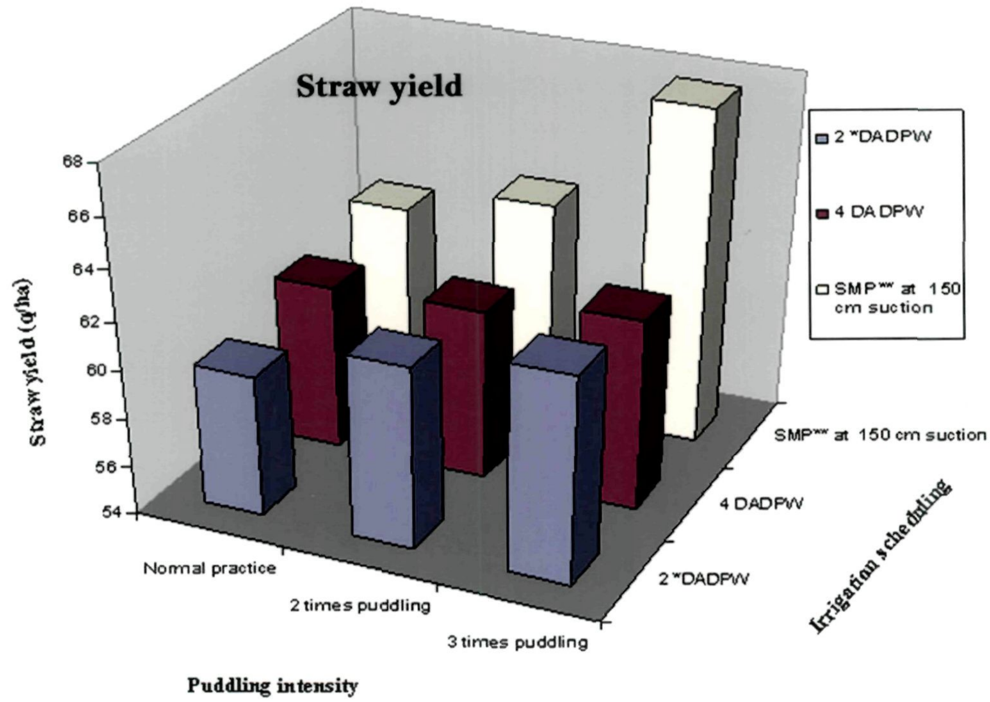
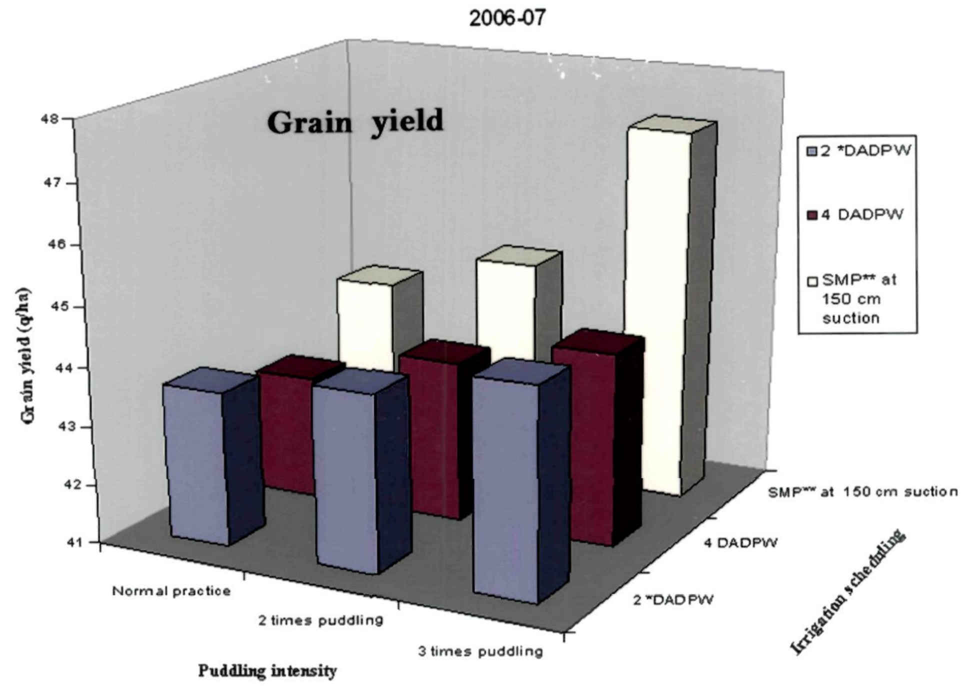


Fig:- 4.3 Interaction effect of puddling intensity and irrigation scheduling on grain and straw yield (q/ha) of rice (2005-06)



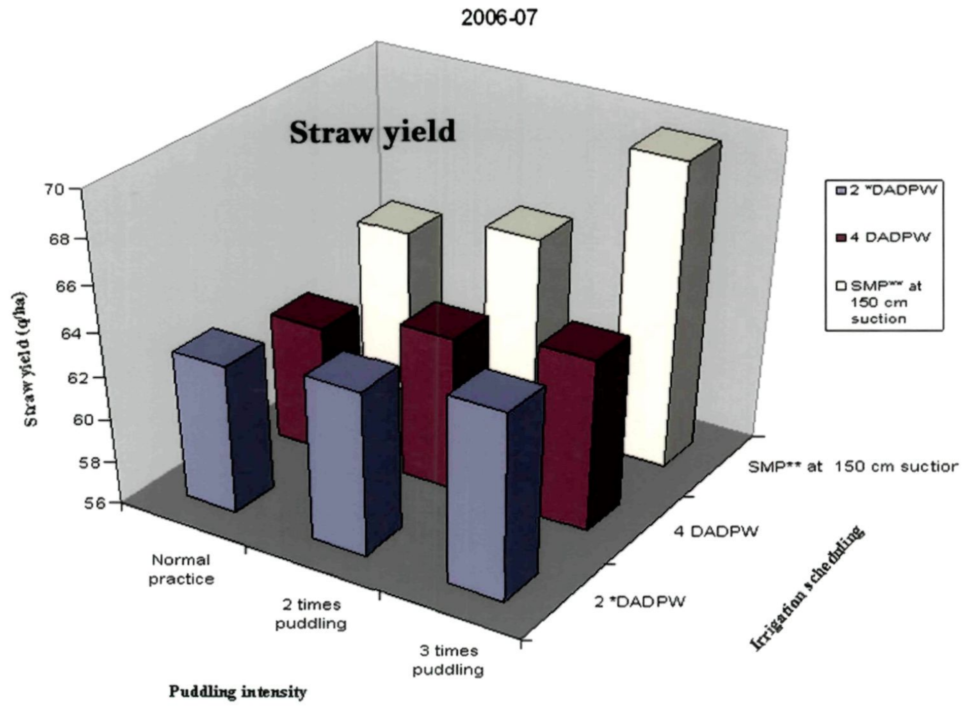


Fig:- 4.4 Interaction effect of puddling intensity and irrigation scheduling on grain and straw yield (q/ha) of rice (2006-07)

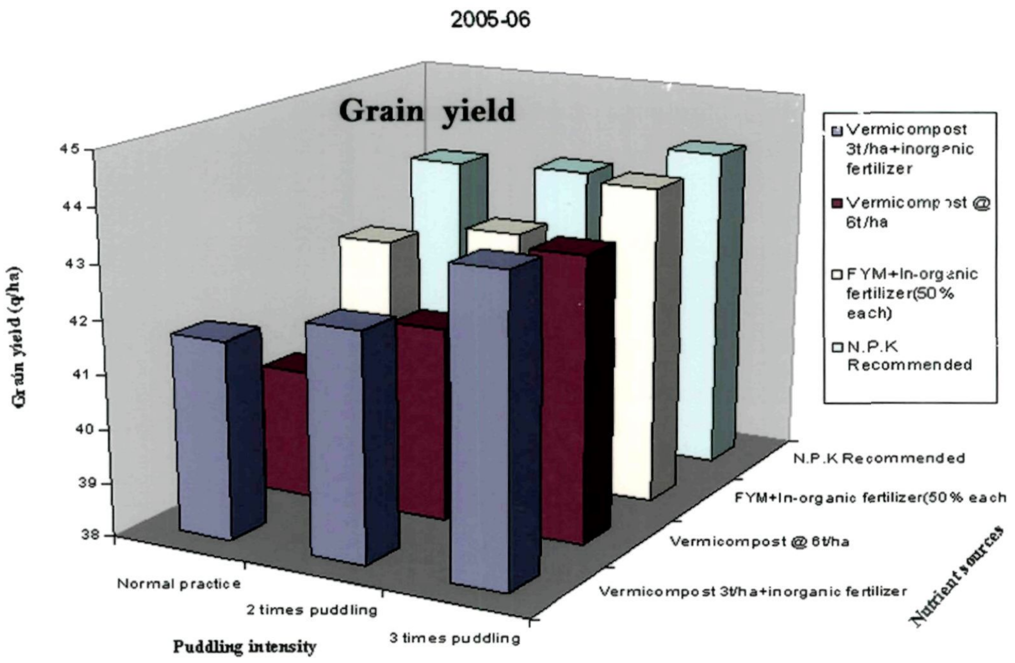
The interaction between different intensities of puddling and different nutrient sources on grain and straw of rice (Table 4.10 and Fig-4.5 and 4.6) at harvest was found to be significant during both the years. Three times puddling at varying levels of nutrient sources increased the grain and straw yield of rice significantly than 2 times puddling and normal practice of puddling except N, P and K at recommended dose (inorganic fertilizer) where normal practice of puddling and 2 times puddling were found to be at par with each other. However, during 2006-07. Three times puddling at varying levels of nutrient sources increased the grain and straw yield of rice significantly than 2 times puddling and normal practice of puddling both were at par with each other. Similarly application of recommended dose of N, P and K (inorganic fertilizer) resulted in significant increase in grain and straw yield of rice at normal practice, 2 times puddling and 3 times puddling intensities over application of FYM+inorganic fertilizer (50%each), vermicompost @ 3t/ha+inorganic fertilizers and vermicompost @ 6t/ha. However during 2006-07, application of vermicompost @ 6t/ha resulted significant increase in grain and straw yield of rice at normal practice, 2 times puddling and 3 times puddling intensities over FYM + inorganic fertilizer (50%each), application of vermicompost @ 3t/ha+inorganic fertilizers and N, P and K (inorganic fertilizer).

4.2.11 Nutrient uptake of rice.

The data on nutrient uptake (Kg/ha) on rice revealed that irrigation scheduling and nutrient sources significantly increased the N, P and K uptake of grain and straw in rice crop where as non-significant difference was observed with different levels of puddling during 2005-06 and 2006-07. (Table: 4.11 and Appendix-V).

Table:4.10. Interaction effect of puddling intensities and nutrient sources on number of grain and straw yield of rice during 2005-06 and 2006-07.

Treatments	Nutrient sources							
	2005-06				2006-07			
	Vermicompost 3t/ha+ inorganic fertilizer	Vermicompost @ 6t/ha	FYM+In-organic fertilizer(50 % each)	N.P.K Recommended	Vermicompost 3t/ha+ inorganic fertilizer	Vermicompost @ 6t/ha	FYM+In-organic fertilizer(50 % each)	N.P.K Recommended
Puddling intensity	Grain yield (q/ha)							
Normal practice	41.68	40.39	42.32	43.39	43.34	45.29	44.07	41.69
2 times puddling	42.23	41.60	42.80	43.46	43.73	45.36	44.60	42.90
3 times puddling	43.61	43.27	43.93	44.07	45.11	46.05	45.63	44.57
CD at 0.5% fixed puddling and varying irrigation		0.55				0.56		
CD at 0.5% fixed irrigation and varying irrigation		0.52				0.52		
	Straw yield (q/ha)							
Normal practice	60.28	57.13	61.65	63.97	62.36	66.05	63.73	59.10
2 times puddling	60.45	60.00	62.67	64.10	62.52	66.18	64.74	62.08
3 times puddling	63.63	62.60	64.40	65.42	65.70	67.50	66.48	64.68
CD at 0.5% fixed puddling and varying irrigation		0.91				1.09		
CD at 0.5% fixed irrigation and varying irrigation		0.82				1.10		



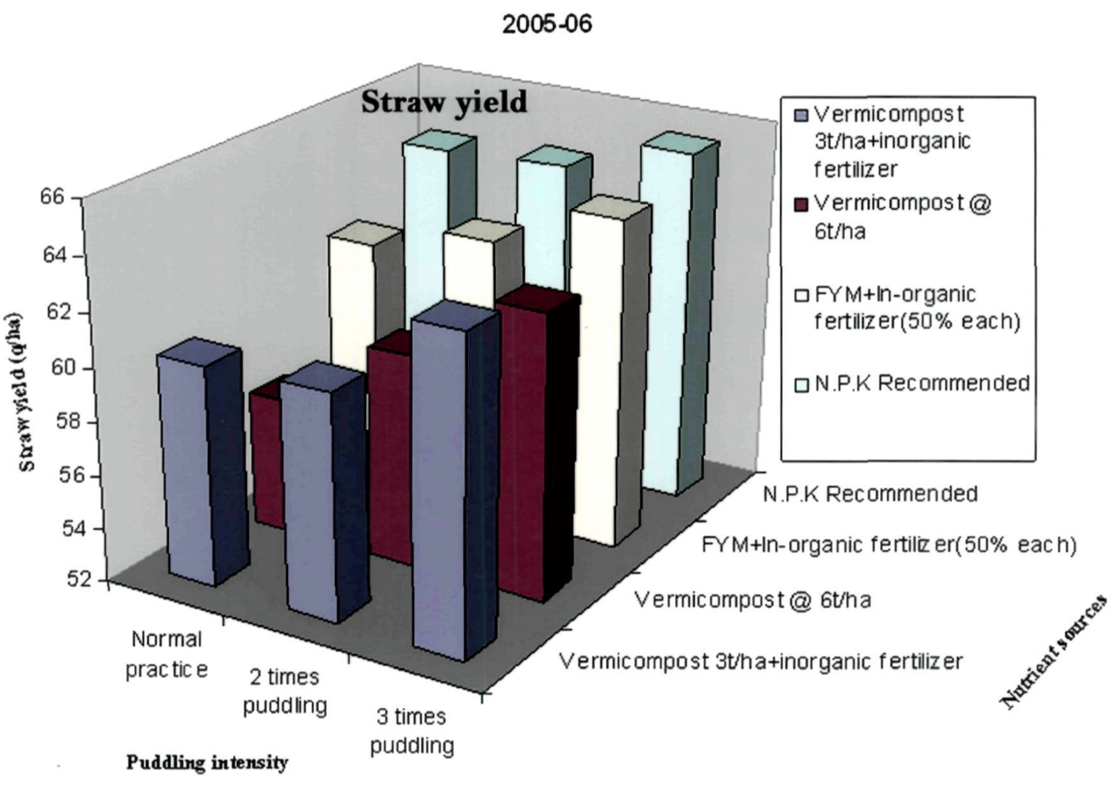
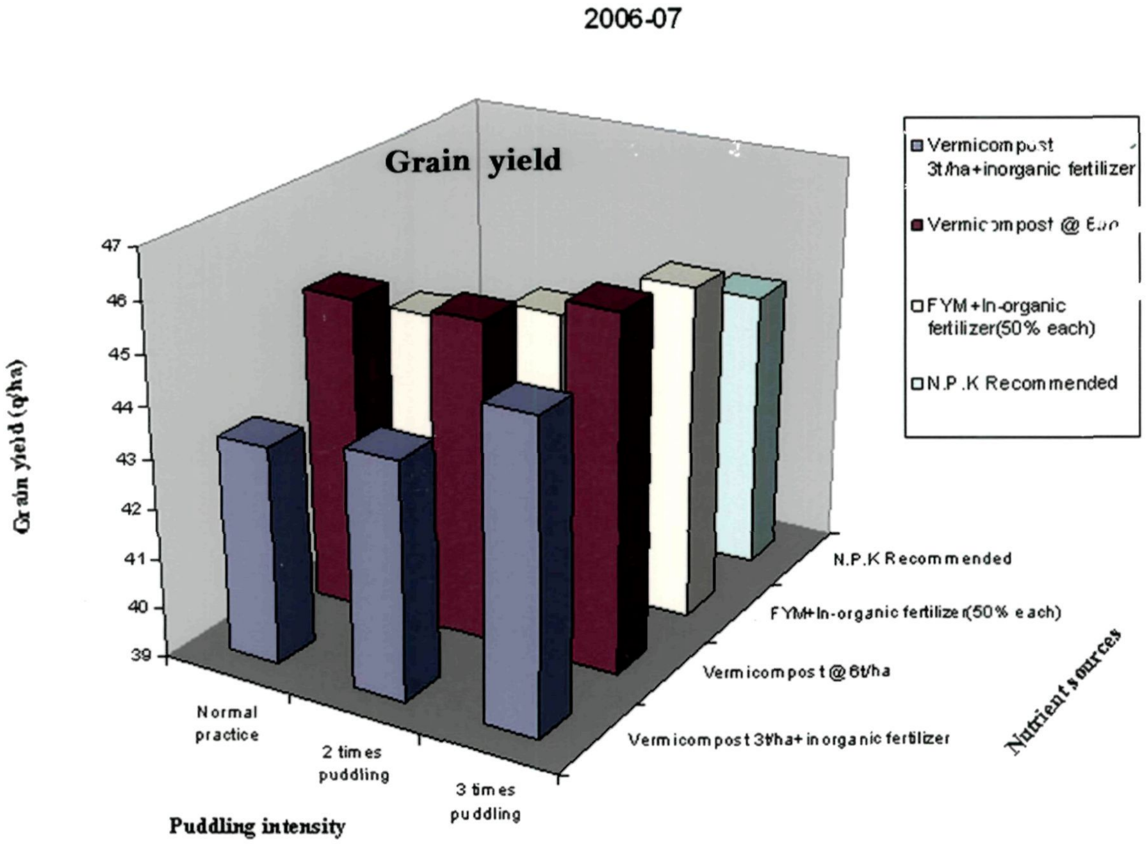


Fig:- 4.5 Interaction effect of puddling intensity and nutrient sources on grain and straw yield (q/ha) of rice (2005-06)



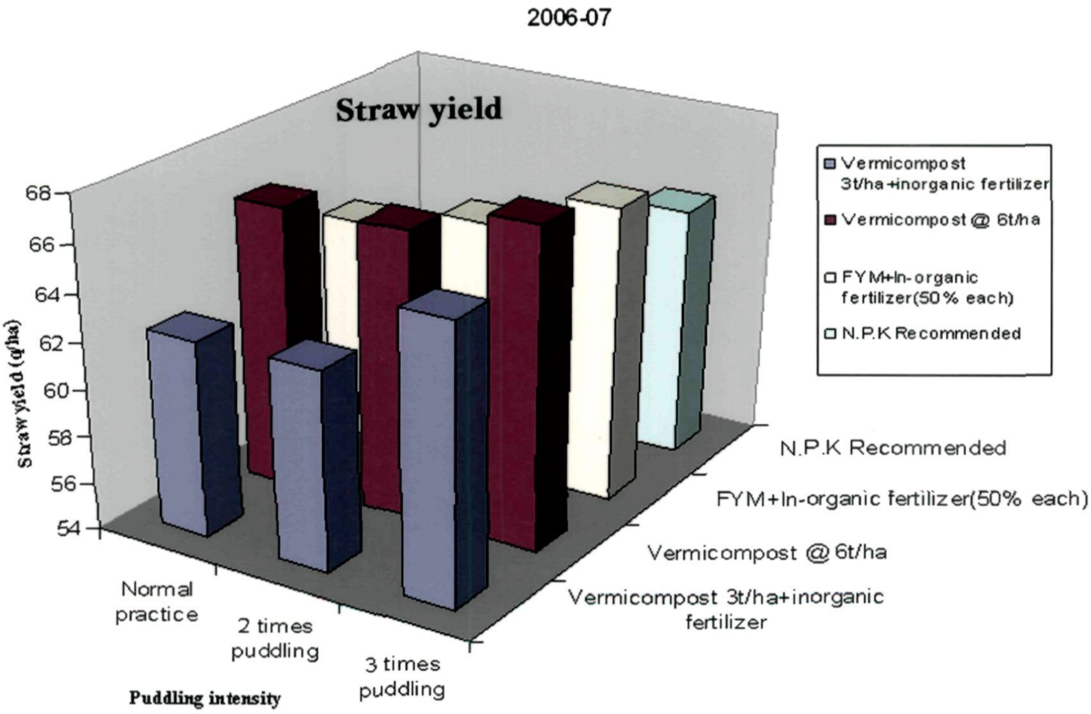


Fig:- 4.6 Interaction effect of puddling intensity and irrigation scheduling on grain and straw yield (q/ha) of rice (2006-07)

Table: 4.11. Effect of various treatments on nutrient uptake (Kg/ha) of rice in rice-wheat cropping system

Treatments	2005-06						2006-07					
	Grain			Straw			Grain			Straw		
	N	P	K	N	P	K	N	P	K	N	P	K
Puddling intensity												
Normal practice	71.82	14.38	21.26	28.45	4.26	85.21	72.65	14.78	21.65	29.07	4.28	86.70
2-times puddling	71.90	14.40	21.32	28.51	4.27	85.90	72.73	14.80	21.71	29.12	4.29	86.78
3-times puddling	71.99	14.41	21.35	28.81	4.29	85.99	72.82	14.81	21.70	29.43	4.32	86.87
C.D. (p=0.05)	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
Irrigation scheduling												
2 DADPW*	72.09	14.46	21.37	28.94	4.28	86.09	72.92	14.87	21.75	29.56	4.29	86.97
4 DADPW	71.37	14.26	21.09	27.87	4.22	85.37	72.20	14.66	21.47	28.49	4.24	86.25
SMP** at 150 cm suction	72.43	14.47	21.47	28.95	4.32	86.25	73.08	14.86	21.83	29.57	4.35	87.13
C.D. (p=0.05)	0.42	0.13	0.25	0.57	0.02	0.08	0.65	0.18	0.22	0.69	0.05	0.25
Nutrient sources												
Vermicompost 3t/ha+inorganic fertilizer	71.67	14.38	21.24	28.47	4.25	85.67	72.00	14.58	21.47	28.74	4.28	86.07
Vermicompost @ 6t/ha	71.31	14.31	21.07	28.12	4.21	85.31	73.91	15.08	22.02	30.04	4.36	87.78
FYM+In-organic fertilizer (50% each)	72.06	14.43	21.38	28.73	4.30	86.06	73.06	14.90	21.84	29.40	4.32	87.13
N.P.K Recommended	72.58	14.48	21.56	29.04	4.32	86.58	71.97	14.64	21.40	28.65	4.21	86.17
C.D. (p=0.05)	0.57	0.09	0.11	0.23	0.02	0.83	0.71	0.14	0.18	0.28	0.06	0.89

*** Days after disappearance of ponded water   ** Soil matric potential**

Among different irrigation scheduling SMP at 150 cm suction though at par with irrigation at 2 DADPW significantly increased the N, P and K uptake in grain and straw of rice than the irrigation at 4 DADPW during 2005-06 and 2006-07.

Among the different nutrient sources recommended dose of N, P and K (Inorganic) increased the N, P, and K uptake in grain and straw during 2005-06 than the FYM + Inorganic fertilizer (50% each), Vermicompost @ 3t/ha+inorganic fertilizer and Vermicompost applied @ 6t/ha. However during 2006-07, Vermicompost @ 6t/ha significantly increased the N, P, and K uptake in both grain and straw than FYM + Inorganic fertilizer (50% each), Vermicompost @ 3t/ha + inorganic fertilizer and recommended N, P, and K (Inorganics).

4.3 Soil studies

4.3.1 Soil moisture before pre irrigation for puddling of rice

The data presented in Table: 4.12 revealed that soil moisture increased with the depth of soil profile and all have differential effect on the soil moisture status. Moisture content (cm) in the soil profile the treatments (60-90 cm) was highest as compared with soil moisture at 0-15 cm, 15-30 cm and 30-60cm soil profile.

Among the soil moisture before pre irrigation for puddling of rice there is a slight difference in moisture content among the different levels of puddling intensity, irrigation scheduling and nutrient sources during 2005-06.

During 2006-07, Puddling intensity with 3 times puddling increase the soil moisture (cm) at 0-15 cm, 15-30 cm and 30-60 cm soil profile than 2 times puddling and

Table: 4.12. Effect of various treatments on soil moisture (cm) before pre irrigation for puddling of rice in rice-wheat cropping system

Treatments	Soil profile (cm)							
	2005-06				2006-07			
	0-15	15-30	30-60	60-90	0-15	15-30	30-60	60-90
Puddling intensity								
Normal practice	0.811	0.950	1.851	2.336	0.782	1.028	2.003	2.399
	(3.40)	(3.77)	(4.14)	(5.19)	(3.28)	(4.08)	(4.48)	(5.33)
2-times puddling	0.816	0.961	1.875	2.347	0.828	1.040	2.029	2.410
	(3.40)	(3.77)	(4.14)	(5.18)	(3.45)	(4.08)	(4.48)	(5.32)
3-times puddling	0.826	0.967	1.880	2.351	0.919	1.047	2.029	2.414
	(3.40)	(3.77)	(4.15)	(5.19)	(3.78)	(4.08)	(4.48)	(5.33)
Irrigation scheduling								
2 DADPW*	0.806	0.944	1.917	2.402	0.910	1.025	2.070	2.453
	(3.40)	(3.77)	(4.15)	(5.20)	(3.84)	(4.09)	(4.48)	(5.31)
4 DADPW	0.826	0.967	1.863	2.327	0.770	1.047	2.016	2.399
	(3.40)	(3.77)	(4.14)	(5.17)	(3.17)	(4.08)	(4.48)	(5.33)
SMP** at 150 cm suction	0.821	1.001	1.838	2.289	0.845	1.083	1.989	2.355
	(3.40)	(3.77)	(4.14)	(5.19)	(3.50)	(4.08)	(4.48)	(5.34)
Nutrient sources								
Vermicompost 3t/ha+inorganic fertilizer	0.826	0.963	1.867	2.335	0.782	0.954	1.863	2.376
	(3.42)	(3.78)	(4.15)	(5.19)	(3.24)	(3.74)	(4.14)	(5.28)
Vermicompost @ 6t/ha	0.811	0.955	1.863	2.335	0.780	1.209	2.327	2.484
	(3.40)	(3.77)	(4.14)	(5.19)	(3.27)	(4.77)	(5.17)	(5.52)
FYM+In-organic fertilizer (50% each)	0.823	0.961	1.863	2.319	0.908	1.086	2.097	2.418
	(3.41)	(3.77)	(4.14)	(5.19)	(3.76)	(4.26)	(4.66)	(5.41)
N.P.K Recommended	0.821	0.964	1.892	2.382	0.664	0.913	1.806	2.336
	(3.40)	(3.76)	(4.15)	(5.19)	(2.75)	(3.56)	(3.96)	(5.09)

*** Days after disappearance of ponded water ** Soil matric potential**
Figures in parentheses are percent values of soil moisture

normal practice, whereas puddling at 30-60 cm resulted in highest soil moisture after 60-90 cm of soil profiles during both year of experimentation.

Among the irrigation levels, application of irrigation at 4 DADPW increased the soil moisture at 0-15 cm soil profile whereas, irrigation at 2 DADPW recorded highest soil moisture at 30-60 cm and 60-90 cm soil profile. Application of irrigation at SMP 150 cm suction recorded highest soil moisture at 15-30 cm soil profile during both the year of experimentation.

Among the nutrient sources, during 2005-06 N, P and K at recommended doses increased the soil moisture (cm) of rice crop at 0-15 cm, 30-60 cm and 60-90 cm of soil profile. However, during the second year of experimentation vermicompost @ 6t/ha resulted in increase in soil moisture statues at 15-30 cm, 30-60 cm and 60-90 cm soil profile.

4.3.2 Soil moisture after harvest of rice

The data presented in (Table: 4.13 and Fig- 4.7) and revealed that soil moisture increased with the depth of soil profile and all the treatments have differential effect on the soil moisture status. Moisture content (cm) in the soil profile (60-90 cm) was highest as compared with soil moisture at 0-15 cm, 15-30 cm and 30-60 cm soil profile.

Application of puddling 3 times increase the soil moisture (cm) at 0-15 cm, 15-30 cm, 30-60 cm and 60-90 cm soil profile than 2 times puddling and normal practice, Among the irrigation levels, application of irrigation at SMP 150 cm suction resulted in higher soil moisture status at 0-15 and 15-30 cm of soil profile whereas, irrigation at 2 DADPW recorded highest soil moisture at 30-60 cm and 60-90 cm soil profile.

Table: 4.13. Effect of various treatments on soil moisture (cm) after harvest of rice in rice-wheat cropping system

Treatments	Soil profile (cm)							
	2005-06				2006-07			
	0-15	15-30	30-60	60-90	0-15	15-30	30-60	60-90
Puddling intensity								
Normal practice	1.250	1.497	3.750	3.794	1.479	1.716	3.764	3.803
	(5.24)	(5.94)	(8.39)	(8.43)	(6.20)	(6.81)	(8.42)	(8.45)
2-times puddling	1.464	1.584	3.814	3.832	1.543	1.795	3.828	3.841
	(6.10)	(6.21)	(8.42)	(8.46)	(6.43)	(7.04)	(8.45)	(8.48)
3-times puddling	1.531	1.796	3.828	3.846	1.618	1.865	3.841	3.855
	(6.30)	(7.00)	(8.45)	(8.49)	(6.66)	(7.27)	(8.48)	(8.51)
Irrigation scheduling								
2 DADPW*	1.413	1.668	3.798	3.816	1.555	1.796	3.812	3.825
	(5.96)	(6.66)	(8.22)	(8.26)	(6.56)	(7.17)	(8.25)	(8.28)
4 DADPW	1.378	1.634	3.821	3.839	1.514	1.754	3.834	3.848
	(5.67)	(6.37)	(8.49)	(8.53)	(6.23)	(6.84)	(8.52)	(8.55)
SMP** at 150 cm suction	1.451	1.782	3.796	3.788	1.570	1.888	3.774	3.797
	(6.01)	(6.71)	(8.55)	(8.59)	(6.50)	(7.11)	(8.50)	(8.61)
Nutrient sources								
Vermicompost 3t/ha+inorganic fertilizer	1.386	1.642	3.776	3.789	1.427	1.663	3.785	3.794
	(5.74)	(6.44)	(8.39)	(8.42)	(5.91)	(6.52)	(8.41)	(8.43)
Vermicompost @ 6t/ha	1.472	1.742	3.870	3.911	1.798	2.066	3.897	3.924
	(6.17)	(6.87)	(8.60)	(8.69)	(7.54)	(8.15)	(8.66)	(8.72)
FYM+In-organic fertilizer (50% each)	1.435	1.693	3.834	3.835	1.688	1.913	3.852	3.840
	(5.94)	(6.64)	(8.52)	(8.58)	(6.99)	(7.50)	(8.56)	(8.59)
N.P.K Recommended	1.367	1.631	3.721	3.750	1.280	1.439	3.726	3.750
	(5.66)	(6.36)	(8.16)	(8.17)	(5.30)	(5.61)	(8.17)	(8.17)

*** Days after disappearance of ponded water ** Soil matric potential**
Figures in parentheses are percent values of soil moisture

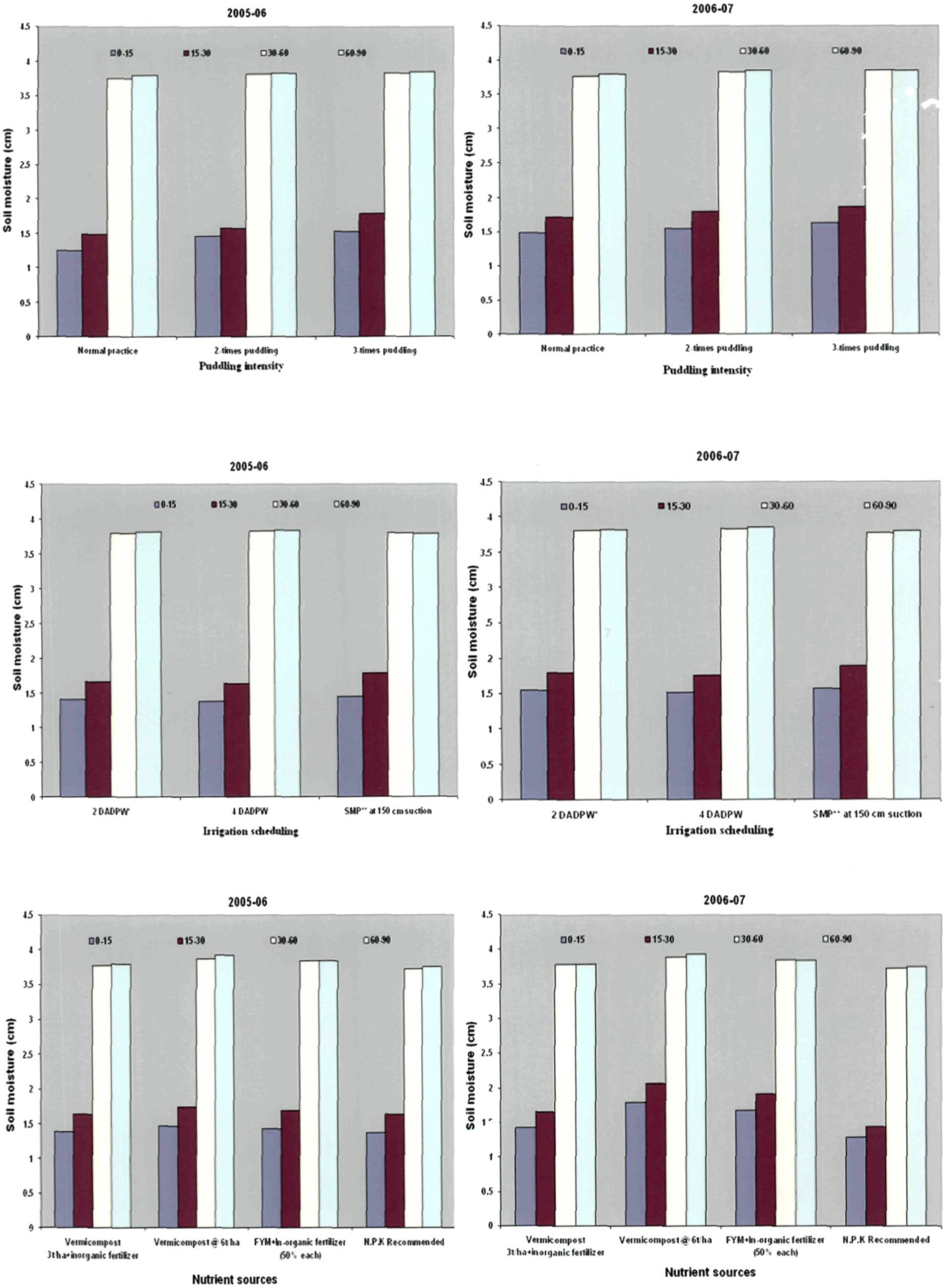


Fig:- 4.7 Effect of puddling intensity, irrigation scheduling and nutrient sources on soil moisture (cm) at harvest of rice crop

Among the nutrient sources, during 2005-06 and 2006-07 application of vermicompost @ 6t/ha increased the soil moisture (cm) of rice crop at 0-15 cm, 30-60 cm and 60-90 cm of soil profile. During the second of experimentation vermicompost @ 6t/ha resulted in increase in soil moisture statues at 0-15 cm, 15-30 cm, 30-60 cm and 60-90 cm soil profile.

4.3.3 Soil moisture before sowing of wheat

The data presented in Table: 4.14 and revealed that soil moisture increased with the depth of soil profile and all the treatments have differential effect on the soil moisture status. Moisture content (cm) in the soil profile (60-90 cm) was highest as compared with soil moisture at 0-15 cm, 15-30 cm and 30-60cm soil profile.

Puddling 3 times increase the soil moisture (cm) at 0-15 cm, 15-30 cm, 30-60 cm and 60-90 cm soil profile than 2 times puddling and normal practice during both the years of experimentation. Among the irrigation levels, application of irrigation at 2 DADPW resulted in higher soil moisture status at 0-15 cm of soil profile whereas, scheduling irrigation at SMP 150 cm suction recorded highest soil moisture at 15-30 cm soil profile (1.84 cm). Scheduling irrigation at DADPW resulted in higher soil moisture at 30-60 and 60-90 cm of soil profile.

Among the nutrient sources, during 2005-06 and 2006-07 application of vermicompost @ 6t/ha increased the soil moisture (cm) of rice crop at 0-15 cm, 15-30 cm, 30-60 cm and 60-90 cm of soil profile during the experimentation.

Table: 4.14. Effect of various treatments on soil moisture (cm) before sowing of wheat in rice-wheat cropping system

Treatments	Soil profile (cm)							
	2005-06				2006-07			
	0-15	15-30	30-60	60-90	0-15	15-30	30-60	60-90
Puddling intensity								
Normal practice	1.228	1.499	3.652	3.654	1.235	1.504	3.679	3.663
	(5.15)	(5.59)	(8.17)	(8.12)	(5.18)	(5.97)	(8.23)	(8.14)
2-times puddling	1.442	1.589	3.715	3.692	1.450	1.696	3.742	3.701
	(6.01)	(6.23)	(8.20)	(8.15)	(6.04)	(6.04)	(8.26)	(8.17)
3-times puddling	1.509	1.752	3.728	3.706	1.516	1.757	3.755	3.715
	(6.21)	(6.83)	(8.23)	(8.18)	(6.24)	(6.24)	(8.29)	(8.20)
Irrigation scheduling								
2 DADPW*	1.391	1.638	3.696	3.673	1.398	1.646	3.724	3.682
	(5.87)	(6.54)	(8.00)	(7.95)	(5.90)	(5.90)	(8.06)	(7.97)
4 DADPW	1.356	1.606	3.722	3.699	1.363	1.611	3.749	3.258
	(5.58)	(6.26)	(8.27)	(8.22)	(5.61)	(5.61)	(8.33)	(7.24)
SMP** at 150 cm suction	1.357	1.750	3.699	3.651	1.437	1.758	3.725	3.219
	(5.62)	(6.59)	(8.33)	(8.28)	(5.95)	(5.95)	(8.39)	(7.30)
Nutrient sources								
Vermicompost 3t/ha+inorganic fertilizer	1.364	1.614	3.672	3.650	1.374	1.619	3.699	3.659
	(5.65)	(6.33)	(8.16)	(8.11)	(5.69)	(5.69)	(8.22)	(8.13)
Vermicompost @ 6t/ha	1.450	1.714	3.794	3.767	1.460	1.719	3.821	3.780
	(6.08)	(6.76)	(8.43)	(8.37)	(6.12)	(6.12)	(8.49)	(8.40)
FYM+In-organic fertilizer (50% each)	1.413	1.596	3.735	3.688	1.420	1.670	3.767	3.697
	(5.85)	(6.26)	(8.30)	(8.25)	(5.88)	(5.88)	(8.37)	(8.27)
N.P.K Recommended	1.345	1.603	3.607	3.603	1.352	1.608	3.634	3.617
	(5.57)	(6.25)	(7.91)	(7.85)	(5.60)	(5.60)	(7.97)	(7.88)

*** Days after disappearance of ponded water ** Soil matric potential**
Figures in parentheses are percent values of soil moisture

4.3.4 Soil bulk density (Mg/m^3)

The data presented in (Table: 4.15and Appendix-VI) revealed a non-significant effect of puddling intensity, irrigation scheduling and nutrient sources on soil bulk density. However, soil bulk density increased with the advancement of depth in the soil profile from 0-15 to 15-30 cm, decreased from 15-30 to 30-60 cm soil depth and there after increased from soil profile of 60-90 cm depth.

4.3.5 Percolation rate (cm day^{-1})

The percolation rate (cm day^{-1}) was significantly affected by puddling intensity, irrigation scheduling and different nutrient sources during 2005-06 and 2006-07 (Table: 4.16, Fig-4.8 and Appendix-VI). Three times puddling decreased the percolation rate significantly than normal practice of puddling and two times puddling during both the years of experimentation. Among the different irrigation treatments, irrigation 4 DADPW decreased the percolation rate significantly than irrigation applied at 2 DADPW and SMP at 150 cm suction during both years of experimentation. Among different nutrient sources, application of vermicompost @ 6t/ha resulted in significant decrease in percolation rate than vermicompost @ 3t/ha + inorganic fertilizers, FYM + inorganic fertilizers (50% each) and the application of recommended dose of N, P and K (inorganics) during both years of experimentation.

4.3.6 Water expense

The data presented in Table: 4.17 and revealed that differential water regimes and treatments bring differences in water expense. Among the different intensities of

Table: 4.15. Effect of various treatments on sources on soil bulk density (mg/m^3) at harvest of rice in rice-wheat cropping system

Treatments	Soil profile (cm)							
	2005-06				2006-07			
	0-15	15-30	30-60	60-90	0-15	15-30	30-60	60-90
Puddling intensity								
Normal practice	1.59	1.68	1.49	1.50	1.57	1.66	1.47	1.48
2-times puddling	1.60	1.70	1.51	1.51	1.58	1.68	1.50	1.50
3-times puddling	1.62	1.71	1.51	1.51	1.60	1.69	1.49	1.50
C.D. (p=0.05)	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
Irrigation scheduling								
2 DADPW*	1.58	1.67	1.54	1.54	1.57	1.66	1.52	1.53
4 DADPW	1.62	1.71	1.50	1.50	1.60	1.68	1.48	1.49
SMP** at 150 cm suction	1.61	1.77	1.48	1.47	1.59	1.69	1.46	1.46
C.D. (p=0.05)	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
Nutrient sources								
Vermicompost 3t/ha+inorganic fertilizer	1.61	1.70	1.50	1.50	1.59	1.68	1.48	1.49
Vermicompost @ 6t/ha	1.59	1.69	1.50	1.50	1.56	1.67	1.47	1.48
FYM+In-organic fertilizer (50% each)	1.61	1.70	1.50	1.49	1.58	1.68	1.48	1.48
N.P.K Recommended	1.61	1.71	1.52	1.53	1.61	1.69	1.51	1.52
C.D. (p=0.05)	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S

*** Days after disappearance of ponded water   ** Soil matric potential**

Table: 4.16. Effect of various treatments on percolation rate (cm day^{-1}) of rice in rice-wheat cropping system

Treatments	Percolation rate(cm day^{-1})	
	2005-06	2006-07
Puddling intensity		
Normal practice	2.13	2.10
2-times puddling	1.93	1.91
3-times puddling	1.69	1.67
C.D. (p=0.05)	0.047	0.053
Irrigation scheduling		
2 DADPW*	1.97	1.95
4 DADPW	1.88	1.86
SMP ** at 150 cm suction	1.90	1.87
C.D. (p=0.05)	0.047	0.053
Nutrient sources		
Vermicompost 3t/ha+inorganic fertilizer	1.87	1.86
Vermicompost @ 6t/ha	1.85	1.83
FYM+In-organic fertilizer(50% each)	1.94	1.91
N.P.K Recommended	2.01	1.96
C.D. (p=0.05)	0.024	0.026

*** Days after disappearance of ponded water** **** Soil matric potential**

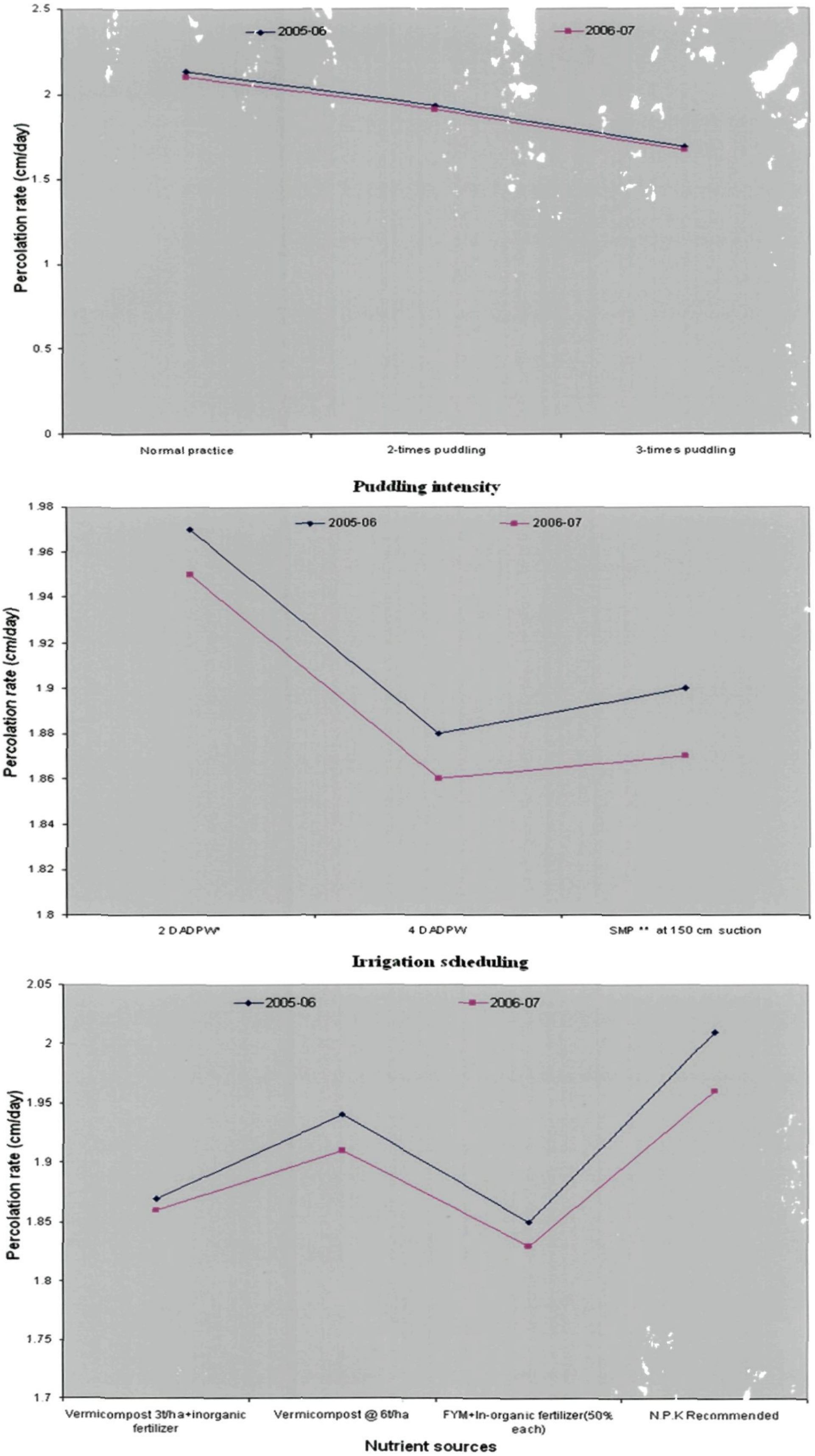


Fig:- 4.8 Effect of puddling intensity, irrigation scheduling and nutrientsources on percolation rate (cm/day)

puddling, puddling at normal practice resulted in maximum water expense followed by 2 and 4 times puddling.

Among the different irrigation treatments, the expense was maximum under irrigation at irrigation 2 DADPW than irrigation at 4 DADPW and SMP at 150 cm suction during both years of experimentation. The water expense was equal under different puddling levels and nutrient sources during 2005-06 and 2006-07.

Among the different nutrient sources N. P and K. at recommended dose (inorganics) resulted in maximum water expense than the application of vermicompost @ 3t/ha + inorganic fertilizers, FYM + inorganic fertilizers (50% each) and vermicompost @ 6t/ha during 2005-06 and 2006-07.

4.3.7 Water expense efficiency

The data presented in Table: 4.17 and revealed that differential water regimes and treatments bring differences in water expense efficiency.

Adoption of puddling 3 times resulted in higher water expense efficiency as compared to normal practice of puddling and 2 times puddling during 2005-06 and 2006-07.

Among the different irrigation scheduling SMP at 150 cm suction increased the water expense efficiency (151.53 and 103.91 kg/ha/cm) than irrigation at 2 DADPW (144.84 and 94.88 kg/ha/cm) and 4 DADPW (102.34 and 81.38 kg/ha/cm) during both the year of experimentation2005-06 and 2006-07.

Among the different nutrient sources, during 2005-06 application of N, P and K at recommended dose resulted in higher water expense efficiency (132.67 Kg/ha/cm) than

Table: 4.17. Effect of various treatments on total water expense and water expense efficiency of rice in rice-wheat cropping system.

Treatments	Effective Rainfall (cm)		Amount of irrigation water (cm)		Water Expense (cm)		Water expense efficiency (Kg/ha/cm)					
							Grain		Straw		Dry matter	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2006-07	2006-07	2006-07	2006-07	2006-07	2006-07
Puddling intensity												
Normal practice	31.98	78.35	60.00	50.00	81.69	117.59	51.34	37.08	74.38	53.43	125.72	90.51
2-times puddling	31.98	78.35	60.00	50.00	81.29	117.34	52.31	37.62	14.52	54.44	66.83	92.06
3-times puddling	31.98	78.35	60.00	50.00	80.98	117.17	53.99	38.70	79.05	56.40	133.03	95.10
Irrigation scheduling												
2 DADPW*	31.98	78.35	80.00	65.00	101.29	132.36	41.85	33.27	60.49	48.10	102.34	81.38
4 DADPW	31.98	78.35	50.00	45.00	71.31	112.40	59.00	38.87	85.84	56.01	144.84	94.88
SMP ** at 150 cm suction	31.98	78.35	50.00	40.00	71.16	107.32	61.45	42.26	90.07	61.66	151.53	103.91
Nutrient sources												
Vermicompost 3t/ha+inorganic fertilizer	31.98	78.35	60.00	50.00	81.39	117.68	52.23	37.44	75.50	53.98	127.74	91.43
Vermicompost @ 6t/ha	31.98	78.35	60.00	50.00	80.99	116.67	51.55	39.05	73.98	57.06	125.53	96.11
FYM+In-organic fertilizer(50% each)	31.98	78.35	60.00	50.00	81.18	117.06	52.99	38.25	77.49	55.51	130.48	93.76
N.P.K Recommended	31.98	78.35	60.00	50.00	81.51	118.16	53.54	36.44	79.13	52.46	132.67	88.90

*** Days after disappearance of ponded water, ** Soil matric potential**

application of vermicompost @ 3t/ha + inorganic fertilizers (127.74 kg/ha/cm), FYM + inorganic fertilizers (50% each)(130.48 kg/ha/cm) and vermicompost @ 6t/ha (125.53 kg/ha/cm). However, during second year of experimentation, application of vermicompost @ 6t/ha resulted in higher water expense efficiency (96.11 kg/ha/cm) than FYM + inorganic fertilizers (50% each) (93.76 kg/ha/cm), vermicompost @ 3t/ha + inorganic fertilizers (91.43 kg/ha/cm) and N, P and K at recommended dose through inorganics (88.90 kg/ha/cm).

4.3.8 Correlation.

The mean correlation coefficient values of two years between different characteristics of crop and the grain yield has been given in Table: 4.18.

Significant positive correlation between dry matter, number of tillers/m^2, straw yield and N, P and K uptake in rice was observed but percolation rate showed negative correlation with grain yield of rice. Positive highly significant co relationship was recorded between number of tillers/m^2 (0.60**) and grain yield of rice. Grain yield also had positive highly significant co relationship with N-uptake of rice (0.56**) and straw yield of rice (0.96**). The correlation coefficient between grain yield and percolation rate (-0.59) were found to be negative.

4.4 Residual effect on succeeding wheat crop

4.4.1 Grain and straw yield of succeeding wheat

Puddling intensity and irrigation scheduling was found to be non-significant in increasing the grain and straw yield of succeeding wheat crop during both the years of experimentation (Table: 4.19, Fig-4.9 and Appendix -V).

Table: 4.18. Mean correlation coefficient between different characters in rice during 2005-06 and 2006-07.

Treatments	Dry matter accumulation (g/m^2)	No. of tillers/m^2	No. of panicles/m^2	1000-grain weight	N-uptake in rice (Kg/ha)	P-uptake in rice (Kg/ha)	K-uptake in rice (Kg/ha)	Percolation rate (cm/day)	Grain yield (q/ha)	Straw yield (q/ha)
Dry matter accumulation (g/m^2)	-	0.36*	0.34*	0.27*	0.32*	0.86**	0.71**	0.01	0.04	0.02
No. of tillers/m^2	-	-	0.55**	0.37*	0.39*	0.53**	0.48*	-0.57**	0.60**	0.56**
No. of panicles/m^2	-	-	-	-0.10	-0.02	0.32	0.16	-0.56	0.51	0.53
1000-grain weight	-	-	-	-	0.48**	0.40*	0.53**	-0.18	0.33*	0.28
N-uptake in rice (Kg/ha)	-	-	-	-	-	0.61**	0.82**	0.01	0.56**	0.49**
P-uptake in rice (Kg/ha	-	-	-	-	-	-	0.92**	-0.03	0.21	0.14
K-uptake in rice (Kg/ha	-	-	-	-	-	-	-	0.04	0.29	0.22
Percolation rate (cm/day)	-	-	-	-	-	-	-	-	-0.59**	-0.59**
Grain yield (q/ha)	-	-	-	-	-	-	-	-		0.96**

*Significant at 0.05 % level of significance

Among the nutrient sources during, 2005-06, the application of vermicompost @ 6t/ha brought significant increase in grain yield of succeeding wheat over vermicompost @ 3t/ha+inorganic fertilizers, FYM+inorganic fertilizers (50% each) and N, P and K applied through inorganic fertilizers at recommended doses. However, during second year 2006-07, application of vermicompost @ 6t/ha though at par with vermicompost @ 3t/ha + inorganic fertilizer, FYM+inorganic fertilizers (50% each) increased the grain and straw yield significantly than recommended N, P and K doses.

Table: 4.19. Effect of various treatments on grain and straw yield (q/ha) of wheat in rice-wheat cropping System.

Treatments	Grain yield (q/ha)		Straw yield (q/ha)	
	2005-06	2006-07	2005-06	2006-07
Puddling Intensity				
Normal puddling (single puddling))	46.70	48.18	75.56	78.72
2-times puddling	46.41	47.83	74.98	77.72
3-times puddling	46.29	47.67	74.74	77.71
C.D. (p=0.05)	N.S	N.S		
Irrigation Scheduling				
2 DADPW*	46.40	47.84	74.96	78.05
4 DADPW	46.38	47.80	74.92	77.96
SMP** 150 suction	46.61	48.04	75.39	78.44
C.D. (p=0.05)	N.S	N.S		
Nutrient sources				
Vermicompost 3t/ha+inorganic fertilizer	46.61	48.14	75.38	78.64
Vermicompost @ 6t/ha	46.74	48.15	75.64	78.67
FYM+In-organic fertilizer(50% each)	46.35	47.74	74.87	77.86
N.P.K Recommended	46.15	47.54	74.47	77.44
C.D. (p=0.05)	0.50	0.54	1.01	1.08

*** Days after disappearance of ponded water   ** Soil matric potential**

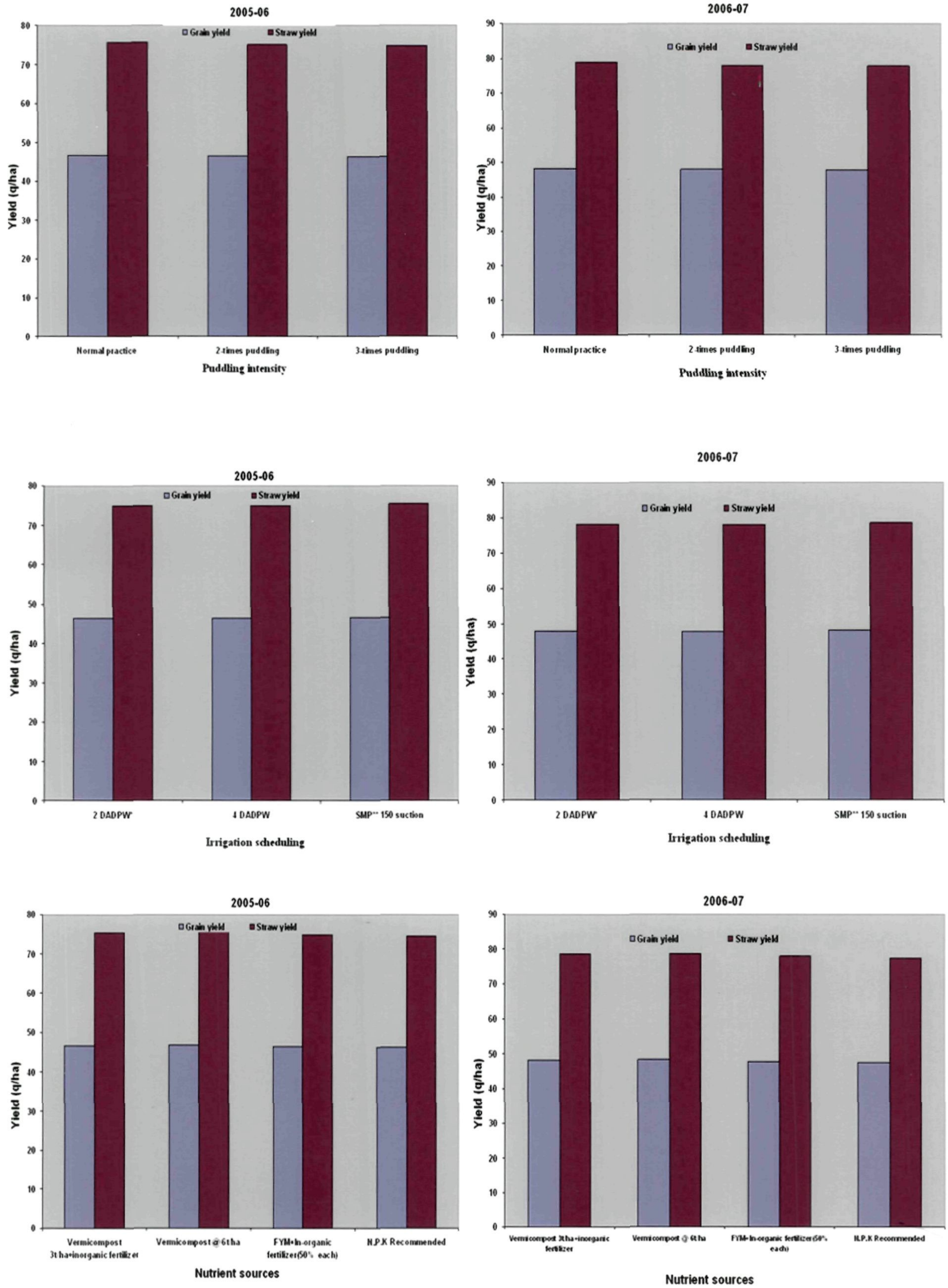


Fig:- 4.9 Effect of puddling intensity, irrigation scheduling and nutrient sources on grain and straw yield (q/ha) of succeeding wheat

DISCUSSION

CHAPTER-V

DISCUSSION

The experimental results presented in the previous chapter gave a detailed account of the "**Effect of puddling intensity, nutrient sources and irrigation scheduling on growth and yield of rice (*Oryza sativa* L.) in rice-wheat cropping system**". The significant experimental findings obtained during the course of experimentation are discussed below with possible explanations and evidences wherever necessary in order to find out the cause and effect relationship among different treatments with respect to various attributes studied and sort out information of practical value. The growth and yield performance of a crop is a function of number of metabolic processes taking place in the plant body, which in turn are affected by a variety of inherent and environmental factors to which the plant is exposed.

Nutrient management, irrigation scheduling and puddling intensity in rice-wheat under present-day agriculture is of paramount importance as the injudicious and untimely use of inorganic nutrients and irrigation for 10-15 years in monoculture is generally known to result in loss of soil fertility, soil organic matter content and soil structure. Various farmers have reported the lowering of nutrient and water expense efficiency. Under this situation, it becomes imperative to evaluate the alternative nutrient sources, irrigation schedules and levels of puddling in rice-wheat cropping system in view of maintaining sustainability of the staple food of the country besides food security.

5.1 Crop Studies of rice

Different nutrient sources, puddling intensity and irrigation schedules not only improved the growth and yield of rice crop but also increased the yield of succeeding wheat than under traditional practice of nutrient supply, irrigation schedules and levels of puddling.

5.1.1 Crop growth

The overall growth of rice crop measured in terms of plant height (cm), dry matter accumulation (g/m^2), and number of tillers/m^2 was comparatively less during the first year of experimentation. This was mainly attributed to less rainfall (31.98 mm) as compared to second year which received a considerable amount of rainfall (78.35 mm). However, significant difference among treatments in terms of plant height (cm), dry matter accumulation (g/m^2) are concerned, it was found that at 60 days of crop age and onwards, the significant differences were observed, which was mainly attributed to the fact that at young stage of crop growth the plant is under the establishment phase and as it grows gradually the plant responses to various factor of growth and development. (Table 4.1, 4.2, 4.3).

Among the levels of puddling, puddling intensity with 3 times puddling resulted in significant increase in number of tillers/m^2 as compared to normal practice of puddling and 2 times puddling which however were found to be at par with each other during both the year of experimentation. This may be owing to the benefit the growth of the crop mainly by lowering the bulk density and soil strength in the root zone and the increase in crop growth might be due to softer seedbed for better establishment and lower weed competition for water and nutrients. Sharma and Datta (1985) reported that puddling intensity increased solubility and decreased leaching losses of plant nutrients. These results are in close conformity to the results given by Kirchhof *et al.*. 2000. Mohanty *et al.*, 2004 and Singh *et al.*, 2006.

Application of irrigation SMP at 150 cm suction increased the plant height (cm), dry matter accumulation (g/m^2) and number of tillers/m^2, significantly at 60 DAT onwards up to 90 DAT than irrigation applied at 2 and DADPW during 2005-06, where as during 2006-07, the irrigation applied either at 2 DADPW was found to be at par with SMP at 150 cm suction but significantly higher than that of 4 DADPW. Significant increase in growth parameters may be owing to enhanced nutrient availability and constant water supply which might have supplied contributed towards proper growth of the crop (Lourduraj and Rajagopal, 1999). These results corroborate the findings of Uppal and Bali., 1994, Hira *et al.*, 2002 and Parihar., 2004.

Among the nutrient sources during, 2005-06, the application of N, P and K at recommended levels brought significant increase in plant height (cm), dry matter accumulation (g/m^2) and number of tillers/m^2 than vermicompost @ 3t/ha + inorganic fertilizers, vermicompost alone @ 6t/ha and FYM + inorganic fertilizers (50% each) at 60 DAT onwards stage. However, during 2006-07, application of vermicompost @ 6t/ha increased the plant height (cm), dry matter accumulation (g/m^2) and number of tillers/m^2 significantly over vermicompost @ 3t/ha + inorganic fertilizer, FYM + inorganic fertilizers (50% each) and N, P and K applied through inorganic fertilizers. The application of organic manures in these treatments and their subsequent decomposition might have helped in release of nutrients in soil slowly through out the crop growth and thus improved growth parameters of rice crop These results are in close conformity to the results given by Banik and Bejbaruah 2004, Singh 2006,and Singh *et. al.*, 2006.

5.1.2 Yield attributes and yields of rice

Grain yield is a resultant of yield attributes and therefore, maximum expression of yield attributes viz. number of panicles/m^2, number of grains/panicle, grain weight/ panicle, and 1000-grain weight was observed with different levels of puddling, irrigation schedules and nutrient sources. (Table: 4.3, 4.6 and 4.8)

Among different intensities of puddling, 3 times puddling was found to increase the number of panicles/m^2, number of grains/panicle, grain and straw yield (q/ha) significantly as compared to normal practice of puddling and 2 times puddling during both the years of experimentation. The increase in grain yield may be due to improved physical environment of the soil, which might have provided a soft bed for better growth, nutrient uptake and increase in water use efficiency (Datta and Kerim, 1974) and provided the favourable environment for root proliferation, crop cover development and dry matter as well, besides maintained the suitable water regimes in puddled soil. These results confirm the finding of Aggarwal *et al.*, 1995, Singh *et al.*, 1995, Ganesh., 2000, Singh *et al.*, 2001., Mohanty *et al.*, 2004 and Tripathi *et al.* 2007.

Among different levels of irrigation, application of irrigation SMP at 150 cm suction were found effective in increasing the number of panicles/m^2, grain weight /panicle, 1000-grain weight, grain and straw yield (q/ha) significantly than irrigation applied at 2 and 4 DADPW during 2005-06, but were at par with the irrigation applied at

2 DADPW during 2006-07. This may be due to the fact that the irrigation applied through SMP at 150 cm suction provided the opportunity of the crop to supply the constant and proper water required for mobilizing the constant nutrient supply which in turn might have helped to promote the metabolic activity of the plant. Uppal and Bali, 1994, Hira *et al.*, 2002, and Parihar., 2004 are of similar opinion.

Among the nutrient sources during, 2005-06, the application of N, P and K at recommended levels brought significant increase in number of panicles/m^2, number of grains/panicle, grain weight/panicle, 1000-grain weight, grain and straw yield (q/ha) of rice than vermicompost @ 3t/ha + inorganic fertilizers, vermicompost alone @ 6t/ha and FYM + inorganic fertilizers (50% each) at harvest. However, during 2006-07 application of vermicompost @ 6t/ha increased the number of panicles/m^2, number of grains/ panicle, grain weight/panicle, 1000-grain weight, grain and straw yield (q/ha) significantly over vermicompost @ 3t/ha + inorganic fertilizer, FYM + inorganic fertilizers (50% each) and N, P and K applied through inorganic fertilizers. The application of vermicompost @ 6 t/ha might have improved the nutrient status and soil health, which might have helped in constant release of soil nutrients besides the vermicompost reported to contain the growth promoting substances which might have influenced the availability of major and minor nutrients, there by yielded higher grain yield and its attributes. The presence of plant growth substances identified as indole compounds, which could be secreted in the cast and were reported by (Sengar *et al.*, 2000). These results were in close conformity with that of Vasanthi and Kumaraswami, 1999, Murali and Setty, 2000, Singh 2006 and Singh *et. al.*, 2006.

5.1.3 Nutrient uptake by rice crop

The data presented in Table- 4.11 revealed that different intensities of puddling were found to be non significant in uptake of N, P and K of rice during both the years of experimentation. Puddling did not generally have a significant effect on nutrient uptake in rice because increased puddling intensity help in retaining more mineral N in profile by reducing N losses. Similarly the available K content of soil may have decreased with increased in puddling intensity in the soil where amount of Fe and Mn could have increased which in turn decrease the P uptake. Similar findings have been also reported by many workers Kukal and Aggarwal, 2002, Kukal and Aggarwal, 2003 and Sidhu *et al.,* 2006.

Among different levels of irrigation, application of irrigation SMP at 150 cm suction though at par with irrigation applied at 2 and 4 DADPW increased the uptake of N, P and K of rice during both the years of experimentation. The reason may be due to enhanced availability of nitrogen in the irrigation regime and increase in P uptake may be because of conversion of ferric phosphate to ferrous phosphate and by forming the phosphohumic complexes that are easily assimilated by the crop. These results corroborate the findings of Balasubramaniam and Krishnarajan 2000.

Besides, there is a close relationship between the total uptake of nutrients with the grain yield of rice crop. Definite proportion of nutrient is always associated with attainable yield of any crop. Among the different nutrient sources recommended dose of N, P and K (Inorganic) significantly increased the N, P, and K uptake in grain and straw of rice crop during 2005-06 than FYM + inorganic fertilizer (50% each), vermicompost

@ 3t/ha + inorganic fertilizer and vermicompost applied @ 6t/ha. The higher uptake of N, P and K nutrients could be due to greater release of nutrients and their ready availability in soil (Jana and Ghosh 1996). The higher uptake was ascribed to the positive effect of N, P and K on cell division, increate in number of root hair and root elongation through which the plant may explore wider area and higher depth for its absorption leading to higher uptake (Oomen *et al.*, 1972). Such findings have also been reported by many workers (Gill *et al.*, 1994, Bhandari *et al.*, 1992, Reddy and Krishnaiah., 1999 and Aulakh *et al.*, 2000). However, during 2006-07, vermicompost @ 6t/ha significantly increased the N, P, and K uptake in both grain and straw of rice than FYM +inorganic fertilizer (50% each), vermicompost @ 3t/ha + inorganic fertilizer. The increase in grain yield with vermicompost may be attributed to the increased availability of nutrients from vermicompost and presence of beneficial micro flora such as nitrogen fixers and phosphate solubilizers (Lee 1992). Like wise, increase in N, P, and K uptake with FYM and vermicompost application may be attributed to numerous favorable improvements in soil conditions, which encourage the proliferation of roots and improved synchrony between supply and plant demand as reported by Minhas and Sood (1996). Supply of the required nutrients through organic and inorganic sources along with vermicompost facilitated balanced nutrition of the crop, which resulted in enhanced grain yield. The best effect of chemical fertilizers could be obtained only in presence of organic manures (Pillai, 1996 and Jeyabal, 1999) Similar results were also obtained by Ravi and Srivatsava, 1997, Murali and Setty, 2000 and Sengar *et al.*, 2000.

5.2 Soil studies

The overall soil study under rice wheat cropping system in terms of soil moisture profile wise in (cm) at varying stages and percolation rate (cm day^{-1}) during both the years of experimentation was taken and discussed as under.

5.2.1 Soil moisture studies.

The data presented in (Table: 4.12, 4.13 and 4.14) revealed that soil moisture before pre irrigation for puddling, after harvest of rice crop and before sowing of wheat increased with the depth of soil profile and all the treatments have differential effect on the soil moisture status. Moisture content (cm) in the soil profile between 60-90 cm was highest as compared with soil moisture between 0-15 cm, 15-30 cm and 30-60cm soil profiles.

Application of puddling 3 times increased the soil moisture (cm) at 0-15 cm, 15-30 cm, 30-60 cm and 60-90 cm soil profile than 2 times puddling and normal practice of puddling and the average profile moisture increase was in the order of 2.76 and 2.71 cm, respectively. Puddling in general, destroy soil aggregation (Woodhead, 1990) and results in the decrease of macro porosity (Jamison, 1953) and increase in micro porosity thereby increasing the moisture retention of soil. Similarly, puddled soil retain more water than unpuddled soils and also the puddled soils release water more slowly than unpuddled soil because of the reduction in transmission pores (Gajri and Majumdhar, 2002).

Among the irrigation levels, application of irrigation at SMP 150 cm suction increased the soil moisture at 0-15 cm and 15-30 cm soil profile whereas, irrigation at 4 DADPW recorded highest soil moisture at 30-60 cm and 60-90 cm soil profile. There was higher profile moisture contribution to the crop where rice was grown under higher irrigation. Similar results was observed by Parihar 2004.

Among the nutrient sources, during 2005-06 and 2006-07 application of vermicompost @ 6t/ha increased the soil moisture (cm) of rice crop at 0-15 cm, 15-30 cm, 30-60 cm and 60-90 cm of soil profile. This may be due to the presence of higher soil organic matter due to the application of organic sources of nutrients. Beneficial effect of soil organic matter on the physical properties of soil is also found in its capacity to absorb water to the extent of several times in dry weight. Organic matter has a significant influence on the amount of retention and transmission of water in soils (Gupta and Larson, 1979). This may be attributed to the reason that the medium texture soils have higher cation exchange capacity and probably have well aggregated soil with the addition of organic matter content. Similarly Gupta *et al.,* 1977 found that incorporation of organic matter increase soil water at all suctions in medium texture soil. Increase in the retention of soil moisture by the addition of organic matter has been recorded by number of investigators (Salter and Haworth, 1961).

5.2.2 Soil bulk density (Mg/m^3)

The data presented in Table: 4.15 revealed a non-significant effect of puddling intensity, irrigation scheduling and nutrient sources did not influence the soil bulk density significantly. However, soil bulk density increased with the advancement of depth in the soil profile from 0-15 to 15-30 cm, decreased from 15-30 to 30-60 cm soil depth and there after increased from soil profile of 60-90 cm depth. A reduction by end of the crop season indicates a partial regeneration of aggregates by biological input to the crop.

These results suggests that puddling decreases the bulk density of soil by bringing the closely pack soil particles back in to suspension (Sharma and Datta, 1985). The slight increase in the bulk density with the increase in the puddling intensity which was found to be non significant which may be due to the sealing of pores by dispersed clay particles and/or by compaction indicating the start of formation of hard pan (Sur *et al.*, 1981). Similar finding was observed by Greenland 1981, Sinclair *et al.*, 1984, and Parihar 2004.

5.2.3 Percolation rate (cm day^{-1})

The percolation rate (cm day^{-1}) was significantly affected by puddling intensity, irrigation scheduling and different nutrient sources during 2005-06 and 2006-07. (Table 4.16)

Three times puddling decreased the percolation rate significantly than normal practice of puddling and two times puddling during both the years of experimentation. In a puddled soil, particles packed closely in parallel orientation, there by restricting water movement (Sharma and Datta, 1985). Puddling of soil also resulted in disruption of soil aggregates and creation of soil water suspension, the differential settling of soil particles results in sealing of puddled surfaces with clay particles there by reducing the percolation (Kukal and Aggarwal, 2003). These findings are also in conformity with the findings of Aggarwal *et al.*, 1995, Kundu *et al.*, 1996 and Coelho *et al.*, 2000. Among the different irrigation treatments, irrigation 4 DADPW decreased the percolation rate significantly than SMP at 150 cm suction. Among different nutrient sources, application of vermicompost @ 6t/ha resulted in significant decrease in percolation rate than vermicompost @ 3t/ha + inorganic fertilizers, FYM + inorganic fertilizers (50% each) and the application of recommended dose of N, P and K (inorganics) during both years of experimentation. Similar results were found by Parihar 2004, Kukal and Sidhu, 2004.

5.2.4 Total water expense and Water expense efficiency

The data presented in Table 4.17 revealed that differential water regimes and treatments bring significant differences in water expense efficiency.

Total water expense was maximum under normal practice of puddling followed by 2 and 3 times puddling. Among the different irrigation schedules, total water expense was maximum where irrigation was applied at 2 DADPW i.e three times more than irrigation at 4 DADPW and SMP at 150 cm suction during both years of experimentation. Among the different nutrient sources maximum water expense was found under N, P, and K at recommended (inorganic) over the vermicompost @ 3t/ha+inorganic fertilizer, FYM + inorganic fertilizer (50% each) and vermicompost @ 6t/ha alone during 2005-06 and 2006-07. Total water expense of the system increased with the increase in frequency of irrigation (Parihar, 2004). Similar finding was observed by Saikia and Dutta 1991, Marazi *et al.*, 1993 and Luikham 2004.

Puddling intensity with 3 times puddling resulted in higher water expense efficiency as compared to normal practice of puddling and 2 times puddling during both the year of experimentation. Higher intensity of puddling of soil not only increased the rice yield but also decrease unproductive water losses viz. percolation and evaporation there by increasing the water expense efficiency (Singh *et al.,* 2001). Combination of soil with high intensity of puddling with various scheduling of irrigation resulted in the highest water expense efficiency further matching the rice growing period with out any decline in the rice yield Singh *et al.*, 1990.

Irrigation scheduling SMP at 150 cm suction resulted in higher water expense efficiency than irrigation at 2 and 4 DADPW during both the crop season. The water expense efficiency increased with decrease in number of irrigations (Marazi *et al.*, 1993). Similar finding was observed by Saikiaa and Dutta 1991, Hira *et al.*, 2002, Luikham, 2004 and Parihar 2004.

Among the different nutrient sources, during 2005-06 application of N, P and K at recommended dose resulted in resulted in higher water expense efficiency than application of vermicompost @ 3t/ha + inorganic fertilizers, FYM + inorganic fertilizers (50% each) and vermicompost @ 6t/ha. This may owing to its decomposition and mineralization. However, during second year of experimentation, application of vermicompost @ 6t/ha resulted in higher water expense efficiency than vermicompost @ 3t/ha + inorganic fertilizers, FYM + inorganic fertilizers (50% each), vermicompost @ 3t/ha + inorganic fertilizers and N, P and K at recommended dose. This may be due to higher water holding capacity as a result of incorporation of organics coupled with high intensity of puddling and varying irrigation schedule. These results are close conformity with that of Singh *et al.*, 1990.

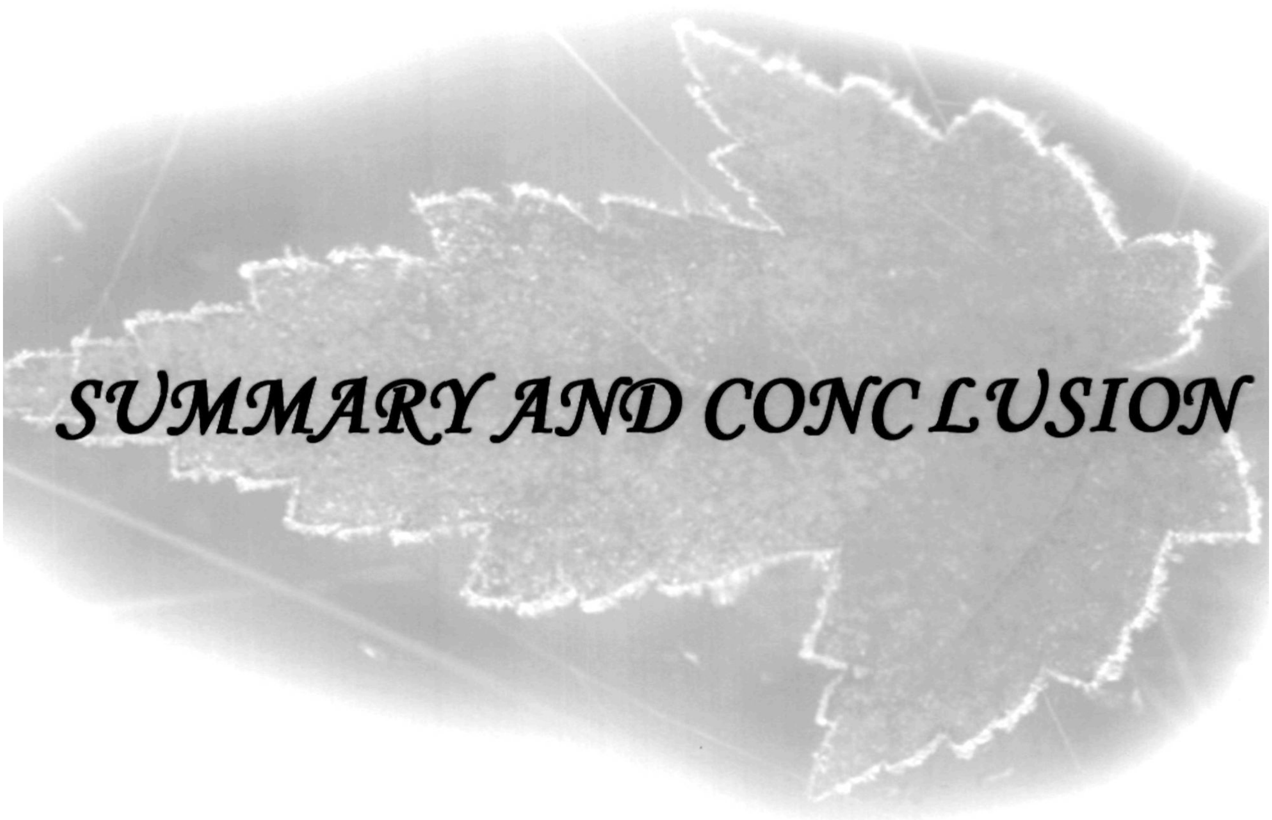
5.3 Residual effect on succeeding wheat crop

The data presented in Table: - 4.17 revealed that differential nutrient sources treatments bring significant differences in grain and straw yield of succeeding wheat crop.

Puddling intensity and irrigation scheduling was found to be non-significant in increasing the grain and straw yield of succeeding wheat crop during both the years of experimentation. This may be because of restricted root growth and soil aeration stress due to presence of a hard layer at 14-20 cm soil depth (Kukal and Aggarwal, 2003). Similarly (Barraclough and Wier, 1998) observed that early shoot growth of wheat was reduced by a hard pan because of the inaccessibility of nitrogen in the sub soil.

Among the nutrient sources during, 2005-06, the application of vermicompost @ 6t/ha brought significant increase in grain and straw yield (q/ha) of succeeding wheat than vermicompost @ 3t/ha + inorganic fertilizers, FYM + inorganic fertilizers (50% each) and N, P and K applied through inorganic fertilizers at recommended doses. However, during 2006-07, application of vermicompost @ 6t/ha though at par with vermicompost @ 3t/ha + inorganic fertilizer, FYM + inorganic fertilizers (50% each) increased the grain and straw yield (q/ha) significantly than recommended N, P and K doses through inorganic fertilizer. Higher grain and straw yield (q/ha) of wheat was owing to improvement in soil physical and chemical properties with incorporation of organic sources (Dillon *et al.,* 1998 and Patidar and Mali 2002). These results corroborate the findings of Pradhan and Mohan 1998, Vaidya and Gabhane, 1998.

SUMMARY AND CONCLUSION



CHAPTER-VI

SUMMARY AND CONCLUSION

An experiment entitled, "**Effect of puddling intensity, nutrient sources and irrigation scheduling on growth and yield of rice (*Oryza sativa* L.) in rice-wheat cropping system**" was conducted during the *kharif* and *rabi* season of 2005-06 and 2006-07 at the Research Farm, Main Campus, Chatha of SKUAST-Jammu. The soil of the experimental field was sandy loam in texture, slightly alkaline in reaction, low in organic carbon and available nitrogen and was medium in available phosphorus and potassium. Rice variety PC-19 was transplanted and all the treatments were imposed as per the technical program and wheat variety PBW-343 was sown and recommended doses of fertilizers were uniformly applied. The experiment comprised of three levels of puddling intensity viz: normal practice, 2 times puddling and 3 times puddling, three levels of irrigation scheduling viz: irrigation scheduling 2 DADPW, 4 DADPW and irrigation at SMP at 150 cm suction and four levels of nutrient sources namely, vermicompost @ 3t/ha+ inorganic fertilizers, vermicompost @ 6t/ha, FYM + inorganic fertilizers (50% each) and recommended N, P, K doses through inorganic fertilizer. The treatments were laid out in split plot design with puddling and irrigation scheduling as main plots whereas different nutrient sources were assigned to sub plots with 3 replications. All recommended package and practices vis a vis plant protection were uniformly followed in all the treatments.

The residual effects of treatments applied in rice on succeeding wheat crop were studied on the plots after harvest of rice crop. The experiment was carried out up to the harvest of wheat crop. The salient findings of the present investigation have been summarized in this chapter.

6.1 Studies on rice crop

6.1.1 Effect of Puddling intensity, irrigation scheduling and nutrient sources

a) Maximum tillers/m^2, number of panicles/m^2, number of grains/panicle, grain and straw yield (q/ha) was recorded in plots with 3 times puddling which resulted in significant increase as compared to normal practice of puddling and 2 times puddling which however were found to be at par with each other during both the year of experimentation

b) Among different levels of irrigation, application of irrigation SMP at 150 cm suction increased the plant height (cm), tillers/m^2, dry matter accumulation (g/m^2), panicles/m^2, grain weight/panicle, 1000-grain weight, grain and straw yield (q/ha) significantly than irrigation applied at 2 and 4 DADPW during the first year of experimentation, However, irrigation applied at 2 DADPW was found to be at par with SMP at 150 cm suction during 2006-07.

c) Among the nutrient sources, during 2005-06, the application of N, P and K at recommended levels brought significant increase in plant height (cm), tillers m^{-2}, dry matter accumulation (g/m^2), panicles/m^2, number of grains/ panicle, grain weight/panicle, 1000-grain weight, grain and straw yield (q/ha) than vermicompost @ 3t/ha+inorganic fertilizers, vermicompost alone @ 6t/ha and FYM + inorganic fertilizers (50% each) at 60 DAT onwards stage. However, during 2006-07, application of vermicompost @ 6t/ha increased the plant height (cm), tillers/m^2, dry matter accumulation (g/m^2) significantly over vermicompost @ 3t/ha + inorganic fertilizer, FYM + inorganic fertilizers (50% each) and N, P and K applied through inorganic fertilizers.

d) Among different levels of irrigation, application of irrigation SMP at 150 cm suction though at par with irrigation applied at 2 and 4 DADPW increased the uptake of N, P and K of rice during both the years of experimentation.

e) Maximum N, P, and K uptake in grain and straw of rice crop was observed in recommended dose of N, P and K (Inorganic fertilizer) than FYM + inorganic fertilizer (50% each), vermicompost @ 3t/ha + inorganic fertilizer and vermicompost applied @ 6t/ha during 2005-06. However during 2006-07, vermicompost @ 6t/ha significantly increased the N, P, and K uptake in both grain and straw of rice than FYM + inorganic fertilizer (50% each), vermicompost @ 3t/ha + inorganic fertilizer

6.1.2 Soil studies

a) Among the different intensities of puddling, puddling with 3 times increased the soil moisture (cm) at 0-15 cm, 15-30 cm, 30-60 cm and 60-90 cm soil profiles than 2 times puddling and normal practice of puddling.

b) Among the irrigation scheduling, application of irrigation at SMP 150 cm suction increased the soil moisture at 0-15 cm and 15-30 cm soil profile whereas, irrigation applied at 4 DADPW recorded highest soil moisture at 30-60 cm and 60-90 cm soil profile.

c) Application of vermicompost @ 6 t/ha increased the soil moisture (cm) of rice crop at 0-15 cm, 15-30 cm, 30-60 cm and 60-90 cm of soil profile.

d) Three times puddling decreased the percolation rate significantly than normal practice of puddling and two times puddling during both the years of experimentation.

e) Significant increase in percolation rate was observed in plots where irrigation was applied 2 DADPW as compared to irrigation applied at 4 days after disappearance of ponded water and SMP at 150 cm suction.

f) Among different nutrient sources, application of vermicompost @ 6t/ha resulted in significant decrease in percolation rate than vermicompost @ 3t/ha + inorganic fertilizers, FYM + inorganic fertilizers (50% each) and application of recommended dose of N, P and K (inorganics) during both years of experimentation.

g) Puddling intensity with 3 times puddling resulted in higher water use efficiency as compared to normal practice of puddling and 2 times puddling during both the year of experimentation.

h) Irrigation scheduling SMP at 150 cm suction resulted in higher water use efficiency than irrigation at 2 and 4 days DADPW during both the year of experimentation.

i) Application of N, P and K at recommended dose resulted in resulted in higher water use efficiency than application of vermicompost @ 3t/ha + inorganic fertilizers, FYM + inorganic fertilizers (50% each) and vermicompost @ 6t/ha. However, during second year of experimentation, application of vermicompost @ 6t/ha resulted in higher water use efficiency than vermicompost @ 3t/ha + inorganic fertilizers, FYM + inorganic fertilizers (50% each), vermicompost @ 3t/ha + inorganic fertilizers and N, P and K at recommended dose.

6.1.3 Residual effect on succeeding wheat crop

a) Significant residual effect of different nutrient sources on succeeding wheat grain yield and straw yield was observed and maximum grain and straw yield was recorded in plots applied with vermicompost @ 6t/ha than recommended doses of N, P and K.

Conclusion

Maximum grain and straw yield was recorded in plots with 3 times puddling which resulted in significant increase as compared to normal practice of puddling and 2 times puddling. Among different levels of irrigation, application of irrigation SMP at 150 cm suction gave significant increase in grain and straw yield than irrigation applied at 2 and 4 DADPW during the first year of experimentation, However, irrigation applied at 2 DADPW was found to be at par with SMP at 150 cm suction during 2006-07. Whereas among the nutrient sources during 2005-06, the application of N, P and K at recommended levels brought significant increase in grain and straw yield than vermicompost @ 3t/ha+inorganic fertilizers, FYM + inorganic fertilizers (50% each) and vermicompost alone @ 6t/ha at 60 DAT onwards stage. However, during 2006-07, application of vermicompost @ 6t/ha increased the plant height, tillers/m^2, dry matter accumulation (g/m^2) significantly over vermicompost @ 3t/ha + inorganic fertilizer, FYM + inorganic fertilizers (50% each) and recommended N, P and K applied through inorganic fertilizers. Henceforth, puddling three times coupled with irrigation through SMP at 150 cm suction and application of vermicompost @ 6t/ha was found to be the best combination for increased production and water use efficiency of rice in rice-wheat cropping system, in sustainable manner owing to increased soil fertility and soil health. While assessing the residual effect in succeeding wheat crop it was observed that significant residual effect of different nutrient sources on succeeding wheat grain and straw yield was observed and maximum grain and straw yield was recorded in plots applied with vermicompost @ 6t/ha than recommended doses of N, P and K.

LITERATURE CITED

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Adachi, K. 1990. Effect of rice and soil puddling on water percolation. *In proceedings of the transactions of the 14th International Congress on Soil Science*. **1**: 81-1291.

Aggarwal, G. C., Sidhu, A. S., Sekhon, N. K., Sandhu, K. S. and Sur, H. S. 1995. Puddling and N management effects on crop response in a rice-wheat cropping system. *Soil and Tillage Research*. **36** : 129-139.

Anonymous 2006. Directorate of Economics and Statistics, Planning and Development Department, Govt. of Jammu and Kashmir, India. *Digest of Statistics*. **pp**. 81-129.

Aujla, T. S., Singh, B., Khera, K. L. and Sandhu, B. S. 1984. Response of rice to differential irrigation at growth stages on a sandy loam soil in Punjab. *Indian Journal of Ecology*. **11**(1): 71-76.

Aulakh, M. S., Khera, T. S., Doran, J. M., Singh, K. and Singh, B. 2000. Yield and nitrogen dynamics in rice-wheat system using green manure and inorganic fertilizer. *Soil Science Society of American Journal*. **64** : 1867-1876.

Balasubramanian, R. and Krishnarajan, J. 2000. Balance sheet of nutrients in direct seeded rice as influenced by irrigation regimes. *Madras Agriculture Journal*. **86**(10-12) : 620-625.

Balasubramanian, R. and Krishnarajan, J. 2001. Post-harvest soil available nutrient status of direct seeded rice (*Oryza sativa* L.) as influenced by water management practices. *Fertilizer News*. **46**(3) : 65-68.

Bali, A. S. and Uppal, H. S. 1999. Irrigation schedule in producing quality basmati rice (*Oryza sativa*). *Indian Journal of Agricultural Sciences.* **69**(5) : 325-328.

Banik, P. and Bejbaruah, R. 2004. Effect of vermicomost on rice (*Oryza sativa*) yield and soil fertility status of rainfed humid sub-tropics. *Indian Journal of Agricultural Sciences.* **74**(9): 488-491.

Barraclough, P. B and Wier, A. H. 1998. Effects of a compacted sub soil layer on root and shoot growth, water use and nutrient uptake of winter wheat. *Journal Agricultural Science Coimbtore*. **110** : 207-216.

Bhandari, A. L., Sood, A., Sharma, K. N and Rana, D. S. 1992. Integrated weed management in a rice wheat system. *Journal of Indian Society of Soil Science.* **40** : 742-747.

Bodman, G. B. 1942. Nomogram for rapid calculation of soil density, water content and total porosity relationship. *Journal of American Society of Agronomy*. **34** : 885-903.

Cochran, W.G. and Cox, G.M. (1957) *Experimental Designs.* Wiley International Publication, New York.

Coelho, M. B., Mateos, L. and Villalobes, F. J. 2000. Influence of compacted loam subsoil layer on growth and yield of irrigated cotton on southern Spain. *Soil and Tillage Research.* **57** : 129-142.

Coleman, E. A. 1944. The dependant of field capacity upon the depth of wetting of field soils. *Soil Science*. **58** : 43-50.

Das, J. C., Sarmah, N. N., Barkakoty, P. K. and Choudhary, A. K. 2000. Effect of irrigation regimes on transplanted summer (AHU) rice in Assam. *Annals of Agriculture Research.* **21**(4): 481-484.

Datta, S. K. and Kerim, M. S. 1974. Water and nitrogen economy of rainfed rice as affected by soil puddling. In : *Proceedings* of *Soil Science Society of America.* **38** : 515-518.

Datta, S. K., Morris, R. A. and Barker, R. 1979. Land preparation and crop establishment for rainfed lowland rice. Selected papers from 1978. *International Rice Research Conference IRRI, Philippines.* **pp** : 189-213.

*Despande, S.B., Fehrenbacher, J.B. and Beavers, A.H. (1971) Genesis and classification of mollisols of Tarai region of U.P. Northern India, *Geoderma, 6*: 195-201.

Dhiman, S. D., Sharma, H. C., Nandal, D. P., Hariom and Singh, D. 1998. Effect of irrigation, methods of crop establishment and fertilizer management on soil properties and productivity in rice (*Oryza sativa*)-wheat (*Triticum aestivum*) sequence. *Indian Journal of Agricultural Sciences.* **49**(2) : 208-212.

Dillon, N. S., Brar, B. S., Daliwal, G. S., Arora, R., Randhawa, N. S. and Dhawan, A. K. 1998. Integrated management of farm yard manure and inorganic fertilizers in rice-wheat cropping system in south western India. *Ecological Agriculture and Sustainable Development* Vol, 1. **Pp** : 604-612.

*Ekwue, E. I., Ohu, J. O. and Wahawa, I. H. 1993. Effect of incorporating two organic materials at varying levels on splash detachment. *Earth surface process*. **18** : 399-406.

Gajri and Majumdhar. 2002. Tillage. *Fundamentals of soil science*. Indian Society of Soil Science. **pp** : 125-132.

Ganai, B. A. and Singh, C. M. 1988. Effect of farmyard manure applied in rice-wheat rotation on physico-chemical properties of soil. *Indian Journal of Agronomy*. **33** : 327-329.

Ganesh, H. V. 2000. Effect of various irrigation schedules on yield and water use in transplanted paddy. *Mysore Journal of Agriculture Sciences*. **34** : 222-226.

Garg, R. N., Aggarwal, P., Gurcharan, S. and Das, D. K. 1996. Effect of puddling and compaction on physical properties and yield of low lands rice. *Indian Journal of Soil Conservation*. **24**(1): 49-53

Gill, H. S. 1979. Studies on economy of N and P through FYM in rice-wheat rotation. *MSc. Thesis,* Punjab Agriculture University, Ludhiana.

Gill, M. S., Singh, T. and Rana, D. S. 1994. Integrated nutrient management in rice-wheat cropping sequence in semi arid tropics. *Indian Journal of Agronomy*. **39**(4) : 606-608.

*Greenland, D. J. 1981. Recent progress in studies in soil structure and its relation to properties and management of paddy soils. *Symposium on paddy soil Nanjing, China. 19-24 october, 1980. Science press, China*. **pp** : 42-58.

Gupta, J. P., Devi, S. and Wali, P. 1999. Influence of FYM and P levels on yield and its uptake in rice. *Annals of Biology*. **15**(1): 55-57.

Gupta, S. C. and Larson, W. E. 1979. Estimating soil water retention characteristics from particle size distribution, organic matter percent and bulk density. *Water Resour Research.* **15** : 1633-1635.

Gupta, S. C., Dowdy, R. H. and Larson, W. E. 1977. Hydraulic and thermal properties of a sandy soil as influenced by incorporation of sewage sludge. *Journal of Soil Science Society of America.* **41** : 601-605.

Hafele, S., Wopereis, M. C. S., Boivin, P. and Diaye, A. M. 1999. Effect of puddling on soil desalinization and rice seedling survival in the Senegal river delta. *Soil and Tillage Research.* **51**(2) : 35-46.

Harinikumar, K. M., Bagyaraj, D. J. and Kale, R. D. 1991. Vesicular asbuscular mycorrhizal propogation in earthworm cast. *Oxford and IBH Publishing Pvt Ltd. New Delhi.* **pp** : 605-610.

Hegde, D. M. 1996. Integrated nutrient supply on crop productivity and soil fertility on rice (*Oryza sativa*)-rice system. *Indian Journal of Agronomy.* **41**(1) : 1-8.

Hegde, D. M. 1998. Effect of integrated nutrient supply on crop productivity and soil fertility on rice (*Oryza sativa*)-wheat (*Triticum aestivum*) system in semi-arid and humid ecosystem. *Indian Journal of Agronomy.* **43**(1) : 7-12.

Hira, G. H., Singh, R. and Kukal, S. S. 2002. Soil matric : a criteria for irrigation to rice (*Oryza sativa*). *Indian Journal of Agricultural Sciences.* 72(4) : 236-237.

Jackson, M. L. 1973. Soil chemical analysis. *Prentice Hall of India Pvt.Ltd,* New Delhi.

Jackson, M.L. 1973. Soil chemical analysis, Prentice Hall Inc., Englewood cliffs, N. J. U.S.A.

Jadhav, A. D., Talashilkar, S. C., Powar, A. G. 1997. Influence of conjunctive use of FYM, vermicompost and urea on growth and nutrient uptake in rice. *Journal of Maharastra Agriculture University*. **22**(2) : 249-250.

Jaggi, I. K. 1986. Efficient use of water by paddy crop in Chattishgarh region. *Indian Farming*. **36**(6): 13.

Jamison, V. C. 1953. Changes in air water relationship due to structural improvement of soils. *Soil Science*. **76** : 143-151.

Jana, M. K. and Ghosh, B. C. 1996. Integrated nutrient management in rice (*Oryza sativa*)-rice crop sequence. *Indian Journal of Agronomy*. **41**(2) : 183-187.

Jeyabal, A., Palaniappan, S. P. and Chelliah, S. 1999. Evaluation of integrated nutrient management techniques in rice. *Oryza*. **36**(3) : 263-265.

Jha, K. P., Chandra, D and Challaiah. 1981. Irrigation requirement of higher yielding rice varieties growth on soils having shallow water table. *Indian Journal of Agricultural Sciences*. **51**(10) : 732-737.

Joshi, A. and Tripathi, S. S. 2006. Pulses and crop diversification in India. *Indian Farmers Digest*. **39**(2) : 23-24.

Kirchhof, G., Priyono, S., Utomo, W. H., Adisarwanto, T., Dacanay, E. V. and So, H. B. 2000. The effect of soil puddling on the soil physical properties and the growth of rice and post rice crops. *Soil and Tillage Research*. **56** : 37-50.

Kukal, S. S and Aggarwal, G. C. 2002. Percolation losses in relation to puddling intensity and depth in a sandy loam rice field. *Agriculture Water Management.* **57** : 49-59.

Kukal, S. S. 2002. Interactive effect of intensity and depth of puddling and water stress on the performance of rice in a sandy loam soil. *Annals of Agriculture.* **23**(1): 131-135.

Kukal, S. S. and Aggarwal, G. C. 2003. Puddling depth and intensity effects in rice-wheat system on sandy loam soil. I. Development of surface compaction. *Soil and Tillage Research.* **72** : 1-8.

Kukal, S. S. and Aggarwal, G. C. 2003. Puddling depth and intensity effects in rice-wheat system on sandy loam soil. II. Water use and crop performance. *Soil and Tillage Research.* **72**: 37-45.

Kukal, S. S. and Sidhu. A. S. 2004. Percolation losses of water in relation to pre-puddling tillage and puddling intensity in a puddled sandy loam rice (Oryza sativa.L.) field. *Soil and Tillage Research.* **78** : 1-8.

Kumar, A. and Prasad, N. K. 2002. Nutrient harvest and soil fertility as influenced by nutrient management in rice (*Oryza sativa*)-forage crop sequences. *Indian Journal of Agronomy.* **47**(2) : 158-162.

Kumar, A., Sarkar, A. K. Singh, R. P. and Sharma, V. N. 1998. Yield and trace metal levels in rice (*Oryza sativa*) as influenced by flash, fertilizer and farmyard manure application. *Indian Journal of Agricultural Sciences.* **68**(9) : 590-592.

Kumar, B. M., Alexander, D. and Latif, P. H. 1988. Efect of water regimes on irrigation needs and yield of short duration rice grown on the soils of Kerala India during summer. *Oryza.* **25**(3) : 261-266.

Kundu, D. K., Ladha, J. K., Lapitan. D. and Guzman, E. 1996. Tillage depth influence on soil N distribution and availability in a lowland rice. *Soil Science Society American Journal.* **60** (3): 1153-1159.

Lakpale, R. and Tripathi, R. S. 1999. Effect of methods of cultivation and irrigation schedules on yield and water requirement of rice. *Journal of Soils and Crops.* **9**(2) : 264-265.

*Lee, K. E. 1992. Some trends and opportunities in earth worm research. *Soil Biological Biochemistry*. **24** : 1765-1771.

Lourduraj, A. C. and Rajagopal, A. 1999. Effect of irrigation regimes and planting geometry on nutrient availability, uptake of nutrients and grain yield in rice. *Madras Agriculture Journal.* **86**(7-9) : 347-351.

Luikham, E., Krishnarajan and Premsekhar, M. 2004. Irrigation and nitrogen application schedules for hybrid "ADTRHI" rice (*Oryza sativa*) in Tamil Nadu. 49(1) : 37-39.

Marazi, A. R., Khan, G. M., Singh, K. N. and Bali, A. S. 1993. Response of rice (*Oryza sativa*) to different nitrogen levels and water regimes in Kashmir valley. *Indian Journal of Agricultural Sciences.* **63**(11) : 726-727.

Matriwade, P. S. and Sheelavantar, M. N. 1994. Influence of green manuring of sesbania rostate on rice (Oryza sativa). *Indian Journal of Agronomy.* **36** (3): 401-403.

Minhas, R. S. and Sood, A. 1996. Effect of inorganic and organic fertilizers on the yield and nutrient uptake by three crops in rotation on acid alfisol. *Journal of Indian Society of Soil Science*. **37** : 257-260.

Misra, H. S., Rathore, T. R. and Pant, R. C. 1990. Effect of intermittent irrigation on ground water table contribution, irrigation requirement and yield of rice in mollisols of Tarai Region. *Agriculture Water Management*. **18** : 231-241.

Mohanty, M and Painuli, D. K. 2003. Land preparatory tillage effect on soil physical environment and growth and yield of rice in a vertisol. *Journal of the Indian Society of Soil Science*. **51**(3): 217-222.

Mohanty, M., Painuli, D. K. and Mandal, K. G. 2004. Effect of puddling intensity on temporal variation in soil physical conditions and yield of rice (*Oryza sativa* L.) in a vertisol of central India. *Soil and Tillage Research*. **76** : 83-94.

Murali, M. K. and Setty, R. A. 2000. Effect of levels of NPK, vermicompost and growth regulator (Triacontanol) on growth and yield of scented rice (*Oryza sativa* L.). *Mysore Journal of Agriculture Sciences*. **34** (4): 335-339.

Nambiar, K. K. M. and Abrol, I. P. 1992. Long term fertilizers experiments in India an over view. *Fertilizer News*. **34**(4) : 11-26.

Narang, R. S. and Singh, N. 1988. Water management studies in rice. *International Rice Research Newsletter*. **13**(4) : 43.

*Nichiporovich, A.A. 1967. Aims of research on the Photosynthesis of plants as a factor of productivity. In: Nichiporovich A.A. (ed) Photosynthesis of productive system. *Israel Programme Science Trans Jerusalem*: **pp** : 3-36.

Olsen, S.R.; Sole, C.V., Wantnabe, F.S.. and Dean, L.A. (1954) Estimation of available phosphorous in soil by extraction with sodium bicarbonate. *USDA circulation, 1939.* **pp**: 1-19.

Oomen, P. K., Oza, A. M. and Subbiah, B. V. 1972. Varietial differences in relatively uptake of soil and fertilizer phosphorous by high yielding varieties of rice and wheat. *Indian Journal of Agricultural Sciences.* **42** (2): 370-374.

Panda, S. C., Rath, B. S., Tripathy, R. K. and Dash, B. 1997. Effect of water management practices on yield and nutrient uptake in dry season rice. *Oryza.* **34** (1): 51-53.

Panse, V.G. and Sukhamate, P.V. (1967) Statistical method for agricultural workers, 3rd ed., ICAR, New Delhi.

Pardhan, S. and Mohan, J. 1998. Response of cereals to azosprillium. *Indian Journal of Agricultural Sciences.* **68**(10) : 701-703.

Parihar, S. S. 2004 (a). Effect of integrated sources of nutrients, puddling and irrigation schedule on productivity of rice (*Oryza sativa*)-wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agronomy.* **49**(2) : 74-79.

Parihar, S. S. 2004 (b). Effect of crop establishment method, tillage, irrigation and nitrogen on production potential of rice-wheat cropping system. *Indian Journal of Agronomy.* **49**(1) : 1-5.

Parihar, S. S. and Sandhu, B. S. 1987. Irrigation of field crops principles and practices. *Indian Councial of Agricultural Research, New Delhi.* **pp** : 142.

Patidar, M. and Mali, A. L. 2002. Residual effect of farmyard manure, fertilizer and biofertilizer on succeeding wheat (*Triticum aestivum*). *Indian Journal of Agronomy.* **47**(1) : 26-32.

Pillai, K. G. 1996. Current scenario in rice and prospectus for sustainable rice production. *Fertilizer News*. **41**(2): 15-23.

Piper, C.S. (1966) *Soil and Plant analysis* (Asian edition), Hans Publishers, Bombay.

Prasad, U. K., Prasad, T. N., Pandey, R. D. and Sahni, R. P. 1990. Response of early paddy to water regimes and nitrogen in calcareous soil. *Indian Journal of Agronomy.* **35**(4) : 364-370.

Purushothaman, S., Jayapaul, P. and Kandasamy, R. 1987. Puddling methods for lowland rice. *IRRI.* **12**(4) : 49.

Ravi, R and Srivastava, O. P. 1997. Vermicompost potential supplement to nitrogenous fertilizers in rice cultures. *International Rice Research Newsletter.* **22** : 30-31.

Reddy, M. N. and Krishnaiah, K. 1999. Current status of crop response to fertilizer in different agro-climatic region. In experiences of all India coordinated rice improvement project. *Fertilizer News*. **44**(4) : 133-126.

*Richards, L. A. and Weaver, L. R. 1943. Fifteen atmospheric pressure as related to the permanent wilting percentage. *Soil Science.* **56** : 331-339.

Saikia, M. and Balasubramaniam, N. 1998. Effect of irrigation and P fertilization on growth and yield of wet-seeded and transplanted rice. *Oryza.* **35**(3) : 260-263.

Saikia, M. and Dutta, T. C. 1991. Response of rice to different irrigation on sandy loam-soil of Assam. *Oryza.* **28** : 359-362.

Saikia, M. and Dutta, T. C. 1992. Response of rice (*Oryza sativa*) to different levels of irrigation and nitrogen on a sandy-loam soil of Assam. *Indian Journal of Agicultural Sciences.* **62**(9): 612-613.

Salter and Haworth. 1961. The available water of a sandy loam soil. II. The effects of FYM and different primary cultivations. *Journal of Soil Science.* **12** : 335-342.

Sandhu, B. S., Khera, K. L., Prihar, S. S. and Singh, B. 1980. Irrigation needs and yield of rice on a sandy loam soil as affected by continuous and intermittent submergence. *Indian Journal of Agricultural Sciences.* **50**(6) : 492-496.

Sandhu, H. 1995. Puddlability and puddling indices of alluvial soils of Punjab. *MSc. Thesis,* Punjab Agricultural University, Ludhiana.

Sawhney, J. S. and Sehgal, J. L. 1984. Effect of rice-wheat and maize wheat crop rotations on aggregation, bulk density and infiltration characteristics of some alluvium-derived soils. *Journal of Indian Society of Soil Science.* **37** (2): 235-239.

Sengar, S. S., Wade, L. J., Baghel, S. S., Singh, R. K. and Singh, G. 2000. Effect of nutrient management on rice (*Oryza sativa*) in rainfed lowland of southeast Madhya Pardesh. *Indian Journal of Agronomy.* **45**(2) : 315-322.

Sharma, A. R. 1999. Effect of farmyard manure and nitrogen fertilizer on performance of rice (*Oryza sativa*) under intermediate deepwater condition. *Indian Journal of Agronomy.* **44**(2): 534-538.

Sharma, P. K. and Datta, S. K. 1985. Puddling influence on soil, rice development and yield. *Soil Science American Journal.* **49** (3):1451-1457.

*Shroff, V. N. and Devaathali, S. 1992. Earthworm farming scope and limitations. *Proceedings of National Seminar on Natural Farming.* **pp** : 126-142.

Sidhu, A. S., Kukal, S. S., Dwivedi, B. S., Singh Dalel., Thind, S. S. and Singh, V. K. 2006. Changes in some macro and micro nutrient status in relation to pre-puddling tillage and puddling intensity in different soils cropped with rice (*Oryza sativa*). . *Indian Journal of Agricultural Sciences.* **76**(3) : 185-188.

Sidhu, A. S., Kukal, S. S., Sandhu, K. S. and Uppal, H. S. 2003. Effect of pre puddling and puddling intensity on water use, nitrogen retention , bulk density and rice (Oryza sativa) yield in sandy loam soil. *Indian Journal of Agricultural Sciences.* **73**(10) : 558-561.

*Sinclair, T. R., Tanner, C. B. and Bennet, J. M. 1984. Water use efficiency in crop production. *Bioscience.* **34** : 36-40.

Singandhupe, R. B. and Rajput, R. K. 1990. Nitrogen uptake by rice as influenced by irrigation regimes and nitrogen in sodic soil. *Journal of Indian Society of Soil Science.* **38**(2): 297-303.

Singh, A., and Singh, N. P. 2006. Direct and residual effects of inorganic sources of nutrients urdbean (*Vigina mungo*)-wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agronomy.* **51**(2): 97-99.

Singh, G., Singh, O. P., Singh, R.G., Metha, R. K., Kumar, V. and Singh, R. P. 2006. Effect of integrated nutrient management on yield and nutrient uptake of rice(*Oryza satia*)-wheat (*Triticum aestivum*) cropping system in lowlands of eastern Uttar Pardesh. *Indian Journal of Agronomy.* **51**(2) : 85-88.

Singh, K. B., Gajri, P. R. and Arora, V. K. 2001. Modelling the effect of soil and water management practices on the water balance and performance of rice. *Agricultural Water Management.* **49** : 77-95.

Singh, N. P., Sachan, R. S., Pandey, P. C. and Bisht, P. S. 1999. Effect of decay long fertilizer and manure application on soil fertility and productivity of rice wheat system in a mollisol. *Journal of Indian Society of Soil Science*. **47**(1) : 72-80.

Singh, R. and Tripathi, R. P. 1998. Infrared thermometry and xylem water potential as an index for the assessment of water stress and scheduling of irrigation in rice. *Indian Journal of Agriculture Research.* **32**(1) : 11-16.

Singh, R., Gajri, P. R., Gill. K. S. and Khera, R. 1995. Puddling intensity and nitrogen use efficiency of rice (Oryza sativa) on a sandy-loam soil of Punjab. *Indian Journal of Agricultural Sciences.* **65**(10) : 749-751.

Singh, V. 2006. Productivity and economics of rice (*Oryza sativa*)-wheat (*Triticum aestivum*) cropping system under integrated nutrient-supply system in recently reclaimed sodic soil. *Indian Journal of Agronomy.* **51**(2) : 81-84.

Singh, Y., Singh, B., Meelu, O. P., and Maskina, M. S. 1990. Nitrogen equivalence of green manure for wet land rice on coarse textured soils. *International Rice Research News Letter* **pp** : 15-23.

Sinha, B. K., Singh, S. R. and Sharma. R. G. 1981. Note on puddling effects on water flow through soils. . *Indian Journal of Agricultural Sciences.* **51** (3): 460-461.

Subbaiah, S. V., Kumar, R. M. and Surekha, K. 2000. Influence of organic manures in conjuction with granulated fertilizers on rice production under transplanted condition. *Oryza.* **37**(4) : 296-299.

Subbiah, B.V. and Asija, G.L. (1956) A rapid procedure for the estimation of available nitrogen in soil. *Current Science*, **25**: 259-60.

Subramanian, S. and Rajagopalan, K. 1979. Effect of water management and nitrogen levels on nutrient uptake of rice. *Indian Journal of Agronomy*. **25**(1) : 77-82.

Sudhakar, G., Lourduraj, A. C., Rangasamy, A., Subbian, P. and Velayutham, A. 2002. Effect of vermicompost application on the soil properties, nutrient availability, uptake and yield of rice-a review. *Agriculture Review.* **23**(2) : 127-133.

Sur, H. S., Prihar, S. S. and Jalota, S. K. 1981. Effect of rice-wheat and maize-wheat rotation on water transmission and wheat root development in sandy loam soil of Punjab. *Soil and Tillagr Research.* **1** : 361-371.

Thakur, D. S. and Patel, S. R. 1999. Growth and sink potential of rice as influenced by split application of nitrogen with and without FYM in inceptisols of eastern part of central peninsular India. *Oryza.* **36**(3) : 280-282.

*Tomati, U., Grappelli, E. and Rossi, W. 1983. Fertilizer from vermiculture as an option for organic waste recovery. *Agrochimica.* **27** : 244-251.

Tripathi, R. P., Gaur, M. K. and Rawat, M. S. 2003. Puddling effects on soil physical properties and rice performance under shallow water table conditions of Tarai. *Journal of Indian Society of Soil Science.* **51**(2) : 118-124.

Tripathi, R. P., Sharma, P. and Singh, S. 2007. Influence of tillage and crop residue on soil physical properties and yields of rice and wheat under shallow water table conditions. *Soil and Tillage Research.* **92** : 221-226.

Uppal, H. S. and Bali, A. 1994. Effect of scheduling and cut-off date of irrigation on yield and quality of rice (*Oryza sativa*) in a non-cracking soil. *Indian Journal of Agronomy.* **39**(4) : 628-630.

Uppal, H. S., Cheema, S. S. and Walia, A. S. 1991. Irrigation need of transplanted rice (*Oryza sativa*) in non-cracking soil. *Indian Journal of Agricultural Sciences.* **61**(9) : 634-636.

Vaidya, P. H. and Gabhane, V. V. 1998. Availability of nutrient in vertisol as influenced sorghum-wheat cropping sequence. *Journal of Soil and Crops.* **8**(1) : 70-72.

Vasanthi, D. and Kumaraswamy, K. 1999. Efficacy of vermicompost to improve soil fertility and rice yield. *Journal of the Indian Society of Soil Science*. **47**(2). 268-272.

Virmani, S. B., Sharawat, K. L. and Burford, J. R. 1982. Physical and chemical properties of vertisols and their management in vertisols and rice soils of tropics. Symposia saper 11th and 12th international congress soil science. *Indian Society of Soil Science, New Delhi, India.* **pp** : 80-93.

Walkley, A. and Black, I.A. 1934. An examination of the Degtjareff method for determining soil organic matter, an a proposed modification of the chromic acid titration method. *Soil Science*, **37**: 29-38.

Woodhead, T. 1990. Problems and opportunities in soil physical management in rice based cropping system. *Transactions of 14th International Congress on Soil Science, Kyoto, Japan.* **1**: 140-145.

*** Original not seen.**

Appendices

APPENDIX-I

Rainfall distribution during crop season in rice in rice-wheat cropping system

Months	Dates		Rainfall (mm)		Cumulative rainfall (mm)	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
July	11	10	9.2	63.0	9.20	63.00
	12	12	8.2	14.2	17.40	77.20
	13	14	3.2	25.0	20.60	102.20
	14	19	5.8	5.2	26.40	107.40
	15	20	33.1	9.0	59.50	116.40
	18	23	9.0	18.4	68.50	134.80
	19	24	1.1	29.0	69.60	163.80
	20	25	11.0	9.4	80.60	173.20
	21	26	4.0	1.0	84.60	174.20
	26	27	60.6	4.4	145.20	178.60
	27	28	13.6	40.2	158.80	218.80
	-	30	-	6.0	158.80	224.80
Aug	02	01	2.8	1.4	161.60	226.20
	03	03	2.0	7.2	163.60	233.40
	04	05	12.2	76.6	175.80	310.00
	05	07	56.0	24.2	231.80	334.20
	07	20	1.2	42.0	233.00	376.20
	08	21	19.0	75	252.00	451.20
	16	24	7.8	1.2	259.80	452.40
	17	27	16.0	1.4	275.80	453.80
	18	28	2.2	9.0	278.80	462.80
	21	-	1.0	-	279.80	462.80
Sept.	09	02	27.8	90.6	306.80	553.40
	14	03	1.0	143.2	307.80	696.60
	18	11	5.1	14.0	312.90	710.60
	23	12	0.6	29.5	319.80	740.10
	26	13	6.3	4.0	319.80	744.10
October	-	20	-	28.0	319.80	772.10
	-	21	-	11.4	319.80	783.50

Source : Meteorological Section, Division of Agronomy, SKUAST-Jammu.

Continued...

Rainfall distribution during crop season in wheat in rice-wheat cropping system

Months	Dates		Rainfall (mm)		Cumulative rainfall (mm)	
	2005-2006	2006-2007	2005-2006	2006-2007	2005-2006	2006-2007
Nov.	-	18	-	11.20	0.00	11.20
Dec.	--	05	-	22.20	0.00	33.40
	-	06	-	5.60	0.00	39.00
	-	26	-	2.00	0.00	41.00
	-	27	-	3.00	0.00	44.00
Jan.	02	-	9.80	-	9.80	44.00
	03	-	21.70	-	31.50	44.00
	16	-	13.90	-	45.40	44.00
	17	-	4.60	-	50.00	44.00
	18	-	18.70	-	68.70	44.00
Feb.	15	10	3.00	4.50	71.70	48.50
	26	11	5.00	24.50	76.70	73.00
March	-	12	-	14.80	76.70	87.80
	-	13	-	6.00	76.70	93.80
	-	19	-	2.80	76.70	96.60
	-	22	-	6.50	76.70	103.10
	-	27	-	7.80	76.70	110.90
	-	28	-	3.40	76.70	114.30
	14	01	1.50	3.20	78.20	117.50
	15	12	32.60	66.40	110.80	183.90
	-	13	-	16.00	110.80	199.90
	-	14	-	15.60	110.80	215.50
	-	20	-	21.00	110.80	236.50
	-	21	-	1.00	110.80	237.50
	-	22	-	11.00	110.80	248.50

Source : Meteorological Section, Division of Agronomy, SKUAST-Jammu.

APPENDIX - II

Weekly meteorological data during crop season

Month	Met. Week	Rainfall (mm)		Mean Relative Humidity (%)		Mean Temperature (^{0}C)		Total Evaporation (mm)	
		2005-2006	2006-07	2005-2006	2006-07	2005-2006	2006-07	2005-2006	2006-07
July	28	059.5	102.2	79.50	79.00	29.10	28.50	2.30	5.40
	29	025.0	014.2	80.00	77.00	28.75	30.50	3.50	6.20
	30	074.2	102.4	75.50	86.50	30.05	28.15	3.40	4.60
August	31	073.0	091.2	80.00	81.00	30.05	30.15	4.10	3.90
	32	020.2	024.2	80.50	80.50	28.60	28.75	4.00	3.30
	33	026.0	000.0	82.00	75.00	29.55	30.35	4.00	4.80
	34	001.0	118.2	78.50	81.00	29.60	29.45	4.30	3.60
September	35	000.0	101.0	74.00	81.00	29.45	26.05	4.70	3.10
	36	027.8	152.2	78.50	81.50	29.55	27.85	3.70	3.40
	37	001.0	043.5	77.50	78.00	22.60	27.85	3.10	3.50
	38	005.7	000.0	79.00	75.00	22.55	28.05	3.10	3.10
	39	006.3	000.0	74.00	67.50	22.40	26.60	3.60	3.20
October	40	000.0	000.0	69.00	67.50	22.60	27.05	3.70	3.00
	41	000.0	000.6	65.00	69.00	25.50	26.60	3.80	2.50
	42	000.0	005.6	62.50	74.00	22.70	22.80	3.40	2.10
	43	000.0	000.0	64.00	74.50	21.95	21.95	3.20	1.80
November	45	000.0	000.0	61.00	74.50	19.15	21.65	3.10	2.20
	46	000.0	012.2	59.00	73.00	17.70	18.95	3.40	1.80
	47	000.0	000.0	60.50	73.00	17.15	17.35	3.40	1.60
December	48	000.0	000.0	63.50	65.50	14.70	14.10	2.50	1.50
	49	000.0	027.8	63.50	83.00	13.65	14.65	2.70	1.10
	50	000.0	000.0	65.50	77.50	12.15	13.10	2.50	1.20
	51	000.0	000.0	68.00	77.50	12.20	14.10	2.10	1.30
	52	000.0	005.0	68.50	87.00	12.45	11.65	2.50	0.90
January	1	031.5	000.0	86.00	73.00	9.85	9.40	0.90	0.80
	2	000.0	000.0	78.00	72.50	11.50	9.60	1.40	1.00
	3	027.2	000.0	71.50	71.50	13.85	10.95	1.20	1.10
	4	000.0	000.0	74.50	69.50	12.70	14.55	2.10	1.40
February	5	000.0	000.0	72.00	80.50	15.50	16.45	2.60	1.70
	6	000.0	028.7	72.00	80.00	16.70	15.80	2.70	1.10
	7	003.0	022.1	68.50	81.00	19.65	12.95	2.60	0.90
	8	000.0	009.3	71.00	77.00	20.00	14.65	2.40	1.40
March	9	005.0	014.1	69.50	75.00	18.35	15.65	2.00	1.30
	10	000.0	000.0	63.50	71.00	19.05	16.35	2.60	1.80
	11	034.1	242.0	76.50	75.00	17.80	16.20	2.30	1.50
	12	000.5	033.0	63.50	73.00	19.15	19.80	3.10	1.70
April	13	000.6	000.0	65.00	68.00	21.45	23.40	3.20	2.40
	14	000.0	000.0	55.50	64.50	23.90	22.80	4.20	2.40
	15	010.0	010.0	45.00	58.50	22.60	26.40	4.20	2.90
	16	000.0	000.0	44.00	51.50	24.4	28.20	4.50	2.90
	17	000.0	000.0	35.00	42.00	29.30	28.30	6.10	3.80

Source : Agro meteorology Section, Division of Agronomy, SKUAST-Jammu

Appendix-III

Analysis of variance for various biometric observations on Plant height and Dry matter of rice under field conditions

Sources of variation	d.f	Plant height (cm)								Dry matter (g/m^2)							
		Mean sum of Square (Days after transplanting)								Mean sum of Square (Days after transplanting)							
		20005-06				20006-07				20005-06				20006-07			
		30	60	90	Harvest	30	60	90	Harvest	30	60	90	Harvest	30	60	90	Harvest
Replication	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P S S	2	7.77	10.03	10.10	9.35	4.34	22.12	18.78	19.37	9.08	27.58	47.25	45.25	9.08	27.58	47.25	45 25
I S S	2	37.91	92.39*	101.36*	103.20*	35.77	105.6*	50.09*	49.86*	83.08	348.1*	614.25*	757.75*	83.08	348.1*	614.25*	757 75*
P X I	4	177.15	513.16	336.91	338.58	182.61	491.89	196.44	197.02	310.83	1464.58	1653.38	2930.75	310.83	1464.58	1653.37	2930.75
Error(a)	16	60.09	7.42	12.71	14.56	23.35	8.17	12.48	13.06	31.37	62.83	28.56	35.38	37.68	43.11	34.71	30.83
N S S	3	59.50	146.9*	118.44*	119.92*	43.63	109.5*	73.17*	74.58*	82.89	284.56*	242.08*	507.64*	642.8*	1328*	1992.1*	1613.64*
P X N	6	0.58	0.12	0.57	0.71	0.56	4.78	4.02	4.16	0.31	1.47	8.92	3.81	0.31	1.47	8.92	3.81
I X N	6	6.49	5.41	4.91	4.99	0.48	8.07	6.24	6.27	0.97	1.64	15.58	6.64	0.97	1.64	15.58	6.64
P X I X N	12	1.76	8.89	3.34	3.39	2.14	6.45	2.26	2.35	0.89	7.31	13.04	5.81	0.89	7.31	13.04	5.81
Error(b)	54	26.12	7.77	8.94	10.63	36.32	3.40	8.70	9.35	33.23	33.56	46.98	40.06	33.51	40.20	36.89	35.48

*** Significant at 0.5% level of probability**

Appendix-IV

Analysis of variance for various biometric observations on yield and yield attributes of rice under field conditions

Sources of variation	d.f	No. of tillers/m²		No. of panicles/m²		No of grains/panicle		Grain weight/panicle (g)		1000-grain weight (g)		Grain yield (q/ha)		Straw yield (q/ha)		Harvest Index (%)	
		MSS		MSS		MSS		MSS		MSS		MSS		MSS		MSS	
		20005-06	20006-07	20005-06	20006-07	20005-06	20006-07	20005-06	20006-07	20005-06	20006-07	20005-06	20006-07	20005-06	20006-07	20005-06	20006-07
Replication	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P S S	2	637.04*	953.34*	1721.33*	1985.04*	161.58*	96.58*	0.00	0.00	0.44	0.44	29.50*	28.58*	99.45*	99.45*	0.68*	0.70*
I S S	2	264.06*	264.37*	544.08*	721.12*	6.58	11.58	0.04*	0.04*	22.99*	6.29*	27.96*	27.68*	98.00*	102.58*	1.07*	0.87*
P X I	4	120.40*	120.37*	721.46*	610.16*	59.33*	49.33*	0.23*	0.23*	18.98	29.30	5.67*	5.87*	24.31*	22.02*	0.77	0.18
Error(a)	16	25.59	31.77	70.99	61.92	17.93	2.78	0.01	0.01	1.58	1.61	0.66	0.68	1.82	1.47*	0.12	0.09
N S S	3	1059.79*	1965.36*	674.44*	1623.19*	142.33*	387.89*	0.02*	0.04*	2.72*	2.73*	17.22*	30.76*	104.15*	104.15*	2.71*	0.73
P X N	6	121.86*	191.55*	32.44	32.44	1.58	5.47	0.01	0.01	1.18	1.10	1.87*	1.76*	7.75*	7.75*	0.29	0.22
I X N	6	22.63	128.50	53.19	53.19	1.92	9.14	0.01	0.01	1.20	0.67	0.44	0.53	2.79	3.65	0.37	0.16
P X I X N	12	33.60	146.36	69.57	69.57	2.67	13.22	0.01	0.01	0.75	0.40	0.58	0.49	2.29	1.86	0.73	0.10
Error(b)	54	49.99	79.50	154.35	154.35	24.69	2.78	0.01	0.01	1.30	1.33	0.62	0.62	2.58	2.62	0.16	0.10

*** Significant at 0.5% level of probability**

Appendix-V

Analysis of variance for various biometric observations on N, P and K uptake of rice and yield of wheat under field conditions

Sources of variation	d.f	N-uptake by rice grains(Kg/ha)		P-uptake by rice grains(Kg/ha)		K-uptake by rice grains(Kg/ha)		N-uptake by rice straw(Kg/ha)		P-uptake by rice straw(Kg/ha)		K-uptake by rice straw(Kg/ha)		Grain yield(q/ha) Wheat		Straw yield(q/ha) Wheat	
		MSS		MSS		MSS		MSS		MSS		MSS		MSS		MSS	
		20005-06	20006-07	20005-06	20006-07	20005-06	20006-07	20005-06	20006-07	20005-06	20006-07	20005-06	20006-07	20005-06	20006-07	20005-06	20006-07
Replication	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P S S	2	0.25	0.25	0.01	0.01	0.07	0.04	1.36	1.36	0.01	0.02	0.25	0.25	1.60	2.42	6.39	9.70
I S S	2	7.78*	7.78*	0.52*	0.52*	1.41*	1.25*	13.81*	13.81*	0.08*	0.11*	7.87*	7.87*	0.61	0.59	2.44	2.36
P X I	4	7.25	7.25	0.51	0.51	6.30	6.72	10.34	10.34	0.33	0.28	7.25	7.25	33.14	34.41	132.55	137.52
Error(a)	16	0.71	1.69	0.07	0.13	0.25	0.19	1.29	1.93	0.00	0.01	0.03	0.24	0.81	0.99	3.24	3.97
N S S	3	8.04*	23.50*	0.15*	1.46*	1.16*	2.39*	4.13*	11.31*	0.07*	0.08*	8.04*	17.95*	1.84*	2.49*	7.37*	10.01*
P X N	6	0.01	0.01	0.00	0.00	0.01	0.04	0.09	0.09	0.00	0.00	0.01	0.01	0.34	0.29	1.37	1.15
I X N	6	0.06	0.06	0.00	0.00	0.01	0.01	0.03	0.03	0.00	0.01	0.06	0.06	0.32	0.40	1.28	1.59
P X I X N	12	0.06	0.06	0.00	0.00	0.02	0.03	0.04	0.04	0.00	0.00	0.06	0.06	0.56	0.58	2.22	2.34
Error(b)	54	1.10	1.70	0.03	0.07	0.04	0.11	0.17	0.26	0.00	0.01	2.29	2.65	0.86	0.99	3.42	3.95

*** Significant at 0.5% level of probability**

Appendix-VI

Analysis of variance for various biometric observations on bulk density and percolation rate after harvest of rice under field conditions

Sources of variation	d.f	Soil bulk density (mg/m^3)								Percolation rate(cm day^{-1})	
		Mean sum of Square (Soil profile Cm)								M S S	
		20005-06				20006-07				20005-06	20006-07
		0-15	15-30	30-60	60-90	0-15	15-30	30-60	60-90		
Replication	2	-	-	-	-	-	-	-	-	-	-
P S S	2	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.00	1.69*	1.69*
I S S	2	0.01	0.02	0.03	0.05	0.01	0.01	0.03	0.05	0.08*	0.08*
P X I	4	0.00	0.02	0.00	0.00	0.00	0.02	0.00	0.00	0.05	0.05
Error(a)	16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
N S S	3	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.15*	0.09*
P X N	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02
I X N	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P X I X N	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Error(b)	54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

* Significant at 0.5% level of probability

VITA

VITA

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Masters Degree	MSc. (Ag.) Agronomy
University and year of award	Allahabad Agricultural Institute-Deemed University, Allahabad. (U.P)
OGPA	9.50/10.00
Ph.D.	Ph.D. (Ag.) Agronomy
OGPA	7.20/10.00
Title of Master's thesis	Studies on weed control in transplanted rice by using different herbicides.