Access to enough food for healthy and productive life is the biggest challenge in the modern ages. Rice (Oryza sativa) plays a vital role in the promotion of peace and harmony throughout the world. It is grown in 113 countries and most of the rice produced is consumed directly as food as it forms the most important staple food on the planet and feeds roughly half the population on a daily basis. Globally rice ranks second to wheat in terms of area covered. Among the cereals Wheat (Triticum sp.) ranks first in area and production in the world. The area represents a fifth of the total area under food grains in India. Wheat occupies about 220 mha which is about 14% of the global arable land area. Wheat production in the world has steadily increased to about 73.7%. South and East Asia has greatly contributed towards increase in global wheat production.

In India rice occupies 43.9 mha, which forms 31% of the total area under food grain with 91.6 million tonnes production (Singhal 2003).

In India wheat occupies a distinct position. Although area under wheat is about 61 per cent of that under rice, it is the crop has brought in the green revolution in India and has paved way for the country's food security.

Presently India with 1.2 billion population has to support 18.6 per cent of the World's population depending on 2.4 per cent global land area is estimated to become 1.4 billion by 2025 and 1.7 billion by 2050 AD needing annually about 380mt and 480 mt food grains respectively (Yadav and singh,2000).

Among the food crops rice and wheat are most important and occupy pivotal position and provide more calories per ha than any other cereals sustaining 5.7 persons per year per ha compared to 5.3 persons for wheat in
**General Introduction**

the world at present level of production. Rice contributes about 18% of the total output per person per day besides their employment to large section of rural population in Asian countries. Wheat makes up 19.2% of the total calorie supply.

In eastern India, rice is extremely an important and strategic crop and occupies about 43 per cent of country’s rice area. The region has the largest area of 18.4 m ha suitable for rice cultivation but the average yield is only 2367 kg/ha compared to national average of 2759 kg/ha mainly because of geographical constraints. Of about 28 mha area under wheat in the country, north eastern plain zone covers 27% area under wheat cultivation and shares 24% of the total production. Eastern zone comprises a small wheat zone of 2% of total area and an equal share of grain production in India.

Rice–wheat is the most important crop sequence in India. This system contributes more than one fourth to total food grain production (Singh et al., 2003) and is back bone of food security in India.

Rice–wheat system is emerging as popular cropping system in irrigated ecology in north eastern region of the country. Rice and wheat combinedly contribute 77%, of which rice–wheat cropping system shares 29% of national food grain production (Hegde, 1998). Rice–wheat system holds a sizeable area of about 10.5 mha in India (Pandey, 1992). About 33% of India’s rice and 42% of wheat is grown in this system (Yadav and Kumar, 2009).

West Bengal is the largest rice producing state in India. Rice is grown in about 5.69 mha area in this state under different physiographic situation. Rice is grown under diverse ecological situation in three seasons. The pre monsoon rice, known as aus, accounts for about 10% of the total rice area. The monsoon rice known as aman is grown from July to December accounts
for 75 % of the total rice area and is grown under rain fed in the medium deep and deep flooded land mostly with traditional varieties and under irrigated condition under flood free shallow low land with mostly modern varieties. The remaining 15 % of the rice area is covered by the winter or dry season rice known as *boro*. Rice is grown with supplementary irrigation during the monsoon season accounts for 21 % of the area.

Rice is the staple food of the people, it accounts for 95% of the food gains produced in the state, compared to 54% for India as a whole. The state's population is still growing at 2.2% per year and is projected to reach 108 million by year 2025, from the 68.1 million recorded in the 1991 population census; the demand for rice is expected to increase by about 68% over the next 30 years. From the present level of 18.2 million tonnes, rice production must increase to 30.5 million tonnes by 2025 in order to avoid a further increase in import / or an increase in the price of rice relative to other food grains.

West Bengal is not a traditional wheat growing state of the country. There is sharp increase in area productivity and production of wheat in 1970s, after which it has remained more or less stable. In West Bengal about 0.4 million ha is under wheat with total production of about 0.9 million tonnes and productivity of 2.3 t per ha (Anonymous 2008).

Though rice is the staple food for the people of West Bengal, wheat is also used to a large extent. Of late, wheat has been included as one of the daily meals and various preparations of wheat. Moreover with economic prosperity, the food habit of people is changing in West Bengal; therefore the demand of wheat is fast rising.

The development of photo - insensitive, high yielding varieties of rice and wheat led to the foundation of rice - wheat system in the country.
General Introduction

In lowland area, the excess moisture remains in the soil after harvest of rice, which delays the sowing of winter season (Rabi) crops like lentil, linseed, Indian mustard and pea, resulting in poor productivity. Under such a situation sowing of wheat is the only option.

Rice - Wheat system is emerging as popular cropping system in irrigated ecology of lower gangetic plain zones of West Bengal. In this system, rice is mostly taken as manually transplanted crop under puddled condition. Since rice is grown under puddled condition which results in the formation of hard pan below the surface, it requires more energy for tillage operation to prepare good seed bed for sowing of wheat crop (Singh et al, 1998) Though under puddled condition the yield is high and water losses through deep percolation and seepage are reduced compared with unpuddled condition, it has its own limitations and ill effects on soil health.

Long - duration of rice varieties and delay in their transplanting delay the wheat sowing resulting in adverse effect on wheat yield. Moreover conventional method of wheat sowing by giving repeated tillage further delays sowing and significantly reduces yield.

Wheat sowing after rice gets delayed due to wet soil condition which takes much time to come in working conditions Also tillage after rice harvest requires more time, labour and energy. On the other hand, zero tillage or reduced tillage minimizes loss on account of delayed sowing as it advances the wheat sowing by 10 – 15 days and also saves time and cost included in field preparation (Pandey et. al. 2005)

In recent years, minimum tillage has gained importance owing to reduced production cost, which can be achieved in parts by reducing the intensity of tillage operation. Zero tillage or minimum tillage also advances sowing of wheat than conventional tillage (Parihar, 2004).
General Introduction

The reduction in grain yield due to delay in wheat sowing has been reported 37.5 kg/ha/day (Pal, et al. 1996) and this can be averted with an appropriate tillage system tailored to meet the crop needs.

Zero tillage, is aimed at restriction of secondary tillage, to seed bed preparation only, for seed germination a satisfactory stand, favorable growing conditions, better utilization of residual soil moisture, less soil compaction, control of soil erosion, reduction in cost of cultivation and thereby higher profit due to reduced cost of cultivation. It has been observed that zero tillage technique ameliorates late planting, reduces weeds and improves fertilizers and water use efficiency (Yadav et al, 2005).

In zero tilled wheat optimum seed rate plays an important role in boosting wheat yield. Very low seed rate reduces plant population and very high seed rate brings more plant competition with the result lower yield is obtained in both the cases. Seed rate depends on the proportion of hard coated seeds, pre - sowing treatments of seeds, land preparation, fertility status, texture, pH, availability and salinity of the soil, fertilizer applications, time of sowing, temperature, soil moisture level, spacing, cultivation practices, availability of irrigation water etc Among agronomical factors that are responsible for the grain yield of wheat, optimum seed rate plays a significant role in enhancing grain yield, as it markedly influences the crop establishment, growth and development of the crop and finally grain yield, It is established fact that yield per unit area is directly correlated with the yield per plant and number of plants per ha. Seed rate influences the capacity of plants to utilize environmental factors in building plant tissues through regulating the absorption capacity of plant and the amount of foliage per unit area.

Seed rate determines the number of plants per unit area as well as distribution of plant over the ground. The yield per unit area is dependent
not only on the number of plants per unit area but also on the distribution of the plants. Seed rate greatly affects yield of crop through determination of plant population. The optimum seed rate is an important factor that affects crop micro-environment by influencing the degree of inter and intra plant competition. Therefore while fixing seed rate for zero tilled wheat the plants should be planted neither too thick nor too thin so that the input use efficiently may be enhanced to the maximum possible extent.

Optimum seed rate not only results in optimum plant population but also luxuriant growth and development of individual plant with efficient significantly affects grain yield of wheat. Plant population adjusted by proper seed rate is one of the major aspects of augmenting productivity of wheat seed rate is known to influence the wheat yield to a great extent as reported by Singh et.al. (1971), Sewa Ram et.al., (1973). Therefore it is considered necessary to obtain information on rate of seed in respect of zero tilled wheat in order to exploit its full yield potential.

After harvest of rice, wheat sowing may be advanced by 10-15 days by adopting the technique of zero tillage. Fertilizer plays a key role in accelerating production. There are two schools of thought regarding the fertilizer use in zero tilled wheat. One emphasizes that under zero tilled wheat the productivity can be increased up to certain extent by supplementing with high dose of fertilizer, whereas other argues that poor growth of zero tilled wheat under adverse compact soil rhizosphere cannot utilize high dose of fertilizer for improving its productivity. There are indications if stagnation or even decline in productivity of wheat after rice due to decline in soil organic matter, over-mining of nutrient reserves, loss of nutrients and non-availability of cost-effective fertilizer.

Both rice and wheat crops grown in sequence require high quantity of nutrients to harness their potential yields (Hegde and Pandey 1989).
General Introduction

Application of inadequate and unbalanced quantity of fertilizers to these crops not only results low crop yields, but deteriorates the soil properties also (Sharma et al. 2003). The advancing of wheat seeding is possible by technique of zero tillage on the residual soil moisture after harvest of rice, as there is no need to prepare field for sowing. But in this system fertilizer management may differ because of rice stubble cause higher nitrate depression for 4 – 6 weeks under zero tillage which result immobilization of nitrogen (Kumar and Yadav, 2005). Therefore higher rates of fertilizer specially nitrogen may be required for zero tilled wheat to exploit yield potential of the crop use efficiency of applied fertilizers needs to be increased to sustain the productivity of wheat. Balanced fertilizer use is considered as promising agro – technique to sustain yield, increase fertilizer use efficiently and restore soil fertility. High yielding varieties of wheat give greater response when N, P and K fertilizer are adequately applied (Rai and Sinha, 1983). Productivity of zero tilled wheat depends on the prevailing environmental conditions during the crop growth which cannot be modified to a great extent under field condition. However, with the adoption of modern agronomic management, favorable soil moisture regime can be created by proper scheduling of irrigation (Mc Donald et al. 1984), as it not only takes care the deleterious effect of high temperature but also increases the input utilization efficiently of the crop (Thakur et al, 2000).

The deleterious effect of water deficit is not equally pronounced over all the growth stages of wheat crop. Similarly soil fertility can be maintained with the use of recommended fertilizer (Singh and Verma, 1990). Productivity of wheat crop is improved due to judicious application of irrigation and fertilizer. Among various factors that affect the yield if wheat, availability of water and fertilizer management are of supreme importance. Water is a key input for all recommended agronomic practices and therefore efficient
utilization of irrigation water is essential for wheat (Nadeem et.al 2007). Under and over irrigation cause lower fertilizer use efficiency of crop (Saren and Jana, 2001). Accordingly critical growth stages based on the availability of irrigation must be worked out for zero tilled wheat, as its water need differs from conventional tilled wheat. Over irrigation not only enhances deep percolation of costly irrigation water but also accelerates the movement of plant nutrients particularly nitrogen beyond the crop root zone. Thus irrigation and fertilizer may interact with each other in increasing the grain yield of wheat.

The weeds are the major hurdle in the adoption of zero tillage technology in wheat. The major problems in zero tillage system lie with the weeds that emerge before the sowing of wheat crop or as a residue of the previous crop (Dhiman et.al, 2001). Though zero tillage in wheat field reduces the infestation of Phalaris minor, it aggravates the problems of some broad - leaf weeds (Yaduraju and Mishra, 2002). If these weeds are not controlled in time, they reduce the wheat yield sustainability up to 10 to 50% (Walia et.al, 1990), depending upon weed intensity and type of weed flora control enhances grain yield by 40.6% (Dixit and Bhan, 1997) and because of paramount significance in reduced tillage system. Evaluation of efficient herbicides suited to a Particular climatic situation for a targeted group of plants needs immediate attention.

To have higher productivity levels, weed management strategies in zero tillage system in wheat are also equally important like other management practices and the recommendations should be situation specific to have maximum quality produce. Success of zero tillage in wheat is largely dependent on solving the key issue of weed management with economic crop yields (Hari Om et.al 2006). Information on different management aspects of zero tillage system in wheat after transplanted rice in Gangetic
alluvial ecosystem of West Bengal is rather meager. Hence, in order to gather adequate information, sets of field experiments were conducted during winter (rabi) seasons of 2008-2010 at water Management station, Ranaghat, Nadia, West Bengal, situated at 23°11' north latitude and 88°11' east latitude with an altitude of 7.0 meter above mean sea level. The study involved assessment of zero tillage systems along with other management practices to exploit wheat productivity after transplanted rice.

The study was undertaken with a view to evolving appropriate package of practices for sustainable production of wheat under zero tillage system after transplanted rice in gangetic alluvial soil conditions of West Bengal. In specific terms the main objectives of the investigations can be outlined as:

(i) Relative performance of zero tillage and conventional tillage system in wheat after transplanted rice.
(ii) To determine optimum seed rate of wheat under zero tillage system for maximization of yield.
(iii) Assessment of fertilizer use and scheduling of irrigation for maximization of wheat productivity under zero tillage system.
(iv) Evaluation of weed management through use of herbicides in zero tillage system of wheat cultivation.
(v) To evolve appropriate package of practices based on zero tillage system involving other cultural requirements for wheat after rice.


Dixit, A. and Bhan, V.M. 1997. Weed control efficiency of Isoproturon applied at different concentrations and in combination with 2, 4-D in Wheat. Indian Journal of weed science, 29 (1,4) : 11-14.


Kumar, Ramesh, and Yadav, D.S. 2005 Effect of zero and minimum tillage in conjunction with nitrogen management in wheat (Triticum aestivum after rice (Oryza sativa). Indian Journal of Agronomy 50 (1) : 54 - 57.


METEOROLOGICAL OBSERVATIONS

Climatic condition

The experimental site belongs to sub-tropical humid climate. The summer is hot and the winter is moderate. May is generally the hottest month of the year. The average temperature ranges from 25 to 36.5°C during summer months and between 10°C to 25°C during winter months. Pre-monsoon rain is common in the month of April and May. Normal monsoon of this region breaks in the first week of June. The average annual rainfall is 1450 mm, mostly precipitated during June to September. Monsoon ceases during October and cool season sets in November. Broadly, the crop growing seasons of this region are classified as (i) dry and warm or pre-kharif (March to May), (ii) wet and warm or kharif (June to October) and (iii) dry and cool or rabi (November to March) seasons. The meteorological data pertaining to the period of experimentation are given in Table A and Table B.

Temperature

Mean maximum and mean minimum temperature of different months showed slight variation in two years. In the first year of cropping season (2009) the mean maximum and minimum temperature were higher as compared with the cropping season of 2010. Those decreased from December to January and then increased up to March. The highest value of monthly mean maximum temperature was recorded in the month of March during both the years of experimentation (35.33°C in 2009 and 31.25°C in 2010). The monthly mean minimum temperature was the lowest in the month of November during both the years (12.15°C in 2009 and 9.05°C in 2010) (Table A).

Rainfall

The mean annual rainfall of the experimental Farm is 1464 mm. South west monsoon sets by second week of June and recedes by second fortnight of October. The rainfall is unimodal and the distribution is uneven. Nearly 90% of the total
annual rainfall is received during the period from June to October. December and January are relatively dry months. During the first year of experiment highest rainfall was received in March 2009 (26.0 mm) and during second year highest rainfall was received in November 2009 (14.3 mm). The total rainfall during the experimental period was 35.5 mm (2008-09) and only 17.0 mm (2009-2010). There is a trend of lower rainfall than the normal in both the years. Only 3 to 5 rainy days were found during period of the experiment (Table B).

Relative humidity

The monthly mean maximum relative humidity was observed ranging from 95.8% to 97.0% (2008-2009) and from 93.3% to 99.7% (2009-2010) during period of the experiment (Table A). However, during afternoon hours the relative humidity was relatively lower.

The monthly mean minimum relative humidity was observed ranging from 45.33% to 53.25% (2008-2009) and from 45.65% to 54.33% (2009-2010) during the period of the experiment (Table A).

Bright sunshine hour

The bright sunshine hours per day widely fluctuated in different months of a year. The monthly mean bright sunshine hour was observed ranging from 7.2 hours/day to 8.6 hours/day (2008-2009) and from 6.9 hours/day to 8.7 hours/day (2009-2010) during the period of the experiment (Table A).

Daily pan evaporation

The highest mean daily pan evaporation ($E_{\text{pan}}$) was observed during the month of March 2009 (3.9 mm d$^{-1}$) and during March 2010 (3.3 mm d$^{-1}$) (Table A). It decreased considerably in the month of December and January due to fall of temperature. In
the summer month of March, the evaporation increased considerably 3.9 and 3.3 mm/day in 2009 and 2010 respectively.

Table A: Meteorological observation during the course of investigation

<table>
<thead>
<tr>
<th>Months</th>
<th>Temperature (°C)</th>
<th>Rainfall (mm)</th>
<th>Relative humidity (%)</th>
<th>Bright sunshine (hrs/day.)</th>
<th>Wind velocity km/hr</th>
<th>Epan (mm d⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>November 2008</td>
<td>31.52</td>
<td>19.33</td>
<td>1.6</td>
<td>95.8</td>
<td>53.25</td>
<td>7.6</td>
</tr>
<tr>
<td>December 2008</td>
<td>30.24</td>
<td>14.52</td>
<td>0.0</td>
<td>96.5</td>
<td>50.33</td>
<td>7.7</td>
</tr>
<tr>
<td>January 2009</td>
<td>27.50</td>
<td>12.15</td>
<td>7.9</td>
<td>96.6</td>
<td>52.45</td>
<td>7.2</td>
</tr>
<tr>
<td>February 2009</td>
<td>30.83</td>
<td>16.45</td>
<td>0.0</td>
<td>97.0</td>
<td>48.65</td>
<td>8.5</td>
</tr>
<tr>
<td>March 2009</td>
<td>35.33</td>
<td>21.00</td>
<td>26.0</td>
<td>95.8</td>
<td>45.33</td>
<td>8.6</td>
</tr>
<tr>
<td>November 2009</td>
<td>29.25</td>
<td>15.33</td>
<td>14.3</td>
<td>93.3</td>
<td>54.33</td>
<td>7.8</td>
</tr>
<tr>
<td>December 2009</td>
<td>25.45</td>
<td>11.10</td>
<td>0.0</td>
<td>99.7</td>
<td>52.00</td>
<td>7.8</td>
</tr>
<tr>
<td>January 2010</td>
<td>23.33</td>
<td>9.05</td>
<td>0.2</td>
<td>99.5</td>
<td>50.25</td>
<td>6.9</td>
</tr>
<tr>
<td>February 2010</td>
<td>26.10</td>
<td>13.33</td>
<td>2.5</td>
<td>98.2</td>
<td>50.10</td>
<td>8.5</td>
</tr>
<tr>
<td>March 2010</td>
<td>31.25</td>
<td>16.10</td>
<td>0.0</td>
<td>97.1</td>
<td>45.65</td>
<td>8.7</td>
</tr>
</tbody>
</table>

Max. = Maximum, Min. = Minimum
### Meteorological Observations

**Table B: Details of Rainfall**

<table>
<thead>
<tr>
<th>Months</th>
<th>Rainfall (mm)</th>
<th>No. of rainy days</th>
<th>Highest Rainfall (mm) In 24 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal (LTA)</td>
<td>Total</td>
<td>2008-09</td>
</tr>
<tr>
<td>November</td>
<td>26.0</td>
<td>1.6</td>
<td>14.3</td>
</tr>
<tr>
<td>December</td>
<td>4.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>January</td>
<td>13.0</td>
<td>7.9</td>
<td>0.2</td>
</tr>
<tr>
<td>February</td>
<td>17.0</td>
<td>0.0</td>
<td>2.5</td>
</tr>
<tr>
<td>March</td>
<td>40.0</td>
<td>26.0</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>100.0</td>
<td>35.5</td>
<td>17.0</td>
</tr>
</tbody>
</table>