Field experiments were conducted during 1999-2000 and 2000-2001 at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi in split-plot design with three replications to assess the effect of INM on wheat under reduced tillage and soil properties. The field experiment was initiated with green manure crop of Dhaincha which was followed by rice and finally test crop of wheat was taken. Recommended doses of N, P and K (120:60:60) were applied to rice and grain and straw yields were recorded during both the years. Four main plot treatments comprising of tillage methods and green manuring and seven sub plot treatments comprising of different combination of chemical and organic nitrogen sources were tested. The tillage practices and INM were examined in wheat crop. Treatments had significant impact on bulk density and water holding capacity of the soil samples collected after harvesting of wheat. The highest value of bulk density was recorded under reduced tillage without green manuring (M1). Among the sub plot treatments, highest bulk density was observed in S1 and lowest in S4. The water holding capacity attained maximum value in S6 and minimum in S1 during both the years of experimentation. Both conventional and reduced tillage practices when combined with green manuring resulted in lower pH of soil samples during both the years. Higher EC was recorded under conventional tillage without green manuring (M3). Among the subplot treatments, higher EC was recorded when N was applied through chemical source alone. Integrated approach with tillage practices significantly increased soil organic carbon, available N, P and K contents in soil after harvesting of wheat crop. In addition to treatment S7 which was recorded maximum N availability, S6 and S4 also resulted in higher N availability. The treatments, in which 50% N was applied through organic source, resulted in higher phosphorus and potassium availability.

Key words: Soil, rice wheat cropping system, manure, NPK.

INTRODUCTION

Rice wheat cropping system provides food security and livelihoods for millions. Rice wheat cropping system alone occupies 13.5 million hectares in the Indo-Gangetic Plans (IGP) of South Asia. Delayed transplanting of rice affects growth and yield not only of rice but also succeeding crop, thereby reducing system productivity and profitability. Conservation agriculture/ technologies like direct seeded rice, zero tillage are being promoted in rice wheat areas of Indo-Gangetic Plans (IGP). The advantage of reducing tillage, retaining crop residues back in field and diversifying rotation to improve soil health and productivity has been realized (Shukla et al., 2013). Rice-wheat cropping system are highly nutrient exhaustive system on INM strategy. The integrated use of organic materials and inorganic nitrogenous fertilizers has received considerable attention in the past with a hope of meeting the farmer's economic need as well as maintaining favourable ecological conditions on long-term basis. The application of
organic materials to different rice based cropping systems and their ability to incorporate nitrogen as well as organic matter, may offer opportunities to increase and sustain productivity of rice-wheat cropping system. The integrated nutrient management helps to restore and sustain fertility and crop productivity. It may also help to check the emerging deficiency of nutrients other than N, P and K. Further, it brings economy and efficiency in fertilizers. The integrated nutrient management favourably affects the physical, chemical and biological environment of soils. Integrated nutrient supply involving conjunctive use of fertilizers and organic sources of nutrients (Roy, 1992) assumes greater significance in India mainly due to two reasons. Firstly, the need for continuous increase in per hectare yield in rice-wheat system requires the application of still higher amounts of nutrients than being used. Present level of fertilizer availability and economic conditions of large number of farmers do not permit applying them in quantities adequate to meet the total plant nutrient needs at the desired level of productivity. Secondly, the results of several long-term experiments in different cropping systems reveal that long-term sustainability of productivity in intensive cropping system could be achieved only through integration of organic and inorganic sources of nutrients (Singh and Singh, 1992).

MATERIALS AND METHODS

Thoroughly planned field experiments were conducted during 1999-2000 and 2000-2001 at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. The experiments were carried out in split-plot design with three replications. The field experiment was initiated with green manure crop of Dhaincha (Sesbania canabena) and after its incorporation at 45 days after sowing, rice seedlings were transplanted. Recommended doses of N, P and K (120:60:60) were applied to rice and straw and grain yields were recorded during both the years. Response of wheat to four main plot treatments, that is, reduced tillage without green manuring (M1), reduced tillage with green manuring (M2), conventional tillage without green manuring (M3) conventional tillage with green manuring (M4) and seven sub plot treatments (that is, 100 %N through urea (S1), 100% N through urea + biofertilizer (Azotobacter) (S2), 75% N through urea + 25% N through paddly left over and sludge + biofertilizer (S3), 50% N through urea + 50% N through paddly left over and sludge + biofertilizer (S4), 75% N through urea + 25% N through sludge + biofertilizer (S5), 50% N through urea + 50% N through sludge + biofertilizer (S6), 100% N through urea + 4 tons ha⁻¹ of sludge + biofertilizer (S7)) were evaluated.

Plots were demarcated in each strip and only rice panicles were harvested in the plots where rice residue incorporation was required. In rest of the plots, the entire rice plants were harvested. Required quantity of fertilizer nitrogen, phosphorus and potassium were applied to wheat through urea, single super phosphate (SSP) and muriate of potash (MOP), respectively. 120 kg ha⁻¹ of nitrogen was considered as full dose (100% N). Recommended doses of phosphorus and potassium i.e. @ 60 kg ha⁻¹ of both were applied uniformly as basal dose to all the plots.

Sludge as organic source of nitrogen was incorporated 20 days before sowing of wheat whereas half the dose of fertilizers N as urea was given as basal application. Remaining half dose of nitrogen was applied in two equal splits at tillering and flowering stages. Wheat seed was inoculated using Azotobacter culture. The important initial soil characteristics of the experimental field were soil type/taxonomic class sandy loam, bulk density 1.52 Mg m⁻³, particle density 2.63 Mg m⁻³, pH 7.8, E.C. 0.25 dS m⁻¹ and organic carbon 0.43%. Available N, P and K (kg ha⁻¹) were 205, 22 and 230, respectively. The bulk density and water holding capacity of the soil samples were determined by gravimetric (core cutter) and circular brass box method (Chopra and Kanwar, 1982). The organic carbon of the soil samples was estimated by Walkley and Black’s wet chromic acid digestion method (1934). The pH and electrical conductivity (E.C.) were measured in 1: 2.5 soil: distilled water suspension with the help of pH meter and E.C. meter, respectively. The plant available N, P and K were determined by alkaline permanganate method (Subbiah and Asija, 1956). Olsen’s method (1954) and ammonium acetate extract with the help of flame photometer (Jackson, 14), respectively. The processed straw and grain samples were digested in sulphuric- selenium- salicylic acid and H₂O₂ system (Novozamsky et al., 1983) and stored in plastic bottles for estimation of nitrogen, phosphorus and potassium. Total nitrogen was determined by colorimetric method as described by Tandon (1993). Total phosphorus was determined by vanadomolybdophosphoric acid yellow colour method (Tondon, 1993). Total potassium was determined flame-photometrically (Jackson, 1973).

RESULTS AND DISCUSSION

Bulk density and particle density

The data pertaining to bulk density and particle density of soil (Table 1) recorded after wheat harvesting indicated that the bulk density and particle density was significantly lower under conventional tillage with green manuring (M4). It was highest under reduced tillage without green manuring (M1). These results indicate that the green manure incorporation resisted bulk density increases due to puddling by maintaining more pore space. Similar findings were also reported by Aggrawal et al. (1997) and Singh and Singh (1996). Rath et al. (2000) reported that the higher bulk density and deteriorated soil structure resulted in poor root growth, which might be the
### Table 1. Effect of reduced tillage and INM on physico-chemical properties of soil.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Bulk density (Mg m$^{-3}$)</th>
<th>Particle density (Mg m$^{-3}$)</th>
<th>Water holding capacity (%)</th>
<th>pH (1:2.5)</th>
<th>EC (1:2.5)</th>
<th>Organic carbon (g kg$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mn (Reduced tillage)</td>
<td>1.44</td>
<td>1.43</td>
<td>2.63</td>
<td>2.57</td>
<td>45.06</td>
<td>46.96</td>
</tr>
<tr>
<td>Mx (Reduced tillage with green manuring)</td>
<td>1.43</td>
<td>1.40</td>
<td>2.55</td>
<td>2.53</td>
<td>47.05</td>
<td>48.65</td>
</tr>
<tr>
<td>Mv (Conventional tillage)</td>
<td>1.42</td>
<td>1.38</td>
<td>2.59</td>
<td>2.54</td>
<td>46.20</td>
<td>47.61</td>
</tr>
<tr>
<td>Mv (Conventional tillage with green manuring)</td>
<td>1.41</td>
<td>1.35</td>
<td>2.54</td>
<td>2.52</td>
<td>46.21</td>
<td>47.98</td>
</tr>
<tr>
<td>CD (P = 0.05)</td>
<td>0.005</td>
<td>0.006</td>
<td>NS</td>
<td>NS</td>
<td>0.33</td>
<td>0.40</td>
</tr>
</tbody>
</table>

### Table 2. Effect of reduced tillage and INM on available nutrient status of post harvest soil of wheat.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Available nitrogen (kg ha$^{-1}$)</th>
<th>Available phosphorus (kg ha$^{-1}$)</th>
<th>Available potassium (kg ha$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>------------------------------------------</td>
<td>-----------------------------------</td>
<td>-------------------------------------</td>
<td>-----------------------------------</td>
</tr>
<tr>
<td>Mn (Reduced tillage)</td>
<td>225.05</td>
<td>227.52</td>
<td>28.98</td>
</tr>
<tr>
<td>Mx (Reduced tillage with green manuring)</td>
<td>235.42</td>
<td>240.23</td>
<td>31.82</td>
</tr>
<tr>
<td>Mv (Conventional tillage)</td>
<td>227.06</td>
<td>229.79</td>
<td>30.28</td>
</tr>
<tr>
<td>Mv (Conventional tillage with green manuring)</td>
<td>238.57</td>
<td>242.13</td>
<td>32.60</td>
</tr>
<tr>
<td>CD (P = 0.05)</td>
<td>3.80</td>
<td>2.54</td>
<td>1.34</td>
</tr>
</tbody>
</table>

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primary reason for poor growth and productivity of wheat crop under zero-tillage.

The decrease in bulk density observed up on rice residue and sludge incorporation could be ascribed to the possible increase in aeration, porosity and promotion of better aggregation by the added carbonaceous matter. Increase in soil aggregation on the incorporation of organic materials viz. paddy straw, paddy straw, sorghum stalk and Ipomea leaves into poorly aggregated soil has been reported by Kaurav and Verma (1982). They also observed that in situ decomposition of organic wastes (used in fresh state) in soil was more effective for the improvement of soil structure, irrespective of the source of the organic matter.

**Water holding capacity**

The data pertaining to the water holding capacity (WHC) of soil under reduced and conventional tillage with and without green manuring of wheat crop have been presented in Table 2. A perusal of the table indicated that the maximum WHC was observed under reduced tillage with green manuring (M2) followed by conventional tillage with green manuring (M4). Green manuring was found to produce higher increment in WHC under reduced tillage when compared to conventional tillage. Similar in nature were the findings of Frede et al. (1994) who reported that higher compaction increased WHC but decreased aeration and thermal conductivity and in the transition phase nitrogen would accumulate and the biological activity will increase. Broder et al. (1984) found that higher water content under reduced tillage soil during early spring paralleled lower nitrifier and higher nitrifier population as compared with conventional tillage. Palaniappan (1990) have reported that the humic substances penetrated the inter lamellar space of clay minerals and influenced the interaction of clay with other soil constituents and ultimately increased the WHC of the soil.

**Soil pH**

Regarding the effect of treatment combinations on soil pH showed that higher pH was recorded under tillage treatment without green manuring during first year. Conventional tillage (M3) was responsible for higher pH value than reduced tillage (M1). Decrease in pH due to sludge application was also reported by Bocko and Szerszen (1962), Nahedh et al. (1973), Subbiah (1976), Ramnathan et al. (1977) and Frezque et al. (1990) who attributed this to decreased mineralization of added organic sources and thereby formation and release of acid forming ions in soil solution. Increased concentration of CO₂ leads to the formation of weak acid and helps in release of adsorbed bases in the solution.

**Electrical conductivity**

Upon going through the data, it becomes clear that higher electrical conductivity was observed under conventional tillage than the reduced tillage. The highest value of electrical conductivity was recorded in the treatment (S1) and the lowest value of E.C. was recorded in case of (S6). Similar findings were advocated by Sekar and Bhatia (1983) who reported substantial changes in E.C. due to application of sludge. Ponnamperuma et al. (1966) also reported that with the application of organic manures such as FYM, the pH and EC of the soil decrease consequent to leaching of some of the bases from soil solution. The overall sub plot treatment effect was found to be significant during both the years.

**Organic carbon**

It is evident that the value of organic carbon content was highest under reduced tillage with green manuring (M2) followed by conventional tillage with green manuring (M4). Mixing of soil is reduced in a zero-tillage system, which may lead to higher organic matter (Bongki, 1996; Singh et al., 1998). The more build-up of organic matter content could possibly be due to lack of thorough mixing of plant debris throughout a considerable depth of soil and the slower rate in break down of organic matter under zero-tillage method improved the percent organic carbon content over conventional method of cultivation (Brar et al., 1983). The highest value of organic carbon content was observed with the treatment supplying (S2) which was significantly higher than other subplot treatments during both the years. This may be ascribed to the more amount of organic matter added through rice residue, sludge and green manure. This is in agreement with findings of Kumar and Mishra (1991), and Dang and Verma (1996). Integrated nutrient supply improved the organic carbon, which was obviously due to addition of organic matter.

**Available nitrogen**

Upon comparing the effects of conventional and reduced tillage practices with and without green manuring, it becomes evident that maximum value of available soil nitrogen was obtained under conventional tillage with green manuring (M4) which was found significantly superior than other main plot treatments, except the treatment comprising of reduced tillage with green manuring (M2). In zero or
Reduced tillage systems, the processes of mineralization and nitrification are slower due to higher population of anaerobic microbes resulting in lesser amount of available nitrogen (Thomas et al., 1973; Dowdell and Cannell, 1975; Doran, 1980; Singh et al., 1998). Conventional tillage with green manuring gave significantly higher available nitrogen content in soil collected after wheat harvesting. The increase in available nitrogen content was presumably due to release of nitrogen after decomposition of green manures, that is, mineralization by microbes. These results are in agreement with the findings of Swarup (1991), Thakur et al. (1995) and Sharma et al. (2001). The maximum value was recorded in the treatment supplying (S1) which was significantly higher than other sub plot treatments, except the treatment S2 during first year. The higher available N content in post harvest soil of S1 may be ascribed to the addition of extra nitrogen through sludge and also to higher release of N in available forms from their native compounds present in soil due to better microbial activity caused by sludge. The minimum value was recorded in the treatment comprising of (S4). Increase in total nitrogen with successive application of one or more nutrient over time was reported by De Datta et al. (1988).

Available phosphorus and potassium

The maximum value of available soil phosphorus and potassium content was obtained under conventional tillage with green manuring (M1) which was found to be significantly superior over other main plot treatments, except M2 (reduced tillage with green manuring) Sharma et al. (2001). Bellakki and Badanur (1997) reported that the increase in available phosphorus might be due to the decomposition of organic matter accompanied by the release of appreciable quantities of CO2 which plays an important role in increasing phosphate availability. The organic material forms a cover on sesquioxides and thus reduces the phosphate fixing capacity of the soil. The maximum value of available phosphorus and potassium in soil was recorded in the treatment (S1). The minimum value of available phosphorus and potassium was recorded in case of (S4).

Conclusion

The findings of the experiments reveal that the integrated nutrient management approach with tillage practices significantly increased the soil fertility especially pertaining to its nutrient contents of organic carbon, available nitrogen, phosphorus and potassium contents after harvesting of wheat crop.

References


