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**Original Article**

# Effect of Rice (*Oryza sativa* L.) Establishment Methods and Integrated Weed Management on Productivity and Soil Fertility in Eastern Himalayas, India

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**ABSTRACT**

Field experiments in 2010 and 2011 was conducted during *kharif* season to evaluate the effect of integrated weed management practices on productivity, nutrient uptake, nutrient harvest index and residual soil fertility status in wetland rice crop (*Oryza sativa* L., Ranjit) under different establishment methods. Wetland rice under SRI method gave significantly higher grain productivity (5.63 tha$^{-1}$) at par with ICM method (5.58 tha$^{-1}$). However, significantly higher grain productivity of wetland rice was obtained with hand weeding twice at 20 and 40 DAT (5.89 tha$^{-1}$) at par with butachlor 50 EC@1.5 kg a.i. ha$^{-1}$ at 3 DAT + cono-weeding at 20 DAT (5.78 tha$^{-1}$). Uptake of N, P and K was recorded higher in grain and straw with SRI method followed by ICM and CRC. Total mean uptake of N, P and K by wetland rice was recorded higher with SRI method (81.06, 21.76 and 42.02 kgha$^{-1}$, respectively) followed by ICM and CRC methods. Meanwhile, hand weeding twice at 20 and 40 DAT recorded significantly higher N, P and K uptake in grain and straw closely followed by butachlor 50 EC@1.5 kg a.i.ha-1 at 3 DAT + cono-weeding at 20 DAT. However, significantly higher mean value of NHI and PHI was recorded with CRC while, higher mean value of KHI was recorded with ICM (34.93%) followed by CRC and SRI. The highest NHI, PHI and KHI were recorded with cono-weeding twice at 20 and 40 DAT (79.80, 58.88 and 36.60%, respectively). The highest mean pH, OC and SMBC of 5.133, 0.58% and 172.78 µgg$^{-1}$ soil, respectively, was recorded in SRI method followed by ICM and CRC. However, the pH, OC, SMBC, available N, P and K in soil had left significantly higher with hand weeding twice at 20 and 40 DAT (264.22, 9.55 and 283.69 NPK kgha$^{-1}$, respectively) over control and in comparison with other treatments. Hence, integrated weed management in SRI with butachlor 50 EC @ 1.5 kg a.i.ha$^{-1}$ + cono-weeding at 20 DAT and ICM with hand weeding twice at 20 and 40 DAT can be adopted to obtain higher productivity, nutrient uptake, nutrient harvest index and better soil health in wetland rice ecosystem of West Garo Hills district of Meghalaya, India as compared to CRC method.

**Keywords**: Establishment method, integrated weed management, Nutrient uptake, Nutrient harvest index, Productivity, wetland rice.

## INTRODUCTION

Wetland rice (*Oryza sativa* L.) is the major cereal crop and staple food for the people of West Garo Hills district of Meghalaya, India. Almost 81 per cent of the people live in rural areas and are predominantly depend upon land and agriculture for their livelihood. The district is situated at latitude between 25º 20´ and 26 º N and longitude between 89 º40´ and 90 º 30´E with the total geographical area of 3715 Sq.km at an average altitude of 657 meter above mean sea level. The population of the district is 6, 42,923 covering 1,663 villages **(**2011 Census) wherein heterogeneous farmers strive hard to feed the ever increasing population. Wetland rice covers about 17.35 thousand hectare with the production of 30.0 thousand metric tonnes and productivity of 1729 kgha-1 in the district which is lower than the national average (2177 $kgha^{-1}$). The low productivity in this part of the country may be due to the acidic nature of the soil unbalanced in its nutrients has resulted in low agricultural productivity and more weed growth as compared to other places even in plains. Weed competition is one of the prime yield limiting biotic constraints in rice production. Transplanted rice, in particular, is infested by heterogeneous types of weed flora consisting of grassy, broadleaf weeds and sedges causing yield reduction up to 76 percent. The loss of rice due to weed competition varies from 20-50% depending upon the various conditions of rice culture in Meghalaya which is much more than any other factor reducing the crop yield (Hazarika *et al*., 2001). Effective control of weeds had increased the grain yield by 85.5% (Mukherjee and Singh 2004). About 60% of the weeds emerge during 7–30 days after transplanting and strongly compete with rice plants up to maximum tillering stage. Therefore, timely weed control at early stage is imperative for realizing desired level of productivity from transplanted rice. The use of herbicides offers selective and economic control of weeds right from the beginning, giving crop an advantage of good start and competitive superiority (Saha, 2005). A number of pre-emergence herbicides like butachlor, pretilachlor, anilofos etc have been recommended for the control of early flushes of grassy weeds in transplanted rice field (Budhar *et al.,* 1991). These herbicides are specific and are effective against narrow range of weed species (Narayana *et al.,* 1999). The intensive use of such herbicides year after year has resulted in herbicide resistance problems and consequently, management of weeds is becoming increasingly more difficult and complex (Rao, 1999). Moreover, continuous use of these herbicides leads to a shift of weed flora from grassy to non-grassy broadleaf weeds and annual sedges (Rajkhowa *et al.,* 2007). Integrated weed management in rice cultivation could result in a broad spectrum weed control especially when herbicides were applied as pre-emergence spray (Sanjay *et al*., 2006). In view of shrinking natural resource base, higher costs, weeds, climatic change, water and labour scarcity, stagnant trend in the yield potential of different high yielding varieties of rice and declining profitability of rice production, the challenge to meet the future food demands for burgeoning population becomes more complex today and it was ever. The poor farmers losing interest in rice cultivation as factor productivity is declining (Das *et al*., 2009) and its profitability is in question with the rise in input costs. New innovations and initiatives are required to make farming system sustainable and economically viable. In such situation, Integrated Weed Management (IWM) with the System of Rice Intensification (SRI) and Integrated Crop Management (ICM) over Conventional Rice Culture (CRC) of stand establishment appears to be a viable alternative of wetland rice cultivation that saves expensive inputs, improves soil health and protect the environmental sustainability. In this context, new technologies like System of Rice Intensification (SRI) and Integrated Crop Management (ICM) appears to have potential that saves inputs, protects the environment and could improve productivity and soil health (Kumar and Shivay, 2004; Satyanarayana *et al.,* 2006; Balasubramanian *et al.,* 2007; Sinha and Talati, 2007). Therefore, the present investigation was undertaken to study the effect of integrated weed management practices on productivity, nutrient uptake, nutrient harvest index and residual soil fertility status of wetland rice under different establishment methods.

## MATERIAL AND METHODS

### Experimental Site

The research was conducted at farmer's field of Puthimari village under Betasing C.D. block in the years 2010 and 2011 during *kharif* season under the ecological conditions of the district of West Garo Hills in the state of Meghalaya, India. The climate of West Garo Hills district experiences a hot summer and a pleasant winter. Normally, the monsoon season starts from the month of June and extends up to the month of September and the rainfall decreases from the month of October. Some of the meteorological data recorded in the West Garo Hills district during the wetland rice growing period of the years 2010-2011 when the study was carried out are given in Table 1. The total rainfall received during the wetland rice growing season was 2328.7mm distributed in 97 days during 2010 and 2036 mm distributed in 81 days during 2011. The soil of the experimental site was sandy loam in texture, acidic in reaction (pH 5.09), low in organic carbon (0.51 %), available N (229.32 kgha$^{-1}$) and available P (8.27 kgha$^{-1}$) but medium in available K (246.29 kgha$^{-1}$).

### Experimental Method

High yielding rice variety 'Ranjit' was used as test crop for all the methods. The experiment included three establishment methods in main plots i.e., $M_1$ - System of Rice Intensification (SRI), $M_2$ - Integrated Crop Management (ICM) and $M_3$ - Conventional Rice Culture (CRC); and five integrated weed management practices in sub-plots i.e.$W_1$ - control, $W_2$ - hand weeding twice at 20 and 40 DAT, $W_3$ - cono- weeding twice at 20 and 40 DAT, $W_4$ - cono- weeding at 20 DAT + hand weeding at 40 DAT and $W_5$ - butachlor 50 EC @ 1.5 kg a.i. ha$^{-1}$ at 3 DAT + cono- weeding at 20 DAT. The experimental was laid out in split plot design (SPD) with three replications, having fifteen treatment combinations. The split plot size was 3×5 m each.

### Nursery Management and Transplanting Method

The nursery for SRI and ICM was prepared using a modified mat nursery (MMN) method. Whereas, for CRC the conventional method was used following 40 kg seedha$^{-1}$, 500 sqm nursery areas, raised bed of 1 m width and 0.15 m height. In MMN, the seedlings were raised in 4 cm layer of soil plus decomposed paddy straw arranged on a firm surface covered with plastic sheet. A low cost bamboo with suitable length divided into equal segments of each bed size was placed over this firm surface covered with plastic sheet. Soil mixture plus decomposed paddy straw was spread uniformly over the plastic sheet and pre-germinated seeds were sown on the soil surface with a seed rate of 50 gm$^{-2}$ and covered with the same soil mixture. The soil mixture (4 m$^3$ for 100m$^2$ of mat nursery) was prepared by mixing 75-80% soil, 15-20% well decomposed farmyard manure (FYM) and 5% rice hull ash. To this soil, 1.5 kg of powdered DAP (Diamonium phosphate) was added and mixed thoroughly. The seedbed was sprinkled with water everyday using a rose can as and when needed. The nursery bed was protected from heavy rains using straw mulching for first 5 days. A nursery of 100m$^2$ area and 10-12 kg of good quality seeds were sufficient for one hectare area with ICM method and 50m$^2$nursery with 5-7 kg seeds were given for SRI method. The seedlings attained one and a half leaf stage in about 10 days and were transplanted by scooping the single seedlings in case of SRI and on 20$^{th}$ day for ICM method (2 -3 leaves). Care was taken to transplant seedlings within 30 minutes of scooping from the nursery to avoid wilting and reduce transplanting shock.

The nurseries for all the three establishment methods were sown on the same day but transplanting date varied as per the requirement of different establishment methods. For SRI 10 days old seedling at 1 seedling/hill was used with 25 cm × 25 cm spacing while for ICM, it was 20 days old seedlings at 2 seedlingshill$^{-1}$ with 20 cm × 20 cm spacing and for CRC, 30 days old seedlings at 3 seedlings/hill with 20 cm × 15 cm spacing was followed. A uniform dose of 80:60:40 NPK $kgha^{-1}$ was applied in the form of urea, single superphosphate (SSP) and muriate of potash (MOP) and FYM @ 5 $tha^{-1}$ was applied at 20 days ahead of transplanting to the main field and incorporated along with last ploughing. Half dose of N and full dose of P and K were applied as basal. Remaining half dose of N was applied in two equal splits at maximum tillering and panicle initiation stage. Harvesting of wetland rice was done at different dates for the different establishment methods at the yellow ripening stage or when about 80 per cent of the grains were matured.

**Productivity of Wetland rice**

The grain productivity of wetland rice was determined from each of the harvested plot as per treatment, threshed, winnowed and sun dried to maintain seed moisture content of 12% and the grain productivity was recorded per plot and expressed as tones $ha^{-1}$. The straw productivity was recorded after threshing and winnowing as well as separation of the grain from the plant and expressed in tones $ha^{-1}$.

**Nutrient uptake by Wetland Rice**

The plant samples (grain and straw) which were dried at 70°C were grinded and analyzed for total nitrogen, phosphorus and potassium content (%). The nutrient uptake was computed by multiplying the respective grain/straw yield with nutrient contents and expressed as $kgha^{-1}$. The nutrient uptake was calculated by using the following formula:

$$\textbf{Nutrient uptake (kgha}^{-1}\textbf{)} = \frac{\text{Nutrient content(\%)} \times \text{Yield (kgha}^{-1})}{100}$$

The total nitrogen was estimated by using Modified Micro Kjeldhal Method (Humphries, 1956). A known quantity of the powdered sample was digested with concentrated sulphuric acid in the presence of digestion mixture. After digestion, the mixture was distilled and ammonia was passed into boric acid, which was then back titrated with standard acid. Phosphorus uptake was determined by Di-acid digestion and yellow colour development method (Jackson, 1973). The colour intensity was measured at 450 ŋm wave length. The amount of phosphorus was then calculated by referring the reading to a standard curve. A known quantity of powdered sample was digested with di-acid. The total potassium was then estimated from the di-acid extract by using Flame Photometric Method (Jackson, 1973).

**Nutrient Harvest Index (NHI)**

Nutrient removal was estimated by multiplying the N, P and K concentration (%) of grain and straw with their respective yield ($kgha^{-1}$) and finally the nutrient uptake by grain and straw was sum up to obtain total nutrient uptake. Nutrient harvest index was computed using the formula given below:

$$\textbf{NHI} = \frac{\text{Uptake of a particular nutrient by the grain}}{\text{Total uptake of that nutrient in biomass (grain + straw)}} \times 100$$

**Nutrient Removal by Weeds**

The weed samples at harvest which were dried at 70°C were grinded and analyzed for total nitrogen, phosphorus and potassium content (%). The nutrient removal by weeds was computed by multiplying the respective total weed biomass yield per hectare with nutrient contents, respectively and expressed as $kgha^{-1}$ for both the season and pooled. The nutrient removal by weeds was calculated by using the following formula:

$$\textbf{Nutrient removal (kgha}^{-1}\textbf{)} = \frac{\text{Weed nutrient content(\%)} \times \text{Weed biomass (kgha}^{-1}\text{)}}{100}$$

**Statistical Analysis**

Data obtained from various studies were statistically analyzed in Split -Plot design using the technique of Analysis of Variance (Gomez and Gomez, 1984). The difference between the treatment means was tested as to their statistical significance with appropriate critical difference (C.D) value at 5 per cent level of probability.

## RESULTS

**Productivity of Wetland Rice**

The pooled data of two years revealed that the significantly higher grain and straw productivity of wetland rice was obtained in SRI methods (5.63 and 7.97 tha$^{-1}$) which was statistically at par with ICM (5.58 and 7.96 tha$^{-1}$) but remained superior to CRC Among the integrated weed management practices, significantly higher grain and straw productivity of wetland rice was obtained with hand weeding twice at 20 and 40 DAT (5.89 and 8.26 tha$^{-1}$) which was statistically at par with by butachlor 50 EC@1.5 kg a.i. ha$^{-1}$ at 3 DAT + cono-weeding at 20 DAT (5.78 and 7.97 tha$^{-1}$) but remained superior over control (Table 2).

**Nitrogen uptake and Nitrogen Harvest Index (NHI)**

The pooled data of two years showed that significantly maximum N uptake by grain and straw was recorded at harvest with SRI (69.63 and 21.43 kgha$^{-1}$) and followed by ICM method (67.70 and 21.26 kgha$^{-1}$). Total uptake of N by rice was recorded higher with SRI method (91.06 kgha$^{-1}$) as compared to ICM and CRC. Among the integrated weed management practices, significantly higher N uptake by rice was recorded with hand weeding twice at 20 and 40 DAT (75.03 and 25.26 kgha$^{-1}$ in grain and straw, respectively) which might be due to higher concentration of N in grain compared to straw. Total N uptake by wetland rice was recorded significantly higher with hand weeding twice at 20 and 40 DAT (100.30 kgha$^{-1}$) which was at par with butachlor 50 EC@1.5 kg a.i.ha$^{-1}$ at 3 DAT + cono-weeding at 20 DAT (Table 2).

However, nitrogen harvest index (NHI) value was recorded (Table 2) significantly higher with CRC (77.39 %) followed by SRI (76.59 %) and ICM (76.37 %). Among the integrated weed management practice, the highest NHI was recorded with cono- weeding twice at 20 and 40 DAT (79.80 %) followed control (77.44 %).

**Phosphorus Uptake and Phosphorus Harvest Index (PHI)**

P uptake by wetland rice at harvest was recorded 12.73 kgha$^{-1}$ with SRI and 12.57 kgha$^{-1}$ with ICM. Total uptake of P by wetland rice was recorded higher with SRI method (21.76 kgha$^{-1}$). Among the integrated weed management practices, significantly higher P uptake by wetland rice was recorded with hand weeding twice at 20 and 40 DAT (13.73 and 9.58 kgha$^{-1}$ in grain and straw, respectively) which might be due to higher concentration of P in grain compared to straw and greater availability of P in the root zone which was absorption by the wetland rice. Total P uptake by wetland rice was recorded significantly higher with hand weeding twice at 20 and 40 DAT (23.31 kgha$^{-1}$) which was at par with butachlor 50 EC@1.5 kg a.i.ha$^{-1}$ at 3 DAT + cono- weeding at 20 DAT(Table 2).

Significantly higher mean value of PHI was recorded with CRC (59.30 %) followed by ICM and SRI. Among the integrated weed management practice, the highest PHI was recorded with cono- weeding twice at 20 and 40 DAT (61.11%) followed by hand weeding twice at 20 and 40 DAT (58.88 %).

**Table 1: Meteorological data during the period of experimentation in the years 2010 and 2011 at Tura, Meghalaya, India**

| Month | Temperature (°C) | | | | Relative humidity (%) | | | | Bright sunshine hours(BSSH) | | Total rainfall (mm) | | Total number of rainy days | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2010 | | 2011 | | 2010 | | 2011 | | | | | | | |
| | Max. | Min. | Max. | Min. | Morn. | Even. | Morn. | Even. | 2010 | 2011 | 2010 | 2011 | 2010 | 2011 |
| **June** | 29 | 20 | 28.04 | 24.66 | 80 | 70 | 88 | 75 | 3.61 | 2.59 | 898 | 350 | 18 | 18 |
| **July** | 28.6 | 21.4 | 27.54 | 23.85 | 77 | 63 | 87 | 84 | 3.36 | 3.12 | 459.2 | 426 | 23 | 20 |
| **August** | 29.6 | 21.8 | 27.58 | 24.32 | 79 | 68 | 90 | 87 | 3.09 | 2.16 | 573.2 | 605 | 23 | 21 |
| **September** | 30 | 22.6 | 24.99 | 22.65 | 72 | 61 | 83 | 81 | 4.25 | 2.57 | 240.9 | 615 | 19 | 18 |
| **October** | 30.1 | 21.5 | 26.58 | 22.81 | 72 | 58 | 79 | 77 | 4.11 | 3.27 | 152 | 36 | 10 | 3 |
| **November** | 28.4 | 19.1 | 22.73 | 19.79 | 79 | 66 | 70 | 69 | 4.74 | 4.14 | 5.4 | 4 | 4 | 1 |
| **Total/Avg.** | **29.28** | **21.07** | **26.24** | **23.01** | **77** | **64** | **83** | **79** | **3.86** | **2.98** | **2328.7** | **2036** | **97** | **81** |

**Table 2: Effect of establishment methods and integrated weed management on productivity, nutrient uptake and nutrient harvest index of wetland rice ( two years pooled data)**

| Treatments | Productivity ($tha^{-1}$) | | Nutrient uptake ($kgha^{-1}$) | | | | | | | | | Nutrient Harvest Index (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grain | Straw | Grain | | | Straw | | | Total | | | | | |
| | | | N | P | K | N | P | K | N | P | K | NHI | PHI | KHI |
| **Establishment Methods(M)** | | | | | | | | | | | | | | |
| $M_1$: SRI | 5.63 | 7.97 | 69.63 | 12.73 | 14.32 | 21.43 | 9.04 | 27.70 | 91.06 | 21.76 | 42.02 | 76.59 | 57.84 | 34.02 |
| $M_2$ :ICM | 5.58 | 7.96 | 67.70 | 12.57 | 14.18 | 21.26 | 8.65 | 26.45 | 88.96 | 21.22 | 40.63 | 76.37 | 59.24 | 34.93 |
| $M_3$ :CRC | 4.91 | 7.62 | 59.72 | 11.25 | 12.34 | 17.50 | 7.80 | 23.56 | 77.22 | 19.05 | 35.91 | 77.39 | 59.30 | 34.55 |
| SEm± | 0.003 | 0.014 | 0.368 | 0.013 | 0.012 | 0.030 | 0.011 | 0.048 | 0.384 | 0.018 | 0.059 | 0.088 | 0.058 | 0.030 |
| **CD(P=0.05)** | **0.013** | **0.055** | **1.446** | **0.053** | **0.045** | **0.117** | **0.045** | **0.188** | **1.508** | **0.072** | **0.231** | **0.346** | **0.229** | **0.116** |
| **Integrated Weed Management(W)** | | | | | | | | | | | | | | |
| $W_1$: Control | 4.14 | 6.67 | 46.07 | 8.69 | 9.87 | 13.34 | 6.52 | 19.46 | 59.41 | 15.22 | 29.33 | 77.44 | 56.88 | 33.58 |
| $W_2$: Hand weeding twice at 20 and 40 DAT | 5.89 | 8.26 | 75.03 | 13.73 | 15.32 | 25.26 | 9.58 | 32.14 | 100.30 | 23.31 | 47.46 | 74.97 | 58.88 | 32.23 |
| $W_3$: Cono- weeding twice at 20 and 40 DAT | 5.40 | 7.97 | 66.11 | 12.47 | 13.50 | 16.61 | 8.02 | 23.10 | 82.73 | 20.49 | 36.60 | 79.80 | 61.11 | 36.60 |
| $W_4$: Cono- weeding at 20 DAT + Hand weeding at 40 DAT | 5.66 | 8.16 | 69.23 | 12.90 | 14.57 | 21.42 | 9.16 | 26.85 | 90.65 | 22.06 | 41.42 | 76.41 | 58.39 | 35.30 |
| $W_5$: Butachlor 50EC@1.5 kg a.i.$ha^{-1}$ at 3 DAT + Cono-weeding at 20 DAT | 5.78 | 8.19 | 71.98 | 13.12 | 14.82 | 23.68 | 9.20 | 27.98 | 95.66 | 22.32 | 42.80 | 75.29 | 58.71 | 34.81 |
| SEm± = | 0.15 | 0.08 | 2.07 | 0.30 | 0.41 | 0.83 | 0.24 | 0.79 | 2.86 | 0.54 | 1.20 | 0.27 | 0.32 | 0.18 |
| **CD(P=0.05)** | **0.44** | **0.22** | **6.04** | **0.89** | **1.20** | **2.42** | **0.69** | **2.31** | **8.35** | **1.57** | **3.49** | **0.79** | **0.92** | **0.51** |
| **Interaction (MxW)** | | | | | | | | | | | | | | |
| SEm± = | 0.233 | 0.119 | 3.228 | 0.470 | 0.637 | 1.284 | 0.367 | 1.229 | 4.447 | 0.831 | 1.854 | 0.427 | 0.494 | 0.273 |
| **CD(P=0.05)** | **0.680** | **0.348** | **9.465** | **1.372** | **1.860** | **3.749** | **1.072** | **3.589** | **13.013** | **3.100** | **5.412** | **1.266** | **1.448** | **0.800** |

**Potassium uptake and potassium harvest index (KHI)**

The pooled data revealed that the potassium uptake was higher in straw than in grain. The increase in K uptake in straw thus strengthens the stalk of rice plant preventing it against lodging and attack by insect pests. The uptake and KHI was significantly different for various establishment methods, integrated weed management practices and their interaction.

The result showed that significantly maximum K uptake was recorded in grain 14.32 and 14.18 $kgha^{-1}$ in grain with SRI and ICM, respectively (Table 2). The highest mean K uptake by straw was recorded with SRI (27.70 $kgha^{-1}$) followed by ICM (26.45 $kgha^{-1}$) method. Total uptake of K by wetland rice was recorded higher with SRI method (42.02 $kgha^{-1}$). Among the integrated weed management practices, significantly higher K uptake by wetland rice was recorded with the treatment of hand weeding twice at 20 and 40 DAT (15.32 and 32.14 $kgha^{-1}$ in grain and straw, respectively). However, total K uptake by wetland rice was recorded significantly higher with hand weeding twice at 20 and 40 DAT (47.46 $kgha^{-1}$).

The potassium harvest index (KHI) value was recorded significantly higher with ICM (34.93 %) followed by CRC and SRI. Among the integrated weed management practice, the highest KHI was recorded with cono- weeding twice at 20 and 40 DAT (36.60 %) followed by cono- weeding at 20 DAT + hand weeding at 40 DAT (35.30 %).

**Interaction Effect of N, P and K Uptake**

The interaction between the establishment methods and integrated weed management practices had significant effect on N, P and K uptake by grain, straw and total uptake by wetland rice as shown in Table 3, 4 and 5, respectively.

Within the same level of integrated weed management, SRI establishment method recorded maximum N, P and K uptake by grains (80.42, 14.76 and 16.47 $kgha^{-1}$) of wetland rice which was statistically at par with ICM method but remained superior over CRC. Similarly, within the same level of establishment methods, hand weeding twice at 20 and 40 DAT gave maximum N , P and K uptake by grain followed by butachlor 50 EC@1.5 kg $a.i.ha^{-1}$ at 3 DAT + cono- weeding at 20 DAT but remained superior over control treatment.

The establishment method of SRI and ICM had recorded significantly higher N, P and K uptake by straw over CRC method. Similarly, all the integrated weed management treatments had also recorded significantly higher uptake of N, P and K by straw over control. The maximum uptake of N, P and K (29.99, 10.45 and 32.79 $kgha^{-1}$) by straw of wetland rice was recorded in SRI method with hand weeding twice at 20 and 40 DAT which was at par with ICM and butachlor 50 EC@1.5 kg $a.i.ha^{-1}$ at 3 DAT + cono- weeding at 20 DAT.

The maximum total uptake of N (110.41 $kgha^{-1}$), P (25.21 $kgha^{-1}$) and K (49.27 $kg^{-1}ha$) was recorded in SRI method with hand weeding twice at 20 and 40 DAT at par with butachlor 50EC@1.5 kg a.i.ha-1 at 3 DAT + cono- weeding at 20 DAT in wetland rice but remained superior over control.

**Nutrient removal by weeds**

The nitrogen removed by weeds at 60 DAT was found significantly higher with SRI method (5.03 $kgha^{-1}$) followed by CRC (3.59 $kgha^{-1}$) and ICM (3.01 $kgha^{-1}$) in pooled value of two years data which might be due to higher weed biomass in SRI (16.11$gm^{-2}$) as compared to other methods. Among the integrated weed management practices, maximum N removed by weeds was recorded in control plot (9.86 $kgha^{-1}$). Presumably, the excessive weed growth prevented rice plants from absorbing adequate amount of N nutrients in control plot. However, significantly lowest N removed by weeds in butachlor 50 EC@1.5 kg $a.i.ha^{-1}$ at 3 DAT+ cono- weeding which was statistically at par with hand weeding twice at 20 and 40 DAT which might be due to less weed biomass (4.66 $gm^{-2}$) (Table 6).

The phosphorus removed by weeds was found significantly higher with SRI method (1.45 $kgha^{-1}$) followed by CRC (1.10 $kgha^{-1}$) and ICM (0.90 $kgha^{-1}$). Among the integrated weed management practices, maximum P removed by weeds was recorded in control plot (3.34 $kgha^{-1}$).

**Table 3: Interaction effects of establishment methods and integrated weed management on nutrient uptake by grain of wetland rice (two years pooled data)**

| Treatments | Nutrient uptake by grain ($kgha^{-1}$) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | | | | P | | | | K | | | |
| | SRI | ICM | CRC | Mean | SRI | ICM | CRC | Mean | SRI | ICM | CRC | Mean |
| $W_1$: Control | 38.00 | 50.85 | 49.36 | 46.07 | 7.14 | 9.15 | 9.79 | 8.69 | 8.38 | 10.83 | 10.41 | 9.87 |
| $W_2$: Hand weeding twice at 20 and 40 DAT | 80.42 | 78.02 | 66.67 | 75.03 | 14.76 | 14.10 | 12.34 | 13.73 | 16.47 | 15.72 | 13.76 | 15.32 |
| $W_3$: Cono- weeding twice at 20 and 40 DAT | 74.95 | 66.51 | 56.87 | 66.11 | 13.72 | 13.02 | 10.67 | 12.47 | 15.11 | 14.33 | 11.05 | 13.50 |
| $W_4$: Cono- weeding at 20 DAT + Hand weeding at 40 DAT | 76.77 | 68.98 | 61.95 | 69.23 | 13.94 | 13.15 | 11.60 | 12.90 | 15.75 | 14.86 | 13.10 | 14.57 |
| $W_5$: Butachlor 50EC@1.5 kg a.i.$ha^{-1}$ at 3 DAT + Cono- weeding at 20 DAT | 78.01 | 74.16 | 63.77 | 71.98 | 14.06 | 13.44 | 11.87 | 13.12 | 15.88 | 15.18 | 13.41 | 14.82 |
| **Mean** | **69.63** | **67.70** | **59.72** | | **12.73** | **12.57** | **11.25** | | **14.32** | **14.18** | **12.34** | |
| **CD(P=0.05)** | | M × W | W × M | | | M × W | W × M | | | M × W | W×M | |
| | | **9.465** | **10.466** | | | **1.372** | **1.533** | | | **1.860** | **2.079** | |

**Table 4: Interaction effects of establishment methods and integrated weed management on nutrient uptake by straw of wetland rice (two years pooled data)**

| Treatments | Nutrient uptake by straw ($kgha^{-1}$) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | | | | P | | | | K | | | |
| | SRI | ICM | CRC | Mean | SRI | ICM | CRC | Mean | SRI | ICM | CRC | Mean |
| $W_1$: Control | 11.89 | 13.93 | 14.21 | 13.34 | 7.03 | 6.19 | 6.35 | 6.52 | 17.75 | 20.39 | 20.23 | 19.46 |
| $W_2$: Hand weeding twice at 20 and 40 DAT | 29.99 | 25.72 | 20.08 | 25.26 | 10.45 | 9.38 | 8.91 | 9.58 | 32.79 | 32.63 | 31.00 | 32.14 |
| $W_3$: Cono- weeding twice at 20 and 40 DAT | 17.65 | 16.32 | 15.87 | 16.61 | 8.84 | 9.17 | 6.04 | 8.02 | 24.78 | 23.72 | 20.79 | 23.10 |
| $W_4$: Cono- weeding at 20 DAT + Hand weeding at 40 DAT | 22.38 | 24.59 | 17.30 | 21.42 | 9.42 | 9.24 | 8.83 | 9.16 | 30.96 | 26.73 | 22.85 | 26.85 |
| $W_5$: Butachlor 50EC@1.5 kg a.i.$ha^{-1}$ at 3 DAT + Cono- weeding at 20 DAT | 25.25 | 25.74 | 20.06 | 23.68 | 9.45 | 9.28 | 8.87 | 9.20 | 32.23 | 28.76 | 22.95 | 27.98 |
| **Mean** | **21.43** | **21.26** | **17.50** | | **9.04** | **8.65** | **7.80** | | **27.70** | **26.45** | **23.56** | |
| **CD(P=0.05)** | | M ×W | W × M | | | M×W | W ×M | | | M ×W | W × M | |
| | | **3.749** | **4.190** | | | **1.072** | **1.197** | | | **3.589** | **4.007** | |

**Table 5: Interaction effects of establishment methods and integrated weed management on total nutrient uptake of wetland rice (two years pooled data )**

| Treatments | Total Nutrient uptake(kgha$^{-1}$) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | | | | P | | | | K | | | |
| | SRI | ICM | CRC | Mean | SRI | ICM | CRC | Mean | SRI | ICM | CRC | Mean |
| $W_1$: Control | 49.89 | 64.78 | 63.56 | 59.41 | 14.17 | 15.34 | 16.13 | 15.22 | 26.12 | 31.22 | 30.63 | 29.33 |
| $W_2$: Hand weeding twice at 20 and 40 DAT | 110.41 | 103.74 | 86.75 | 100.30 | 25.21 | 23.48 | 21.25 | 23.31 | 49.27 | 48.35 | 44.76 | 47.46 |
| $W_3$: Cono- weeding twice at 20 and 40 DAT | 92.60 | 82.84 | 72.74 | 82.73 | 22.56 | 22.18 | 16.72 | 20.49 | 39.89 | 38.06 | 31.84 | 36.60 |
| $W_4$: Cono- weeding at 20 DAT + Hand weeding at 40 DAT | 99.15 | 93.56 | 79.25 | 90.65 | 23.36 | 22.39 | 20.43 | 22.06 | 46.71 | 41.58 | 35.96 | 41.42 |
| $W_5$: Butachlor 50EC@1.5 kg a.i.ha$^{-1}$ at 3 DAT + Cono- weeding at 20 DAT | 103.26 | 99.90 | 83.83 | 95.66 | 23.51 | 22.72 | 20.73 | 22.32 | 48.11 | 43.94 | 36.36 | 42.80 |
| **Mean** | **91.06** | **88.96** | **77.22** | | **21.76** | **21.22** | **19.05** | | **42.02** | **40.63** | **35.91** | |
| **CD(P=0.05)** | | M ×W | W ×M | | | M × W | W × M | | | M ×W | W × M | |
| | | **13.01** | **14.46** | | | **2.43** | **2.71** | | | **5.41** | **6.05** | |

**Table 6. Weed biomass and Nutrient removal by weeds at 60 DAT as affected by establishment methods and integrated weed management in wetland rice**

| Treatments | Weed biomass (gm$^{-2}$) | Nutrient removal by weeds (kgha$^{-1}$) | | |
|---|---|---|---|---|
| | | N | P | K |
| **Establishment Methods(M)** | | | | |
| $M_1$: SRI | 16.11 | 5.03 | 1.45 | 5.30 |
| $M_2$ :ICM | 10.15 | 3.01 | 0.90 | 3.01 |
| $M_3$ :CRC | 12.61 | 3.59 | 1.10 | 3.94 |
| SEm± | 0.073 | 0.080 | 0.010 | 0.029 |
| **CD(P=0.05)** | **0.213** | **0.233** | **0.029** | **0.086** |
| **Integrated Weed Management(W)** | | | | |
| $W_1$: Control | 28.60 | 9.86 | 3.34 | 10.22 |
| $W_2$: Hand weeding twice at 20 and 40 DAT | 4.66 | 1.25 | 0.29 | 1.20 |
| $W_3$: Cono- weeding twice at 20 and 40 DAT | 14.70 | 4.10 | 1.06 | 4.42 |
| $W_4$: Cono- weeding at 20 DAT + Hand weeding at 40 DAT | 11.60 | 3.07 | 0.76 | 3.24 |
| $W_5$: Butachlor 50EC@1.5 kg a.i.ha$^{-1}$ at 3 DAT + Cono- weeding at 20 DAT | 5.22 | 1.12 | 0.29 | 1.35 |
| SEm± = | 1.12 | 0.40 | 0.10 | 0.43 |
| **CD(P=0.05)** | **3.28** | **1.17** | **0.30** | **1.26** |
| **Interaction (MxW)** | | | | |
| SEm± = | 1.742 | 0.625 | 0.161 | 0.667 |
| **CD(P=0.05)** | **5.088** | **1.834** | **0.470** | **1.949** |

However, significantly lowest P removed by weeds in butachlor 50 EC@1.5 kg a.i. $ha^{-1}$ at 3 DAT+ cono- weeding which was statistically at par with hand weeding twice at 20 and 40 DAT. Presumably, the excessive weed growth prevented rice plants from absorbing nutrients in control plot (Jacob and Syriac, 2005).

The potassium removed by weeds was found significantly higher with SRI method (5.30$kgha^{-1}$) followed by CRC (3.94 $kgha^{-1}$) and ICM (3.01 $kgha^{-1}$). Among the integrated weed management practices, maximum K removed by weeds was recorded in control plot (10.22 $kgha^{-1}$). However, significantly lowest K removed by weeds in hand weed3ing twice at 20 and 40 DAT which was statistically at par with butachlor 50 EC@1.5 kg a.i$ha^{-1}$ at 3 DAT+ cono- weeding at 20 DAT. This might be due to lower dry weight of weeds in treatment of hand weeding twice at 20 and 40 DAT (Table 6).

The interaction between establishment method and integrated weed management was found significant in terms of nutrient removed by weeds (Table 7). Treatment combination of $M_1W_1$ i.e. SRI method with control plot recorded significantly higher removal of N, P and K (12.74, 4.19 and 13.52 $kgha^{-1}$, respectively) and lower removal by the treatment combinations of $M_1W_5$ i.e. SRI with butachlor 50 EC@1.5 kg a.i.$ha^{-1}$ at 3 DAT+ cono- weeding at 20 DAT (1.08, 0.24 and 1.38 $kgha^{-1}$, respectively) at par with $M_2W_2$ i.e. ICM with hand weeding twice at 20 and 40 DAT (1.04, 0.25 and 0.96 $kgha^{-1}$, respectively) compared to other treatment combinations

## Residual Soil Fertility Status

### *pH, Organic carbon and Soil Microbial Biomass Carbon (SMBC) status*

The results showed that the soil pH, organic carbon and SMBC was significantly influenced by establishment methods and integrated weed management practices in wetland rice during both the years as well as mean data. However, the interaction between establishment methods and integrated weed management could not bring any significant changes in pH, organic carbon and SMBC content in soil.

Among the establishment methods, a significantly decreasing trend of pH, organic carbon and SMBC was shown from SRI to ICM and CRC in both the years and mean data of two years. The highest mean pH, OC and SMBC of 5.133, 0.58 per cent and 172.78 $\mu gg^{-1}$ soil, respectively, was recorded in SRI method followed by ICM and CRC. However, among the integrated weed management practice, the significantly highest mean pH, OC and SMBC was recorded with cono- weeding twice at 20 and 40 DAT at par with hand weeding twice at 20 and 40 DAT followed by cono- weeding at 20 DAT + hand weeding at 40 DAT over control (Table 8). The change of pH, OC and SMBC might be due to the decomposition of weeds which was put inside the soil during weeding. Similarly, Das *et al.,* (2010) revealed that the decomposition of organic matter was marginally improved the soil organic carbon and soil microbial biomass carbon (SMBC). The increase in SMBC was attributed to presence of easily water soluble carbon which acts as a source of energy for soil microorganisms was also reported by Manna *et al.,* (2001). The application of chemical fertilizers along with the organic sources increased pH and organic carbon was report by Bhat *et al*., (2005); Naik and Yakadri, (2004) and Saha *et al*., (2007). Choudhary *et al*., (2010) was also reported at IARI, New Delhi that the highest soil microbial biomass carbon (SMBC) was recorded to 148 µg/g soil at 60 DAT of lowland rice under SRI method of cultivation with hybrids and growth promoting *rhizobacteria.*

## Post –Harvest Available N, P and K Status

All the three establishment methods differed significantly among each other in respect of available N, P and K in soil during both the years and mean data. The impact of establishment methods and integrated weed management practices on soil available nitrogen revealed that the available nitrogen increased after harvest of the crop in both the years. The establishment method of SRI had left significantly highest amount of available N in soil over ICM and CRC.

**Table 7: Interaction effect of establishment methods and integrated weed management on nutrient removal by weeds in wetland rice (two years pooled data)**

| Treatments | Nutrient removal by weeds (kgha$^{-1}$) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | | | | P | | | | K | | | |
| | SRI | ICM | CRC | Mean | SRI | ICM | CRC | Mean | SRI | ICM | CRC | Mean |
| $W_1$: Control | 12.74 | 8.01 | 8.82 | 9.86 | 4.19 | 2.82 | 3.00 | 3.34 | 13.52 | 8.17 | 8.96 | 10.22 |
| $W_2$: Hand weeding twice at 20 and 40 DAT | 1.20 | 1.04 | 1.51 | 1.25 | 0.26 | 0.25 | 0.37 | 0.29 | 1.07 | 0.96 | 1.55 | 1.20 |
| $W_3$: Cono- weeding twice at 20 and 40 DAT | 5.49 | 3.15 | 3.67 | 4.10 | 1.43 | 0.72 | 1.03 | 1.06 | 5.65 | 3.08 | 4.52 | 4.42 |
| $W_4$: Cono- weeding at 20 DAT + Hand weeding at 40 DAT | 4.64 | 1.90 | 2.67 | 3.07 | 1.11 | 0.44 | 0.74 | 0.76 | 4.87 | 1.71 | 3.14 | 3.24 |
| $W_5$: Butachlor 50EC@1.5 kg a.i.ha$^{-1}$ at 3 DAT + Cono-weeding at 20 DAT | 1.08 | 0.97 | 1.29 | 1.12 | 0.24 | 0.29 | 0.35 | 0.29 | 1.38 | 1.13 | 1.53 | 1.35 |
| **Mean** | **5.03** | **3.01** | **3.59** | | **1.45** | **0.90** | **1.10** | | **5.30** | **3.01** | **3.94** | |
| **CD(P=0.05)** | | M × W | W×M | | | M × W | W × M | | | M × W | W ×M | |
| | | **1.83** | **2.02** | | | **0.470** | **0.524** | | | **1.95** | **2.18** | |

**Table 8: Effect of establishment methods and integrated weed management on residual soil fertility status of wetland rice (two years pooled data)**

| Treatments | *p*H | Organic Carbon (%) | Soil Microbial Biomass Carbon (µgg$^{-1}$ soil) | Available nutrients (kgha$^{-1}$) | | |
|---|---|---|---|---|---|---|
| | | | | N | P | K |
| **Establishment Methods(M)** | | | | | | |
| $M_1$: SRI | 5.133 | 0.55 | 172.78 | 257.75 | 9.24 | 268.70 |
| $M_2$ :ICM | 5.078 | 0.53 | 165.06 | 253.26 | 8.67 | 265.53 |
| $M_3$ :CRC | 5.016 | 0.50 | 150.31 | 245.93 | 8.64 | 257.03 |
| SEm± | 0.006 | 0.001 | 0.258 | 0.200 | 0.039 | 0.650 |
| **CD(P=0.05)** | **0.023** | **0.005** | **1.012** | **0.786** | **0.152** | **2.553** |
| **Integrated Weed Management(W)** | | | | | | |
| $W_1$: Control | 4.527 | 0.45 | 122.67 | 233.13 | 7.50 | 226.94 |
| $W_2$: Hand weeding twice at 20 and 40 DAT | 5.214 | 0.55 | 173.69 | 264.22 | 9.55 | 283.69 |
| $W_3$: Cono- weeding twice at 20 and 40 DAT | 5.220 | 0.56 | 175.61 | 253.42 | 9.11 | 275.23 |
| $W_4$: Cono- weeding at 20 DAT + Hand weeding at 40 DAT | 5.220 | 0.55 | 171.15 | 254.47 | 9.07 | 269.33 |
| $W_5$: Butachlor 50EC@1.5 kg a.i.ha$^{-1}$ at 3 DAT + Cono- weeding at 20 DAT | 5.198 | 0.54 | 170.46 | 256.31 | 9.03 | 263.59 |
| SEm± = | 0.023 | 0.01 | 4.28 | 2.24 | 0.14 | 2.33 |
| **CD(P=0.05)** | **0.067** | **0.03** | **12.48** | **6.55** | **0.40** | **6.81** |
| **Interaction (MxW)** | | | | | | |
| SEm± = | 0.036 | 0.015 | 6.631 | 3.483 | 0.217 | 3.671 |
| **CD(P=0.05)** | **NS** | **NS** | **NS** | **10.179** | **0.466** | **10.831** |

NS: Non-Significant

The highest mean value of 275.57 kgha$^{-1}$ in SRI compared to ICM and CRC which might be due to higher organic carbon content and soil microbial activity. Among the integrated weed management practices, the available N in soil had left significantly higher with hand weeding twice at 20 and 40 DAT (264.22 kgha$^{-1}$) over control as well as in comparison with other treatments (Table 8). Similar finding was also reported by Bhat *et al*., (2005) and Chaure *et al*., (2005).

Available P content was higher in SRI (9.24 kgha$^{-1}$) compared to ICM ( 8.67 kgha$^{-1}$) and CRC which was also the increasing trends over initial value. The available P in both the years increased after the application of the treatments. This result is in conformity with the findings of Singh *et al*., (2006). Bhat *et al*., (2005) was also reported an increasing trend in available P which was observed in the soil due to the application of organic sources. Among the integrated weed management practices, the highest P content in soil was recorded with hand weeding twice at 20 and 40 DAT (9.55 kgha$^{-1}$) which was significantly higher over control and other treatments.

Similarly, the available K content in soil was also showed significant increase over the initial value and the highest K content was recorded with SRI method followed by ICM and CRC. The available K content of soils after harvest of crop varied significantly due to various integrated weed management practices under three different establishment methods. The two hand weeding treatment recorded significantly higher amount of available K content ( 283.69 kgha$^{-1}$) in comparison to control as well as other treatment. The status of potassium in the soil increased over the initial value where FYM was applied during the wet season (Maiti *et al*., 2006).

**Interaction effect of available N, P and K status**

Interaction between establishment methods and integrated weed management on nutrient status of soil was significant (Table 9). Within the same level of integrated weed management, SRI establishment method recorded maximum available N, P, and K value (257.75, 9.24 and 268.70 kgha$^{-1}$, respectively) than ICM and CRC. Similarly, within the same level of establishment methods, hand weeding twice at 20 and 40 DAT had left maximum available N, P and K content (264.22, 9.55 and 283.69 kgha$^{-1}$, respectively) in soil after the harvest of wetland rice.

Hence, the N, P and K removed by weeds were found significantly higher with SRI method followed by CRC and ICM during both the years. Among the integrated weed management practices, maximum N, P and K removed by weeds were recorded in control during both the years. A significantly decreasing trend of pH, organic carbon and SMBC was shown from SRI to ICM and CRC in both the years and mean data of two years. The highest mean pH, OC and SMBC of 5.133, 0.58 per cent and 172.78 µgg$^{-1}$ soil, respectively, was recorded in SRI method followed by ICM and CRC. However, among the integrated weed management practice, the significantly highest mean pH, OC and SMBC was recorded with cono- weeding twice at 20 and 40 DAT at par with hand weeding twice at 20 and 40 DAT followed by cono- weeding at 20 DAT + hand weeding at 40 DAT over control. The establishment method of SRI had left significantly highest amount of available N, P and K in soil over ICM and CRC. The highest mean value of 244.31, 9.24 and 268.70 NPK kgha-1, respectively were recorded in SRI compared to ICM and CRC. Among the integrated weed management practices, the available N, P and K in soil had left significantly higher with hand weeding twice at 20 and 40 DAT (264.22, 9.55 and 283.69 NPK kgha-1, respectively) over control as well as in comparison with other treatments.

## DISCUSSION

The higher grain and straw productivity in wetland rice might be due to higher numbers of effective tillers per hill, panicle length, and test weight etc in SRI compared to ICM and CRC. This finding was in corroboration with the findings of Thakur *et al*., (2010); Mankotia *et al*., (2006); Sinha and Jagesh (2007); Balasubramanian *et al*., (2006) and Chitle *et al.,* (2006).

**Table 9: Interaction effect of establishment methods and integrated weed management on residual soil fertility status in wetland rice (two years pooled data)**

| Treatments | Nutrient status of soil (kgha$^{-1}$) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | | | | P | | | | K | | | |
| | **SRI** | **ICM** | **CRC** | **Mean** | **SRI** | **ICM** | **CRC** | **Mean** | **SRI** | **ICM** | **CRC** | **Mean** |
| $W_1$: Control | 217.34 | 242.06 | 240.01 | 233.13 | 7.61 | 7.69 | 7.21 | 7.50 | 235.99 | 222.51 | 222.30 | 226.94 |
| $W_2$: Hand weeding twice at 20 and 40 DAT | 267.37 | 271.30 | 253.99 | 264.22 | 9.69 | 9.91 | 9.06 | 9.55 | 289.65 | 293.26 | 268.14 | 283.69 |
| $W_3$: Cono- weeding twice at 20 and 40 DAT | 265.62 | 250.50 | 244.14 | 253.42 | 9.70 | 8.60 | 9.03 | 9.11 | 282.75 | 277.00 | 265.94 | 275.23 |
| $W_4$: Cono- weeding at 20 DAT + Hand weeding at 40 DAT | 266.79 | 251.16 | 245.45 | 254.47 | 9.62 | 8.58 | 9.01 | 9.07 | 268.69 | 274.39 | 264.92 | 269.33 |
| $W_5$: Butachlor 50EC@1.5 kg a.i.ha$^{-1}$ at 3 DAT + Cono- weeding at 20 DAT | 271.62 | 251.27 | 246.04 | 256.31 | 9.60 | 8.58 | 8.89 | 9.03 | 266.43 | 260.51 | 263.83 | 263.59 |
| **Mean** | **257.75** | **253.26** | **245.93** | | **9.24** | **8.67** | **8.64** | | **268.70** | **265.53** | **257.03** | |
| **CD(P=0.05)** | | M×W | W × M | | | M × W | W × M | | | M × W | W × M | |
| | | **10.18** | **11.35** | | | **0.640** | **0.696** | | | **10.83** | **11.79** | |

Moreover, the pooled data of two years was also showed similar trend in grain and straw productivity with hand weeding twice at 20 and 40 DAT which might be due to less weed competition as compared to other treatments. Similar finding was also reported by Pandey, (2009); Singh *et al.*, (2008); Sanjay *et al.*, (2006); Choudhury and Thakuria (1998); Raju *et al.*, (2001); Banerjee *et al*., (2008); Uphoff (2003); Krishna (2000) and Padmavati *et al.*, (1998).

The maximum uptake of N by grain, straw and total uptake in SRI method followed by ICM method which might be due to higher grain yield reported by Barison (2002) and Sanjay *et al.*, (2006). Hand weeding twice at 20 and 40 DAT recorded higher N uptake (75.03 and 25.26 kgha$^{-1}$ in grain and straw, respectively) which might be due to higher concentration of N in grain compared to straw (Saha *et al.*, 2007). The higher nutrient harvest index with control might be due to the reason that under nutrient starved condition, plant tries to extract more from the soil and converts maximum towards seeds for completion of life cycle (Das *et al*., 2010). The massive and long functioning root growth which comes in contact with larger volume of soil might have absorbed more amounts of moisture and nutrients which is in evidence with significant high phosphorus uptake (Patel *et al*., 2008; Barison (2002) and Sanjay *et al.,* 2006). Hand weeding twice at 20 and 40 DAT (13.73 and 9.58 kgha$^{-1}$ in grain and straw, respectively) which might be due to higher concentration of P in grain compared to straw and greater availability of P in the root zone which was absorption by the wetland rice( Saha *et al*., 2007 and Sanjay *et al.*, 2006). The excessive weed growth prevented rice plants from absorbing adequate amount of nutrients in control plot (Jacob and Syriac, 2005). . Sanjay *et al.,* (2006) reported that nutrient removed by weeds in broadcast sowing method was significantly higher compared to line transplanting and drum seeding. Among the weed management treatments, application of pre-emergence herbicide followed by hand weeding at 30 DAT recorded significantly lowest removal of N, P and K compared to other treatments and higher under unweeded check. The nutrient removal by the weeds is to the tune of 21.4, 2.12 and 22.0 kg N, P and K per hectare, respectively, which however differs with condition of cropping. Under transplanted conditions, the weeds deplete 25.0, 5.8 and 63.4 kg N, P and k per hectare, respectively (Kaushik and Mani, 1977). Mohamed Ali, (1978) reported that the uptake of nutrients is highest in unweeded plots. The N, P and K uptake were highest under planting of rice through SRI than under conventional rice (Barison, 2002).

The application of organic sources like FYM and BGA was showed a slight increase in soil organic C (Bhat *et al*., 2005). Similarly, Naik and Yakadri, (2004) reported that there was an increase in soil organic C due to the application of organic sources and 150 kg N through fertilizer. The application of chemical fertilizers along with the organic sources increased organic carbon by 0.71 per cent (Saha *et al*., 2007). Application of 25 kg N/ha in combination with 75 kg N organic sources resulted in improved pH. On the other hand, Bhat *et al*., (2005) reported that there was a little variation in soil pH due to integrated nutrient management after harvest of the crop.

Soil microbial biomass carbon (SMBC) and nitrogen (SMBN), soil microbial community structure, and crop yields were studied in a long-term (1982–2004) fertilization experiment carried out in Suining, Sichuan province of PR China showed that the soil microbial biomass was higher in soil treated with CFM than in soil treated with CF alone, and that NPKM gave the highest rice and wheat yields. The SMBC and SMBN were higher after rice than those after wheat cropping. SMBC correlated closely with soil organic matter. Average yields of wheat and rice for 22 years were higher and more stable in the fertilized plots than in control plots. This study demonstrated that mixed application of N, P, and K with additional M amendment increased soil microbial biomass, diversified the bacterial communities and maintained the crop production in the Calcareous Purplish Paddy soil (Gu *et. al*., 2009). Choudhary *et al*., (2010) reported at IARI, New Delhi that the highest soil microbial biomass carbon was recorded to 148 µg/g soil at 60 DAT of lowland rice under SRI method of cultivation with hybrids and growth promoting *rhizobacteria*. The increase in SMBC was attributed to presence of easily water soluble carbon which acts as a source of energy for soil microorganisms (Manna *et al.*, 2001). The application of composts marginally improved the soil organic carbon, whereas, the improvement in soil microbial biomass carbon (SMBC) was significantly improved ($P < 0.05$) due to application of various composts and farmyard manure (Das *et al*., 2010).

The soil fertility status significantly increased with the application of FYM along with half the recommended dose of NPK total (30: 15:15) under clay loam soil having pH 6.9, low in available N and P and high in available K. Maximum reduction was observed in control treatment, while a considerable decrease was noticed under recommended dose of fertilizers alone (Dilip, 2002). Under gypsum amended alkali soils of Haryana, there was a marginal improvement in soil N, P and K status when 100 and 150 per cent RDF were given. Organic carbon, available P and K were increased with organic sources of nutrient application either alone or in combination with fertilizers over fertilizers alone in dryland condition of Phulbani (Jena *et al*., 2000). Available N, P and K content was improved under INM compared to its initial soil fertility during the *kharif* season in Jharkhand (Singh *et al*., 2005). There was a slight increase in N contents due to the application of organic sources like FYM and BGA (Bhat *et al*., 2005). In a field experiment conducted in the *vertisols* of College of Agriculture, Nagpur, Maharashtra during the *kharif* season, it was observed that application of 25 kg N/ha through urea in combination with 75 kg N through sun hemp green matter/ha resulted in more soil available N (291.54 kg/ha) with rice variety Pusa Basmati (Chaure *et al*., 2005). Chaure *et al*., (2005) also reported that by the application of inorganic fertilizers 25 kg N (urea)/ha in combination with 75 kg N (sun hemp green matter)/ha resulted in the highest K (299.82 kg/ha) content in soil. The status of potassium in the soil increased over the initial value where FYM was applied during the wet season (Maiti *et al*., 2006). Singh *et al*., (2006) reported that there was a buildup of available P in soil in all nutrient management practices including fertilizers alone over the farmer’s practice. An increasing trend in available P was observed in the soil due to the application of organic sources like FYM and BGA (Bhat *et al*., 2005).

## CONCLUSION

It can be concluded that integrated weed management in system of rice intensification (SRI) method with butachlor 50 EC @ 1.5 kg a.i.$ha^{-1}$ + cono- weeding at 20 DAT and integrated crop management (ICM) method with hand weeding twice at 20 and 40 DAT can be recommended for higher productivity, nutrient uptake, nutrient harvest index and better soil health in wetland rice ecosystem of West Garo Hills district of Meghalaya, India as compared to conventional rice culture (CRC) method.

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