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Rice Waste and Tillage Management in Guilan Rice Paddy Fields: An Essential Approach to Sustainable Agricultural Management

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Abstract

One of the major contributors to air pollution, soil environmental degradations and health risks in paddy fields is the production of high volumes of rice growing activities' wastes. Poorly managed rice husk and straw (such as burning) can be problematic since they threaten rice-based cropping system and farmers' economy. One promising approach to decrease their negative effects is to use alternative managerial practices to guaranty both food security and sustainable agriculture and to address waste management issues. Currently, the burning rice wastes burning and off season's tillage are two hot topics that is of interest to numerous agricultural researchers. The main purpose of this study was to explore the effects of rice residues burning on a number of crucial paddy soil chemical and physical characters, rice yield and yield component, rice pests, diseases, and common weeds populations. The current one-year field experiment was carried out in five factors factorial arrangement in a randomized complete block design with three replications. The treatments were tillage methods at three levels (non-plowing, autumn plowing, and winter plowing), and crop residues' management at two levels (residues burning and residues conservation). The chemical (Total N, Zn content and OC %) and physical (infiltration rate) properties of paddy soil were significantly affected by residual management ($p < 0.05$), except bulk density. The initial soil organic carbon percentage (2.18%) and consequently initial infiltration rate (2.04) increased at the conservative management of the residues in combination with plowing by around 0.51 percent, 2.69 and 2.81, respectively. Furthermore, the 1000 grains weight and filled grains weight were increased by abovementioned treatments by around 8 and 9 percent, respectively. The rate of emergence of rice stem borer was negatively affected by winter and autumn plowing more than 4 times, with non-significant difference between winter and autumn plowing. The applied treatments had not any significant effect on studied rice weed populations, except weed 1 that tillage management caused a decrease about 2 times in its population. The applied treatments (alone and/or in combination) not only can certainly contribute to the reduction of rice weed, pest and disease populations but also strongly recommend to improve some important soil physical and chemical properties.

Keywords:

Organic matter; tillage method; residues burning; residues conservation; Zn; pest Stem Borer

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INTRODUCTION

Rice is the predominant staple food for around half of the world population, especially in Asian countries, where more than 80 percent of the rice is produced and consumed. Over the last ten decades, rice as a strategic agricultural crop has experienced two considerable jumps, with rice production tripling as a result of new genetic discovering and brilliant agronomic improvements. However, the rapid growth in world population (1.12 growth rate) and economic developments have created tremendous pressure for more and more rice production. In order to further increase in rice production to meet growing demand and to conserve agricultural resources, two options are available, namely expanding the rice growing area and enhancing the rice yields per unit area. Therefore, security and sustainability in agricultural crop sectors will be two upcoming challenges in the near future. Whereas the sustainable agriculture will ideally have a crucial and parallel role in agro- ecosystems' conservation, food security is the main backbone of constant and healthy food supply (Skaf et al., 2019).

Similar to many developing countries, Iran is facing unsustainable and uneconomic land use. Therefore, there is an urgent need to use land in the most scientific and sustainable ways. A part of the problem can be solved by renewable source since the biomass raw material source used in the production of rice grain can be repeatedly grown or harvested at the same location, or/and with new tillage issues.

Rice as a staple crop is important and commercially produced in the majority of coastal plains of Guilan Province. Despite rice grain, about one million ton of rice straw and other post -harvest rice residues were left in Guilan paddy fields (238 thousand hectares) annually, that which can be used in industrial activities, livestock feeding, and providing fuel. However, unfortunately, almost all of these agricultural residues are burned by local farmers (Yaghoubi et al., 2019). Due to the

large rice cultivated area during the last decades (230000 ha), burning rice straw has become one of the main sources to air pollution, where the large losses going into the atmosphere up to 80 percent of N. On the contrary, reasonable management of rice plant residues or post-harvest wastes will improve physical and chemical conditions of paddy soil and consequently increase rice grain yield. Therefore, in spite of its positive or negative effect on soil and rice yield, making the decision for how the burning of rice residues, alone or in combination with other agricultural practices (types of tillage) might affect the farmer income need to investigate. Moreover, several authors reported a significant increase of grain yield and yield attributes due to the addition of higher amount of carbon content through burning processes. Organic matter is a fundamental component of soil fertility due to its effects on physical (aggregates stability), chemical (increasing the storage capacity of macro and micronutrients) and biological (enhancing soil microbial activities) properties of soil (Giti, 2010). On the other hand, burning of rice residues by rice farmer might have some gained benefits such as: increasing soil fertility, the cheapest and easiest way for removing large loads of the produced rice straw, shorten turn over time of following crops, decreasing labour cost Yao et al. (2015) showed that rice residues' management plus tith depth increases the mechanical properties of soil and thereby causes more susceptibility of rice farming. The results also revealed that increasing organic carbon of the soil through burning practices increased 1000 grains weight.

Tillage which is the practice of modifying the state of soil in order to provide suitable conditions to crop growth. Topsoil tillage is among the most important factors affecting soil characters, and crop yield and yield component. Among the crop production factors, tillage contributes up to 20 percent and affects the sustainable use of soil resources through its influence on soil properties, and

also weeds, pests, and diseases control (Alam et al., 2014). The proper tillage practices can overcome a number of soil constraints including bulk density, water penetration rate and permeability index (Rasooli Sharbiani & Abbaspoor Gilandeh 2013), whereas improper tillage management may cause various undesirable features (such as soil structure destruction, reduction or loss of soil organic matter and fertility status. The fact that using the appropriate method of land preparation and type of tillage equipment's have an immense effect on physical and chemical soil properties, and consequently on agricultural crop productivity (Tripathi, 2007; Lithourgidis, 2006). Tillage methods effects on soil properties such as temperature, storage, and distribution of soil moisture (Lampurlanes et al., 2001), soil compaction (Lapen, 2004), soil organic matter (O.C) and soil N content (Yadav et al., 2017, Ghimire et al., 2017). Rice crop production could be enhanced by applying proper tillage operation and selecting suitable crops residues management patterns. The current research findings emphasis that conservative tillage practices compare to the traditional tillage practices had more impact on yield as well as the soil-water-plant ecosystem of rice growing regions. For example, shallow tillage operation, there was more resistance to irrigation water penetration (regardless of the mixing of rice straw). Also, root length in deep tillage was more than the superficial tillage. Zhu et al. (2014) through a field study using different tillage operations and return of residues in a wheat-rice rotation system in China showed that return of crop residues to the field could increase soil OM and microbial activity.

Concerning the fact that the burning of rice plant residues, especially straw and bran is, therefore, a common management practice of rice residues amongst paddy farmers at country scale. With respect to the foregoing reasonable environmental effects and beneficial impacts on the yields of rice straw burning, one promising approach to decrease

their negative effects is to use alternative managerial practices to guaranty both food security and sustainable agriculture and to address waste management issues (Akbari et al., 2018). Therefore, the current research as a part of a mega project aimed to investigate the effect of rice straw and post-harvest waste burning and different conservative tillage operations on the growth, yield and yield component of rice, and chemical and physical properties of paddy soil in order to achieve maximum yield and maintaining the quality of soil in a long-term plan to achieve sustainable agriculture goals (specific objectives). Furthermore, the general objectives of this study were to evaluate the effect of the aforementioned treatments on Stem borer (main pest), Blast (main disease) and Barnyard grass (main weed) populations.

METHODOLOGY

The present study was conducted at a rice field (with a total area of 1800 m²) Islamabad village, Pirbazar rural district, Rasht, Guilan Province, Iran (N and E) (Figure 1) during April to September of 2015. The current one-year field experiment was carried out in five factors factorial arrangement in a randomized complete block design with three replications.



Figuer1. Field Location

The treatments were tillage methods at three levels (non-plowing, autumn plowing, and winter plowing), and crop residues' management at two levels (residues burning and residues conservation) (Figures 2 and 3).



Figure 2. Implementing tillage treatments



Figure 3. Treatments

For soil properties (before and after treatment application), soil samples were collected from the experimental plots ($10 \times 10 \text{ m}^2$) at the depth of ploughing layer (0–30 cm) to determine soil physical and chemical properties including; bulk density (cylinder method), particle density (Pycnometer method, ASTM Standards), aggregates mean weight diameter (wet sieving method), Soil texture (hydrometric method), PH (PH meter), electrical conductivity of the soil saturation extract (using EC-meter), organic matter content (Walkley Black method), N (Kjeldahl method), Phosphorus (Olsen method), potassium (flame photometer), water penetration in soil (double cylinders), soil mechanical strength (Penetrometer), soil moisture, plant micro-elements (Iron, manganese, zinc and nitrogen by atomic absorption).

The experimental treatments including different tillage methods (non-plowing, autumn plowing, and winter plowing), management of crop residues (burning of the residues and conservative residues operation) were applied before transplanting stage. The common Iranian local rice variety (Hashemi) was transplanted in the experimental plots (10 m

$\times 10 \text{ m}$) as a rice genotype in $30 \text{ cm} \times 30 \text{ cm}$ configuration with three seedlings per hill on May 5, 2015. Regionally recommended N, P and K fertilizers were applied in all treatment's plots, according to the local application timing. Nitrogen fertilizer as urea at the rate of 150 kg ha^{-1} (50 basal, 50 top dressing at the start of tillering and 50 top dressing at the start of the flowering stage) was applied to each plot. Potassium as muriate of potash and Phosphorus as KH_2PO_4 at the rate of 70 kg ha^{-1} was applied to each pot as a basal fertilizer to maintain a constant level of K and P. All the conventional managerial practices such as watering, fertilizer split application, weeding and pest control were conducted on time and when necessary due to rice research institute of Iran agricultural operation bulletin.

The data recording and sampling started at around the vegetative growth stage (26 days after transplanting) on June 1. Theoretically, the first sampling time coincided with the attack of first-generation of rice stem borer, causing a lot of damage on rice crop production, annually. Whereas the first generation of rice stem borer was not existed, the pest control operation was not carried out. Although, in case of visible and considerable damage by stem borers, a biological or chemical control using trichogramma wasps, or chemical control with appropriate pesticides would be undertaken. All data recording and sampling (such as stem borer damage and weed number), and yield and yield component in each plot were carried out in a square meter space (Figure 5).



Figure 4. Pest stem borer



Figure 5. Weed

At the end of June (24th), daily monitoring and sampling of all plots were done concurrently with the attack of second -generation rice stem borer. Thus, the number of infected plants per day was identified and their stems were sampled at the peak time of the attack. Subsequently, the time of pest control and its proper biological control were done. In early July, based on the amount of rainfall and increasing the moisture content of the paddy farm, the number of infected bushes to the blast disease was recorded. Blast disease is one of the common diseases in Guilan rice fields (Figure 6).



Figure 6. Blast disease

In the year of the experiment, the summer rainfall duration was July 9 to July 12. Leaf blast disease sampling was carried out on July 25, 2015. Panicle blast symptoms were not observed. At the ripening stage of rice plant a bordered area of 1 m² of each plots, that previously labelled, was harvested where the following yield and yield attributes were recorded on 5 plants: total and active tiler number, number of grains/panicle, 1000-grain weight (g), filled and unfilled grain per 1000 grains and yield per hectare. Irrigation water penetration rate of soil (by

double cylinder method) and soil mechanical strength using penetrometer were re-measured immediately after harvesting time. Moreover, soil samples were taken to determine the percentage of moisture content.

The SAS program was used for the analysis of variance (ANOVA) and the mean comparison through LSD (0.05) of all data.

RESULTS AND DISCUSSION

Physical and chemical properties of soil

The physical and chemical properties of studied soil were summarized in Table 1. Soil analysis showed that soil had Silty Loam in texture having 13.66 percent sand, 72.77 percent silt and 13.55 percent clay, 2.19 percent OC and C: N ratio of 10:1. It had a total N of 0.21 percent, available P of 11.61 ppm, and available K of 81.11 ppm. Soil pH of 7.55 (neutral) and electrical conductivity of 1.64 dS.m⁻¹ indicated that the selected paddy soil had not any severe problem for rice cultivation. Moreover, the selected soil physical analysis showed bulk and actual density of 0.64 and 2.48 gcm⁻³, respectively, and consequently higher porosity about 76 percent and medium soil surface water penetration by 2 mm. min⁻¹.

Table 1

Some Physical-Chemical Properties of Soil before Implementing Treatments

Properties	Measure
pH	7.55
ECe (dS.m ⁻¹)	1.64
Bulk density (g.cm ⁻³)	0.64
Actual density (g.cm ⁻³)	2.48
Organic carbon (%)	2.19
Total nitrogen (%)	0.21
Available phosphorus (mg.kg ⁻¹)	11.61
Available potassium (mg.kg ⁻¹)	81.11
Sand (%)	13.66
Silt (%)	72.77
Clay (%)	13.55

Soil organic matter

The results of the analysis of variance (ANOVA) showed that the organic matter content percentage was significantly affected by residual management and tillage methods ($p<0.01$), and their interactions ($p<0.01$) (Table 2).

The response pattern of organic matter content to applied treatments and across their levels was different. The maximum increase in OM% was obtained with conservative residual management by about 23.4 percent, whereas in tillage management the highest increase in OM% was recorded at winter tillage by about 17 percent (non-significant difference with autumn tillage,

14.5%) (Table 3).

These data suggested that the conservative residual management was more effective than the rest of the treatments to increase OM percent of studied paddy soil. It is in line with Sui et al. (2016) that revealed adding rice residues to top- soil of paddy soil is the easiest and most effective way to increase soil OM percent and consequently N content. Furthermore, due to significant interaction effect of applied treatments, Table 3 indicated that the most effective treatment combination was recorded for autumn tillage with conservative residues management (2.88, 42%) compared to the rest of treatment combination (2.34, 23%) and control plot (2.18).

Table 2

Analysis of Variance for Soil Physical Properties, Zink, Weed, Blast and Pest Stem Borer of Rice as Affected by Residue Management and Tillage System

Sources of variations	df	Mean square				
		Weed1	Weed2	Blast	Pest stem borer	Zn
Block	2	0.055 ^{ns}	0.16 ^{ns}	0.05 ^{ns}	0.05 ^{ns}	15.04 ^{ns}
Residual Management (A)	1	0.00 ^{ns}	0.22 ^{ns}	0.05 ^{ns}	0.22 ^{ns}	153.70**
Tillage (B)	2	*5.72	0.50 ^{ns}	0.72 ^{ns}	8.72*	33.73*
B×A	2	0.16 ^{ns}	0.05 ^{ns}	0.05 ^{ns}	0.05 ^{ns}	4.33 ^{ns}
Error	10	0.78	0.23	0.18	0.65	8.13
CV (%)	17	47.02	144.91	156.46	56.05	20.59

* $p<0.05$ and ** $p<0.01$, "ns" is not significant at the level of 5%

Table 3

Analysis of Variance for Soil Physical and Chemical Properties, of Rice as Affected by Residue Management and Tillage System and Yield of Rice

Treatment	Total nitrogen (%)	Organic matter (%)	Bulk density (g.cm ⁻³)	Infiltration (mm/min)	Thousand seed weight(g)	Filled seeds weight (g)
Residual burning	0.21 ^b	2.18 ^b	0.60 ^a	2.04 ^b	25.10 ^b	24.53 ^b
Residual conservation	0.27 ^a	2.69 ^a	0.52 ^a	2.81 ^a	27.24 ^a	26.86 ^a
No-tillage	0.21 ^b	2.20 ^b	0.59 ^a	2.00 ^c	26.62 ^a	25.97 ^a
Autumn tillage	0.25 ^{ab}	2.52 ^a	0.55 ^a	2.38 ^b	25.50 ^a	25.11 ^a
W tillage	0.26 ^a	2.58 ^a	0.55 ^a	2.91 ^a	26.39 ^a	26.00 ^a

* $p<0.05$ and ** $p<0.01$, "ns" is not significant at the level of 5%

These findings are in accordance with Meena et al. (2015), who indicated by the application of different tillage operations and residual managements, adding of rice residues (straw and post-harvest wastes) significantly increase the OM percent of studied area. It might be due to on time incorporation of rice residues with soil in winter which high rainfall increase the soil moisture and this condition save and increase the added organic matter for upcoming cultivation season. It is evident from Table 3 that rice residues burning recorded lowest organic matter content among all treatments (2.18%). It also seems possible that autumn tillage (less soil moisture compare to winter) and non-conservative residual management (in this case burning of rice straw and post-harvest waste) caused serious reduction of the essential nutrient, and hence a considerable reduction in soil fertility (Dobermann & Fair Hurst, 2002).

Total N

According to the analysis of variance (ANOVA) the total N percentage was significantly affected by residual management, tillage methods and their interactions ($p < 0.05$) (Table 2).

Similar to the response pattern of organic matter percentage to experimental treatments, the highest total N was recorded in residues management by about 0.27 percent (28.5% increase) for conservative management, whereas in tillage management the highest increase was found at winter tillage by about 0.26 percent (23% increase) compare to initial total N content of studied paddy soil (0.21%) (Table 3). In contrary to OM percent, the data showed significant differences among tillage operations, especially winter and autumn tillage. This data clearly indicated that adding organic matter to paddy soil is still the quick and sustainable way to increase both OM percent and its consequent N content (through OM decomposition). Similar significant effects were reported by Meena et al. (2015) and Dobermann and fair Hurst, (2002).

The interaction effects of experimental treatments on total N (Table 3) showed that the conservative management of the rice residues across with all tillage operation methods increased the total N content. The highest increase for former treatment combination was recorded in autumn tillage (0.30%, 43% increase), followed by winter tillage (0.27%, 28.5% increase). In contrast to the positive and significant effect of conservative management of the rice residues on the total N content, the burning of rice residues negatively significantly decreased on it averagely around 7 percent. Therefore, these results confirmed the previous findings of some researchers (Dobermann & fair Hurst, 2002; Du et al., 2014, Dwivedi et al., 2012; Huang et al. 2015 and El-Sayed and El-Sobky, 2017) that burning of rice residues cause complete loss of N content and its consequent results is shortage of paddy soil available nutrients for next cropping season.

Available Zinc

Next to N, P and K, zinc (Zn) is the most vital nutrient for rice production that its deficiency can cause 20 to 80 percent yield reduction (Dobermann & Fair Hurst, 2000). The total Zn content of rice aerial part negatively significantly affected (decreased) by tillage operation management ($p < 0.05$) and rice residue management ($p \leq 0.01$), whereas their interaction effects did not significantly influence the available Zn content (Table 2).

The interaction effects of experimental treatments on Zn concentration of rice tissues (Table 3) showed that the burning residues of rice across with all tillage operation methods increased the Zn content of rice tissues compared to the treatment of conservative residues. The highest increase for former treatment combinations belonged to autumn tillage with burning (23.31, 93.6% increase), followed by no-tillage with burning residues (19.61%, 62.8% increase) compared to the lowest record (12.04 mg Zn kg⁻¹ plant tissues). Therefore, these results confirmed the previous finding of Dober-

mann and fair Hurst (2002) who indicated that rice straw and post-harvest wastes (all remain tissues) are either removed from the field, burned before next crop, piled or spread in soil surface, incorporated in the paddy soil, or used as mulch to control pest, disease, weed and moisture conservation. These added residues are also a vital source of micronutrients, particularly Zn and Si (Alfonso Rodriguez et al., 2015). Therefore, burning the rice straw by producing mineral ash can increase the soil available Zn. The rice tissues Zn concentration significantly influenced by applied Zn in both sufficient and insufficient rice varietal genotypes, and the highest increased Zn concentration was obtained in the highest applied Zn level over control (Kabeya & Shankar 2013; Mahmoud Soltani et al., 2017).

1000 -grain weight and filled grain weight

The 1000 -grain weight and filled grain weight are the most important morphological parameters for increasing rice production. The results of analysis of variance for two important physiological characters were summarized in Table 2. The response pattern of these parameters is quite similar. While both of them were significantly affected with residues management and its levels at 0.05 confidence level, the tillage operation management and its levels did not show any significant effect on them. Also, the combined effect of treatments on these characters are significant at the 0.05 confidence level. It was evident that rice residues management and its levels played a major role in affecting yield attributes of cultivated rice variety (Hashemi). The highest increases in the 1000 -grain weight and filled grain weight were obtained in the conservative management of rice residues plots by about 8.5 and 9.5 percent, respectively. Therefore, the analyzed data (Table 3) suggested that the burning of rice straw recorded lower 1000 -grain weight and filled grain than the rice conservative residues treatment. It is due to losses of macronutrients (NPK) through the burn-

ing treatment and hence a considerable reduction in soil fertility (Dobermann & Fair Hurst, 2002). Also, these results are in accordance with Gursoy et al. (2010); Berhe et al. (2013); Huang et al. (2015) and El-Sobky, (2017). On the other hand, Heidari and Jafari (2004) indicated that some conservative residues management (the chopping and incorporating of chopped tissues) by increasing the soil organic matter can enhance soil fertility and thereby improving the crop yield and yield component.

Infiltration rate

According to ANOVA results in Table 2, the infiltration rate (IFR) of studied paddy soil positively significantly affected by both tillage operation management and rice residues management ($p < 0.05$), whereas their interaction effects positively significantly influenced it at 1 percent confidence level. The initial paddy soil infiltration rate (2.10 mm.min^{-1}) positively significantly increased by all treatments and their levels, and their interaction. The highest increase percentage (45.5%) in IFR across each treatment alone was recorded in winter tillage treatment (2.91 mm.min^{-1}), followed by conservative residues management (40%, 2.81 mm.min^{-1}). Furthermore, the maximum increase percentage (76.5%) was observed with the interaction effects of the conservative residue's management with winter tillage operation method (3.53 mm.min^{-1}) followed by the combined effects of the conservative residue's management with autumn tillage operation method (39%, 2.76 mm.min^{-1}). The results clearly indicated that the addition of organic carbon through residues management at any conditions when accelerated by pre-season tillage operations hence a considerable increase in IFR. It is due to reclamation effect of organic carbon on both soil porosity and structure. The results of the current study were in accordance with those reported by Ray and Gupta (2001), Chegeni et al. (2014) and Rasooli Sharbiani and Abbaspoor Gilandeh (2008) who revealed significant in-

crease in soil permeability due to increase of the rice crop residues or green manures prior to seasonal tillage, or along with tillage operation management.

Rice stem borer, Blast and weed population

An emerging issue in sustainable agriculture to avoid using chemical control of rice pests, diseases and weed is the potential of conservative crop residues management and preseasons operations. Recently, conservation agriculture is defined as agriculture of the future, the future of agriculture. Therefore, the crop production based on these technologies (no tillage or aimed tillage with residues management) can overcome the concern of environmental degradation (Singh & Sidhu, 2014).

The analysis of variance of the monitored pest (stem borer), disease (rice blast) and weeds populations were presented at Table 2. Whereas the blast and weed 3 did not significantly affect by applied treatments and their interactions, the stem borer and weed 1 population only negatively significantly affected by tillage treatment and its levels ($p < 0.05$). Therefore, the analyzed data (Table 3) suggested that crop residue has the potential to control weed growth (in this study non-significantly but numerically), thereby suppressing the possible increase of weed intensity in aimed and/or no tillage cropping systems. It is due to shading or allelopathic effects, and also this might reduce chemical control and weed competition for nutrients and water (Singh & Sidhu, 2014). Moreover, both autumn and winter tillage operations, with non-significant differences, decreased the monitored pest (stem borer), disease (rice blast) and weeds populations by around 4 times, 4 times and 2-5 times, respectively. It is in line with Orazi Zadeh et al., (2003), Bhagat et al. (1996) who reported that the winter plow (second plow) effectively decreased the weed populations. At the current study barnyard grass (*Echinochloa crus-galli*) reduction in plots was more considerable than the rest. Also, the retention

of rice residues (straw and post-harvest wastes) on the soil surface of paddy fields have frequently been associated with an increased incidence of crop diseases. The results of current study (Table 3) indicated that conservative rice residues increased 50 percent (0.33) the rice blast compared to rice residues burning (0.22). The rice residue can operate as an inoculum source and maintain favorable moisture and temperature conditions in the top 10-15 cm of soil where the pathogens are most active (Cook, 2001).

CONCLUSION

The current study as a part of a mega project was carried out in farmer field condition to explore and find answers for the recent important question: how can achieve the sustainable agriculture aspects through conservation agriculture? The burning of the rice residues, conservative residues management, and different pre-season tillage operation were used as some sustainable agriculture methods. Burning the rice residues had a significant adverse effect on soil fertility indexes and thereby exhibit suppressed grain yield and some yield attributes due to lesser N availability, organic carbon and irrigation water permeability. Therefore, adding rice straw and post-harvest wastes are a key consideration when we attempt to optimize soil fertility factors. Also, proper tillage management (especially winter plowing) by minimizing the nutrient and organic carbon losing may increase the crop production factors. Therefore, the results of this project recommended that: to avoid and overcome existence pressure on rice farming sector opening the windows of sustainable agriculture is vitally needed. Also, conservative residues operation in combination with winter plowing is more favorable to optimal rice yield. In spite of gaining more attention to these abovementioned aspects in recent years the short-term and long-term research in this area is also strongly recommended.

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APPENDIX

Table A1. Analysis of Variance and interaction effects of residue management and tillage treatments on soil physical and chemical properties and yield of rice

Tillage	Residual management	Total nitrogen (%)	Organic matter (%)	Bulk density (g.cm ⁻³)	Infiltration (mm/min)	Thousand seed weight (g)	Filled seeds weight(g)
No-tillage	residual burning residual conservation	0.18 ^b 0.25 ^{ab}	2.03 ^c 2.37 ^{bc}	0.64 ^a 0.54 ^{ab}	1.83 ^{cd} 2.16 ^{bc}	25.25 ^{bc} 25.76 ^{bc}	24.81 ^{bc} 25.42 ^{bc}
Autumn tillage	residual burning residual conservation	0.20 ^b 0.30 ^a	2.17 ^{bc} 2.88 ^a	0.58 ^{ab} 0.52 ^{ab}	2.00 ^c 2.76 ^b	24.69 ^{bc} 28.55 ^a	23.92 ^{bc} 28.03 ^a
Winter	residual burning residual conservation	0.25 ^{ab} 0.27 ^a	2.34 ^{bc} 2.82 ^a	0.60 ^a 0.50 ^{ab}	2.30 ^{bc} 3.53 ^a	25.38 ^{bc} 27.41 ^{ab}	24.88 ^{bc} 27.13 ^{ab}

* and ** are significant at 5 and 1%, respectively, "ns" is not significant at the level of 5%

Table A2. Analysis of Variance main effects of residue management and tillage treatments on weed, blast and pest stem borer, Weed (1, 2) of rice

Treatment	Weed (1)	Weed (2)	Blast	Stem borer
Residual burning	1.88 ^a	0.44 ^a	0.22 ^a	1.33 ^a
Residual conservation	1.88 ^a	0.22 ^a	0.33 ^a	1.55 ^a
No-tillage	3.00 ^a	0.66 ^a	0.66 ^a	2.83 ^a
Autumn tillage	1.66 ^b	0.16 ^a	0.00 ^a	0.66 ^b
Winter tillage	1.50 ^b	0.16 ^a	0.16 ^a	0.83 ^b

* and ** are significant at 5 and 1%, respectively, "ns" is not significant at the level of 5%

Table A3. Analysis of Variance and interaction effects of residue management and tillage treatments

Treatment		Zinc	Stem borer
Residual burning (1)	no-tillage (1)		
	autumn tillage (2)	19.61 ^a 13.30 ^{ab} 17.39 ^b	2.66 ^{ab} 0.66 ^b 0.66 ^b
	winter tillage (3)		
Residual conservation	no-tillage (1)		
	autumn tillage (2)	12.04 ^{ab} 9.13 ^b 11.60 ^{ab}	3.00 ^a 1.66 ^b 1.50 ^{ab}
	winter tillage (3)		

* and ** are significant at 5 and 1%, respectively, "ns" is not significant at the level of 5%

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