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THE IMPACT INTERACTION OF THREE DIFFERENT TILLAGE METHODS AND RICE RESIDUAL MANAGEMENT ON SOIL PHYSICAL PROPERTIES AND RICE GROWTH

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Abstract. One of the major problems of rice cultivation in Guilan is traditional rice cultivation along with autumn tillage and burning last year's residual, which besides wasting this valuable organic source is followed by environmental pollution in September and October each year. This study aimed to evaluate three different methods of tillage as far as soil physical properties and rice growth under crop residual burning and conservation conditions are concerned. Therefore, an area of 1,800 square meters was chosen in Islamabad Village, Pirbazar District, Rasht. A factorial experiment was designed and conducted in a randomized complete block design with 6 treatments in 3 replications and in 18 plots (each plot = 10 × 10 square meters). Treatments included tillage factor with no-tillage, autumn and winter tillage methods; and residue management factor included crop residual burning and conservation. The results showed that the amount of soil organic matter in residual burning and residual conservation was 2.18% and 2.69%, respectively, showing a 0.51% increase in organic matter. The amount of organic matter in no-tillage method (2.20%) showed a significant decrease of 0.32% and 0.38% compared with autumn tillage (2.52%) and winter tillage (2.58%), respectively. Surface water infiltration in soil before performing treatments was 2.01 mm per minute, which was significantly increased by 2.81 mm per minute in crop resid-

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ual conservation treatment, 2.91 mm per minute in winter tillage and 2.38 mm per minute in autumn tillage. Rice grain weight was significantly increased in residual conservation and no-tillage conditions. According to the results of this study, incorporation of rice residues into the soil by plowing can be recommended.

Keywords: organic matter, tillage method, residues burning, residues conservation, nitrogen

INTRODUCTION

238 thousand hectares of rice fields of Guilan produce one million tons of rice straw each year. Most farmers attempt to burn these agricultural residues, which are a huge source of nutritious and organic matter. In addition to the destruction of a part of agriculture wealth, burning them will lead to air pollution, dangerous digestive-respiratory diseases, and various social problems due to a temperature inversion phenomenon, particulate matter emission, and poisoning livestock (Borji 2006).

Organic matter plays an important role in improving the quality of soil physical properties, including its role in the stability of soil particles (facilitating the production of aggregates), increasing water infiltration rate in the soil and reducing runoff (Raupp 2001), reducing the risk of erosion, developing soil porosity, increasing the holding capacity of air and water, facilitating the development and growth of root (Lado *et al.* 2004), preventing soil compaction by holding down the bulk density, preventing the creation of strata and hard shells and cracking, increasing the ability of tillage and changes in soil properties such as viscosity reduction, and increasing soil permeability and softness (Farenhorst 2006).

Organic matter as a source of nutrients (nitrogen, sulfur, phosphorus and potassium) helps to retain nutrients and prevents their loss through increasing the cation and anion exchange capacity. Organic matter improves buffer properties and pH stability of soil (Oorts *et al.* 2004, Liang *et al.* 2006). Organic matter also reduces the negative effects of pesticides, heavy metals and many other pollutants in soil (Farenhorst 2006, Shepherd *et al.* 2001). As a result, it can be said that the loss of crop residues and organic matter is a threat to sustainable agriculture and crops (Ghimire *et al*. 2012, 2014, 2017). Therefore, it is essential to maintain or increase soil organic matter.

Today, it is possible to achieve sustainable agriculture, food security and more production through agricultural engineering. It is also necessary to conduct applied research for optimal use of inputs in the production of basic products. Tillage is one of the factors influencing production, which provides soil physical conditions for plant growth (Aqa Seyed Ali *et al*. 2008). Reduced tillage operations could save time and planting period. Therefore, new approaches in sustainable management of agriculture suggest replacing conventional approaches with conservation tillage system. Along with a cover of plant residues on the soil surface, this can prevent erosion, increase soil organic matter and improve soil physical properties. Therefore, it maintains beneficial soil microorganisms. While preventing the loss of soil moisture, this has a positive effect on increasing crop yield (Sabzevari *et al*. 2009).

Ram *et al*. (2013) conducted a study in North West India and concluded that burning rice residuals by farmers led to the contamination of air, soil and water, while residual conservation could also increase soil organic matter, maintain soil moisture, and reduce irrigation water use. Product yield was increased in treatments in which plant residues were returned to soil. Hider's (2013) studies in southwestern Bangladesh showed that large amounts of rice straw, terrain elevation, and distance from the farm urged farmers to burn rice residues. Teravest *et al.* (2015) studied the situation of crop production and soil water in no-tillage system, conservation tillage and conventional tillage (traditional) in Nkhotakota, Malawi. The results showed that the permeability and the moisture content of the soil increased in no-tillage system and in no-tillage system with crop residues conservation compared to conventional tillage. They suggested that short species should be used, rice cultivation should be focused on lands of average height, and farmers should be trained to preserve residuals in paddy field.

There have been many studies on crop residual conservation in agricultural land of large areas in Iran and different tillage methods have been evaluated, but unfortunately researches on this field have been neglected in Guilan where paddy cultivation is the main cultivation. It may be due to the different climate and the special nature of soil in this area which is different from that of other regions of Iran and traditional rice cultivation. In the past 3 years, the Governor of Guilan and Agriculture Organization of Guilan has attempted to encourage farmers not to burn the crop residues. Therefore, the present study reviews the role of crop residue management in three tillage systems (i.e. no-tillage, autumn tillage, and winter tillage) on soil properties and rice yield.

MATERIALS AND METHODS

To implement the research, a land of 1,800 square meters was chosen in Islamabad Village, Pirbazar District, Rasht (37/37885348 longitude and 49/53998912 latitude). A factorial experiment was designed and conducted in a randomized complete block design.

Treatments were including A) tillage factor: 1) no-tillage, 2) autumn tillage, 3) winter tillage, and B) crop residues management factor: 1) rice residues burning, and 2) rice residues conservation. Each treatment was conducted in 3 replications and 18 plots of 10 × 10 square meters before the implementation of treatments, two sets of undisturbed and disturbed soil. Samples have been taken with a cylinder and sampled with an auger (from 0–30 cm depth), respectively to measure some soil properties.

Bulk density and particle density, mean weight of aggregate diameter, soil texture by hydrometer method pH, ECe, saturated hydraulic conductivity, organic carbon, total nitrogen, available phosphorus and potassium absorbed infiltration rate and soil mechanical resistance were measured. Crop residue management treatments, including residual burning and residual conservation combined with three different tillage methods were applied from October 2015 to August 2016. In order to burn crop residues in no-tillage system (Figure 1), rice stubble were left on the soil surface in no-tillage system and burnt with matches as conventional method. In autumn and winter tillage systems rice residues were incorporated into the soil by plowing with tiller (Figure 2).

Fig. 1. Residual burning treatment

Fig. 2. Implementing tillage treatments

In early April, the grain seeds of Hashemi rice variety were immersed into a solution of salt water and carboxin thiram antiseptic solution was then added to prevent possible fungal diseases in nursery period. The land was fertilized before planting and during the plant growth as recommended by the province's Department of Agriculture and Hashemi rice seedlings were transplanted with 20×20 cm space in the main land on May 5. After rice was harvested and lands were dried, the infiltration rate was measured by double ring method, soil mechanical resistance was measured by penetrometer, and soil moisture content was measured simultaneously when determining soil resistance. The second phase of soil sampling (with the cylinder and the auger for undisturbed and disturbed samples, respectively) was done to determine some physical properties of soil. After the harvest, the rice yield components, including thousand-seed weight, filled seeds weight in thousand seeds, and empty seeds weight in thousand seeds, were measured.

Statistical analysis using SAS9.3 and comparison of means by LSD method was done at 1 and 5% level.

RESULTS AND DISCUSSION

Results of soil sample analysis of experimental site have been presented in Table 1. As a result, the land had low bulk density, soil organic matter was 2.9%, and soil texture was silty loam. Table 2 shows the results of variance analysis of data on the effect of treatments on some physicochemical properties of soil after rice harvesting. The results showed a significant effect of rice residues management and tillage system on soil organic matter and total nitrogen. There was a significant interaction between residues management and tillage on soil organic matter, total nitrogen, surface water infiltration into the soil, and 1,000-grain weight. According to Table 2, rice residues management, tillage system and their interaction showed a significant effect on soil organic content and infiltration rate at 5% level. The same results have also been observed in the cases of 1,000-grain weight. The effect of investigated factors and their interactionon the same soil physical and chemical properties and 1,000-grain weight of rice can be seen in Table 3 and 4. The results showed (Table 3) that applying rice residues management could significantly increase the amount of soil organic matter from 2.18% in residual burning to 2.69% in residual conservation. The amount of soil organic matter in no-tillage treatment was 2.20%, which was increased to 2.52 and 2.58 after applying winter and autumn tillage, respectively. Sui *et al*. (2016) also have reported that an increase in rice residues could result in increased carbon and nitrogen in rice field soil.

Table 1. Some physical-chemical properties of soil before implementing treatments

Properties	Measure
pH	7.55
ECe ($dS \cdot m^{-1}$)	1.64
Bulk density ($g.cm^{-3}$)	0.64
Actual density ($g \cdot cm^{-3}$)	2.48
Organic carbon (%)	2.19
Total nitrogen (%)	0.21
Available phosphorus ($mg \cdot kg^{-1}$)	11.61
Available potassium ($mg \cdot kg^{-1}$)	81.11
Sand (%)	13.66
Silt (%)	72.77
Clay (%)	13.55
Soil surface penetration (mm/min)	2.01
Porosity (%)	75.41

Total nitrogen for residual conservation treatment was 0.27%, which significantly decreased to 0.20% for residual burning treatment. By adding organic matter to the soil, increased the amount of total nitrogen. There was a direct relationship between total nitrogen and soil organic matter. Due to the moist and wet lands of northern Iran in autumn and winter, it seems that tillage with

Table 2. Analysis of the results of variance analysis of data on the effect of treatments on soil properties and thousand-seed weight

Sources of variations	df	Mean Square					
		Soil organic matter	Soil total nitrogen	Bulk density	Infiltration	Thousand-seed weight	Filled seeds weight
block	2	0.013**	0.18^{ns}	0.0004^{ns}	4.41*	0.75*	0.15^{ns}
residual management (A)	1	0.006*	0.4*	0.0002^{ns}	3.86*	0.80*	0.56*
tillage (B)	2	0.007*	0.43*	0.0003^{ns}	4.29*	0.37^{ns}	0.37^{ns}
B×A	2	0.08**	0.62*	0.0007^{ns}	9.52**	0.86*	0.52*
error	10	0.001	0.10	0.0005	0.80	0.21	0.13
CV (%)	17	17.2	14.4	4.00	37.0	1.33	1.08

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

Table 3. The effect of residue management and tillage treatments on soil physical properties and yield of rice

Treatment	Total nitrogen	Organic-matter	Bulk density	Infiltration	Thousand-seed weight	Filled seeds weight
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}
winter tillage	0.26^{a}	2.58^{a}	0.55^{a}	2.91^{a}	26.39^{a}	26.00^{a}

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

Table 4. The interaction of residue management and tillage treatments on soil physical properties and yield of rice

Tillage	Residual management	Total nitrogen	Organic-matter	Bulk density	Infiltration	Thousand-seed weight	Filled seeds weight
no-tillage	residual burning	0.18^{b}	2.03^{c}	0.64^{a}	1.83^{cd}	25.25^{bc}	24.81^{bc}
	residual conservation	0.25^{ab}	2.37^{bc}	0.54^{ab}	2.16^{bc}	25.76^{bc}	25.42^{bc}
autumn tillage	residual burning	0.20^{b}	2.17^{bc}	0.58^{ab}	2.00^{c}	24.69^{bc}	23.92^{bc}
	residual conservation	0.30^{a}	2.88^{a}	0.52^{ab}	2.76^{b}	28.55^{a}	28.03^{a}
winter	residual burning	0.25^{ab}	2.34^{bc}	0.60^{a}	2.30^{bc}	25.38^{bc}	24.88^{bc}
	residual conservation	0.27^{a}	2.82^{a}	0.50^{ab}	3.53^{a}	27.41^{ab}	27.13^{ab}

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

burying crop residues compared to leaving organic matter on the surface led to delayed oxidation of organic matter and increased organic matter in tillage conditions compared to no-tillage conditions. Meena *et al.* (2015) studied the effects of tillage and crop residue management on soil properties. The results showed that residual conservation and adding the residues into the soil by tillage resulted in increased soil nitrogen and organic matter.

The greatest amount of total nitrogen and organic matter was observed in tillage treatment with residual conservation, which was significantly higher than residual burning in all three methods of tillage. The researchers explained that tillage reduced water loss and nitrogen resulted in increased soil nitrogen, organic matter, and soil fertility (Du *et al*. 2014, Dwivedi *et al.* 2012, Huang *et al.* 2015).

Water infiltration rate was 2.01 mm per minute before implementing the treatments. After the implementation of treatments, it increased to 2.81 mm per minute in residues conservation system, 2.91 mm per minute in winter tillage, and 2.38 mm per minute in autumn tillage. Adding crop residues or green manure before paddling increased soil permeability and improved soil physical properties (Ray and Gupta 2001). Residual conservation accompanied by tillage increased water infiltration rate (Chegeni *et al*. 2014). Rasooli Sharbiani and Abbaspour Gilandeh (2008) also reported that further tillage increased soil porosity, which would, thus, increase water infiltration.

Residual conservation significantly increased thousand-grain weight, while the effects of tillage management were not significant on thousand-grain weight. Xu *et al.* (2009) concluded that residual conservation had a significant effect on crop yield. Leaving the crop residues had also a significant effect on crop yield and increased the yield (Erenstein 2002). There was also a significant interaction effect between residue management and tillage on thousand-grain weight. The highest weight of thousand grain and filled grain was seen in autumn tillage with residual conservation where thousand-grain weight was 3.86 grams more compared to no-tillage treatment with residual burning. Berhe *et al.* (2013) reported that management and tillage had a significant effect on grain yield and its quality. Similar results have been obtained by Gürsoy *et al.* (2010). It seems that tillage by improving the surface permeability of soil and increasing soil organic matter and total nitrogen has increased grain yield. Other studies also showed that increased organic matter due to tillage led to increased product (Dawe *et al*. 2000, Regmi *et al*. 2002, Ladha *et al*. 2003, Hobbs *et al.* 2008).

CONCLUSIONS

The results showed that the amount of soil organic matter in residual burning and residual conservation was 2.18% and 2.69%, respectively, showing a 0.51% increase in organic matter. The amount of organic matter in no-tillage method (2.20%) showed a significant decrease of 0.32% and 0.38% compared with autumn tillage (2.52%) and winter tillage (2.58%), respectively. Surface water infiltration in soil before performing treatments was 2.01 mm per minute, which was significantly increased by 2.81 mm per minute in crop residual conservation treatment, 2.91 mm per minute in winter tillage and 2.38 mm per minute in autumn tillage.

Total nitrogen for residual conservation treatment was 0.27%, which significantly decreased to 0.20% for residual burning treatment but by adding organic matter to the soil, increased the amount of total nitrogen. Autumn tillage and residual conservation caused a 0.30% increase in thousand-grain weight. Rice grain weight was significantly increased in residual conservation and no-tillage conditions. Therefore, rice residues addition is useful with soil tillage treatment. Residual conservation with tillage is beneficial for crop and soil physics. Organic carbon, total nitrogen and infiltration rate have been increased due to residual management with tillage system as well as 1,000-grain weight. Therefore, incorporation of rice residues into the soil by plowing is recommended.

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