EFFECTS OF CROP RESIDUE ON MOISTURE CONDITIONS AND CRACK FORMATION IN PADDY SOILS OF GUILAN PROVINCE

EFFETS DE DECHETS DE MOISSON SUR LA CONDITION D'HUMIDITE ET LA FORMATION DE FISSURE SUR LES SOLS DE PADDY DANS LA PROVINCE DE GUILAN

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ABSTRACT

The role of water and irrigation is vital in cultivation of rice in Iran. The dominant method of irrigatiing paddy in Iran is continuous flooding, which changes to periodical water application in times of water shortage. Soil cracks are the main problem in periodical irrigation. The amount of water required in this method is much more than flooding irrigation. Crop residues in paddy fields are able to prevent the establishment of cracks and to reduce their intensity. In this research, effect of different levels of rice straw on crack formation in some paddy soils of Guilan Province, Iran, is studied. The experiment was performed in split-split plots based on complete randomized blocks design, using four soil textures and three replications. The main factors evaluated were rice-stem residues in seven levels and crack treatments including three dry stages and two wet conditions. Results showed that interaction of level of rice straw and crack treatment on soil moisture content and the number of days to crack formation was statistically significant ($p<0.01$). Adding different levels of rice straw made a knock-on effect on moisture content with respect to control. Furthermore, it can be influential in delating crack formation. At all levels of crop residues, crack formation was observed in longer periods of time, as compared to control treatment. Nevertheless, soil moisture was higher with respect to control. The overall results showed that application of organic materials in soil could delay crack formation and its intensity.

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Key Words: *Paddy field, Periodical irrigation, Crop residue, Soil moisture, Delays to crack formation.*

RESUME

L'eau et l'irrigation joue un rôle important dans la cultivation du riz en Iran. Le système d'inondation continue est la méthode principale utilisée en Iran laquelle change en application d'eau périodique dans le cas de la pénurie d'eau. Cela donne lieu au problème principal de la formation des fissures dans les sols. La quantité d'eau exigée dans cette méthode est plus qu'exigée dans l'irrigation par inondation. Les déchets de moisson dans des rizières peuvent empêcher la formation des fissures et réduire leur intensité. Dans cette recherche, on a étudié l'effet des niveaux différents de paille de riz sur la formation des fissures sur certains sols de paddy dans la Province de Guilan en Iran. L'expérimentation a été menée sur les champs divisés compte tenu de la conception en bloc randomisée complète, utilisant quatre textures de sol avec trois répétitions.

Les facteurs principaux évalués étaient des résidus de tige de riz aux sept niveaux et des traitements des fissures, y compris trois étapes sèches et deux conditions humides. Les résultats ont montré que l'interaction entre le niveau de la paille de riz et le traitement de fissure a exercé un effet significatif sur la teneur en eau du sol et le nombre de jours ($p < 0.01$). L'utilisation des différents niveaux de paille de riz a aussi exercé un effet sur la teneur en eau du sol par rapport au système de contrôle. En outre, cela peut être utilisé pour retarder la formation de fissure. À tous les niveaux de déchets de moisson, plus de durée de temps était constaté pour la formation de fissure par rapport au traitement de contrôle. Cependant, la teneur en eau du sol était plus élevée en ce qui concerne le système de contrôle. Les résultats ont montré que l'application de matières organiques sur le sol pourrait retarder la formation de fissure et son intensité.

Mots clés: *Rizière, irrigation périodique, déchets de moisson, humidité du sol, ralentissement de la formation de fissure.*

1. INTRODUCTION

In recent years, world's fresh water resources are decreasing and water shortage is one of the prominent limitations in agricultural productivity and food security in the 21st century. Also, According to the report of International Rice Research Institute (IRRI) in 1995, demand for rice will be growing gradually over the coming years, and there should be 70% more rice production in contrast to the current situation to prevent rice shortages (IRRI, 1995; Bhagat, 2003).

In Iran, the prevalent irrigation method of the paddy fields is ponding method. But, in order to increase the water use efficiency in rice production, it changes to intermittent watering when there is a water shortage (Ou et al., 1999).

Many reports indicate that in using intermittent irrigation, it is possible to save water consumption without any significant reduction in yield.

In the intermittent method, after saturating the soil, irrigation is stopped and the next irrigation is applied when there is no water on the soil surface. At this stage, soil starts to crack. Cracks are the main problem in intermittent method. After the formation of cracks in a paddy soil, a lot more water is needed to irrigate the filed than a field without cracks. Moreover, cracks can damage plant roots and reduce the yield. There are some reports that show high soil organic matter content can prevent cracking and reduce its intensity.

The effect of straw mulching on crack formation during the fallow period was investigated on an Epiaqualf and a Pellustert in the Philippines (Cabangon and Tuong, 2000). Cracks did not completely close upon rewetting, resulting in high water loss during land preparation of the control plots (without soil management). Straw mulching helped conserve moisture in the soil profile, and reduced mean crack width by 32% of the control. Mulching did not significantly reduce crack depth and the amount of water used in land preparation.

Straw mulching minimizes soil shrinkage by reducing evaporation from soil surface (Hundal and Tomar, 1985).

Jafari (2008) evaluated the irrigation management in a silty clay paddy soil using three levels of crack width (3-4 mm, 1.5 cm and 2.5 cm) and three depths of water (irrigation to fill the cracks, and 2.5 cm and 5 cm of water depth over the soil surface). The results showed that initial soil moisture content has significant effect on the rate of water infiltration in cracked soils, and a major part of irrigation water is spent for filling the cracks in the beginning of infiltration process.

In the present research, effect of adding different levels of rice straw to four paddy soils on moisture content and number of days to crack formation was studied.

2. MATERIALS AND METHODS

a) Experiment site

Guilan province, with an area of 14711 km^2 is located in the northern part of Iran extending from 48° 25° to 50° 34° east longitude and 36° 36° to 38° 37° north latitude. This experiment was carried out in the Rice Research Institute, 10 km from the city of Rasht, the capital of Guilan province. This area has average annual precipitation of 1369 mm, average air temperature of 15.9° C, and relative humidity of 81%.

b) Experimental design and treatments

The pot experiment was performed as split-split plots based on completely randomized blocks design with three replicates. Four soil textures as the main factor, rice straw as sub-factor in 7 levels (0, 2, 3, 4, 5, 6 and 7% by weight), and soil moisture condition as sub-sub factor in 2 stage (wet and dry condition) in 5 levels: primary stage (T_1), initial crack stage (T_2, area of cracked soil = 13-17 cm^2), final crack stage (T_3, area of cracked soil in the pots = 55-59 cm^2), stage of final crack return to initial crack (W_1) and stage of crack disappearance (W_2)) were considered. Treatments T_1 to T_3 resemble paddy fields short of irrigation water.

Rice straw (as crop residue) was collected from paddy fields and cut into approximately 1-2 cm pieces. The soil samples from four paddy fields with texture of silty clay, silty clay loam, clay loam, and sandy loam were air-dried and crushed. Each soil was mixed with the above percentages of rice straw and poured into big plastic containers and saturated. The containers had some small holes at the bottom so that they could be wetted or drained. This action facilitates decomposition of organic matter. The containers were put in free air space to be under normal conditions of sunshine and rain for six months. Then, the soil content of each container was mixed with enough water to be saturated and ready for proper puddling. The puddled soil was transferred to smaller pots of 16 cm diameter and 10.5 cm height. These pots had drain holes at the bottom.

Crack formation was monitored by measuring surface cracks or the separation of soil from the pot rim. To estimate cracked area, the topsoil of pots was photographed and AutoCad software was used for this purpose.

c) Characteristics of rice straw and soils

Organic carbon (C), potassium (K), phosphorus (P), Nitrogen (N), and C/N ratio of rice straw were determined by standard methods in the laboratory.

d) Soil moisture content

Soil samples were taken with special cylinders at each cracking stage. Samples were weighed and then oven-dried for 48 hours at 105 ° C. Dried soil samples were weighed again. Soil moisture content was computed as:

$$\theta = \left(\frac{W - W_d}{W_d - W_c}\right) \times 100 \qquad (1)$$

where θ is soil moisture content (% by weight), W is weight of wet soil sample and cylinder (g), W_d is weight of dry soil sample and cylinder (g), and W_c is weight of cylinder (g).

e) Data analysis

After collection of required data, SAS software was used to analyze the data. If the F test was significant, means were compared by LSD test at 5% probability level.

3. RESULTS AND DISCUSSION

The results of chemical composition of rice straw are shown in Table 1. Table 2 shows particle analysis, texture, and organic matter content of the studied paddy soils.

Table 1. Chemical specifications of rice straw

C/N	Organic matter (%)	K (%)	P (%)	N (%)
24	15	1.96	0.2	0.629

K = Potassium, P = Phosphorus, N = Nitrogen, and C = Carbon.

Table 2. Particle analysis, texture, and organic matter content of the studied soils

Soil texture	Sand (%)	Silt (%)	Clay (%)	Organic matter (%)
Silty clay	7	43	50	1.44
Silty clay loam	15	45	40	1.95
Clay loam	39	28	33	1.05
Sandy loam	78	12	10	0.33

a) Effect of rice straw on soil moisture content

Interaction of level of rice straw and crack treatment on soil moisture content was statistically significant ($p<0.01$).

The highest and lowest moisture content was in the 7% straw treatment, crack treatment T_1 (62.76%) and crack treatment T_3 (9.73%) (Table 3).

Table 3. Interaction of levels of rice straw and crack treatment on moisture content

levels of crop residue	Crack treatment				
	T_1	T_2	T_3	W_1	W_2
Control (0%)	51.11^{f}	41.31^{n}	12.65^{t}	33.71^{s}	36.37^{r}
2 weight percent	53.03^{e}	42.08^{lm}	12.86^{t}	37.28^{q}	38.81^{p}
3 weight percent	53.9^{d}	42.12^{l}	19.24^{vw}	39.60^{o}	42.48^{j}
4 weight percent	54.27^{d}	41.35^{mn}	10.29^{vw}	43.26^{k}	46.49^{i}
5 weight percent	58.23^{c}	42.84^{kl}	10.98^{uv}	46.25^{i}	48.29^{h}
6 weight percent	59.94^{b}	44.79^{j}	11.06^{u}	49.49^{g}	50.78^{f}
7 weight percent	62.76^{a}	46.92^{i}	9.73^{w}	51.24^{f}	52.72^{e}

Values followed by the same letter are at par($P<0.05$)

Figure 1 shows the effect of rice straw levels on soil moisture content in the dry stage. As can be seen, adding rice straw increased the amount of moisture in each treatment T_1 and T_2, as compared to control treatment. But in treatment T_3, significant difference of moisture was not observed for various levels of rice straw. Moreover, this figure displays that in all rice straw levels (from control treatment to 7%), the highest amount of moisture content belongs to treatment T_1 and the lowest amount is related to T_3.

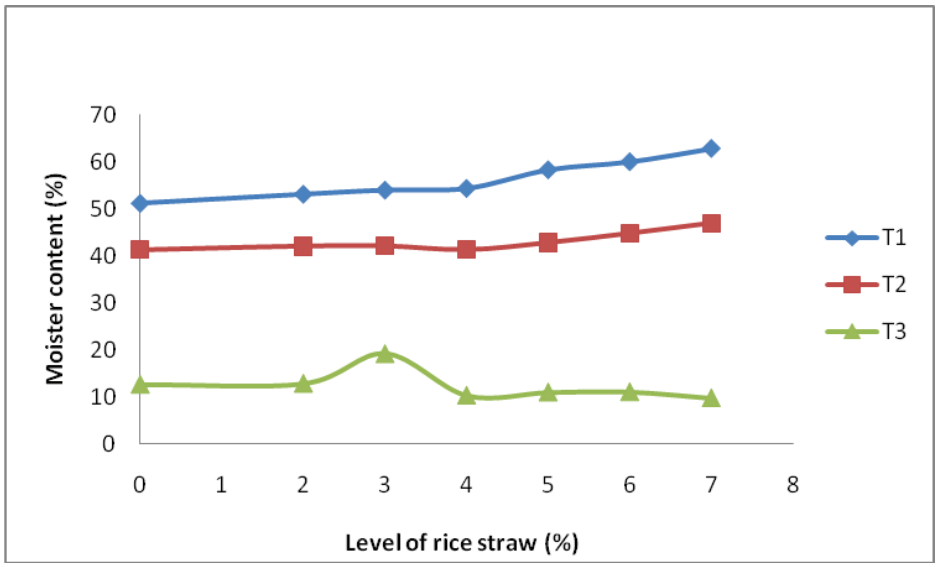

Fig. 1. Effect of rice straw levels on moisture content in dry stage

Figure 2 describes the effect of rice straw levels on soil moisture in wet condition. As can be seen, in all rice straw levels (from 2% to 7% treatments), the moisture content increased in each stage of W_1 and W_2 as compared to control treatment. Also, the moisture content in treatment W_2 is a little bit more than the W_1 treatment at every straw level.

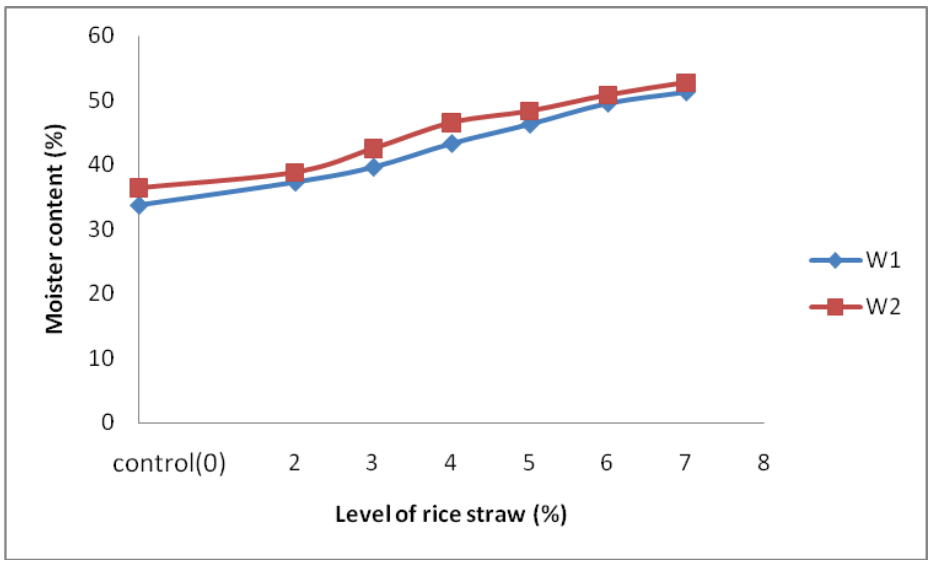

Fig. 2. Effect of rice straw levels on moisture content in wet stage

Comparison of Figures 1 and 2 indicates that the difference in moisture content for wet treatments was not as much as dry treatments.

Generally, it is noteworthy that in both dry and wet stages, adding various levels of rice straw caused an increase in moisture content. Previous researches also point out this effect. It is well known that incorporation of organic matter into soils increases the water holding capacity (Plaster, 2008). Soil holds water according to its texture. However, the level of organic matter also determines how much water a soil can hold. Arkansas soil scientists have reported that for every 1% of organic matter content, the soil can hold 16,500 gallons of plant-available water per acre of soil down to one foot depth (Sullivan, 2002). Results of the current study that are presented in Figures 1 and 2 confirm the above findings.

b) Effect of rice straw on number of days to crack formation

Effect of level of rice straw and crack treatments on number of days to crack formation were statistically significant ($p<0.01$). The greatest number of days to crack formation (52.75) was observed in 7% straw treatment and T_3, and the least number of days (5.5) was in T_1 and control treatment (Table 4).

Figure 3 illustrates the effect of rice straw level on number of days to crack formation in dry stage. As can be seen, increasing rice straw could delay the number of days to crack formation. Particularly, adding 7% rice straw could delay crack formation up to 7 and 8 days in treatments T_1 and T_2, respectively.

Figure 4 shows the effect of rice straw levels on number of days to crack formation in wet stage. This figure indicates that increasing the level of rice straw (from 2% to 7%) didn't have a steady trend in two treatments of W_1 and W_2. Further studies are needed to explain this ambiguity.

Table 4. Interaction of level of rice straw and crack treatment on number of days to crack formation

levels of crop residue	crack treatment				
	T_1	T_2	T_3	W_1	W_2
Control (0%)	5.5z^{2}	11.75^{y}	45.00^{g}	16.75^{s}	35.75^{j}
2 weight percent	6.25^{z3}	13.25^{w}	45.00^{g}	12.00^{x}	26.75^{m}
3 weight percent	6.5^{z4}	13.75^{v}	46.5^{f}	4.75^{z1}	25.75^{n}
4 weight percent	8.00^{z5}	15.25^{u}	48.5^{e}	9.75^{z}	35.25^{k}
5 weight percent	8.5^{z6}	15.5^{t}	50.75^{c}	20.25^{p}	41.25^{i}
6 weight percent	9.25^{z7}	18.00^{r}	51.75^{b}	23.00^{o}	43.00^{h}
7 weight percent	9.75^{z}	19.25^{q}	52.75^{a}	29.25^{l}	50.00^{d}

Values followed by the same letter are not different significantly ($P<0.05$)

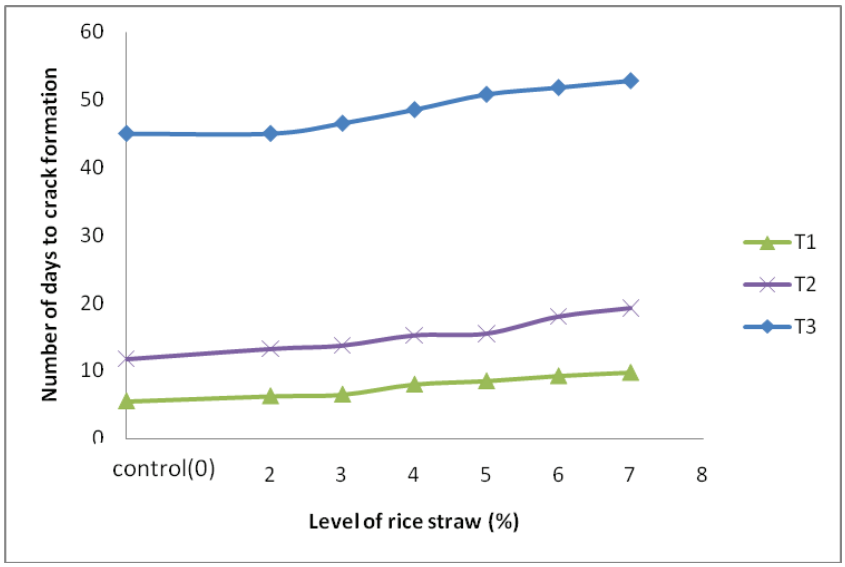

Fig. 3. Effect of rice straw levels on number of days to crack formation in dry stage

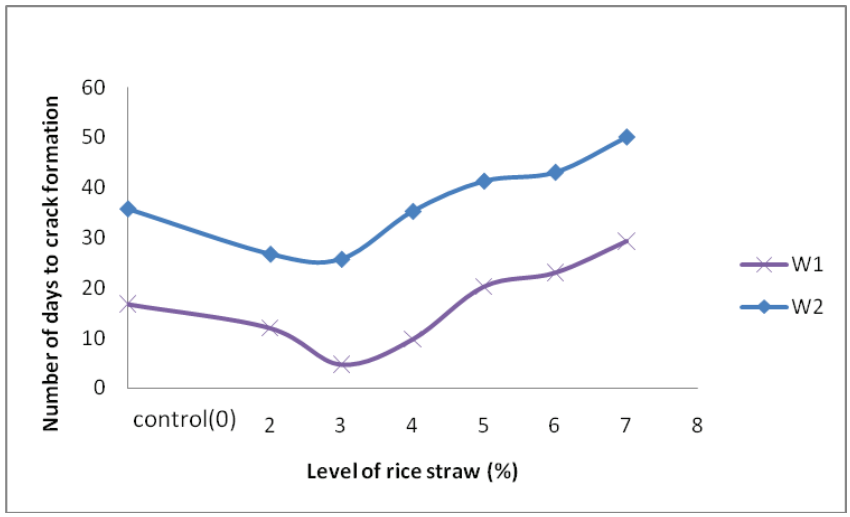

Fig. 4. Effect of rice straw levels on number of days to crack formation in wet stage

4. CONCLUSIONS

Effect of seven levels of rice straw on moisture content and amount and intensity of cracks in four paddy soils was studied. The results were promising. The conclusions drawn from this study are summarized as:

1- Effect of rice straw treatments and levels of crack treatments on soil moisture content and number of days to crack formation was significant.

2- Adding 2-7% rice straw increased soil moisture content as compared to control treatment. In all rice straw treatments, the soil moisture content decreased from crack treatment T_1 to T_3 in dry stage. In all rice straw treatments, the soil moisture content increased from crack treatment W_1 to W_2 in wet stage.

3- Adding rice straw (from 2-7%) increased number of days to crack formation in all three dry stages, but there was no steady trend in the wet stages.

4- Rice straw could delay number of days to crack formation in the soils with higher moisture content. It is a very significant result that higher levels of rice straw can delay crack formation for longer times by means of keeping more moisture in the soil.

5- Delaying crack formation up to several days using rice straw would be a challenge for the case of water limitation in the paddy fields.

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