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Rates and Methods of Rice Straw Application to Wheat and Rice Crops and the Implications on Crop Productivity as Well as some Soil Properties

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TWO FIELD experiments one on wheat and one on rice succeeding wheat (2009 / 2010 wheat, 2010 rice) were carried out on a clayey soil at Ghazala El-khis on Efficient Productivity Institute farm, Sharkhia-Governorate to study the effect of rice straw residue applied to wheat on yield and nutrient uptake of wheat and also the residual effect of such residues on rice crop which succeeded the wheat crop. Rates were 4.8, 9.5 and 14.3 Mg (mega grams) ha^{-1}, methods were surface application followed by incorporation in the 30 cm top soil, and application in ditches 40 cm deep (tunnels) spaced at 2,3and 4m between each other. Application of straw caused slight decrease in wheat grains and marked decreases in straw yields. Ditch application recorded greater values over surface application. Uptake of N and P by wheat was lower due to rice residue application but for K, it gave higher values over the non-treated and the highest values were recorded at the 3^{rd} rate with ditches treatment of 2m distance. There was a residual effect on yields of rice as well as NPK uptake and protein percent over treatment not receiving rice straw residue in the preceding wheat crop. The ditch method was superior to the broadcast method; and decreased with increasing the spacing between ditches, as well with the decrease in the rate of application. The results also indicated positive effects on bulk density as well as organic matter and NPK contents in soil. Greater values were obtained at the rate of the 14.3 Mg ha^{-1} with ditches method of 2m distances.

Keywords: Wheat plants, Rice plants, Residual effect, Straw residue, Ditches.

Crop residues are regarded as waste materials that require disposal, but they are important natural material resources and not wastes. Incorporation of cereal straws of wide C: N ratio, immobilizes soil N and adversely affects yield of the succeeding crop (Sidhu and Beri, 1989). Rice straw left in the field after harvesting is generally burnt by many farmers in Egypt, although contains nutrients. Burning these residues cause loss of organic matter and plant nutrients and environmental pollution. Verma and Bhagat (1992) reported that rice straw had positive effects on rice yield and N uptake. Tawfic and Gomaa (2005), Zeidan *et al*. (2005) and Yaduvanshi & Sharma (2008) reported that farmyard manure application enhanced wheat yield and N, P and K uptake. Niveta *et al*. (2006) reported that mineral fertilizers gave higher yield of wheat than rice.

Gong *et al*. (2009) and Liu *et al*. (2010) showed that, long term addition of organic manure showed beneficial effects on wheat and maize. Application of organic materials to wheat crop gave significant increases in grain and straw yields, crop index, harvest index, and N, P and K uptake. Crop residues convert farm wastes into useful products and provide nutrients for crops, and maintain soil physical and chemical conditions (Powel and Unger, 1997 and Jimenez *et al*., 2002) Incorporation of rice straw and animal manure in soil increased organic matter, available N, P , K, Zn, Cu, Fe and Mn and improved soil aggregation, porosity and bulk density (Verma and Bhagat, 1992). Sarwar *et al*. (2008) reported that pH and SAR decreased due to addition of composted organic residues, also available N, P, K, Ca and Mg as well as organic content increased. Burning rice straw causes black clouds in Egypt which would lead to respiratory problems to humans .The current study was conducted to study the effect of rice straw application to the soil on wheat productivity and the residual effect on the succeeding rice crop and soil properties in Sharkhia Governorate.

Material and Methods

A field experiment was carried out with rice and wheat (season 2009-2010) and the succeeding crop of rice (season 2010) at the farm of Faculty of Technology and Development (Ghazala El-Khis) – Sharkia Governorate to study the effect of rice straw application on wheat crop and the residual effect on the succeeding rice crop. Main characteristics of the soil and the rice straw residues are recorded in Table 1. The treatments were replicated thrice in a split plot design. The main plots were assigned to the rate of straw application (4.8, 9.5 and 14.3 Mg ha^{-1}). The sub plots were assigned to the method of application (surface incorporation into the 30 cm top layer and deep application in 40 cm deep at distances of 2-, 3-and 4- m each tunnel treatment). An additional treatment without straw application was done .The area of the experimental plot was 48 m^2. The straw residues were cut by a machine to obtain parts with high surface area. Chemical fertilizers were added to the residues at recommended NPK doses. Phosphorus at 17 kg P as super phosphate (6.8% P) and 48 kg K in the form of potassium sulfate (40 % K) ha^{-1}, respectively were added to each crop. For nitrogen, 214 kg N as urea (46.5% N), and 179 kg N as ammonium sulfate (21% N) were applied for wheat and rice, respectively. P and half K rates were added before wheat sowing or rice transplanting, the other K half was given with the second N split. Nitrogen was added in three equal splits at planting, 30 days after sowing and 60 days after sowing for wheat, for rice nitrogen splits were before transplanting, 30 days after transplanting and 45 days after transplanting.

Seeds of wheat (*Triticum aestivum* L., cv Sakha 93) were seeded on 30^{th} of November, 2009, broadcast at a rate of 143 kg ha^{-1}. seedlings of rice (*Oryza sativa* L., cv Sakha 101) were transplanted on 15^{th} July, 2010, 2-3 seedlings $hill^{-1}$ at 15 cm x 20 cm. Recommended cultural practices were followed to raise the crops of wheat and rice. The crops were harvested at maturity, and yields were recorded. Plant samples were taken and analyzed for NPK. After rice harvest, composite soil samples from the 20 cm top layer from each plot were collected and analyzed. Analysis of samples as well as soil were determined according to

Chapman and Pratt (1961).Soil particle size distribution and other physical analysis were done according to Piper (1950).

TABLE 1. Physicochemical analysis of tested soil and chemical properties of rice straw residue .

Analysis of soil of the experimental site											
Fine sand %	Coarse sand %	Silt %	Clay %	Textural class	EC (dSm^{-1})	OM (gKg^{-1})	$CaCO_3$ %	Total N (gkg^{-1})	Available N $mgkg^{-1}$	Available P $Mgkg^{-1}$	Available K $Mgkg^{-1}$
11.2	5.8	20.4	62.6	Clay	1.10	18.30	2.20	1.23	160	19	290
Chemical properties of rice straw residue											
OC (g kg^{-1})			**C/N ratio**		**Total N (g kg^{-1})**		**total P (g kg^{-1})**		**total K (g kg^{-1})**		
40.46			83		0.49		0.066		1.43		

Results and Discussion

Effect of organic residues on wheat production

The data in Table 2 represent the wheat production under different rates of rice straw application. The addition of rice straw within all tested rates resulted in decreases in grains, and straw compared to the no-rice straw (NRO) treatment which received NPK only. On an average, the greatest value of wheat straw yield was 7.9 ton ha-1 with a decrease of 3.54% compared with the NRO treatment. In the case of tunnel treatments, data show significant differences between treatments. The main effect show greatest decrease in yield with increasing the rate of applied rice straw. Decreases were statistically non-significant with grains, but significant with straw. The decreases due to applying 1^{st} 2^{nd} and 3^{rd} of straw were 8.2, 9.3 and 12.9 % for grain yield and 3.5, 6.1 and 9.4 %, respectively for straw yield. Such a pattern of decreased yields with increased application of straw occurred with all methods of application. Sidhu and Beri (1989) reported that, incorporation of cereal straws of wide C: N ratio immobilize soil N and adversely affected yield of crops.

Concerning to the main effect of the method of straw application, data show significant greater yields of grains and straw with ditch method compared with the surface incorporation and the greater the distance between the ditches the higher was the yield. Incorporating straw in the soil surface makes the soil plough layer subject to a greater immobilization of available N compared with ditch method. Besides, a straw incorporation in close-distance ditches would be subject to greater N-immobilization. These results agree with Bunt (1988), Van Kessel *et al*. (2000) and Qian & Schoenau (2002), who stated that immobilization in soil occurs with organic materials of high C: N ratio. Cheshire *et al.* (1999) stated that, when straw remains in the field after harvest, its rapid decomposition is important to minimize the negative effect due to immobilization of available nutrients. Azam *et al.* (1991) reported that added mineral N following straw incorporation into the soil in order to overcome yield decrease due to N immobilization.

TABLE 2. Effect of organic fertilization with different rates of rice straw residues to wheat (using different methods of application) on grain and straw yields of wheat (Mg ha^{-1}).

Application rate (A)	Incorporation method (B)				Mean	Incorporation method (B)				Mean
	Surface incorporated	In a tunnels at distances of				Surface incorporated	In a tunnels at distances of			
		2 m	3 m	4 m			2 m	3 m	4 m	
	grain yield					straw yield				
4.8 Mg ha^{-1}	4.041	4.344	4.508	4.617	4.377	7.616	7.787	8.037	8.151	7.899
9.5 Mg ha^{-1}	3.827	4.334	4.513	4.624	4.325	7.283	7.438	7.906	8.135	7.690
14.3 Mg ha^{-1}	3.311	4.310	4.382	4.610	4.153	6.664	7.135	7.792	8.087	7.421
Mean	3.727	4.329	4.467	4.617		7.188	7.454	7.911	3.414	
L.S.D$_{0.05}$ (A)	Ns					0.200				
L.S.D$_{0.05}$ (B)	0.231					0.042				
L.S.D$_{0.05}$ (AB)	Ns					Ns				
Receiving no straw = 4.767 Mg ha^{-1}						Receiving no straw = 8.187 Mg ha^{-1}				

Notes: (1) Mg (mega gram) = (10^6 g).
(2) Egyptian feddan (fed) = 0.42 hectare (ha)

Residual effect of organic residues on the succeeding rice crop

The data in Table 3 show the residual effect of organic residues on rice production under different rates of rice straw residues with two methods of application. Addition of residues within all tested rates for all methods of application (surface as well as ditches) resulted in positive effect on grain and straw of rice. Verma and Baghat (1992), Cassman *et al*. (1993), Bird *et al.* (2001) and Kaewpradit *et al*. (2009) reported that straw and animal manure incorporation increased rice yields and N uptake. Increases obtained in the current study were associated with increases in the rate of application. The values were greater in ditches than in surface incorporation at all rates of application. Incorporation of rice straw into soil reduces N loss (Shindo and Nishio, 2005).

The ditch method gave higher values than the surface incorporation one. Yield of grain and straw decreased with increasing the distance between ditches. Compared with surface application, the 2- 3- and 4-m ditch distance gave average increases of 12.4, 5.3 and 4.7% for grains, respectively, increases for straw were 2.7, 10.1 and 13.0 %, respectively.

Nutrient uptake

Wheat crop

The N- uptake in wheat grains and straw are recorded in Tables 4 and 5. All treatments receiving rice straw contained lower N- uptake in wheat grain and straw compared with the treatment not receiving straw. This demonstrates marked immobilization of available N in the soil caused by rice straw residue. These results are in a good agreement with those of Elliot *et al*. (1981), Verma and Bhagat (1992), Azam *et al*. (1993), Soon (1999), Varendarpal Singh *et al*. (2006) *and* Sharma & Parasad (2008) who stated that applying rice straw residue to the soil reduced N- uptake by wheat grain and straw due to their wide C:N ratio which decreased the availability of N to growing plants through immobilization of mineral N forms into organic N forms. The current results show that N- uptake decreased with increasing the rate of application.

With respect to the effect of method of application, data show that, the ditch method gave greater values in N- uptake. The uptake increased with increasing distance between ditches. Regarding grain protein content, data in Table 6 show lower protein content in treatments of the surface incorporation as well as those of the ditch method, particularly those of the 2- and 3-m distance as compared with content in the no-straw application. Contents in the ditch method were greater than in the surface application method. Contents decreased with increasing straw –application rate. Average decreases for the 1^{st}, 2^{nd}, and 3^{rd} rates were 11.5, 15.3 and 21.2%, respectively. The ditch method surpassed the surface application method by averages of 16.1, 25.7, and 40.01 % for the 2-, 3- and 4- m distance, respectively. The greater the distance between ditches, the higher are the contents of protein.

TABLE 3. Effect of organic fertilization with different rates of rice straw residues to wheat crop (using different methods of application) on grain and straw yields of rice crop which succeeded the wheat crop (residual effect) (Mg ha^{-1}).

Application rate (A)	Incorporation method (B)				Mean	Incorporation method (B)				Mean
	Surface Incorporated	In a tunnels at distances of				Surface incorporated	In a tunnels at distances of			
		2 m	3 m	4 m			2 m	3 m	4 m	
	grain yield					straw yield				
4.8 Mg ha^{-1}	5.229	5.548	5.412	5.391	5.396	6.290	7.012	6.433	6.566	6.576
9.5 Mg ha^{-1}	5.255	6.062	5.492	5.493	5.572	6.464	7.309	6.476	6.500	6.688
14.3 Mg ha^{-1}	5.319	6.152	5.762	5.683	5.729	6.735	8.392	7.483	6.617	7.307
Mean	5.267	5.921	5.548	5.515		6.497	7.571	6.797	6.562	
L.S.D$_{0.05}$ (A) L.S.D$_{0.05}$ (B) L.S.D$_{0.05}$ (AB)	Ns 0.467 Ns					Ns 0.807 Ns				
Receiving no straw = 5.005 Mg ha^{-1}						Receiving no straw = 6.276 Mg ha^{-1}				

Notes: (1) Mg (mega gram) = (10^6 g) .
(2) Egyptian feddan (fed) = 0.42 hectare (ha) .

TABLE 4 . Effect of methods and rates of rice straw residues on NPK-uptake (Kg ha^{-1}) in wheat grain.

Application rate (A)	Incorporation method (B)				Mean	Incorporation method (B)				Mean	Incorporation method (B)				Mean
	Surface incorporated	In a ditches at distances of				Surface incorporated	In a ditches at distances of				Surface incorporated	In a ditches at distances of			
		2 m	3 m	4 m			2 m	3 m	4 m			2 m	3 m	4 m	
	N- uptake					P- uptake					K- uptake				
4.8 Mg ha^{-1}	69.52	94.58	103.97	109.17	94.31	16.02	16.21	17.18	18.30	16.99	29.92	37.27	34.13	34.96	34.08
9.5 Mg ha^{-1}	64.43	84.90	96.30	110.55	89.05	13.40	14.45	16.23	18.02	15.52	32.54	39.68	39.29	39.60	37.77
14.3 Mg ha^{-1}	54.45	75.22	83,63	101.41	78.68	10.88	14.22	15.78	17,99	14.71	28.63	40.65	39.08	39.48	36.96
Mean	62.61	84.97	94,53	107.05		13.42	14.95	16.47	18.11		30.37	39.20	37.51	38.01	
L.S.D$_{0.05}$ (A) L.S.D$_{0.05}$ (B) L.S.D$_{0.05}$ (AB	ns 11.31 Ns					1.29 0.93 1.62					ns 3.83 Ns				
Receiving no straw = 114.88 kg ha^{-1}						Receiving no straw = 19.99 kg ha^{-1}					Receiving no straw = 28.61 kg ha^{-1}				

Notes: (1) Mg (mega gram) = (10^6 g) .
(2) Egyptian feddan (fed) = 0.42 hectare (ha) .

TABLE 5. Effect of methods and rates of rice straw residues on NPK-uptake (Kg ha^{-1}) in wheat straw.

Application rate (A)	Incorporation method (B)				Mean	Incorporation method (B)				Mean	Incorporation method (B)				Mean
	Surface incorporated	In a ditches at distances of				Surface Incorporated	In a ditches at distances of				Surface incorporated	In a ditches at distances of			
		2 m	3 m	4 m			2 m	3 m	4 m			2 m	3 m	4 m	
	N- uptake					P- uptake					K- uptake				
4.8 Mg ha^{-1}	19.06	30.92	33.49	42.13	31.39	6.02	6.55	7.59	7.90	7.02	199.51	229.05	226.67	209.92	216.29
9.5 Mg ha^{-1}	16.71	27.54	32.94	39.58	29,20	5.55	6.40	6.88	7.57	6.59	195.21	234.36	224.27	223.43	219.32
14.3 Mg ha^{-1}	13.33	20.94	22.82	35.58	23.18	4.88	5.74	6.57	7.05	6.07	184.38	238.57	237.55	224.74	221.32
Mean	16.37	26.47	29.75	39.10		5.47	6.24	7.02	7.50		193.04	234.00	229.50	219.37	
L.S.D$_{0.05}$ (A) L.S.D$_{0.05}$ (B) L.S.D$_{0.05}$ (AB	1.42 2.08 Ns					0.31 0.50 Ns					ns 29.23 ns				
Receiving no straw = 44.22 kg ha^{-1}						Receiving no straw = 8.12 kg ha^{-1}					Receiving no straw = 192.4 kg ha^{-1}				

Notes: (1) Mg (mega gram) = (10^6 g).
(2) Egyptian feddan (fed) = 0.42 hectare (ha).

TABLE 6. Effect of organic fertilization with different rates of rice straw residues to wheat (using different methods of application) on grain protein content (g kg^{-1}) of wheat and rice plants

Application rate (A)	Incorporation method(B)				Mean	Incorporation method(B)				Mean
	Surface incorporated	In a tunnels at distances of				Surface incorporated	In a tunnels at distances of			
		2 m	3 m	4 m			2 m	3 m	4 m	
	wheat grain					rice grain				
4.8 Mg ha^{-1}	98.9	125.0	132.2	136.9	122.6	8.68	102.5	98.4	96.2	96.0
9.5 Mg ha^{-1}	96.8	112.0	123.0	137.7	117.4	9.15	105.2	99.7	96.2	98.2
14.3 Mg ha^{-1}	94.7	100.1	109.8	132.3	10.92	93.9	113.1	102.2	98.1	101.8
Mean	96.8	112.4	121.7	135.6		90.7	106.9	100.1	96.8	
L.S.D$_{0.05}$ (A) L.S.D$_{0.05}$ (B) L.S.D$_{0.05}$ (AB)	Ns 14.4 Ns					2.27 3.57 Ns				
Receiving no straw = 138.6 g kg^{-1}						Receiving straw = 85.1 g kg^{-1}				

Notes: (1) Mg (mega gram) = (10^6 g)
(2) Egyptian feddan (fed) = 0.42 hectare (ha)

Regarding P- uptake, results are similar to those of N. Data recorded in Table 4 indicate lower P- uptake in treatments given rice straw compared with the treatment not receiving straw. Such a pattern is in line with that of N- uptake and indicates immobilization and decrease in available nutrients due to rice straw application. These results are in agreement with those obtained by Elliot *et al*. (1981), Verma and Bhagat (1992), Azam *et al*. (1993), Can (1999) and Varendalpal *et al*. (2006).

P-uptake decressed as the rate of straw application increased. The ditch method was greater compared with the surface method. P-uptake increased with increasing distance between ditches. These findings are in harmony with those obtained by Elliot *et al*. (1981) and Sharma & Parasad (2008) who reported that rice straw being of wide C: N ratio reduces the availability of nutrients to growing plants through immobilization. Varinderpal *et al*. (2006) found that incorporation of crop residues increased P adsorption as well as resistance to P release in soils.

Data of Table 4 indicate that application of rice straw caused pronounced positive effect on wheat K- uptake. The uptake increased when the rate increased. Average increased at 1^{st}, 2^{nd} and 3^{rd} rates of application were 19.1 , 32.0 and 29.2% , respectively for uptake in grains and 12.4 , 14.0 , 15.0 %, respectively for uptake in straw. The ditch method surpassed the surface method by averages of 30.4, 23.5 and 25.3%, respectively for K-uptake in grains and 21.2, 18.9 and 13.6 % for uptake in straw.

These findings are in harmony with those obtained by Kaur and Benipal (2006). Data also reported that K- uptake decreased with increasing the distance between ditches. Increases with the 2- , 3- and 4-m spacing were 37.0, 31.1 and 32.9 %, respectively for K- uptake in grains and 21.6, 19.3 and 14.0 % for K-uptake in straw of wheat.

Rice crop

Data presented in Tables 7 and 8 illustrate the effect of applying rice straw residue to wheat on uptake of N, P and K in the rice crop which succeeded the wheat. Data show higher values for all treatments as compared with the no – straw treatment.

Regarding N- uptake ,increases due to 1^{st}, 2^{nd} and 3^{rd} rates of application averaged 21.2, 28.7 and 39.6 % respectively for uptake in grains; 24.0 , 29.1 and 46.4 %, respectively for uptake in rice straw. The ditch method gave greater N- uptake than the surface method. The increases due to the surface method, averaged 12.2, % for grains N- uptake and 13.2 % for straw N- uptake Increases due to 2 – m 3 – m , and 4 –m spacing ditch method were 49.0 % 33.2 % and 25.7 %, respectively for uptake in grains and 57.7 , 36.0 and 25.2%, respectively for N- uptake in rice straw. Increased N- uptake of rice grain and straw by application of rice straw residue also has been reported by Kaewpradit *et al*. (2009).

TABLE 7. Effect of organic fertilization with different rates of rice straw residues to wheat (using different methods of application) on NPK-uptake (Kg ha^{-1}) in rice grain of the rice crop which succeeded the wheat (residual effect).

Application rate (A)	Incorporation method(B)				Mean	Incorporation method(B)				Mean	Incorporation method(B)				Mean
	Surface Incorporated	In a ditches at distances of				Surface incorporated	In a ditches at distances of				Surface incorporated	In a ditches at distances of			
		2 m	3 m	4 m			2 m	3 m	4 m			2 m	3 m	4 m	
	N- uptake					P- uptake					K- uptake				
4.8 Mg ha^{-1}	78.99	99.34	92.63	90.20	90.30	12.23	20.33	19.52	16.16	17.07	7.00	14.99	12.02	11.71	11.42
9.5 Mg ha^{-1}	83.54	110.88	94.84	91.96	95.92	13.30	27.85	20.87	16.68	8.27	7.52	23.44	15.47	12.09	14.64
14.3 Mg ha^{-1}	86.89	120.86	108.60	97.20	103.39	17.76	29.94	27.39	24.23	10.43	9.12	24.75	16.64	13.35	15.97
Mean	83.13	110.36	98.70	98.13		14.42	26.04	22.59	19.02		7.88	21.06	14.71	12.38	
L.S.D$_{0.05}$ (A)	Ns					2.28					2.57				
L.S.D$_{0.05}$ (B)	14.95					2.09					1.29				
L.S.D$_{0.05}$ (AB	Ns					Ns					2.21				
Receiving no straw = 74.07 kg ha^{-1}						Receiving no straw = 11.52 kg ha^{-1}					Receiving no straw = 6.36 kg ha^{-1}				

Notes: (1) Mg (mega gram) = (10^6 g) .
(2) Egyptian feddan (fed) = 0.42 hectare (ha) .

TABLE 8. Effect of organic fertilization with different rates of rice straw residues to wheat (using different methods of application) on NPK-uptake (Kg ha^{-1}) in rice straw of the rice crop which succeeded the wheat (residual effect)

Application rate (A)	Incorporation method (B)				Mean	Incorporation method (B)				Mean	Incorporation method (B)				Mean
	Surface Incorporated	In a ditches at distances of				Surface Incorporated	In a ditches at distances of				Surface incorporated	In a ditches at distances of			
		2 m	3 m	4 m			2 m	3 m	4 m			2 m	3 m	4 m	
	N- uptake					P- uptake					K- uptake				
4.8 Mg ha^{-1}	47.08	61.67	55.57	54.81	54.79	5.33	6,81	6.66	5.64	6.12	89.11	120.64	102.63	94.94	101.84
9.5 Mg ha^{-1}	49.08	67.43	57.07	54.74	57.07	6.21	8.40	7.74	6.38	7.19	100.17	130.71	109.41	100.53	110.22
14.3 Mg ha^{-1}	53.99	80.02	67.71	57.17	64.71	7.52	10.85	10.35	7.45	9.04	109.84	160.60	136.42	105.01	127.97
Mean	50.05	69.71	60.12	55.34		6.36	8.69	8.26	6.50		99.70	137.33	116.14	100.15	
L.S.D$_{0.05}$ (A) L.S.D$_{0.05}$ (B) L.S.D$_{0.05}$ (AB	Ns 7.35 Ns					1.43 3.14 Ns					19.49 39.48 Ns				
Receiving no straw = 44.20 kg ha^{-1}						Receiving no straw = 5.14 kg ha^{-1}					Receiving no straw = 87.87 kg ha^{-1}				

Notes: (1) Mg (mega gram) = (10^6 g) .
(2) Egyptian feddan (fed) = 0.42 hectare (ha).

For grain protein content, data in Table 6 show higher protein content in treatments of the surface incorporation as well as those of the ditch method, particularly those of the 2 and 3m distance as compared with content in the no-straw application. Contents in the ditch method were greater than in the surface application method. Contents increased with increasing straw –application rate. Average increases for the 1^{st} 2^{nd} and 3^{rd} rates were 12.8, 15.4 and 19.6%, respectively. The ditch method was superior to the surface application method by averages of 17.9, 10.5. and 6.7 for the 2-, 3- and 4- m distance, respectively. The greater the distance between ditches, the less contents of protein.

With respect to P- uptake ,increases due to 1^{st}, 2^{nd} and 3^{rd} rates of application averaged 48.1 , 70.9 and 115.5 %, respectively for uptake in grains, 19.0 , 39.8 and 75.9 %, respectively for uptake in rice straw. The ditch method gave greater p- uptake than the surface method. The increases due to the surface method, averaged 25.0 % for grains P- uptake and 23.6 % for straw P- uptake Increases due to 2 – m 3 – m and 4 –m spacing ditch method were 126.0 %, 96.9 % and 65.1 %, respectively for uptake in grains and 69.0, 60.7 and 26.4%, respectively for uptake in rice straw. These results are similar to those obtained by Sharma and Parasad (2002), who found that incorporation of crop residue resulted in building up organic C and increased P uptake by rice.

Regarding K uptake in rice (grain and straw), data in Table 6 show that all treatments recorded greater values than control. Increases due to 1^{st}, 2^{nd} and 3^{rd} rates of application averaged 79.8, 143.5 and 151.3 %, respectively for uptake in grains; 15.9, 25.4, and 45.6 %, respectively for uptake in rice straw. The ditch method gave greater K- uptake than the surface method. The increases due to the surface method, averaged 24.0 % for grains K- uptake and 13.5 % for straw K- uptake Increases due to 2- m, 3- m and 4- m spacing ditch method were 231.5 % 131.5 % and 94.8 %, respectively for uptake in grains and 56.3, 33.7 and 13.98%, respectively for uptake in rice straw. These results are in agreement with those obtained by Prasad and Sinha (2000) and Saha *et al*. (2009).

Overall assessment of response to rice straw application

Applying rice straw gave negative response to the crop of wheat to which it was applied. This is an indication of removal of available nutrients to soil micro-organisms which must have been active in removing soluble N for building their bodies (*i.e*., immobilizing N) due to abundant amounts of energy organic materials (the rice straw of the wide C:N ratio). However, following several months of being in the soil, the rice straw must have undergone intensive decomposition, narrowing its C: N ratio due to consuming energy rich components. This would lead to a net mineralization of organic N- particularly the N in the dead micro-organisms. For this reason, the residual effect of showed positive response and increased yield and NPK uptake of the rice crop which succeeded to wheat crop.

Soil bulk density

Generally, application of rice straw to the soil decreased bulk density in all treatments (Table 9). These results are in agreement to those obtained by Bhagat and Verma (1991), He and Liu (1992), Prasad and Sinha (2000) and Bhagat *et al*. (2003) who stated that lower soil bulk density and higher porosity were realized after the application of rice straw and organic residues. Bulk density responded significantly to treatments (Table 7). Regarding to the rate of application of rice straw, data show that bulk density decreased when the rate increased. The lowest value (1.26 gm cm^{-3}) was realized at 1^{st} rate of application.

For methods of application, the results indicate that ditch method gave lower bulk density than surface method. Ditches at 2 m distance showed an average of 1.27 Mg m^{-3} while that of surface treatment gave an average of 1.30 Mg m^{-3}.

NPK and organic matter in soil

Different rice straw treatments showed positive residual effects on soil contents of NPK and organic matter and recorded greater values than the not receiving straw residue treatment (Table 10). Increases obtained occurred with increasing the rate of organic residues in all methods of application. The ditches method gave higher values than the surface incorporation method. Higher values were obtained at 3^{rd} rate which gave average increases of 11.9, 12.1, 26.7 and 40.4% for N, P, K and organic matter contents of soil compared to the no- straw treatment. These findings are in agreement with those obtained by Bhagat and Verma (1991), Sharma Prasad and (2002) and Kaewpradit *et al*. (2009) who reported that the practice of residue incorporation may be better to sustain arable soils and represents an interesting method of managing soil fertility and the soil organic matter content is related strongly to the amount of residues added and the organic matter is regarded as the ultimate source of nutrients and microbial activity in the soil.

With respect to the effect of methods of application, data show that the ditch method surpassed the surface incorporation method. The 2-, 3- and 4- m distance treatments showed average increases over the surface application as follows: 24.19, 16.93 and 12.1%, respectively for N, 23.78, 15.0 and 9.33% respectively for P, 50.6, 31.5 and 17.9 %, respectively for K and 24.6, 17.3 and 8.2% for organic matter

Conclusion

The study assessed the use of rice straw applied by surface method compared with application in ditchesat rates ranging from 4.8 to14.3 Mg ha^{-1}. Results show that application of rice straw to wheat crop in a ditches of 4m distance between each other resulted in wheat grain yield which is relatively equal to the conventional yield produced by the farmers using no rice straw. The residual effect of straw application for both the two methods of application increased rice grain yield. Bulk density was decreased whereas porosity as well as NPK and organic matter contents were increased by straw application following rice.

TABLE 9. Effect of organic fertilization with different rates of rice straw residues to wheat (using different methods of application) on soil bulk density (kg m^{-3}) and organic matter content (%) after harvesting rice crop.

Application rate (A)	Incorporation method (B)				Mean	Incorporation method (B)				Mean
	Surface incorporated	In a tunnels at distances of				Surface incorporated	In a tunnels at distances of			
		2 m	3 m	4 m			2 m	3 m	4 m	
	Soil bulk density (kg m^{-3})					Soil organic matter content (%)				
4.8 Mg ha^{-1}	1.33	1.30	1.31	1.32	1.32	2.13	2.65	2.46	2.31	2.39
9.5 Mg ha^{-1}	1.31	1.28	1.29	1.29	1.29	2.20	2.70	2.62	2.38	2.48
14.3 Mg ha^{-1}	1.29	1.26	1.27	1.28	1.28	2.26	2.87	2.67	2.46	2.57
Mean	1.31	1.28	1.29	1.30		2.20	2.74	2.58	2.38	
$L.S.D_{0.05}$ (A)	0.02					0.051				
$L.S.D_{0.05}$ (B)	0.016					0.063				
$L.S.D_{0.05}$ (AB)	Ns					0.11				
	Receiving no straw = 1.34 gm cm^{-3}					Receiving no straw = 1.83 %				

TABLE 10. Effect of rates and methods of application of rice straw residues on soil contents of NPK

Application rate (A)	Incorporation method (B)				Mean	Incorporation method (B)				Mean	Incorporation method (B)				Mean
	Surface incorporated	In a ditches at distances of				Surface incorporated	In a ditches at distances of				Surface incorporated	In a ditches at distances of			
		2 m	3 m	4 m			2 m	3 m	4 m			2 m	3 m	4 m	
	Total N (%)					P mg kg^{-1} soil					K mg kg^{-1}				
4.8 Mg ha^{-1}	0.120	0.148	0.130	0.129	0.132	24.31	27.90	26.86	24.76	25.96	312	425	382	365	371
9.5 Mg ha^{-1}	0.125	0.157	0.150	0.138	0.143	24.92	28.70	28.07	27.78	27.37	331	510	425	365	407.75
14.3 Mg ha^{-1}	0.128	0.157	0.154	0.151	0.148	25.70	36.17	31.25	29.39	30.63	343	550	490	433	454
Mean	0.124	0.154	0.145	0.139		24.98	30.92	28.73	27.31		328.67	495	432.33	387.67	
$L.S.D_{0.05}$ (A)	0.008					0.69					10.06				
$L.S.D_{0.05}$ (B)	0.009					0.43					6.71				
$L.S.D_{0.05}$ (AB	Ns					0.75					11.63				
Receiving no straw = 0.118 %						Receiving no straw = 23.15 mg kg^{-1} soil					Receiving no straw = 290 mg kg^{-1}				

Notes: (1) Mg (mega gram) = (10^6 g) .
(2) Egyptian feddan (fed) = 0.42 hectare (ha) .

Recycling rice straw residue in long - term wheat - rice system in ditches of 4m distance between each other at any rate of application will improve soil physical, chemical and biological properties and increase crop productivity particularly following long time after application. Thus would enable the farmers to get rid of rice straw in a safety manner to avoid the problem of burning it which not only lead to loss of huge biomass but also cause environmental pollution. In addition, long - term application of rice straw residue may reduce the use of inorganic fertilizers and then decrease soil pollution.

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طرق ومعدلات إضافة قش الأرز إلى محصول القمح والأرز والتداعيات على الإنتاج وبعض خواص التربة

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أجريت تجربتين واحدة على محصول القمح والثانية على محصول الأرز الذي يعقبه خلال موسم الزراعة 2009 /2010 للقمح وموسم الزراعة 2010 للأرز على أرض طينية بمزرعة كلية التكنولوجيا والتنمية بناحية غزالة الخيس بمحافظة الشرقية بغرض دراسة تأثير إضافة بقايا قش الأرز على إنتاجية القمح والأرز وكذلك بعض خواص التربة. أضيفت بقايا قش الأرز بمعدلات 4,8 ، 9,5 ، 14,3 ميجاجرام/هكتار بطريقتين: الأولى : سطحية مع دمجها لعمق 30 سم (طبقة الحرث) ، الثانية : في أنفاق بعمق 40 سم على مسافات 2، 3 ، 4 متر من بعضها البعض وكانت النتائج كالآتي :

أولا: تأثير إضافة بقايا قش الأرز إلى التربة على المحصول الحالي (القمح)
- إضافة بقايا قش الأرز إلى التربة أدى إلى انخفاض طفيف في حبوب القمح وانخفاض ملحوظ في محصول القش. وقد سجلت الإضافة في الأنفاق أفضل محصول حبوب وقش بالمقارنة بالإضافة السطحية .
- أيضا أدى إضافة قش الأرز إلى التربة إلى انخفاض في امتصاص عنصري النيتروجين والفوسفور بينما حدث زيادة في امتصاص عنصر البوتاسيوم بالمقارنة بمعاملة الكنترول (بدون بقايا قش الأرز) وقد أعطت المعاملة 14,3 ميجاجرام/هكتار ذات مسافات الأنفاق 2 م أعلى زيادة في امتصاص عنصر البوتاسيوم .

ثانيا: التأثير المتبقي على المحصول اللاحق (الأرز)
- أظهرت النتائج وجود تأثير متبقي لبقايا قش الأرز المضافة إلى المحصول السابق (القمح) أدى إلى زيادة محصول القش والحبوب و امتصاص عناصر النيتروجين والفوسفور والبوتاسيوم وكذلك محتوى البروتين في الحبوب للمحصول اللاحق (الأرز) في جميع المعاملات بالمقارنة بمعاملة الكنترول (بدون بقايا قش الأرز).
- كان التأثير متفوقا في حالة الإضافة في أنفاق بالمقارنة بالإضافة السطحية وأن أفضل نتائج تم الحصول عليها في معاملة الأنفاق 2م ومعدل إضافة 14,3 ميجاجرام / هكتار.

ثالثا: التأثير المتبقي على بعض خواص التربة
- أظهرت النتائج تأثيرات إيجابية على الكثافة الظاهرية للتربة ، محتوى التربة من المادة العضوية وكذلك محتوى التربة من عناصر النيتروجين والفوسفور والبوتاسيوم وقد أعطت معاملة الإنفاق 2 م مع معدل إضافة لقش الأرز 14,3 ميجاجرام / هكتار أعلى النتائج .