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EFFICIENCY OF VARIOUS ORGANIC RESIDUES FOR ENHANCING RICE-WHEAT PRODUCTION UNDER NORMAL SOIL CONDITIONS

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Abstract

Rice-wheat system is one of the most important cropping sequences adopted on large areas not only in Pakistan but also in many other countries of the world. Rice and wheat straw is the main crop residue that is largely burnt due to introduction of mechanical harvesters. This burning poses diversified pollution problems like ashes, production of heat and toxic gases and burning of nearby useful plants. The cost of production of rice and wheat crops is going high and high due to ever escalating prices of chemical fertilizers. The burning of precious organic matter is the major factor of low fertility status and poor physical properties of soil. Resultantly, the soils cannot give yield of crops according to the full potential. The cost of crop production can be brought down and newly emerging problem can be controlled if sources of nutrients available at farm (crop residues and animal wastes) be brought under the input cycle. The compost, FYM and Sesbania green manure were used for nutrient supplementation alone and along with chemical fertilizer for rice and wheat crops. Crop yields significantly increased with the use of compost in combination with chemical fertilizer (3.94 t ha^{-1} for rice and 5.73 t ha^{-1} for wheat), FYM (3.36 t ha^{-1} for rice and 4.38 t ha^{-1} for wheat) and Sesbania green manure (2.86 t ha^{-1} for rice and 3.50 t ha^{-1} for wheat). However, compost proved superior to farmyard manure as well as Sesbania green manure. The pollution problem created due to burning of rice and wheat residues could also greatly be solved.

Introduction

Organic matter is regarded as a very important parameter of soil fertility and productivity. It has number of important roles to play in soil, both in their physical structure, sink for plant nutrients and medium for biological activities. Organic matter has greatest contribution to soil productivity. It provides nutrients to the soil, improves water holding capacity and helps the soil to maintain better aeration for seed germination and plant root development (Zia *et al*., 1993). Use of compost can be beneficial to improve organic matter status in soil because compost is rich source of nutrients with high organic matter content. Depletion of nutrients and poor organic matter contents of Pakistani soils can only be replenished by applying compost to these soils (Sarwar, 2005).

Compost prepared from crop residues, leaves, grass clippings, plant stalks, wines, weeds, twigs and branches are very good alternative which proved useful in many countries of the world. Use of compost has not only been adopted to enhance soil organic matter and enrich it in different nutrients but also to control the environmental pollution from debris. In Pakistan, this field remained ignored and no systematic study was conducted to standardize the composting technology. Raw manure use has often been associated with imbalances in soil fertility (Kuepper, 2003) because it is often rich in specific nutrients like phosphate or potash. In contrast an effective composting process converts raw waste products into humus, which is relatively stable, and chemically active organic fraction found in fertile soils.

According to the experiments of Sarwar (2005), the grain yield and yield components (plant height, number of fertile tillers and 1000 grain weight) of rice and wheat increased significantly with the application of different organic materials but compost proved the most superior in this regard. The combination of compost with chemical fertilizer further enhanced the biomass and grain yield of both crops (Sarwar *et al*., 2007; Sarwar *et al.,* 2008). The soil pH_s was lowered and SAR decreased due to acidic effect of compost and other organic materials, formation of acids, release of Ca and leaching of Na. The available amount of all the major plant nutrients and organic matter increased in the soil. Thus, plant uptake of nutrients increased when compost and other organic materials were applied. The effect of combination of compost and chemical fertilizers was also positive. Keeping in view the situation of nominal quantity of organic matter status, low fertility and high salt content in the soils of Pakistan, the present study was undertaken to evaluate the usefulness of various organic substrates for rice-wheat production under normal soil conditions.

Materials and Methods

The prepared compost (organic matter = 48.15 % and C/N ratio = 13.33) was dried, sieved and used for nutrient supplementation alone and along with chemical fertilizer for rice and wheat crops in soil (pH_s = 8.19, EC_e = 2.35 dS m^{-1}, SAR = 7.20 (m mol $L^{-1})^{½}$ and organic matter = 0.35 %). The other organic materials used were Farmyard manure (organic matter = 40.36 % and C/N ratio = 13.04) and Sesbania green (organic matter = 46.87 % and C/N ratio = 14.33) manure. Randomized complete block design (RCBD) with four replications was applied to lay out the experiment with treatments (1) Control, (2) Recommended fertilizer {(Rice (NPK) = 100-70-70 kg ha^{-1} & (Wheat (NPK) = 140-110-70 kg ha^{-1}}, (3) Green manure 12 t ha^{-1}, (4) Farmyard manure 12 t ha^{-1}, (5) Compost 12 t ha^{-1}, (6) Compost 24 t ha^{-1}, (7) Green manure 12 t ha^{-1} + recommended fertilizer, (8) FYM 12 t ha^{-1} + recommended fertilizer, (9) Compost 12 t ha^{-1} + recommended fertilizer and (10) Compost 24 t ha^{-1} + recommended fertilizer.

The experiment was started from rice crop followed by wheat. Compost was incorporated one month before transplanting rice seedlings in the field. Rice crop was harvested at maturity. Seedbed was prepared for subsequent wheat crop through plowing and wheat seeds were sown at field capacity moisture. At maturity, plant data like number of tillers and plant height of rice and wheat were recorded from 1×1 m random at 3 places of each plot while whole plot was harvested and threshed for straw and grain yield data of rice and wheat crops respectively.

Results and Discussion

Height of rice plants increased significantly with the addition of organic materials alone and with chemical fertilizer (Table 1). Minimum plant height (117.3 cm) was observed in control that was increased to the maximum where compost (24 t ha^{-1}) in combination with fertilizer was applied. Sesbania green manure and FYM without chemical fertilizer remained non-significant with each other whereas compost (24 t ha^{-1}) + recommended fertilizer was followed by the combined use of FYM and compost (12 t ha^{-1}) and chemical fertilizer showing values of 142.2 and 141.3 cm respectively. Almost similar trend was noticed for plant height of wheat crop (Table 2). Maximum height in this case was 110.5 cm (T_{10}) against the lowest value of 98.0 cm for control. Thus,

Table 1. Effect of compost, Sesbania green manure and FYM on yield and yield parameters of rice in normal soil.

Treatments	Maximum plant height (cm)	No. of fertile tillers / plant	1000 grains Weight (g)	Total biomass (t ha^{-1})	Paddy yield (t ha^{-1})
Control	117.3 e	22.0 e	20.3 c	12.54 f	2.41 e
Recommended fertilizer	124.0 d	26.2 d	21.5 b	13.79 e	2.75 d
Sesbania green manure 12 t ha^{-1}	131.0 b	25.0 d	21.0 b	16.59 c	2.86 d
FYM 12 t ha^{-1}	131.7 b	25.7 d	21.3 b	16.77 c	2.93 d
Compost 12 t ha^{-1}	127.3 c	27.2 c	22.7 a	14.28 d	2.82 d
Compost 24 t ha^{-1}	129.3 c	29.2 b	22.3 a	14.92 d	3.09 c
Sesbania green manure 12 t ha^{-1} + fertilizer	141.2 a	27.0 c	20.6 c	18.71 b	3.06 c
FYM 12 t ha^{-1} + fertilizer	142.2 a	27.3 c	20.5 c	19.91 a	3.36 b
Compost 12 t ha^{-1} + fertilizer	141.3 a	30.0 b	22.2 a	16.37 c	3.52 b
Compost 24 t ha^{-1} + fertilizer	142.8 a	31.5 a	21.7 b	17.97 b	3.94 a

Table 2. Effect of compost, Sesbania green manure and FYM on yield and yield parameters of wheat in normal soil.

Treatments	Maximum plant height (cm)	No. of fertile tillers/plant	1000 grains weight (g)	Total biomass (t ha^{-1})	Grain yield (t ha^{-1})
Control	98.0 e	6.5 f	31.5 d	7.42 f	2.56 d
Recommended fertilizer	106.7 c	7.2 d	39.3 b	10.54 d	3.50 c
Sesbania green manure 12 t ha^{-1}	103.0 d	7.1 de	39.5 a	9.66 e	3.50 c
FYM 12 t ha^{-1}	102.7 d	7.3 d	40.1 a	9.54 e	3.83 c
Compost 12 t ha^{-1}	107.2 b	7.6 cd	40.5 a	11.33 c	4.27 b
Compost 24 t ha^{-1}	107.5 b	8.0 bc	42.2 a	12.63 b	4.59 b
Sesbania green manure 12 t ha^{-1} + fertilizer	105.2 c	7.7 cd	35.5 c	10.04 cd	4.42 b
FYM 12 t ha^{-1} + fertilizer	104.9 c	7.9 bc	37.4 b	12.23 b	4.38 b
Compost 12 t ha^{-1} + fertilizer	108.2 b	8.9 ab	39.8 a	14.42 ab	5.08 a
Compost 24 t ha^{-1} + fertilizer	110.5 a	9.8 a	41.6 a	15.57 a	5.73 a

Table 3. Economics of the experiment under normal soil.

	Parameters	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}
1	**Variable cost of treatments**	-	43.47	92.28	74.64	76.20	152.40	135.75	118.11	119.67	195.87
2	**Yield**										
	a. Rice grains	2.41	2.75	2.86	2.93	2.82	3.09	3.06	3.36	3.52	3.94
	b. Rice straw	10.13	11.22	13.73	13.84	11.46	11.83	15.65	16.55	12.85	14.03
	c. Wheat grains	2.56	3.50	3.50	3.83	4.27	4.59	4.42	4.38	5.08	5.73
	d. Wheat straw	4.86	7.04	6.16	5.71	7.06	8.04	5.62	7.85	9.34	9.84
3	**Income**										
	a. Rice grains	386.20	440.69	458.32	469.53	451.91	495.17	490.37	538.44	564.08	631.39
	b. Rice straw	162.08	179.52	219.68	221.44	183.36	189.28	250.40	264.80	205.60	224.48
	c. Wheat grains	328.32	448.88	448.88	491.20	547.63	588.67	566.87	561.74	651.51	734.87
	d. Wheat straw	155.52	225.28	197.12	182.72	225.92	257.28	179.84	251.20	298.88	314.88
4	**Gross income**	1032.12	1294.37	1324.0	1364.9	1408.8	1530.4	1487.5	1616.2	1720.07	1905.62
5	**Net income**	1032.12	1250.90	1231.7	1290.3	1332.6	1378.0	1351.7	1498.1	1600.40	1709.75
6	**Net Income over control**	-	154.78	93.12	151.65	236.50	281.88	213.13	359.47	504.28	613.63
7	**Percent increase over control**	-	14.99	9.02	14.69	22.91	27.31	20.65	34.83	48.86	59.45
8	**Benefit cost ratio (BCR)**	-	3.56	1.009	2.03	3.10	1.85	1.57	3.04	4.21	3.13

addition of organic materials appreciably increased the height of both rice as well as wheat plants. Differences among various treatments for number of fertile tillers/plant were found significant statistically for both rice as well as wheat crops. Data revealed that maximum fertile tillers of rice plant were counted in treatment T_{10} (31.5), which were followed by T_9 and T_6 indicating values of 30.0 and 29.2 respectively (Table 1). Treatments T_2 to T_4 were observed as non-significant with each other statistically. Similarly, treatments T_5, T_7 and T_8 were at par. Control treatment showed the minimum tillers (22.0). Addition of Sesbania, farmyard manure and compost significantly increased tillering in wheat crop and the trend was similar to that of rice crop (Table 2). According to the data, minimum tillers were observed in T_1 (6.5) against maximum of 9.8 for T_{10}. In this case, Sesbania and farmyard manure proved inferior to compost when used alone as well as in combination with chemical fertilizer.

Use of organic materials alone was found beneficial for 1000 grain weights of paddy but the magnitude was decreased when chemical fertilizer was added with organic materials in all the treatments. It was obvious that maximum weight of 1000 paddy grains was recorded in T_5 which was at par with T_6 and T_9 indicating values of 22.7, 22.3 and 22.2 g respectively (Table 1). According to Table 2, weight of 1000 grains of wheat was significantly less in control (31.5 g) compared to all other treatments. Maximum weight (42.2 g) was in T_6, which showed a decreasing trend in treatments T_{10}, T_5, T_4, T_9 and T_3 respectively. These 6 treatments were at par with each other statistically.

Total biomass of crops is very important parameter because grain yield ultimately depends upon it. Combined application of organic materials and chemical fertilizer enhanced the total biomass of both rice and wheat crops that were noted as significant statistically over control (Tables 1 & 2). Maximum biomass of rice (19.91 t ha^{-1}) was recorded in T_8 where FYM (12 t ha^{-1}) was applied in combination with chemical fertilizer followed by T_7 and T_{10} (18.71 and 17.97 t ha^{-1}) respectively whereas minimum (12.54 t ha^{-1}) was noted in control. Addition of chemical fertilizer with all the organic materials was significant over sole use of the latter. Similar trend was noted for wheat crop where control treatment showed the lowest value (7.42 t ha^{-1}) while T_{10} remained at top with 15.57 t ha^{-1} (Table 2). Grain yield of paddy increased significantly when Sesbania, farmyard manure and compost was applied alone as well as in combination with chemical fertilizer (Table 1). The application of compost 24 t ha^{-1} with fertilizer yielded maximum paddy grains (3.94 t ha^{-1}) that was followed by T_9, T_8 and T_6 respectively exhibiting values of 3.52, 3.36 and 3.09 t ha^{-1}. Minimum paddy yield (2.41 t ha^{-1}) was observed in control that was inferior to all other treatments. The treatment T_{10} showed the maximum wheat grain yield of 5.73 t ha^{-1} followed by 5.08 t ha^{-1} for T_9 (Table 2). Control treatment proved poorest with a value of 2.56 t ha^{-1}. Use of chemical fertilizer in combination with all organic materials, especially with compost, enhanced the grains yield significantly. When organic materials were applied alone, even then they showed significant differences over control indicating an increasing trend in grain yield.

Application of various inorganic and organic amendments, different processes and biochemical changes taking place in the soil as well as efficiency of various man operated activities results consequently into yield of crops. Crop yield is the ultimate task of farming practices for increase in income. Different yield parameters (maximum plant height, number of fertile tillers $plant^{-1}$, 1000 grains weight and total biomass) and yield of rice and wheat crops increased significantly with the use of chemical fertilizer alone or in combination with various organic materials applied in the form of Sesbania green

manure, FYM and compost in both field experiments (Tables 1 & 2). The use of compost proved superior to FYM and Sesbania green manure when applied alone or in combination with chemical fertilizer. The improvement in grain yields of rice as well as wheat crops was due to different processing occurring in a chain. Addition of different organic materials like Sesbania green manure, FYM and compost enhanced the organic matter status of the soil that has been regarded a key factor determining soil fertility and productivity. This increase in soil organic matter content improved the physical properties of the soil and would have caused increased root development that acted positively in more uptakes of water and nutrients. The decomposition of applied organic materials resulted in reduction of soil pH as various acids (amino acid, glycine, cystein and humic acid) or acid forming compounds were released from the addition of organic materials (Brady & Weil, 2005). This reduction in soil pH increased the availability of nutrients of alkaline soil that were used by the plants. The enhanced uptake of K by rice and wheat improved the metabolic activities in the plants. As summation all above processes, various yield components (maximum plant height and number of fertile tillers plant^{-1}) of rice as well as wheat crops were positively affected and ultimately these components contributed towards increase in grain yields of these crops.

Tiwari *et al*., (2001) and Zaka *et al*., (2003) noted the carry over effect of FYM applied to the rice crop on the grain production of succeeding wheat crop. Similarly, many other researchers like Dixit & Gupta, (2000), Selvakumari *et al*., (2000), Sarwar *et al*., (2007), Khoshgoftarmanesh & Kalbasi, (2002), Pattanayak *et al*., (2001), Jagadeeswari & Kumaraswamy, (2000), Swarup & Yaduvanshi, (2000), Ahmad *et al*., (2002) and Parmer & Sharma, (2002) also claimed increased yields of rice as well as wheat crops with the use of different organic materials alone or in combination with mineral fertilizer.

Economics: A treatment adjudged effective technically might not be economical if costs are more than benefits obtained. Therefore, economic analysis is the ultimate yardstick to recommend a technology. Maximum Benefit Cost Ratio (BCR) of 4.21 was found with the combined use of fertilizer with compost 12 t ha^{-1} (T_9) against the minimum BCR (1.009) in treatment of Sesbania 12 t ha^{-1} (T_3) when soil was normal. Use of compost alone 12 t ha^{-1} (T_5) indicated 3.10 BCR Benefit Cost Ratio of 2.03 and 3.04 was determined with the use of FYM alone and in combination with fertilizer (T_4 & T_8) respectively. Although maximum increase in net income (59.45 %) was realized by the application of compost 24 t ha^{-1} + fertilizer (T_{10}) but comparatively lesser BCR (3.13) was determined for this treatment. Thus, the most economical treatment when adjudged through yardstick of BCR was compost (12 t ha^{-1}) + recommended level of fertilizer (T_9).

Conclusions

Farmers practicing rice-wheat system in Pakistan particularly and elsewhere in the world generally under similar climatic and soil conditions are recommended to compost the rice and wheat straw coupled with animal dung and other crop residues instead of burning or wasting otherwise. The composts such prepared will not only supplement the chemical fertilizers but also reduce the environmental pollution. In this strategy, the cost of production is also reduced. Hence, higher yield with resultantly more income is expected for the farming community in this system of farming. The overall fertility and productivity of the land can be improved on sustainable basis.

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