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VARIATIONS IN NUTRIENT CONCENTRATIONS OF WHEAT AND PADDY AS AFFECTED BY DIFFERENT LEVELS OF COMPOST AND CHEMICAL FERTILIZER IN NORMAL SOIL

G. SARWAR[1], H. SCHMEISKY[2], N. HUSSAIN[3], S. MUHAMMAD[4] M.A. TAHIR[1] AND U. SALEEM[1]

[1]*University College of Agriculture, University of Sargodha, Sargodha, Pakistan*
[2]*University of Kassel, Nordbahnnof Str-1A, 37213, Witzenhausen, Germany*
[3]*Soil Salinity Research Institute (SSRI), Pindi Bhattian, Punjab, Pakistan*
[4]*Directorate of Organic Farming, NARC, Islamabad, Pakistan*

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 if sources of nutrients available at farm (crop residues and animal wastes) be brought under the input cycle. The compost was used for nutrient supplementation alone and along with chemical fertilizer for rice and wheat crops. Plant samples of rice and wheat were analyzed for nutrients (N, P, K, Ca and Mg) and it was observed from the data that concentration of these nutrients increased significantly with the application of compost. The nutritional status of plants was further strengthened when chemical fertilizer was combined with compost. Hence, compost can be used to enrich the chemical composition of rice and wheat straw as well as grains and at the same time the pollution problem created due to burning of rice and wheat residues could also greatly be solved.

Introduction

Irrigated areas of the Punjab Province of Pakistan mainly consist of three agro ecological zones; rice, central mixed and cotton. Rice-wheat, wheat-fodder/maize and cotton-wheat are the three major and distinctive crop rotations of these zones respectively (Ibrahim *et al.*, 2008). Rice and wheat crops not only provide food security but also former are a major source of foreign exchange earnings. World famous Basmati varieties of rice are grown in the rice zone. Rice is sown on 2.22 M ha in Pakistan with mean yield of 2.01 t ha^{-1}. Wheat is grown on 8.03 M ha and average yields are 2.39 t ha^{-1} (Anon., 2003). Burning of the straw of rice and wheat is the common practice adopted by farming community of this zone. It was direly needed that this huge wastage of precious organic matter should be directed to a beneficial use through an appropriate research. Therefore, use of compost alone and along with chemical fertilizer was studied to observe its impact on nutritional concentration of rice and wheat.

*Corresponding author's e-mail address: seerver@yahoo.com

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 *et al*., 2008).

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.

According to Sarwar *et al*., (2007), 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*., 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 low organic matter status and low fertility of Pakistani soils, the present study was undertaken to evaluate the usefulness of compost for enrichment of nutrition in the straw as well as grains of rice and wheat 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 %). 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) Compost 12 t ha^{-1}, (4) Compost 24 t ha^{-1}, (5) Compost 12 t ha^{-1} + recommended fertilizer and (6) 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. Samples of rice and wheat (straw & grains) from each treatment were analyzed for total nitrogen, total phosphorus, potash, calcium and magnesium. All the collected data were subjected to statistical analysis.

Results

The concentration of total nitrogen increased both in wheat and paddy straw significantly with the use of compost at various levels alone or in combination with fertilizer (Table 1). The trend of improvement in total N concentration of straw for both crops was similar. The lowest percentage of total N (0.38 & 0.32 %) determined for control enhanced in all subsequent treatments and was the highest (0.73 & 0.75 %) with the application of fertilizer and compost 24 t ha^{-1} (T6) for wheat and paddy straw respectively. Almost similar behaviour of compost was noted for the total nitrogen percentage in wheat as well as paddy grains with significant differences for each other (Table 2). The minimum content of total N (0.97 & 1.09 %) for control enhanced to the maximum level of 2.21 and 2.28 % in T6 for wheat and rice grains respectively. Use of chemical fertilizer (T2) remained superior to compost 12 t ha^{-1} alone (T3).

Application of organic materials in the form of compost at two different levels enhanced the total phosphorus content in wheat and paddy straw and combination of chemical fertilizer with compost further improved the total P concentration in straws of both crops (Table 1). The treatments differed from control significantly in terms of statistics. The lowest concentration of total P (0.01%) for control in wheat straw increased to the level of 0.05% with the use of compost 24 t ha^{-1} + fertilizer (T6) and was followed by T5 and T4 with values of 0.04% for each. In paddy straw, the minimum value of total P (0.01%) analyzed for control improved in all subsequent treatments and was maximized in T6 to the level of 0.04%. A trend of improvement in total phosphorus concentration of wheat and paddy grains was noted with the use of compost and fertilizer alone and in combination at various levels. The differences among various treatments remained significant in terms of statistics (Table 2). The lowest content of total P (0.19 & 0.16%) determined for control enhanced in all treatments and approached the highest values of 0.32 and 0.29% in T6 for wheat and paddy grains respectively. The treatment T5 followed the maximum concentration with values of 0.27 and 0.27% for wheat and paddy grains respectively.

The status of potassium improved in wheat and paddy straw with the application of compost and fertilizer at various levels with significant differences among treatments when examined statistically (Table 1). The maximum concentration (2.46%) of potash was determined with the use of compost 24 t ha^{-1} + fertilizer (T6) in wheat straw against the minimum of 1.30% for control. The treatments T2 and T3 were assessed as at par statistically. Application of compost 12 t ha^{-1} along with fertilizer (T5) followed the T6 indicating 2.34% potash concentration. In paddy straw, the lowest value of potash (1.50%) estimated for control approached the highest level of 2.20 % in T6 and was followed by T5 exhibiting 2.06% value. Use of chemical fertilizer alone (T2) remained inferior to compost. The concentration of potassium in wheat and paddy grains also improved with the application of compost and fertilizer at various levels and treatments exhibited significant differences with each other (Table 2). The pattern of increase in K concentration of wheat as well as paddy grains was almost same in terms of statistics. The highest K concentration (0.63 & 0.52%) was estimated in T6 against the lowest of 0.33 and 0.23% for control of wheat and paddy grains respectively.

Table 1.Variations in N, P, K, Ca and Mg concentrations of wheat and paddy straw as affected by different levels of compost and chemical fertilizer in normal soil.

Treatments	Wheat straw					Paddy straw				
	Total nitrogen	Total phosphorus	Total potash	Ca	Mg	Total nitrogen	Total phosphorus	Total potash	Ca	Mg
	%			mg kg^{-1}		%			mg kg^{-1}	
T1-Control	0.38 F	0.01 E	1.30 E	1966 E	436 E	0.32 E	0.01 D	1.50 D	2007 F	401 C
T2-Recommended fertilizer	0.56 D	0.03 C	1.55 D	3360 C	493 C	0.57 C	0.02 C	1.56 D	3477 D	530 B
T3-Compost 12 t ha^{-1}	0.52 E	0.02 D	1.58 D	2956 D	462 D	0.52 D	0.02 C	1.65 C	3046 E	476 B
T4-Compost 24 t ha^{-1}	0.60 C	0.04 B	1.68 C	3502 B	471 D	0.58 C	0.03 B	1.71 C	3666 B	522 B
T5-Compost 12 t ha^{-1} + fertiliser	0.62 B	0.04 B	2.34 B	3493 B	536 B	0.68 B	0.03 B	2.06 B	3532 C	521 B
T6-Compost 24 t ha^{-1} + fertiliser	0.73 A	0.05 A	2.46 A	3778 A	571 A	0.75 A	0.04 A	2.20 A	3955 A	608 A

*Letters within the figures represent statistical analysis and figures bearing similar letters are non significant for each other.

Table 2. Variations in N, P, k, Ca and Mg concentrations of wheat and paddy grains as affected by different levels of compost and chemical fertilizer in normal soil.

Treatments	Wheat grains					Paddy grains				
	Total nitrogen	Total phosphorus	Total potash	Ca	Mg	Total nitrogen	Total phosphorus	Total potash	Ca	Mg
	%			mg kg^{-1}		%			mg kg^{-1}	
T1-Control	0.97 F	0.19 E	0.33 F	710 F	348 F	1.09 F	0.16 E	0.23 D	778 E	255 F
T2-Recommended fertilizer	1.34 D	0.26 D	0.51 D	978 D	601 D	1.31 D	0.21 C	0.30 C	1041 C	355 C
T3-Compost 12 t ha^{-1}	1.28 E	0.25 D	0.49 E	851 E	528 E	1.24 E	0.20 D	0.31 C	911 D	277 E
T4-Compost 24 t ha^{-1}	1.40 C	0.28 B	0.55 C	1001 C	650 C	1.38 C	0.21 C	0.39 B	1050 C	311 D
T5-Compost 12 t ha^{-1} + fertiliser	1.95 B	0.27 C	0.57 B	1036 B	756 B	2.10 B	0.27 B	0.40 B	1103 B	431 B
T6-Compost 24 t ha^{-1} + fertiliser	2.21 A	0.32 A	0.63 A	1170 A	882 A	2.28 A	0.29 A	0.52 A	1147 A	488 A

*Letters within the figures represent statistical analysis and figures bearing similar letters are non significant for each other.

The application of compost and fertilizer at various levels enhanced the calcium concentration in wheat and paddy straw and differences among various treatments remained significant when examined statistically (Table 1). The use of chemical fertilizer alone (T2) proved superior to compost 12 t ha^{-1} (T3). The minimum concentration (1966 mg kg^{-1}) of calcium determined in wheat straw for control improved in all subsequent treatments and was maximized (3778 mg kg^{-1}) with the use of compost 24 t ha^{-1} + fertilizer (T6). In paddy straw, the lowest concentration (2007 mg kg^{-1}) of calcium estimated for control approached the highest level of 3955 mg kg^{-1} in T6 and was followed by T4 with values of 3666 mg kg^{-1}. The content of calcium in wheat and paddy grains enhanced significantly when compared with control after the use of compost and chemical fertilizer (Table 2). The minimum value (710 mg kg^{-1}) of calcium estimated in control for wheat grains improved to the maximum level of 1170 mg kg^{-1} in T6 and was followed by T5 exhibiting value of 1036 mg kg^{-1}. None of the treatment in this case was noted as non-significant with each other. In paddy grains, the minimum value (778 mg kg^{-1}) determined for control enhanced to the maximum level of 1147 mg Kg^{-1} in T6 while T5 followed it with 1103 mg kg^{-1} calcium concentrations.

Significant differences among various treatments were observed for magnesium concentration in wheat and paddy straw after the application of fertilizer and compost at various levels alone and in combination (Table 1). In wheat straw, the content of Mg increased from the minimum value of 436 mg kg^{-1} (T1) to 571 mg kg^{-1} when compost 24 t ha^{-1} + fertilizer (T6) was applied to the soil and it was followed by the combination of fertilizer and compost 12 t ha^{-1} (T5) with value of 536 mg kg^{-1}. Use of chemical fertilizer alone (T2) proved beneficial than compost application at both levels without chemical fertilizer (T3 and T4). The lowest value (401 mg kg^{-1}) of Mg determined for control in paddy straw enhanced to the highest level of 608 mg kg^{-1} in T6 and was followed by T4 exhibiting 522 mg kg^{-1} Mg concentrations. The concentration of Mg in wheat and paddy grains also improved significantly with the addition of compost and fertilizer alone and in combination (Table 2). The minimum content (348 mg kg^{-1}) of Mg estimated for control in wheat grains increased in all subsequent treatments and was maximized in T6 to the level of 882 mg kg^{-1} while T5 followed it with value of 756 mg kg^{-1}. In paddy grains, the highest value of 488 was analyzed in T6 against the lowest of 255 mg kg^{-1} for control. Higher concentration of Mg was recorded for wheat grains as compared to paddy.

Discussion

The chemical composition of plants is a translation of conditions under which, they complete their life cycle completely or a part of it (Marschner, 1995). The chemical composition is a net summary of all the changes either positive or negative, which are faced by the plants. The nutrient uptake is directly or indirectly affected by many factors like total concentration as well as available quantity of different nutrients, root development, aeration, water potential, climatic conditions and other related soil parameters (Leigh & Jones, 1984). Beside all these, the presence of a nutrient in available form for the plant has to play the deciding role. Mostly fertility status of Pakistani soils is very low (Zia *et al.*, 1994). Application of nutrients in readily available form rapidly enhances the availability of that nutrient in the soil but all is neither taken up by plants nor remain permanently in available form. The dynamic processes are always in operation in the soil and a major part of the applied nutrients is accelerated into unavailable forms. Some fraction of it may be permanently fixed but when organic materials are applied, the overall fertility status of the soil is built up, the total reserve of nutrients is increased and a stage for enhanced availability is set up (Brady & Weil, 2005). The present study was investigated to evaluate the possibilities of replenishing the nutrient pole in the soil. It was observed that major nutrients uptake by wheat and rice was significantly increased when compost at variable rates was applied to the soil. The concentration of N, P and K in rice and wheat straw as well as grains improved appreciably as shown in Tables 1 & 2. Maximum concentration of these nutrients was recorded when inorganic and organic sources of nutrients were combined with each other. The application of chemical fertilizer alone was better than control but remained inferior to all other treatments. Nitrogen and phosphorus concentrations were higher in grains than straw while K content was more in straw compared with grains (Kuzyakov, 2002).

Secondary nutrients play important roles in the plant life. Calcium is an essential part of cell structure and plays its role in cell division. It is absorbed by the plants in the form of calcium ion i.e., Ca^{2+}. Magnesium is an integral part of chlorophyll and thus, is linked with photosynthesis. In plant tissues, it is absorbed in the form of Mg^{2+}. It plays an important role in energy transfer processes in plants (Tandon, 2000). The results of the present studies (Table 1 & 2) indicated that concentration of calcium and magnesium in straw and grains of rice and wheat increased under different treatments. The compost treatments alone or in combination with chemical fertilizer were the strategy with maximum concentration of these nutrients. The application of organic materials significantly changed the status of secondary elements in the soil. The water-soluble forms of Ca + Mg in the soil significantly increased which resulted in higher uptake of these two nutrients by the plants. There is always a direct relationship between the soil concentration of nutrients and its quantity taken by the plants.

It has been observed in studies of Sarwar *et al.*, (2008) on soil parameters that organic matter, nitrogen, phosphorus and potassium contents of soil significantly enhanced due to different treatments of this study especially, when organic matter was added alone or along with chemical fertilizer. The exchange reactions enhanced due to the release of hydrogen ion from the decomposition of organic materials resulted in more availability of Ca & Mg for plants. Hence, the concentration of these nutrients in the soil solution increased from where the plants absorbed them in more quantities. This increased availability of N, P and K resulted in more uptakes of these nutrients by the plants. The pH of the soil also indicated a positive change i.e., a shift towards neutrality. This positive change enhanced the solubility of different nutrients especially phosphorus in the soil. The form of phosphorus ion may have converted from PO_4^{3-} to HPO_4^{2-} or even H_2PO^- for short periods, which resulted in increased concentration of phosphorus in the plants. Similarly, production of hydrogen ions during decomposition of organic materials would have helped the release of K from exchange site or from the fixed pole. The solubility of many nutrients salts increases in the acidic medium like compost, which may have resulted in more availability of nutrients for the plants (Brady & Weil, 2005). The good physical conditions of the soil resulted from improved relative properties like water holding capacity, infiltration rate, porosity, hydraulic conductivity, bulk density and ability against sudden temperature changes favoured root growth. The more root volume enhanced nutrient uptake. The presence of K in appropriate quantities catalyzed the metabolism processes (activator of dozens of enzymes responsible for plant processes; energy metabolism, starch synthesis, nitrate reduction and sugar degradation. It helps in regulating the opening and closing of stomata of leaves) and resulted in higher concentration of other nutrients.

The observations of Mahmood *et al*., (1983) supported some of the above presented logics. They argued that the phenolic compounds particularly the humic compounds of compost enhance the uptake of nutrients due to higher nutrient content of the substrates like compost. The solubilization of soil K in the presence of humus matter of compost was regarded as another cause of more nutrient uptake. Tiwari *et al*., (2000) noticed faster rate of mineralization and greater utilization of nutrients through the use of green manure in combination with chemical fertilizer. Pattanayak *et al*., (2001) reported that N, P, K, Ca and Mg uptake was the highest in the treatments receiving green manuring of dhancha with SSP + URP source of phosphorus and the lowest in no green manuring treatment with URP source. Other scientists (Selvakumari *et al*., 2000; Dixit & Gupta 2000; Sarwar *et al*., 2003) also observed increased uptake of N, P and K by various plants when inorganic and organic sources of nutrients in the form of chemical fertilizer, FYM, green manure and compost were applied to the soil. Similarly, the findings of Yaduvanshi, (2001); Singh *et al*., (2002); Tabassam *et al*., (2002) were again in the same direction of enhancement in the uptake of major plant nutrients i.e., N, P and K.

Conclusion

Application of compost and chemical fertilizer strengthened the mineral nutritional status of rice-wheat plants. As these plant nutrients are necessary to carry out different metabolic processes in plant body, so their enhancement by any ways in plant tissues enables them to perform their functions more efficiently.

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