Soil & Environ. 29(1): 47 - 52, 2010
www.se.org.pk
Online ISSN: 2075-1141
Print ISSN: 2074-9546

Variation in root growth and nutrient element concentration in wheat and rice: Effect of rate and type of organic materials

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Abstract

People have different opinions regarding the use and importance of organic amendments for sustainable crop production. The objectives of the included comparison of different types and levels of farm manure (FM) and compost on root growth and nutrient concentrations of wheat (Triticum aestivum L.) and rice (Oryza sativa L.). The experiments were laid out to compare different types and levels of farm manure and compost with the recommended mineral fertilizer. Significant difference ($P<0.05$) were recorded for root length of both wheat and rice crops. The nutrient concentrations exhibited varying effects of different amendments. The concentration of N in wheat grain and straw (1.67 and 0.71 %, respectively) was significantly greater as compare to control ($P<0.05$) than treatments of compost at 500 kg ha^{-1} and farm manure at 40 Mg ha^{-1}, respectively. The root lengths of both wheat and rice were increased significantly ($P<0.05$) by the application of farm manure and compost.

Key words: Inorganic fertilizer, compost, farm manure, NPK, wheat-rice

Introduction

Ever increasing population in Pakistan has quest for increased production and nutrient demand from the existing resources. The use of mineral fertilizers has long been studied for their efficiency to enhance crop production. The recent trend to increase productivity through integrated resource management arose the interest in managing nutrient resources from non-mineral substances. The production of different manures (farm manure and dairy manure) has to be utilized in an effective manner. The use of organic resources has been reported to increase not only productivity but also nutrient concentrations in different plant parts. These plant parts are later on consumed by humans and animals to compensate their requirements.

Wheat (*Triticum aestivum* L) and rice (*Oryza sativa* L.) are important cereal crop in Pakistan. These are also major cash crops for the farmers and handsome amount of foreign exchange is earned through export of rice. Thus, their role in strengthening the economy of the country may not be neglected. The need of the hour is to devise technologies capable of providing the maximum so that the resource poor farmers may adopt it. The inefficient utilization of available resources as well as the poor availability of the inputs to the farmers needs to be addressed (Dixit and Gupta, 2000). The present energy and food crises are forcing the resource poor farmers of Pakistan to adopt resource conservative and eco-friendly technologies. The organic residues use is very viable option to provide nutrition to the plants and ultimately to animals and humans (Gallardo-Larva and Nogales, 1987; Sial *et al*., 2007). Sustainable crop yield may be obtained by organic manures and compost because of their ability to provide plant nutrients (Korsaeth *et al*., 2002; Ibrahim *et al*., 2008).

Nutrients are absorbed through soil environment/roots and it is the capacity of the rooting system to provide the essential nutrient elements and water to the growing plant. The plant nutrients composition is correlated with their translocation and the conditions where they complete their life or a part of life cycle (Marschner, 1995) and this is the net summary of beneficial or harmful changes faced by the plants. Many factors like root growth, water potential, soil and climatic conditions, aeration and total and available concentration of different nutrients affect the plant nutrient uptake (Sarwar *et al*., 2007). Zia *et al*. (1994) reported low fertility status of Pakistani soils and various soil processes (spatial and temporal) may change the part of nutrient to an unavailable form. But Brady and Weil (2005) reported that some fraction of applied nutrients may be fixed permanently and the addition of organic residues will overall enhance the soil fertility status.

The use of organic materials (farm manure and compost) is an effective and eco-friendly approach

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(Gallardo-Larva and Nogales, 1987) for reducing the large volume of organic waste and the nutrients stored in them are returned to soil (Zahir *et al*., 2007). In the study presented here, the effects of different levels of farm manure and compost were compared on the nutrient concentrations in straw and grain of wheat and rice and their rooting behavior.

Materials and Methods

The pot experiments were conducted in the net house of the Institute of Soil & Environmental Sciences, University of Agriculture, Faisalabad.

For Wheat

Wheat variety Inqulab-91 was used for the experiment. The air dried soil used in the study was sandy clay loam (sand, silt and clay 56.0, 19.83, 24.17%, respectively) collected from the Experimental Farm of University of Agriculture, Faisalabad. The glazed pots were filled with soil @ 12 kg pot^{-1}. The treatments described below were mixed thoroughly into the soil before filling the pots. In control, recommended NPK @ 200-150-105 kg ha^{-1}, respectively, were used as urea, diamonium phosphate and sulphate of potash. The pots were placed in the net house according to completely randomized design with three replicates under ambient temperature and light. The concentration of N, P and K in farm manure was 1.42, 0.39 and 1.21%, respectively, whereas in compost was 2.25, 0.43, 1.59%, respectively. The treatments used for comparison in both the experiments were as follows.

MF = Control (mineral fertilizer)
FM_{10} = Farm manure at 10 Mg ha^{-1}
FM_{20} = Farm manure at 20 Mg ha^{-1}
FM_{30} = Farm manure at 30 Mg ha^{-1}
FM_{40} = Farm manure at 40 Mg ha^{-1}
C_{300} = Compost at 300 kg ha^{-1}
C_{400} = Compost at 400 kg ha^{-1}
C_{500} = Compost at 500 kg ha^{-1}

The management practices were uniform for all the treatments and canal water was used for irrigation. The plants were grown up to maturity and the grain and straw samples were collected for analysis of N, P and K concentration (Ryan *et al*., 2001).

For Rice

The same set of treatments was used for rice experiment. The variety used was Super Basmati. Twenty five day old nursery seedlings were transplanted into the pots (6 plants pot^{-1}) under ambient temperature and light. The pots were kept flooded with canal irrigation water during growth period. The plats were grown up to maturity and harvested. The rice straw and grain samples were collected and analyzed for NPK determination (Rayan *et al*., 2001).

Root length determination

The roots were collected from the pots (both for wheat and rice). The soil and other debris were removed from the roots by gentle washing of the sample. The samples thus collected were stored in polythene bags and stored at 4 °C for further determinations. Newman's line intersection method (Newman, 1966) modified by Tennant (1975) was employed to determine the root length by using the following relationship.

$$R = \frac{\pi N A}{2H}$$

Where R = total root length
N = number of intersections between the root and random lines
A = area of the rectangle
H = total length of straight lines and
π = 3.14 (constant).

Data Statistics and Analysis

The experiments were laid out under completely randomized arrangement with three replicates. Analysis of variance technique was employed to find out the significance, and treatment means were compared by least significant difference (Steel and Torrie, 1980). The analytical software Statistix 8 was used to carry out data analysis.

Results and Discussion

Nutrient concentrations in wheat grain and straw

The N concentration in wheat (both straw and grain) varied significantly by the application of treatments ($P<0.05$). Nitrogen is very important for plant growth because of constituent of major cell parts and protein production (Tandon, 2000). The application of farm manure and compost resulted in an increased N concentration in wheat straw and grain (Table 1). The maximum N concentration in wheat straw (0.71 %) was recorded where farm manure was applied at 40 Mg ha^{-1} while, for wheat grain the maximum N concentration (1.67 %) was recorded for 500 kg ha^{-1} compost application.

Phosphorus is a part of energy compounds and also associated with root development and fruit ripening (Tandon, 2000). The presence of phosphorus is essential for plant survival and is absorbed as $H_2PO_4^{-1}$ and HPO_4^{-2}. The data regarding the P concentration in wheat straw and grain indicated non-significant differences among different treatments of farm manure and compost (Table 1). But the application of farm manure and compost resulted in an increase in P concentration when compared with mineral fertilizer control.

2008). The rice straw N concentration was also significantly affected with the application of treatments. It appears that rice plants prefer to acquire N from transformations of organic sources to maintain their life (Ahmad *et al*., 2008; Naeem *et al*., 2009) and to produce dry matter (Sarwar *et al*., 2008). The soil amended with organic substances provides a suitable rooting environment for plant growth and establishment. Rekhi *et al*. (2000) concluded that the addition of organic manure and compost might compensate for chemical fertilizer and might provide a substitution under field conditions.

Table 1. Nutrient concentrations in wheat grain and straw as affected by different types and levels of organic residues

Treatment	Grain			Straw		
	N	P	K	N	P	K
	%					
Control (mineral fertilizer)	0.92	0.15	0.29	0.34	0.02	1.21
Farm manure at 10 Mg ha^{-1}	1.03	0.16	0.33	0.39	0.03	1.72
Farm manure at 20 Mg ha^{-1}	1.30	0.18	0.40	0.41	0.03	1.74
Farm manure at 30 Mg ha^{-1}	1.26	0.21	0.42	0.46	0.04	1.84
Farm manure at 40 Mg ha^{-1}	1.40	0.21	0.46	0.71	0.05	1.90
Compost at 300 kg ha^{-1}	1.51	0.19	0.45	0.48	0.06	1.97
Compost at 400 kg ha^{-1}	1.42	0.19	0.43	0.53	0.05	1.93
Compost at 500 kg ha^{-1}	1.67	0.21	0.47	0.52	0.04	2.03
Minimum	0.92	0.15	0.29	0.34	0.02	1.21
Maximum	1.51	0.21	0.47	0.71	0.06	2.03
$LSD_{0.05}$	*0.38*	*NS*	*NS*	*0.17*	*NS*	*0.30*

Effect of farm manure and compost on K concentration in wheat straw was significant (*P<0.05*) while non-significant differences were recorded for wheat grain (Table 1). The maximum K concentration (2.03 %) in wheat straw was observed where compost was applied at 500 kg ha^{-1} and the minimum (1.21 %) was in case of mineral fertilizer control. Although non-significant differences were recorded for K concentration in wheat grain yet the maximum was recorded for 500 kg ha^{-1} compost application. The possible reason for increased K concentration in wheat straw and grain with the application of farm manure and compost may be attributed to better soil conditions. Sarwar *et al*. (2008) reported an increased K concentration in wheat straw and wheat grain with application of different green manures alone and in combination with mineral fertilizer.

Nutrient concentrations in rice grain and straw

The chemical composition of any plant is an important parameter to compare the performance of treatments applied. The concentrations of N in paddy straw and grain showed significant differences (*P<0.05*) at different levels of farm manure and compost (Table 2). A comparison with that of control (Table 2) revealed that farm manure @ 40 Mg ha^{-1} recorded the maximum grain N concentration (1.55 %). This increase in N concentration could be due to slow and continued supply of plant nutrients and improvement in soil physical conditions (Iqbal *et al*., 2008; Sarwar *et al*., 2008).

Non-significant differences were observed regarding P concentration in rice straw and grain (*P>0.05*). The data (Table 2) depicted that the maximum P concentration (0.106 %) in rice straw was recorded with farm manure at 10 and 20 Mg ha^{-1} and compost at 300 kg ha^{-1}. In case of P concentration in grains, the treatment 40 Mg ha^{-1} farm manure recorded the highest P concentration (0.33 %) in grains and the least was recorded for FM at 10 Mg ha^{-1}.

Rice straw and grain K concentration was greater with 40 Mg ha^{-1} FM. The results for K concentrations in straw and grain showed non-significant differences among all the treatments (*P>0.05*). The maximum K in rice straw (2.08 %) was recorded in case of 40 Mg ha^{-1} FM and the minimum (1.47 %) with compost at 500 kg ha^{-1} (Table 2). The maximum K concentration in grain (0.43 %) was observed in case of farm manure at 30 Mg ha^{-1} which was at par (0.42 %) with FM application of 40 Mg ha^{-1}. The maximum rice straw K concentration is also attributed to the increased root length (Figure 1). Nevens and Reheul (2003) reported the beneficial effects of integrated use of organic and inorganic materials in enhancing the fertilizer use efficiency by the slow release of the applied nutrients and reduced nutrient losses (Paul and Clark, 1996). The results are in agreement with other studies reporting the combined effect of organic and inorganic nutrient sources on rice productivity (Pandey *et al*., 1999; Ghosh and Sharma, 1999; Zahir *et al*., 2007). Some others even reported that organic materials with adequate chemical fertilizers (nitrogen) may produce higher yield and nitrogen accumulation than conventional inorganic N fertilizers alone (Singh *et al*., 1994; Chung *et al*., 2000).

significant differences (*P<0.05*) revealed that improvement in root length was brought about by the improved soil properties with the application of organic matter (Boparai *et al*., 1992). The application of FM at 30 Mg ha^{-1} resulted in 18% increase in root length followed by FM at 20 Mg ha^{-1} with 14% increase when compared with control. Compost application at 400 and 500 kg ha^{-1} increased the root length by 5% compared with control (Figure 1). The farm manure and compost resulted in significant increase in root length (*P<0.05*) when compared with control (Figure 1). The maximum root length (21538 mm) was observed in case of farm manure application at 40 Mg ha^{-1} (19% increase over control). The inorganic fertilizer recorded the lowest root length (18080 mm) which was at par (19209 cm) with FM at 10 Mg ha^{-1}. The differences in root length may be attributed to the improved soil chemical and physical conditions and better nutrient availability (Oussible *et al*., 1992). Compost application at 500 kg ha^{-1} increased root length by 9% and it was at par with FM at 10 Mg ha^{-1} (Figure 1). Yang *et al*. (2004) reported an increase in root length and root volume with the application of integrated use of mineral fertilizer and farm yard manure.

Table 2. Nutrient concentrations in rice grain and straw as affected by different types and levels of organic residues

Treatment	Grain N	Grain P	Grain K	Straw N	Straw P	Straw K
	%					
Control (mineral fertilizer)	1.05	0.26	0.28	0.80	0.027	1.62
Farm manure at 10 Mg ha^{-1}	1.10	0.18	0.29	0.62	0.106	1.80
Farm manure at 20 Mg ha^{-1}	1.50	0.31	0.40	0.91	0.106	1.52
Farm manure at 30 Mg ha^{-1}	1.55	0.29	0.43	1.11	0.095	1.82
Farm manure at 40 Mg ha^{-1}	1.48	0.33	0.42	0.94	0.084	2.08
Compost at 300 kg ha^{-1}	1.15	0.26	0.28	0.78	0.106	1.68
Compost at 400 kg ha^{-1}	1.29	0.22	0.37	0.87	0.103	1.47
Compost at 500 kg ha^{-1}	1.29	0.20	0.37	0.77	0.087	1.50
Minimum	1.05	0.18	0.28	0.62	0.027	1.47
Maximum	1.55	0.33	0.43	1.11	0.106	2.08
$LSD_{0.05}$	*0.34*	*NS*	*NS*	*0.24*	*NS*	*0.60*

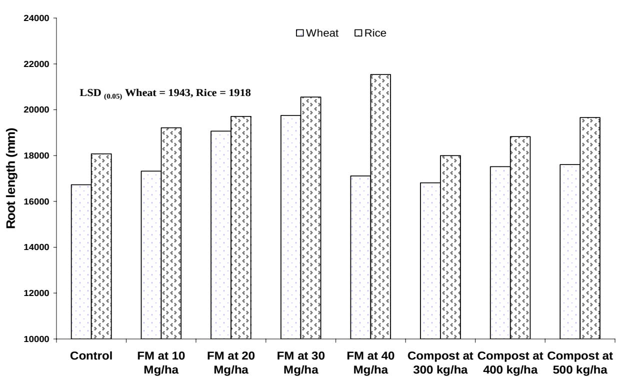

Figure 1. Root lengths of wheat and rice at various levels of farm manure and compost compared with mineral fertilizer (n = 3)

Root length of wheat and rice

Root growth is a very good indicator of the efficiency of the treatments applied in studying the plant growth. The application of farm manure and compost resulted in increased root length of wheat and rice plants grown in pots (Figure 1). The largest value of root length of wheat (19749 mm) was recorded in case of FM at 30 Mg ha^{-1}. The

Conclusion

The incorporation of organic materials into soil may improve root growth and efficiency in nutrient uptake by wheat and rice plants. Variation in NPK concentrations existed with the use of different rates and types of organic materials. It is possible to get highly nutritive food product with the integrated use of organic and inorganic inputs. The useful effect of organic materials on soil conditions is undoubtful. Further field studies may provide better understanding of processes and phenomena, of the nutrient uptake improvement.

Acknowledgements

The data presented here is part of PhD dissertation of senior author at University of Agriculture, Faisalabad, Pakistan.

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