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Article

The Effects of Slow-release Nitrogen Fertilizer Using Wastepaper on the Growth of Radish Plants

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The aim of this study was to investigate the effects of slow-release nitrogen fertilizer (SRNF) on the growth of radish plants. Wastepaper was deinked by alkaline solution and SRNF was produced from fertilizer impregnated wastepaper, which applied to an experimental plot compared with a urea fertilized plot. The plant height and total chlorophyll content of the radishes were higher while they were treated with SRNF than with urea. Some agronomic and chemical components were also observed and significant differences between the two fertilizers were found. When the soil was treated with SRNF, the pH, organic matter and total nitrogen content were higher than in the soil which was treated with urea.

Key words: Slow-release fertilizer, Nitrogen, Wastepaper, Radish

Introduction

Wastepaper is not only useful for house breaking puppies and lining bird cages, but also great for enhancing and protecting the environment. Some scientists showed that there are myriad uses of wastepaper, all of which can help the environment (Auburn, 1997). Wastepaper is a large part of organic waste, takes a long time to break down in landfills, and also takes up a lot of space while it is decomposing. But it has many beneficial uses besides landfills, so looking at ways of using them in agricultural applications has begun (Edwards, 1997). Incorporating wastepaper into the soil improves soil organic matter and conserves moisture of the soil (Peng et al., 1978).

Nitrogen is the most important mineral element in fertilization programs because plants usually need N in greater amounts than other mineral nutrients. Losses of nitrogen are caused by leaching, erosion, volatilization, denitrification, and fixation in soil organic matter. Low nitrogen use efficiency (NUE), i.e., the amount of N fertilizer recovery by the plant in relation to the total amount of N fertilizer added, is directly related to the level of applied N fertilizer and inversely related to N fertilizer applications (Weinbaum et al., 1992). Other factors and agricultural practices such as irrigation, the time of N application also affect NUE. However, slow-release fertilizer provides a gradual nutrient supply for a long period of time, which improves fertilizer use efficiency and reduces leaching losses (Khan et al., 2008b). In spite of these great advantages, the use of slow-release fertilizers in horticultural practice is limited to turf grass and ornamental crops in U.S.A. (Zhang et al., 1998). The relatively low use of these materials in crops is related to economic considerations compared to the traditional N sources (Maynard and Lorenz, 1979).

Vegetables have been very important crops in Korea as a major farmers' income source being 29% of their total farming income, and as an indispensable component of their diet for many years. Per capita consumption of vegetables in Korea increased greatly from 60 kg in 1970 to 152 kg in 2003. One of the unique characteristics of the Korean vegetable industry is that the diversity of vegetable crops has been considerably narrow as the ten major vegetables have occupied about 80% of the total acreage as well as the produce value, although about eighty different kinds of vegetables have been grown in Korea (Park, 2006).

When quick-acting urea fertilizer is supplied to cultivate vegetables in the early stage of growth, different diseases are frequently induced. As a result, various attempts were carried out to develop slow-release nitrogen fertilizer (SRNF) for the last fifty years (Lunt, 1971). Ureas and other urea form fertilizers as SRNF had also been applied to turf grasses, garden trees and upland crops. These forms of fertilizers are relatively inexpensive. It was

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reported that over 1 million tones of paper waste sludge such as newspaper, magazines and packing boxes were produced. Wood industrial factories have reused them as raw material for the production of fiberboard. The utilization of ripening sludge fertilizers mixed with sawdust, hog manure and urea to recycle the paper waste slurry contain over 60% organic matter (Chang et al., 1992). Other scientists have also tried to improve the utility through an infiltration technique of organic matter and synthetic resin into fibrous cell walls (Allan, 1991; Allan and Ritzenthaler, 1992; Bailey et al., 1994). However, recycling wastepaper to develop a slow-release fertilizer, rather than dumping it in landfills is an environmentally friendly practice. Therefore, the objective of this study is to observe the effects of SRNF using wastepaper on the growth of radish plants.

Materials and Methods

Preparation of SRNF using wastepaper Old newspaper (ONP) is the second largest component of wastepaper and it makes up 14% of total waste in municipal solid waste (Hervani, 2005). In this study, ONP was used as raw material due to easy availability. ONPs were first cut into pieces and mixed in 1-2% alum solution at 30 to 40℃ using a defibrator and washed with cold water to remove toxic compounds and finally obtained pure pulp slurry. After the fibers were produced from ink-removed pulp slurry in a 12 inch x 12 inch deckle box, they were dried at 100 ± 5℃ in a dry oven. A urea saturated solution was fully impregnated into fiberboards and then dried at 75 ± 5℃ for 24 h. The resulting fertilizer materials were finally manufactured under 100 psi at 50℃ through a thermal press and then uniformly sliced. The chemical components of prepared SRNF using wastepaper are presented in Table 1 and the

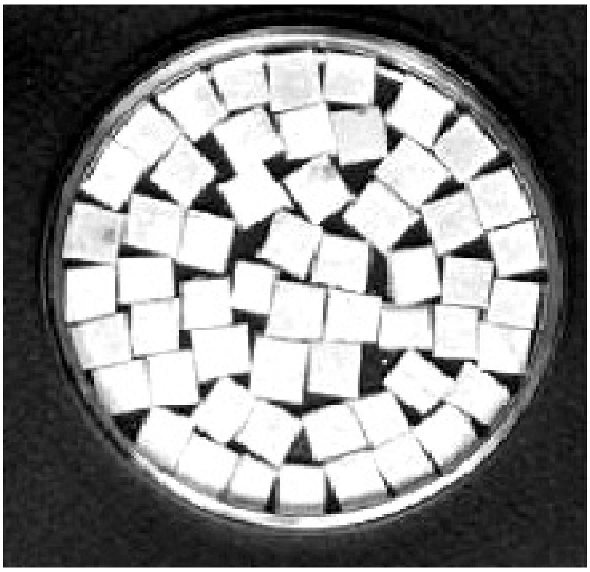

Fig. 1. Shapes of urea and SRNF.

shapes of the fertilizer are in Fig 1. The total-nitrogen content of finally made fertilizer was measured by the Kjeldahl method and the contents of P, K, Ca, Mg, As, Cd, Cr, Cu, Pb and Zn were determined by using inductively coupled plasma-atomic emission spectroscopy (ICP-AES). Release of N into the soil solution and distilled water was determined with an elemental analyzer (Vario EL III) and all samples were analyzed in triplicate (Khan et al., 2008a).

Soil sampling Prior to the experiment, soil was collected from the experimental fields of Kyungpook National University, Daegu, Korea and sampled from topsoil (0-20 cm). The samples were transported to the laboratory, spread on trays to remove rocks, roots, and other larger particles, and sieved with 2-mm mesh sieves. Soil samples were air-dried for 48 h and stored in plastic bags. The physico-chemical properties of soil before the experiment are shown in Table 2. The soil used in this

Table 1. Chemical properties of SRNF using wastepaper

N	P	K	Ca	Mg	As	Cd	Cr	Cu	Pb	Zn
%					mg kg^{-1}					
28	0.05	0.02	0.58	0.20	-	-	18.1	151.0	10.3	54.8

Table 2. Physico-chemical properties of the experimental soil before the experiment.

Texture	pH	OM	T-N	Av. P_2O_5	CEC	Ex. Cations		
						Ca^{2+}	Mg^{2+}	K^+
	1:5	g kg^{-1}		mg kg^{-1}	cmol kg^{-1}	cmol kg^{-1}		
Sandy loam	5.5	1.05	0.12	49	7.3	2.98	0.20	0.10

experiment had low fertility, as shown to be low value at all soil chemical properties in Table 2.

Treatment and cultivation Approximately 15 kg of soils (dry weight basis) were filled in 1/2000 a pots. There was a hole in the bottom of each pot. All pots were leached three times with water prior to planting the seeds. The application rates of N-P_2O_5-K_2O were 160-120-160 kg per ha. Nitrogen was omitted and only P and K were supplied as the basal dressing in the control pot. Urea and SRNF were used as the source of N fertilizer. The fertilization was performed in amounts of 40, 30 and 30% of total N fertilizer through 3 applications i.e., basal, one time top dressing and two times top dressing. However, SRNF was supplied only as a basal fertilizer. Three seeds of radish were sown into each experimental pot on July 20, 2006. When the seeds sprout and produced 2-3 leaves after 10 days of sowing, they were thin out to one seedling. The experiment was done by a completely randomized design with five replications. There were 3 treatments of control, urea application, and SRNF application.

Data collection The growth observations such as plant height of radishes were carried every 10 days at the early stage and every 5 days after the middle stage. The chlorophyll content was measured 40 days after sowing. The chlorophyll content analysis was performed by Yoshida's method (Yoshida, 1972).

First of all, the soil samples were air-dried, ground using a mortar and pestle and passed through a sieve with 2mm diameter openings. The soil pH (Soil : distilled water = 1:5), organic matter, available P_2O_5 and total nitrogen were analyzed by pH meter, Tyurin, Lancaster and Kjeldahl methods, respectively. After the extraction of soil in 1N-$NH_4$0Ac solution (pH 7), exchangeable Ca, Mg and K were measured using an atomic absorption spectrophotometer. Parts of the radishes were taken 50 days after sowing. The sampled plant parts were dried in a dry oven at 60℃ for 3 days pulverized using a warring blender and sieved into a 0.45mm sieve plate. The total N-contents were measured by the Kjeldahl method. After dissolving the pulverized samples (0.5g) into 10ml of digestion solution ($HClO_4$: H_2SO_4 : H_2O = 18 : 1 : 11), the P_2O_5 was quantitatively analyzed by the Vanadate method and K, Ca and Mg were done using an atomic absorption spectrophotometer (AAnalyst 700, PerkinElmer, USA). The results of the total chlorophyll content in the leaves, leaf and root length, diameter of root and fresh weight of the radishes were subjected to an analysis by Duncan's New Multiple Range Test (DNMRT) to compare the mean values with different treatments. The significance was determined at the $P < 0.05$ levels.

Results and Discussion

Release patterns of N from fiber matrix Static and flow methods were used in soil solution and distilled water as solutions to determine the release amount of N from fertilizer-impregnated fiber mat and the samples were collected at different times. The release rate of N in soil solution was found to be low and steady in the early stages but gradually increased with immersion time. This type of release pattern was also observed for distilled water. Release of N continued even after 30 days from static and flow methods. Both the cumulative released amount was much higher in the soil solution than in distilled water. Dissolution occurred when N was released in both liquids. However, the difference in the release amount of N for the two liquids is due to the presence of counter ions in the soil solution. In addition, N fertilizer impregnated into the surface and micropores of secondary fibers where large numbers of hydroxyl groups are present as part of the cellulose structure. This introduces the possibility of hydrogen bonding between urea and the hydroxyl groups at the C_6 position, which means that fertilizer impregnated into wastepaper could function as a slow-release fertilizer with maximum uptake and utilization of the nutrients (Khan et al., 2008a).

Chemical components and shapes of SRNF N, P_2O_5, and K_2O contents of SRNF prepared with wastepaper were 28, 0.05 and 0.02%, respectively. In Table 1, toxic metals like Cr, Cu, Pb and Zn were detected but the contents were considerably lower than the standards of Korean Fertilizer Regulation (Khan et al., 2008a). In addition, As and Cd were not present in the prepared SRNF using wastepaper. The shape of SRNF were flat forms of magnitude 0.5 x 0.5 x 0.2 cm with length x width x thick (Fig. 1).

Effect of SRNF on the changes in growth of radish plants Changes in plant height of radishes treated with urea and SRNF using wastepaper are presented in Fig. 2.

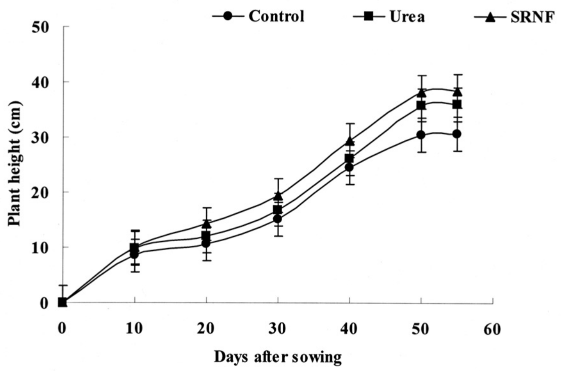

Fig. 2. Changes in the plant height of radishes treated with urea and SRNF.

The changes in plant height of radishes were almost similar at the early growth stage when treated with urea and SRNF. After 10 days of the early growth stage, height of the radishes began to show difference, as being higher in SRNF treatment compared with urea treatment. The growth difference continued to the end of experiment.

The total chlorophyll content in the leaf of radish was measured after 40 days of sowing. The chlorophyll content in the SRNF treated plant was 0.21 mg/g fresh weight which is higher than that of the urea treated plant (Table 3). The differnece was statistically significant at 5% level. Consequently, the effect of SRNF using wastepaper over urea on increasing the chlorophyll content in the leaves of radish was admitted. There were significant differences in the leaf length, root length and fresh weight of radishes (top) when treated with urea and SRNF (Table 4). In addition, there were no differences at a 5% level of significance in root diameter and fresh weight of root using urea and SRNF.

Table 3. Total chlorophyll content in the leaves of radishes at 40 days after sowing.

Treatment	Total chlorophyll content†
	$mg\ g^{-1}$ fr. Wt.
No treatment	0.98 c
Urea	1.03 b
SRNF	1.24 a

† Values within a column followed by the same letter do not differ significantly (P < 0.05) by Duncan's New Multiple Range Test (DNMRT).

Effect of SRNF on nutrient adsorption by radish plants Table 5 presents the nutrient contents in a whole radish plant at 50 days after sowing in different treatments. There were some changes observed in the inorganic nutrient contents of the radish plants 50 days after sowing between urea and SRNF application. The content of total-nitrogen and K_2O was higher when the radish was treated with SRNF than urea. It was due to the slow-release effect of N from wastepaper. On the other hand, the content of P_2O_5, CaO and MgO was lower in SRNF application than the urea application.

The effect of urea and SRNF on the chemical components in the top and root of the radishes at harvest is reported in Table 6 and 7, respectively. In case of the top of the radishes (Table 6) treated with SRNF, the content of total-nitrogen, Ca and Mg was lower than the urea treated plants, but the content of P was almost

Table 4. Leaf length, root length, diameter of root and fresh weight of radishes.

Treatment	Leaf length†	Root length†	Root diameter†	Fresh weight†	
				Top	Root
	cm			$g\ pot^{-1}$	
No treatment	24.2 c	6.4 c	4.4 b	60.1 c	562 b
Urea	29.0 b	7.6 a	5.4 a	178.9 b	855 a
SRNF	32.1 a	6.8 b	5.3 a	183.3 a	832 a

† Values within a column followed by the same letter do not differ significantly (P < 0.05) by Duncan's New Multiple Range Test (DNMRT).

Table 5. Chemical components in the whole radish plant at 50 days after sowing.

Treatment	T-N	P_20_5	K_2O	CaO	MgO
	%				
No treatment	0.85	1.25	8.90	0.81	0.29
Urea	1.01	1.57	9.43	0.95	0.35
SRNF	1.45	1.44	9.51	0.89	0.31

Table 6. Chemical components at the top of radishes treated with urea and SRNFS at harvest.

Treatment	Top				
	T-N	P	K	Ca	Mg
	---------- mg kg^{-1} ----------				
No treatment	1.19	0.73	4.99	1.26	0.82
Urea	2.01	1.12	5.33	1.58	1.05
SRNF	1.84	1.11	6.01	1.49	1.01

Table 7. Chemical components at the root of radishes treated with urea and SRNFS at harvest.

Treatment	Top				
	T-N	P	K	Ca	Mg
	---------- mg kg^{-1} ----------				
No treatment	0.69	1.30	6.92	0.59	0.27
Urea	1.25	1.42	6.87	0.63	0.29
SRNF	1.34	1.41	6.90	0.61	0.25

similar between two treatments. However, in the root of the radishes (Table 7), the content of total-nitrogen and K in the SRNF treated plants was higher than the urea treated plants. But, the content of Ca and Mg was higher in urea treated plot than SRNF. In addition, the content of P in radish roots remained almost similar in all treatments.

Effect on chemical properties of soil after experiment The soils treated with SRNF showed a higher pH, organic matter contents and CEC than the soil treated with urea, but the contents of exchangeable cations (Ca^{2+}, Mg^{2+}, K^{+}) showed no difference (Table 8). In addition, the content of available P_2O_5 was higher when treated with urea than SRNF. But, the total-nitrogen content in the soils treated with SRNF was higher than in the soils treated with urea, which revealed that the nitrogen released from the slow-release fertilizer was maintained longer than urea.

Conclusion

It can be concluded from this investigation that SRNF has a positive effect over urea on the growth of radishes. The plant height and total chlorophyll content of radishes was higher in the application of SRNF than urea. There were significant differences in the leaf length and root length of the radishes between urea and SRNF application. However, there were no significant differences in the case of the root diameter and fresh weight of root. The total-nitrogen content was also higher in SRNF application than the urea application. Finally, the pH, organic matter and CEC of soil were also higher in SRNF treated soil than the urea treated one. Therefore, it is evident from the above findings that the SRNF has a positive effect on the growth radish plants.

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References

Allan, G.G., R. Negria, and P. Ritzenthaler. 1992. The microporosity of pulp: the properties of paper made from pulp fibers internally filled with calcium carbonate. Tappi J. 75(3):239-244.

Allan, G.G. 1991. New technologies based on the microporosity of

Table 8. Physico-chemical properties of the experimental soil after harvest.

Treatment	pH	OM	T-N	Av. P_2O_5	CEC	Ex. Cations		
						Ca^{2+}	Mg^{2+}	K^{+}
	1:5	------ g kg^{-1} ------		mg kg^{-1}	cmol kg^{-1}	------ cmol kg^{-1} ------		
No treatment	5.8	1.25	0.08	84	6.4	2.84	0.14	0.07
Urea	5.4	1.02	0.10	88	6.1	2.73	0.12	0.05
SRNF	5.6	1.14	0.11	78	6.3	2.72	0.11	0.05

cellulosic pulp fibers. Tappi J. 45(9):986-990.

Auburn, A. 1997. Newspaper benefiting the environment enhancing landscapes. News release. Alabama Agricultural Experiment Station, Auburn University, Alabama, USA.

Bailey, G., M. Dana, and R. Lefroy. 1994. Micropore structure of pulp cellulose fiber for filling of inorganic fillers. Tappi J. 77(2):211-219.

Chang, K.W., S.D. Kim, W.Y. Choi, and K.S. Lee. 1992. Agricultural utilization of paper mill sludge manure compost II. Effects on the growth of carrot (*Daucus carota* L.). Korean J. Soil Sci. Fert. 25:155-159.

Edwards, J. 1997. Newspaper benefiting the environment, enhancing landscapes. News release. Alabama Agricultural Experiment Station. US Department of Agriculture.

Hervani, A.A. 2005. Can oligopsony power be measured? The case of U.S. old newspapers market. Resour. Conserv. Recy. 44:343-380.

Khan, M.A., W. Mingzhi, B.K. Lim, and J.Y. Lee. 2008a. Utilization of waste paper for an environmentally friendly slow-release fertilizer. J. Wood Sci. 54(2):158-161.

Khan, M.A., K.W. Kim, W. Mingzhi, B.K. Lim, W.H. Lee, and J.Y. Lee. 2008b. Nutrient-impregnated charcoal: an environmentally friendly slow-release fertilizer. Environmentalist. 28(3):231-235.

Lunt, O.R. 1971. Controlled-release fertilizer. Achievements and potential. J. Agr. Food Chem. 9:797-800.

Maynard, D.N. and O.A. Lorenz. 1979. Controlled-release fertilizers for horticultural crops. Hortic. Res. 1:79-140.

Park, H.G. 2006. Genetical improvement of Brassica in Korea. Acta Hort. (ISHS). 706:31-48.

Peng, P.H., W.R. Ernst, G.L. Bridger, and E.M. Hartley. 1978. Slow-release fertilizer materials based on magnesium ammonium phosphate. Pilot-plant granulation studies. Ind. Eng. Chem. Process Des. Dev. 18(3):453.

Weinbaum, S.A., J.R. Scott, and T.M. Dejong. 1992. Causes and consequences of over fertilization in orchards. HortTechnology. 21:112-120.

Yoshida, S. 1972. Laboratory manual for physiological studies of rice (2nd ed.). IRRI, Los Bans, Philippines.

Zhang, M., M. Nyborg, and S.S. Malhi. 1998. Comparison of controlled-release nitrogen fertilizers on turfgrass in a moderate temperature area. Hort. Sci. 33(7):1203-1206.