 The Open Horticulture Journal, 2013, 6, 24-28

The Effects of Slow-Release Fertilizer Using Wastepaper on Growth of Chinese Cabbage

Modabber Ahmed Khan[1,*], Kwang-Hwa Jeong[1], Bu-Kug Lim[2] and Jong-Yoon Lee[2]

[1]*Animal Environment Division, National Institute of Animal Science, R.D.A., Suwon 441-706, South Korea;* [2]*Department of Wood Science & Technology, Kyungpook National University, Daegu 702-701, South Korea*

Abstract: In order to raise awareness about environmental protection, people are paying more attention now-a-days in reusing wastepaper. As a result, most countries in the world have already made significant progress related to wastepaper recycling technology. This study was conducted to investigate the effects of slow-release fertilizer (SRF) on Chinese cabbage production. Wastepaper was deinked and the SRF was produced from fertilizer impregnated wastepaper. A field experiment was conducted to evaluate the effects of a general fertilizer along with compost and SRF without compost on the cabbage production. The leaf length, total chlorophyll content, and fresh weight of head of cabbage were significantly improved through the application of the SRF than general fertilizer. Some agronomic and chemical components were also observed and found significant differences between the two fertilizers. In addition, pH and organic matter contents were higher in the soils fertilized with the SRF. Our results show that though the amount of SRF applied was larger compared to that of general chemical fertilizer, cabbage production was increased due to the application of SRF.

Keywords: Impregnation, recycling, chemical fertilizer, environment.

INTRODUCTION

In order to raise awareness about environmental protection, people are paying more attention now-a-days in reusing wastepaper. As a result, most countries in the world have already made significant progress related to wastepaper recycling technology. Through wastepaper recycling technology, good economic and social benefits as well as saving the resources and protecting the environment could be achieved. Wastepaper can be reused as a part of raw materials for paper making to make new paper such as newsprint for newspaper and cardboard for boxes. Thus, it is necessary to explore other ways in reusing of wastepaper.

Wastepaper is a large part of waste, taking a long time to breakdown in landfills, and also taking up a lot of space while it is decomposing. Therefore, recycling of wastepaper is a good way to save landfills, which has a positive effect on the areas surrounding the landfills. Effects of various types of wastepaper have been evaluated in composting experiments [1-10]. Incorporating wastepaper into the soil improves soil organic matter, moisture content, physical conditions and the arable layer [11]. In order to develop the highly intensive agriculture, more chemical fertilizers are applied to the soil that results in runoff and leaching of nutrients, soil degeneration, and environment deterioration. One possible way to improve nutrient use efficiency while reducing the environmental hazards is using controlled release or slow-release fertilizers. In contrast to the conventional type, slow-release fertilizers have many advantages, such as decreasing fertilizer loss rate, supplying nutrients for a longer period of time, lowering application frequency and minimizing potential negative effects associated with over dosage [12,13]. Furthermore, recycling of wastepaper to develop a slow-release fertilizer, rather than dumping off in landfills, is an environmental friendly practice. To keep this in consideration, wastepaper was deinked by alkaline solution and the SRF was produced from fertilizer impregnated wastepaper to provide a gradual nutrient supply, which improves N fertilizer use efficiency and reduces leaching losses.

It is well known that vegetables have short growth periods with high production. Cabbage was selected for this work because of its worldwide distribution and its high N requirement. Therefore, nitrogen fertilization is crucial for achieving high yields [14]. Cabbage can be cultivated in domestic gardens for its compact head and the yield is directly associated with circumstances of the vegetative growth. Like all leafy vegetables, cabbage also requires N-P-K fertilizers to maintain high growth rates. However, the main objective of this study was to observe the effects of the SRF on cabbage production compared with general chemical fertilizers.

MATERIALS AND METHODS

Preparation of SRF

Old newspaper (ONP) is the second largest component of wastepaper and it makes up 14% of total waste in municipal solid waste [15]. Old newspapers (ONPs) were used in this study as raw material due to its' easy availability. ONPs were cut into pieces (15.24 cm x 2.54 cm) and mixed in 1-2% alum solution at 30-40^{o}C using a defibrator to obtain pure pulp slurry. When secondary fibers were produced from deinked pulp slurry, fibers were placed into a deckle box measuring 30 x 30 cm and were dried at 100 ± 5^{o}C in a dry oven. Ammonium nitrate (NH_4NO_3) and potassium pyro-

*Address correspondence to this author at the Animal Environment Division, National Institute of Animal Science, Rural Development Administration, Suwon 441-706, Republic of Korea; Tel: +82-31-290-1716;
Fax: +82-31-290-1731; E-mail: khan023@rda.go.kr

1874-8406/13

phosphate ($K_4P_2O_7$) saturated solutions were impregnated into fiberboards, which were then dried at 75 ± 5°C for 24 h. The resulting fertilizer materials were finally manufactured at 100 kPa at 50°C through a thermal press and then uniformly sliced. The chemical components of SRF using wastepaper are presented in (Table **1**).

Field Experiment

A field experiment was conducted from August to November 2005 in a 50 m^2 plot at Kyungpook National University, Daegu, Korea using Chinese cabbage (*Brassica campestris* var. Pekinensis) as a test crop. The seeds were sown at a rate of 0.6 kg/ 1,000 m^2 and seedlings were thinned with a desired spacing of 75 cm x 45 cm in Mid-August of 2005 in order to harvest in October and November of the same year.

Fertilization

Three types of local chemical fertilizers were used with an amount of 32, 7.8 and 19.8 kg per 1,000 m^2 of N, P_2O_5 and K_2O, respectively. During land preparation, 75 kg compost, 50% urea (46% N), the whole amount of fused and super phosphate (20% P_2O_5), and 50% KCl (60% K_2O) was applied along with chemical fertilizers as basal doses. The rest of the 50% urea and KCl were applied during head formation stage. The SRF was applied once in the cabbage field as a basal dose without compost. The amount of SRF and chemical fertilizer applied in the field are presented in (Table **3** and Table **4**).

Nutrient Content Estimation

The percentages of T-N and P_2O_5 were estimated by macro Kjeldahl and Vanadate method [16] and K_2O was measured by ICP (Leman LAB PS series). The contents of Ca, Mg, As, Cd, Cr, Cu, Pb, and Zn were determined by ICP-AES.

Analytical Procedure of Soil

Soil pH was determined in 1:5 soil/water ratio by a pH meter (Orion 3 star, Thermo Scientific, USA). Organic matter was determined by Tyurin method [17]. To determine available P_2O_5, the extracting phosphate was analyzed with the Lancaster method described by [18]. After the extraction of soil in 1N NH_4OAc solution (pH 7), exchangeable Ca, Mg and K were measured using an atomic absorption spectrophotometer. Measuring procedure of CEC described in detail by Rayment and Higginson [19]. T-N was determined by the micro-Kjeldahl digestion method [20].

Observation and Chlorophyll Content Measurement

The growth observation of cabbage was carried at intervals of 10 days at the early stage and at intervals of 5 days after the middle stage. The total chlorophyll content was measured after 50 days and performed by Yoshida's method [21].

Analytical Procedure of Inorganic Ingredients

The plant parts of Chinese cabbage were collected after 70 days. The collected heads were dried in the drying oven at 60˚C for 3 days and pulverized using a mixer (Warring Laboratory and Science) and sieved them into 0.45-mm sieve plate. After dissolving the pulverized samples (0.5 g) into 10 ml digestion solution [$HClO_4$: H_2SO_4 : H_2O = 18 : 1 : 11 (v/v/v)], P_2O_5 was quantitatively analyzed by vanadate method and K, Ca and Mg were measured by atomic absorption spectrophotometer. Total N-contents were measured by micro-Kjeldahl method.

Statistical Analysis

The results were analyzed by Duncan's New Multiple Range Test (DNMRT) to compare the mean values with different treatments. All statistical analyses were performed using SAS software program version 9.2 (SAS Institute Inc., Cary, NC). The significance was determined at $P < 0.05$ levels.

RESULTS AND DISCUSSION

The chemical properties of the SRF (dry matter basis) are presented in (Table **1**). The contents of N, P, K in the SRF were 28.2, 21.05 and 13.02%, respectively. Toxic metals such as Cr, Cu, Pb and Zn were detected but the contents were considerably lower than the standards of Korean Fertilizer Regulation [11]. Moreover, As and Cd were not detect-

Table 1. Chemical Properties of SRF Using Wastepaper (Dry Matter Basis)

N	P_2O_5	K_2O	Ca	Mg	As	Cd	Cr	Cu	Pb	Zn
……………………………………… % ………………………………………										
28.2	21.05	13.02	0.58	0.20	ND	ND	0.002	0.015	0.001	0.005

ND Not detected.

Table 2. Physico-Chemical Properties of Soil Used for Experiment

pH	OM	T-N	Av. P_2O_5	Ex. Cations (cmol kg^{-1})			
1:5 (H_2O)	….. g kg^{-1}…..		mg kg^{-1}	CEC	Ca^{2+}	Mg^{2+}	K^+
5.5	1.05	0.12	49	7.3	2.98	0.20	0.10

able in the prepared SRF. The soil of the cultivated plots was inorganically silty clay loam and the area was used as a grass field in the previous year. The characteristics of the soil are shown in (Table **2**).

Table 3. The Amount of SRF Applied to the 50 m^2 Plot as Basal Dose

Nutrient		
N (kg)	P (kg)	K (kg)
6.12	1.80	6.81

Chemical and SRF application: N, P_2O_5 and K_2O of 32, 7.8 and 19.8 kg per 1,000 m^2.

Table 4. The Amount of Chemical Fertilizer Applied to the 50 m^2 Plot

Stage of application	Urea (46% N)	Fused and super phosphate (20% P_2O_5)	KCl (60% K_2O)	Compost
Land preparation	1.75	1.94	0.84	75
Head formation	1.75		0.84	

Chemical and SRF application: N, P_2O_5 and K_2O of 32, 7.8 and 19.8 kg per 1,000 m^2.

Successive changes in maximum leaf length of Chinese cabbage treated with chemical fertilizer and the SRF are presented in (Fig. **1**). It can be seen that the plants in both treatments grew well. The cabbage growth on both fertilized plots was normal. The leaf growth rate of chemical fertilizer plots was slightly better than that of SRF cabbage plots until 30 days of the trail but started decreasing thereafter. The leaf length of SRF plants were growing faster after trial day 30 and remained higher than that of the chemical fertilizer plots. The total leaf growth rate of SRF cabbages was slightly higher than that of the chemical fertilizer plants, but the difference did not achieve significance.

The total chlorophyll content in the leaves of Chinese cabbage is shown in (Table **5**). The chlorophyll content in the leaves of Chinese cabbage fertilized with the SRF was 0.52 mg g^{-1} fresh weight, which is higher than chemical fertilizer treated plot. Significant differences of total chlorophyll contents exist among the treatments ($P < 0.05$).

Table 5. Total Chlorophyll Content in the Leaves of Cabbage After 50 Days

Treatments	Total chlorophyll content (mg g^{-1} F.W.)
Chemical fertilizer	1.45 b
SRF	1.97 a

Mean values within a column followed by the same letter are not significantly different at 5% level by the Duncan's New Multiple Range Test (DNMRT).

Fig. (**2**) represents the effect of chemical fertilizer and SRF on fresh weight of head of Chinese cabbage after 70 days. Fresh weight of head of Chinese cabbage was heavier when fertilized with the SRF than chemical fertilizer. Furthermore, there was a significant difference ($P < 0.05$) observed on fresh weight of head of Chinese cabbage in these treatments.

The length and width of head, number of leaf per head and fresh weight of Chinese cabbage were investigated to observe the effect of chemical fertilizer and the SRF, which is presented in (Table **6**). The head length and width of Chinese cabbage fertilized with SRF was longer and wider than that fertilized with a chemical fertilizer. Because of high vegetative growth, the number of leaves was increased in the SRF than in chemical fertilizer treated plot. Finally, it was found that the fresh weight of Chinese cabbage when treated with chemical fertilizer was lighter than that in the plot fertilized with the SRF. The length and width of head, number of leaves per head and fresh weight of Chinese cabbage were significantly ($P < 0.05$) different between treatments.

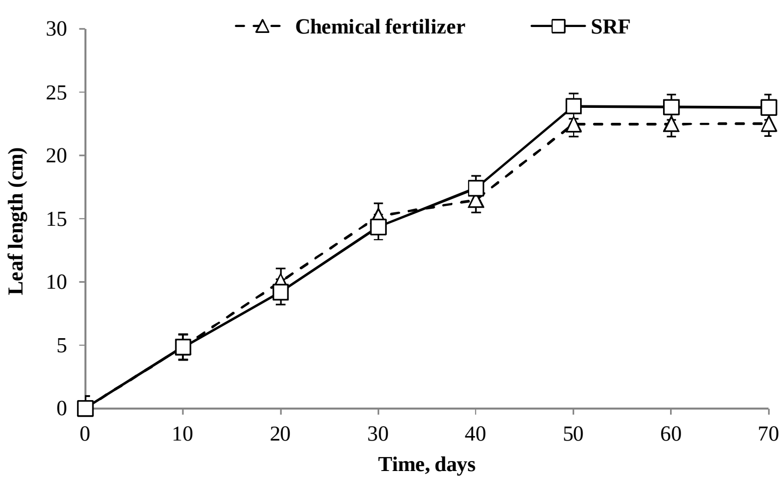

Fig. (1). Changes in maximum leaf length of cabbage under different treatments at various growth stages. Values plotted represent the means from triplicate values, and the vertical bars represent standard error.

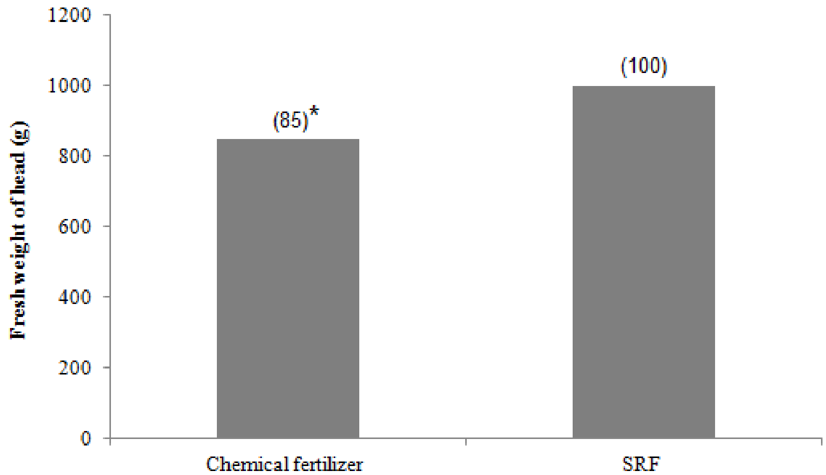

Fig. (2). Fresh weight of head of cabbage treated with chemical fertilizer and SRF after 70 days.
* Number in parenthesis presented the mean value. Mean values within a column followed by the same letter are not significantly different at 5% level by the Duncan's New Multiple Range Test (DNMRT).

Table 6. Length and Width of Head, Number of Leaves Per Head and Fresh Weight of Cabbage

Treatments	Head length (cm)	Head width (cm)	No. of leaves per head
Chemical fertilizer	23.6[b]	14.1[b]	43[b]
SRF	24.4[a]	16.5[a]	46[a]

Mean values within a column followed by the same letter are not significantly different at 5% level by the Duncan's New Multiple Range Test (DNMRT).

Table **7** reveals the chemical components in the head of Chinese cabbage (dry matter basis) after 50 days and harvest day. After 50 days, it presumed that the contents of all chemical components fertilized with the SRF was larger than other treatment except the amount of P_2O_5, but the contents of CaO after harvest was smaller than chemical fertilizer treated plot. In addition, total-N content in Chinese cabbage was larger in the SRF fertilized plots than that of chemical fertilizer treated plots.

The physico-chemical properties of the experimental soil after harvest are shown that the soil treated with the SRF showed higher pH, organic matter and available phosphorus than the soils were treated with a chemical fertilizer [22]. On the other hand, cation exchange capacity (CEC) and the contents of exchangeable cations (Ca, Mg, K) were almost similar when the soils treated with chemical fertilizer and the SRF. Total-N content in the soils treated with the SRF was smaller than in the soils treated with general chemical fertilizer because chemical fertilization was maintained up to the late growth stage.

The growth of cabbage in this study indicates that SRF could be used as a good fertilizer for cabbage and could represent a feasible alternative to chemical fertilizers. The unique characteristic of SRF is that it was applied in the cabbage filed only at the time of land preparation and was found more effective than general chemical fertilizers. Although the initial leaf length of chemical fertilized cabbages was better, their growth decreased after a certain point through the trial possibly because of N deficiency whereas the level of available N for plants could remain for a longer time in the case with the SRF plots.

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 fertilizer 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. The SRF has certain advantages and disadvantages. By using the SRF, nutrients could be released dur-

Table 7. Chemical Components in the Head of Cabbage (Dry Matter Basis) Treated with Chemical Fertilizer and SRF After 50 Days and Harvest

Treatments	After fifty days					After harvest				
	T-N	P_2O_5	K_2O	CaO	MgO	T-N	P_2O_5	K_2O	CaO	MgO
	……………………. % ……………..………					……………..……. % …………..………				
Chemical fertilizer	0.79	1.43	8.73	1.03	0.66	1.63	1.39	7.76	1.45	0.63
SRF	1.14	1.40	8.92	1.19	0.81	1.91	1.44	7.78	1.43	0.84

ing a longer period of time. Chemical fertilizer can burn plant roots if provided in large excess quantities, and even when it is dosed correctly, it will have to be reapplied more frequently as it dissolve quickly and disappear from the root zone sooner. To reduce maintenance and cut down on laborious re-applications of fertilizer, the SRF can make nutrients available in small amounts over an extended period. Even though the SRF tends to be more expensive but due to its longer period of availability means fewer applications will be used. More research; however, can be conducted in the same research field to estimate the long-term effect of SRF on soil.

CONCLUSION

The results of this study demonstrate that the leaf length and chlorophyll content in the leaves of Chinese cabbage were significantly higher when treated with the SRF than chemical fertilizer treated plot. The SRF has also some positive significant effects on fresh weight of head, length and width of head, and number of leaves per head of Chinese cabbage. In addition, T-N content after 50 days and harvest was higher when treated with the SRF. The soils treated with the SRF had higher values of pH, organic matter and available phosphorus. Compared to general chemical fertilizers, SRF using wastepaper showed superior result for cabbage production. Therefore, it is concluded that cabbage production was increased with SRF, which can be used for successful cabbage production.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflicts of interest.

ACKNOWLEDGEMENT

Declared none.

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Received: August 21, 2013 Revised: November 06, 2013 Accepted: December 10, 2013