

# Effect of Liquid Pig Manure and Chemical Fertilizers on Shoot Growth and Nitrogen Status of Young “Fuyu” Persimmon Trees

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## Abstract

Liquid pig manure (LPM), digested from pig slurry, has been used as a nutrient source substituting chemical fertilizer (CF) for some crops. This experiment was conducted to evaluate the effect of different levels of CF and LPM in early July on nitrogen (N) uptake of pot-grown young “Fuyu” persimmon (*Diospyros kaki*). The total N and potassium (K) from CF and LPM applied to a 3 L pot were 1.2 g N and 1.15 g K for the low and 2.4 g N and 2.3 g K for the high level. From 2 weeks after the applications, secondary shoots started to grow for the CF but none for the LPM. Two nutrient sources did not significantly affect the amount of N increase in different tree parts from July 1 to August 6. At the high level, tree total N increased by 80% from 551 mg for the CF and by 31% from 583 mg for the LPM. The nutrient sources did not affect soil pH. The soil that received LPM contained more organic matter ( $P = 0.048$ ), available phosphorus (P) ( $P = 0.002$ ), and exchangeable  $K^+$  ( $P = 0.001$ ) and  $Mg^{2+}$  ( $P = 0.009$ ) than the soil that received CF on August 6. These results indicated that N in LPM becomes available later but its effect is more durable than CF.

## Keywords

Liquid Pig Manure, Persimmon, Shoot Growth, Nitrogen Uptake, Nitrogen Partition

## 1. Introduction

The use of pig slurry as a source for plant nutrients has become of a serious interest in South Korea because its disposal is strictly monitored. Results of a

number of studies indicated that LPM can be used as a nutrient source for crops as long as it is properly digested in a fermenting facility [1] [2]. Since LPM contains various inorganic nutrients which are necessary for crop growth [3] [4] [5], it is applied as a basal fertilizer especially for paddy rice [6] [7] and for fruit crops [8] [9]. Soil spreading of LPM, adjusted to contain 100% of N recommendation, was as effective as CFs in onion [2], rice [10], and pear [9]. No adverse effects of LPM on crop growth and soil properties were reported. While replacement of CFs with LPM in persimmon growing should undoubtedly have some merits, no comparative studies have been conducted with two different sources of nutrients for the trees. If CF can be substituted with LPM partially or completely in persimmon orchards, environmental pollution can be reduced from the illegal disposal of pig slurry and growers can save cost of supplying CF.

In persimmon orchards, similar amounts of N and K are supplied usually from June to July as supplemental fertilizers. Since persimmon trees are rather sensitive to N supply, not only an excessive N but the fast-acting N source may cause the occurrence of vigorous water sprouts and undesirable secondary shoot growth [11]. Excessive soil N is a major contributor of nitrate contamination of groundwater [12] [13]. On the other hand, if the N source is too slow to become available for the trees its effect on tree development may be less than desired: if N becomes available later in the season, it delays fruit maturation [14]. Therefore, when LPM is applied to persimmon orchard supplementally, it is important to understand the effect of different amounts of LPM on tree growth and N uptake within a certain time period rather than the whole season. Responses to CF and LPM applications in summer on N uptake have not been compared in other fruit crops. This experiment was conducted to evaluate the effect of different amounts of CF and LPM in summer on N uptake and secondary shoot growth of young persimmon trees.

## 2. Materials and Methods

### 2.1. Materials

Sixteen 2-year-old “Fuyu” trees were used for this experiment. The trees were grafted on one year old *D. kaki* seedlings grown in 3 L pots in spring two years ago and grown under a rain shelter in Sweet Persimmon Research Institute, Gimhae, South Korea. Pots, spaced at 50 × 50 cm, contained sandy loam soil and they were not fertilized until the treatment. The chemical properties of the pot soil before treatments are shown in **Table 1**. LPM used in this experiment was collected from an aerobically-digesting facility for pig slurry. Chemical properties of the LPM are shown in **Table 2**. Trees were supplied with about 0.7 L·d<sup>-1</sup> water throughout the experiment with a sprinkler irrigation system.

### 2.2. Treatment

With two nutrient sources, CF and LPM, and two levels of each, the treatments were arranged in a 2 × 2 factorial design with three single-tree replicates using

**Table 1.** Chemical properties of the soil used to evaluate application effect of chemical fertilizer and liquid pig manure. Soil was collected from pots grown with 2-year-old “Fuyu” persimmons before the treatments.

pH	Organic matter (g·kg <sup>-1</sup> )	Total N (g·kg <sup>-1</sup> )	Available P (mg·kg <sup>-1</sup> )	Exchangeable cation (cmol <sup>+</sup> ·kg <sup>-1</sup> )		
				K	Ca	Mg
7.4	39.9	2.2	372	0.17	12.2	2.08

**Table 2.** Chemical properties of liquid pig manure used to compare with application effect of chemical fertilizer on 2-year-old “Fuyu” persimmons.

pH	Organic matter	Total N	Available P	K	Ca	Mg
8.4	17.0	4.0	0.71	3.84	0.56	0.10

twelve trees. An additional four trees were used for analysis at start of the experiment before the first treatment on July 1. Each nutrient source at low and high levels was supplied to the pot on July 1, 3, and 5 in three equal aliquots. LPM of 300 (low) and 600 mL (high) was poured on soil surface of the pots on each treatment date. The treatment of LPM was established not to injure trees based on our preliminary study. For the CF treatment, urea and potassium chloride (KCl) were fertigated with 1% (w/v) solutions as was commonly done in the orchard. Urea and KCl were adjusted to have the equivalent amount of total N and K contained in the LPM. Uptake and partitioning of K were not of primary interest in this study, but it was nonetheless incorporated in this CF treatment to mimic the composition of the LPM. The total N and K supplied to a pot were 1.2 g N and 1.15 g K for the low and 2.4 g N and 2.3 g K for the high level.

### 2.3. Sampling, Plant Measurement and N Analysis

Secondary shoot growth was monitored to assess the response of the trees to different nutrient sources and their levels. Four trees on July 1 and the remaining 12 trees on August 6 were destructively harvested and divided into various tree parts. N contents in July 1 samples served as the basis for comparison with those in August 6 samples. The trees were divided into leaves, aerial woods, and roots. Aerial woods were separated into shoots, secondary shoots, 1- to 2-year-old woods (old woods) while the roots were divided into small ( $\leq 2$ ) and large ones ( $> 2$ ) according to their diameter in mm. After drying at 80°C for 48 h, the samples were ground with a Wiley mill (3383-L10; Thomas Scientific, Swedesboro, NJ) to pass through a 20-mesh screen. To determine total N, 0.2-g sub-samples were analyzed with a Kjeldahl instrument (Kjeltec 2300, Foss Co., Höganäs, Sweden) using the micro-Kjeldahl method [15]. By taking the concentration of N in the different tree parts and their dry weights (DWs), N contents in each part were calculated. Differences in the amount of N between July 1 and August 6 are considered the amount absorbed and distributed to different tree parts.

## 2.4. Soil Analysis

Soil samples were collected from soils remained after excavating roots from four pots on July 1 before treatments and the remaining 12 pots on August 6. Organic matter and various elements were analyzed according to the Methods for Chemical Analysis of Soils and Plants [16]. Briefly, soil pH was measured with distilled water (1:5 with H<sub>2</sub>O) with a pH meter (Orion 520A; Orion Research Inc., Boston, MA). Organic matter was measured by Tyurin method [17]. Total N content was determined after the Kjeldahl digestion. The available P was determined using the Lancaster method. Exchangeable K<sup>+</sup>, Ca<sup>2+</sup>, and Mg<sup>2+</sup> were estimated by using inductively coupled plasma spectroscopy (Analyst 300; Perkin-Elmer, Norwalk, CT) after extracting with 1 M ammonium acetate (NH<sub>4</sub>OAc).

## 2.5. Statistical Analysis

Statistical analyses were performed by analysis of variance using SAS software (version 8 for Windows; SAS Institute, Cary, NC).

## 3. Results and Discussion

### 3.1. Secondary Growth and N Concentration in Different Tree Parts

From 2 weeks after the treatments, unnecessary secondary shoots started to grow for the CF but none for the LPM. Treating with either the low or the high level of CF produced secondary shoots by August 6 (Figure 1), exhibiting the final DWs of 3.4 and 2.9 g per tree, respectively. Table 3 shows N concentrations in different tree parts measured on August 6. N concentration was not significantly affected in all tree parts by different nutrient sources. However, N concentration was higher especially in shoots, old woods, and small roots at the high level of both CF and LPM. No occurrence of secondary shoot growth of the trees receiving LPM suggested that N uptake by those trees was slower than that by the



**Figure 1.** Shoot growth of 2-year-old “Fuyu” persimmons supplied with chemical fertilizer (left) or liquid pig manure (right) that contained 1.2 g nitrogen. No secondary shoots were grown when supplied with liquid pig manure. Photos were taken on Aug. 6.

**Table 3.** Nitrogen (N) concentration in different tree parts of 2-year-old “Fuyu” persimmon on August 6, 36 d after applications of chemical fertilizer (CF) and liquid pig manure (LPM) on July 1.

Treatment		Leaf	Aerial wood			Root	
Source	Level <sup>b</sup> (g/tree)		Shoot	2 <sup>nd</sup> shoot	Old wood	Small	Large
N (% DW)							
CF <sup>a</sup>	Low	2.17 ± 0.04	0.97 ± 0.07	1.56 ± 0.1	0.51 ± 0.01	0.96 ± 0.08	0.86 ± 0.16
	High	2.20 ± 0.02	1.18 ± 0.09	1.58 ± 0.1	0.73 ± 0.06	1.43 ± 0.29	0.97 ± 0.13
LPM	Low	1.96 ± 0.07	0.78 ± 0.07	-	0.59 ± 0.06	1.13 ± 0.07	0.59 ± 0.11
	High	2.12 ± 0.15	1.06 ± 0.08	-	0.70 ± 0.04	1.41 ± 0.10	0.90 ± 0.11
Source (S)		NS	NS		NS	NS	NS
Application level (L)		NS	*		**	*	NS
S × L		NS	NS		NS	NS	NS

<sup>a</sup>CF: fertigated with urea and potassium chloride (KCl) solution; <sup>b</sup>Levels (g/pot): low, 1.2N - 1.15K; high, 2.4N - 2.3K. Data represented are means ± SE (n = 3). NS: non-significant, \*: significant at P ≤ 0.05, \*\*: significant at P ≤ 0.01.

trees receiving CF. Excessive N uptake during summer would cause vigorous growth of water sprouts and secondary shoots with the concurrent deterioration of fruit quality [11] [18]. It appeared that LPM could be more favorable to keep tree vigor stable than CF as long as the method for its application was carefully controlled in terms of the time and quantity.

### 3.2. Nitrogen Partition in a Tree

**Table 4** shows the amount of N absorbed and distributed to different tree parts between July 1 and August 6. Two nutrient sources did not significantly affect the amount of N increase in different tree parts. Of the total aerial wood, N in secondary shoots accounted for 28% at the low and 17% at the high CF. At the high level of both CF and LPM, N increase tended to be higher in all tree parts except secondary shoots. A significant N increase was observed in the leaves (P = 0.044) and large roots (P = 0.027) at the high level of application. Total N was 80% more for the CF (551 vs. 993 mg) and 31% more for the LPM (582 vs. 766 mg per tree) at the high level. Considering that the trees that received LPM absorbed a similar amount of N to the ones that received CF (**Table 4**), LPM could be an acceptable supplemental source of nutrients as has been previously reported for nectarine [8] and pear [9]. Total N content per tree increased more with the high level of both LPM and CF, however, the extent of the increase was less with LPM than with CF. It appeared that, unlike CF, N in LPM was not readily available for the tree since it mostly exists in organic forms and it would require some time to mineralize them [3] [19].

### 3.3. Chemical Properties of Soil

It is of interest whether the LPM application changes chemical properties of the soil at the end of the experiment. The soil that received LPM contained more organic matter, available P, and exchangeable K<sup>+</sup> and Mg<sup>2+</sup> than the soil that received CF (**Table 5**). Organic matters in the LPM soils increased by 10 and 24%

**Table 4.** Nitrogen (N) increase in different tree parts of 2-year-old “Fuyu” persimmon for 36 d after applications of chemical fertilizer (CF) and liquid pig manure (LPM) on July 1. The N increase was calculated from N contents in different tree parts between July 1 and Aug. 6 by taking the concentration of N in the tree parts and their dry weights.

Treatment		Leaf	Aerial wood				Root			Total
Source	Level <sup>b</sup>		Shoot	2 <sup>nd</sup> shoot	Old wood	Total	Small	Large	Total	
N (mg/tree)										
CF <sup>a</sup>	Low	218 ± 4	68 ± 10	53 ± 14	65 ± 26	186 ± 44	8 ± 54	138 ± 10	147 ± 43	551 ± 36
	High	326 ± 34	77 ± 20	47 ± 21	148 ± 43	272 ± 84	218 ± 82	176 ± 14	395 ± 93	993 ± 175
LPM	Low	212 ± 30	69 ± 25	0	97 ± 28	166 ± 32	101 ± 32	104 ± 19	205 ± 38	583 ± 58
	High	278 ± 26	87 ± 19	0	111 ± 3	198 ± 17	140 ± 51	150 ± 19	290 ± 68	766 ± 75
Source (S)		NS	NS	**	NS	NS	NS	NS	NS	NS
Application level (L)		*	NS	NS	NS	NS	NS	*	*	*
S × L		NS	NS	NS	NS	NS	NS	NS	NS	NS

<sup>a</sup>CF: fertigated with urea and potassium chloride (KCl) solution; <sup>b</sup>Levels (g/pot): low, 1.2N - 1.15K; high, 2.4N - 2.3K. Data represented are means ± SE (n = 3). NS: non-significant, \*: significant at P ≤ 0.05, \*\*: significant at P ≤ 0.01.

**Table 5.** Chemical properties of pot soils sampled on Aug. 6 as affected by applications of chemical fertilizer (CF) and liquid pig manure (LPM) on July 1 on 2-year-old “Fuyu” persimmons.

Treatment		pH	Organic matter (g·kg <sup>-1</sup> )	Total N (g·kg <sup>-1</sup> )	Available P (mg·kg <sup>-1</sup> )	Exchangeable cation (cmol <sup>+</sup> ·kg <sup>-1</sup> )		
Source	Level <sup>b</sup>					K	Ca	Mg
CF <sup>a</sup>	Low	7.4 ± 0.1	39.2 ± 4.4	1.28 ± 0.32	138 ± 37	0.151 ± 0.02	11.8 ± 1.6	1.58 ± 0.12
	High	7.3 ± 0.0	37.3 ± 1.0	1.20 ± 0.20	155 ± 4	0.122 ± 0.01	10.3 ± 1.0	1.42 ± 0.11
LPM	Low	7.4 ± 0.0	43.0 ± 2.6	1.85 ± 0.06	278 ± 58	0.266 ± 0.08	11.4 ± 0.8	1.88 ± 0.18
	High	7.4 ± 0.1	46.1 ± 1.4	1.74 ± 0.02	328 ± 13	0.607 ± 0.08	9.8 ± 0.4	1.93 ± 0.05
Source (S)		NS	*	NS	**	**	NS	**
Application level (L)		NS	NS	NS	NS	*	NS	NS
S × L		NS	NS	NS	NS	**	NS	NS

<sup>a</sup>CF: fertigated with urea and potassium chloride (KCl) solution; <sup>b</sup>Levels (g/pot): low, 1.2N - 1.15K; high, 2.4N - 2.3K. Data represented are means ± SE (n = 3). NS: non-significant, \*: significant at P ≤ 0.05, \*\*: significant at P ≤ 0.01.

at the low and high levels, respectively, compared with those of the respective CF. Contents of available P and exchangeable K<sup>+</sup> for the LPM were 1.8 ~ 5-fold higher than those for the respective CF. Higher total N content was also observed in the LPM soils although not statistically significant. High contents of organic matter in the LPM soil on August 6 (Table 5) indicated that much of the organic matter still remained undecomposed in the soil by that time. Soil organic matters could slowly release inorganic nutrients through mineralization, the process of which helps to decrease the extent of nutrient leaching from irrigation [19]. Therefore, it is probable that the soil organic matter from the LPM could have contributed to significant increases of total N, available P, and exchangeable K<sup>+</sup> and Mg<sup>2+</sup> in the soil.

## 4. Conclusion

It is concluded that N in LPM becomes available later but its effect is more durable than CF. LPM application, adjusted to spread earlier in time and less in quantity, should thus be a satisfactory substitute for supplemental N supply in persimmon growing. More studies are needed to optimize the time and quantity of LPM under orchard conditions.

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