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# Effects of Alum Sludge Application on Root Growth of Forage Sorghum (*Sorghum bicolor* × *S. bicolor*) Cultivated in Mountainous *Kumsan* District

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## Abstract

Forage sorghum (*Sorghum bicolor* × *S. bicolor*) was cultivated for knowing the effect of alum sludge application on its root growth in a mountainous site, *Kumsan*. And the results obtained are as follows:

The available $P_2O_5$ content in the soil seemed to decrease with the advance of level of alum sludge application. And plant P content decreased with the advance of sludge application without phosphate fertilizer.

With phosphate fertilizer, root number of the forage was greater than that without the fertilizer.

The root growth of forage sorghum was the highest with NPK and the least in control and alum application, and it is not recommended to apply NPK and alum together for the growth of the forage root.

(**Key words** : Root, Sorghum, Mineral, Sludge, Kumsan)

## I. Introduction

We have previously reported effects of alum sludge application on the growth of forage sorghum (*Sorghum bicolor* × *S. bicolor*) (Kim et al., 1997). It is necessary to investigate the effect of the sludge on root growth of the forage sorghum and also to know the effect of alum sludge with or without phosphate fertilizer on the growth of sorghum root.

In such a mountainous site as *Kumsan* their effects of fertilizer might be different to the growth of forage crops because of its significant difference of fertility of humus content, phosphate ($P_2O_5$) status, acidity status, lime requirement status, potassium (K) supply, magnesium supply and of cation exchange capacity in Korean woodland (Weinberger et al., 1983). In Korea, roughly two thirds are not even over 300m high, and 300~600 m in altitude was around 20% of total territory (Weinberger et al., 1983). It was considered to be necessary to study the influence of altitude on the growth of forage crops when fertilizer or organic material like sludge was applied to the field. And it is inevitable to study the effect of sludge application on the plant growth whether the effect is positive or negative (Chang et al., 1992; Chang et al, 1993), in order to use such wastes as sludge from water supply treatment plants to agricultural soil without much hazard (Sparks, 1995). It was thought that the effect of applying such wastes as alum sludge easily appear on root growth, and it is known that alum in the soil had an adverse effect for phophorus (P) utilization by plant (Mengel and Kirkby, 1978).

The present experiment was carried out at the site

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with an altitude of 260 meters in a mountainous *Kumsan* district. Forage sorghum was cultivated in the experimental field for the first time after its reclamation. The main purpose of the experiment was to know the effect of alum sludge on the root growth of forage sorghum with or without phosphate fertilizer.

## II. Materials and Methods

The experimental field was situated at a mountainous site with an altitude of 260 meters in Joongbu University, at *Kumsan* county in Chungchong Nam-do prefecture. The period of experiment was from May to November of 1993. The field was newly established on May 26, 1993. Alum sludge with or without phosphate fertilizer for *Experiment 1* and the sludge and/or NPK fertilizers for *Experiment 2* were applied on June 17 and on June 7, respectivley. The seeds of forage sorghum, Pioneer 931 (*Sorghum bicolor* × *S. bicolor* L.), were sown on June 23. And the forage roots were harvested on November 11, 1993.

We have carried out two experiments. The purpose of *Experiment 1* was to know the difference of root growth with or without phosphate ($P_2O_5$) fertilizer when alum sludge was applied to the forage sorghum. The *Experiment 2* was to know the effect of alum sludge application on the root growth with 4 treatments (Control, Alum, Alum+NPK and NPK) as shown in Table 1. The instruments used for analysing plant and soil mineral were as follows; potassium (K) was by flame photometry (Corning, Flame photometer 410), phosphorus (P) by spectrophotometry (Milton Roy, Spectronic 210) on a wavelength of 425 nm, calcium (Ca) and magnesium (Mg) by atomic absorption spectrometry (Shimadzu, AA 680) on their wavelength of 422.7 nm and 285.2 nm, respectively.

Statistical analyses were carried out conventionally (Son and Park, 1999). The other aspects for the present experiment (Kim et al., 1997) and the methods of chemical analyses were already written in our previous reports (Chang et al., 1992; Chang et al., 1993).

Table 1. The design of alum sludge experiments 1 and 2

| Treatment | Alum sludge* (ton/ha on a FW** basis) | Chemical fertilizer (kg/ha) |
|---|---|---|
| Experiment 1 (with 1 replicate) | | |
| Alum 1 | 57 | $P_2O_5$ = 0 |
| Alum 2 | 170 | $P_2O_5$ = 0 |
| Alum 3 | 283 | $P_2O_5$ = 0 |
| P + Alum 1 | 57 | $P_2O_5$ = 200 |
| P + Alum 2 | 170 | $P_2O_5$ = 200 |
| P + Alum 3 | 283 | $P_2O_5$ = 200 |
| Experiment 2 (with 3 replicates) | | |
| Control | 0 | 0 |
| Alum | 133 | 0 |
| NPK*** | 0 | $N:P_2O_5:K_2O$ = 200:200:200 |
| Alum + NPK | 133 | $N:P_2O_5:K_2O$ = 200:200:200 |

* : moisture content of alum sludge was 80%
** : fresh weight
*** : nitrogen (N), phosphorus (P) and potassium (K) fertilizers.

# III. Results and Discussion

Fig. 1 shows the experimental field, a mountainous site, in the campus of Joongbu University on October 23, 1993. The soil was dark and blackish as shown in the photograph. Kim et al. (1997) reported that alum sludge had higher content of exchangeable Ca, 11.6 $me/_{100g\ alum}$ and also contained a considerable level of available Al (2.2%).

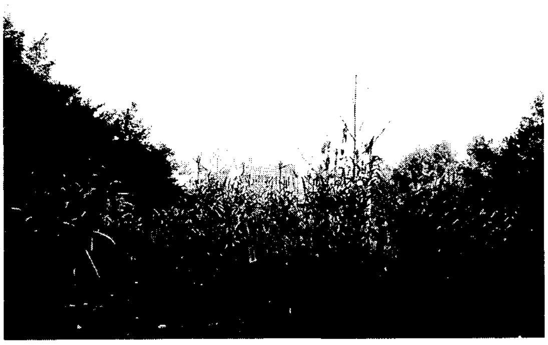

Fig. 1. Mountainous experimental field in the campus of Joongbu University.

**Experiment 1**

And Table 2 shows the effect of alum sludge and/or phosphate fertilizer application on chemical components of experimental soil. From the table we can see that the phosphate content in soil (71 ± 14 $ppm/_{100\ g\ soil}$) with phosphate fertilizer was more than the value of (57 ± 9 $ppm/_{100\ g\ soil}$) without the fertilizer. The available $P_2O_5$ content in the soil seemed to decrease with the advance of level of alum sludge application, and the tendency was more clear with the P fertilized condition (from 81 to 55 ppm) than that without the P fertilizer (from 63 to 46 ppm). From Table 2 the available $P_2O_5$ content in the experimental soil, 71 ppm, on 'Control' was lower than the value of 254 ppm in the reclaimed soil at *Taejon* near to *Kumsan* (Chang et al., 1992), and lower than 122 ppm after the growth of *Altari* radish (*Raphanus sativus* L.) at the soil of 'Control' plot at *Taejon* (Chang et al., 1993). The content of 77 ppm was similar value of 'very dark brown soil' of the Isle of *Jeju* (ASI, 1985).

The exchangeable Mg content increased with P fertilizer like that of available $P_2O_5$, while the K and Ca contents in the soil were higher on the condition without P fertilizer. The reason of advance

Table 2. Effect of alum sludge and/or phosphate (P) fertilizer application on chemical components of soil before (Sep. 2, 1993) and after the harvest (Nov. 11, 1993)

| Treatment \ Element | Av.* $P_2O_5$ (ppm) | Exch.** K | Exch. Ca | Exch. Mg |
|---|---|---|---|---|
| | | (mg/100g soil) | | |
| Before the harvest*** | 67 ± 7 | 9.1 ± 4.7 | 60 ± 29 | 7.0 ± 4.1 |
| After the harvest Control*** | 67 ± 12 | 9.0 ± 1.2 | 63 ± 35 | 11.7 ± 6.1 |
| 57 ton/ha | 63 | 7.3 | 155 | 6.1 |
| 170 ton/ha | 62 | 10.3 | 404 | 9.0 |
| 283 ton/ha | 46 | 15.5 | 460 | 10.3 |
| Mean*** (without P fertilizer) | 57 ± 9 | 11.0 ± 4.1 | 339 ± 162 | 8.4 ± 2.1 |
| P + 57 ton/ha | 81 | 9.6 | 246 | 16.6 |
| P + 170 ton/ha | 78 | 9.6 | 226 | 12.7 |
| P + 283 ton/ha | 55 | 9.3 | 376 | 14.1 |
| Mean*** (with P fertilizer) | 71 ± 14 | 9.5 ± 0.1 | 282 ± 81 | 14.4 ± 1.9 |

* : available
** : exchangeable
*** : mean ± standard deviation of 3 replicates.

of the Mg content in soil was possibly the Mg element in the P fertilizer. The exchangeable K content in the soil was higher when there had not been phosphate fertilizer. It is considered that the amount of forage production was greater with the P fertilizer (Table 4) and the growth of forage has taken the K from the soil (Kim et al., 1988). The exchangeable Ca content in the soil was same level before the experiment and 'Control' after the experiment. The mean value of the Ca content (339 mg) without phosphate fertilizer was higher than that with the fertilizer (282 mg/100 g soil) and the difference among the levels of sludge application with P fertilizer was more (155~460 mg) than those without P fertilization (246~376 mg /100 g soil). The reason of the difference of the Ca content between the two groups of treatment in the soil seemed to be similar to the exchangeable K content. Because the alum sludge contained considerable Ca, 11.6 me/100 g alum (Kim et al., 1997), the Ca content increased with the advance of sludge application.

Table 3 shows the effect of alum sludge and/or the P fertilizer application on chemical components of Pioneer 931 plant after the harvest. This presentation is not for root, but for top part of the plant. With P fertilizer application the K content of the top part of the forage sorghum decreased, while the Mg content of the part of the forage increased.

Without phosphate fertilizer P content of the plant, as shown in Table 2, decreased with the advance of sludge application, while the P content tended to increase with the advance of sludge application on the condition with phosphate fertilization. The reason of this different tendency was not explained clearly, but there might be a specificity of available $P_2O_5$ in sludge, for exemple, between dried and fresh conditions (Chang et al., 1993). At those higher levels of alum sludge application without phosphate fertilizer, much Al component might be responsible for the decrease of P uptake (Mengel and Kirkby, 1978). While the exchangeable Ca content in soil between the two groups (with and without phosphate fertilization) was different (Table 2), there was not difference between the plant Ca contents in this Table. The K and Mg contents of the plant had the same tendency with those in soil.

Though it was not shown in the Table, there was a close relation between top part and underground part (stubble + root) as a fresh weight basis ($r = 0.9167$, $n=N-2=4$, $P<0.05$). And Table 4 shows the

Table 3. Effect of alum sludge and/or phosphate (P) fertilizer application on chemical components after the harvest of the top part of Pioneer 931 plant (Nov. 11, 1993)

| Element / Treatment | P | K | Ca | Mg |
|---|---|---|---|---|
| | (mg/g plant, as a dry matter basis) | | | |
| Control | 0.98 ± 0.31 | 16.1 ± 1.5 | 11.6 ± 0.9 | 2.17 ± 0.27 |
| 57 ton/ha | 0.95 | 14.6 | 11.9 | 2.16 |
| 170 ton/ha | 0.83 | 17.0 | 8.6 | 1.96 |
| 283 ton/ha | 0.84 | 17.4 | 11.0 | 1.48 |
| Mean* (without P fertilizer) | 0.87 ± 0.06 | 16.3 ± 1.5 | 10.5 ± 1.7 | 1.86 ± 0.34 |
| P + 57 ton/ha | 0.85 | 11.8 | 11.1 | 2.10 |
| P + 170 ton/ha | 0.94 | 16.1 | 9.6 | 1.77 |
| P + 283 ton/ha | 0.91 | 11.9 | 11.3 | 2.33 |
| Mean* (with P fertilizer) | 0.90 ± 0.04 | 13.2 ± 2.4 | 10.6 ± 0.9 | 2.06 ± 0.28 |

* : mean ± standard deviation of 3 replicates.

effect of alum sludge and/or phosphate fertilizer on plant growth of Pioneer 931.

Though there was not significant difference between two groups of treatments, fresh yield of the (root + stubble) with phosphate fertilizer was more than 2 times. The more roots on (P + alum) might tell an effect to lessen the hazardous wastes from water supply treatment plants (Sparks, 1995) of phosphate fertilizer. But there was not significantly adverse effect of sludge on the root fresh weight. It can be said from these results that alum sludge has negative effect on the root growth principally at earlier stage with making root less numerous.

**Experiment 2**

Though data were not shown in the Table, in *Experiment* 2 there was a very close correlation between top part and underground part (stubble + root) as a fresh weight basis (r = 0.9513 **, n= 12-2=10).

Table 5 shows the effect of sludge and/or fertilizer application on the growth of underground part of Pioneer 931. The mean value of (root+stubble) fresh weight on 'Alum+NPK' was 5 times more than that on 'Control' or on 'Alum', and further the yield on NPK' was around twice to that on 'Alum+NPK'. The mean value of root number on 'Control', 'Alum' and on 'Alum+NPK'

Table 4. Effect of alum sludge and/or phosphate (P) fertilizer application(s) on root growth of Pioneer 931

| Treatment \ Item | Stubble + root weight (kg FW**/ha) | Number of root (number/plot) |
|---|---|---|
| Alum 57 ton/ha | 773 | 19 |
| Alum 170 ton/ha | 1,166 | 20 |
| Alum 283 ton/ha | 1,513 | 17 |
| Mean*** (without P fertilizer) | 1,150 ± 370a* | 18.6 ± 1.5a |
| P + alum 57 ton/ha | 5,206 | 23 |
| P + alum 170 ton/ha | 2,803 | 23 |
| P + alum 283 ton/ha | 3,450 | 23 |
| Mean*** (with P fertilizer) | 3,819 ± 1,243a | 23.0 ± 0.0b |

* : Different characters in the same column show significant difference ($P<0.05$).
** : Fresh weight
*** : Mean ± standard deviation of 3 replicates.

Table 5. Effect of alum sludge and NPK applications on root growth of Pioneer 931

| Treatment \ Item | Stubble + root weight (kg FW***/ha) | CV**** of weight(%) | Number of root (number/plot) | CV**** of number (%) |
|---|---|---|---|---|
| Control | 562 ± 413a** | 73 | 19.0 ± 2.6a | 13 |
| Alum | 615 ± 340a | 55 | 18.3 ± 4.7a | 25 |
| Alum + NPK* | 3,025 ± 1,452b | 48 | 18.3 ± 1.1a | 6 |
| NPK | 5,369 ± 889c | 16 | 24.6 ± 0.5b | 2 |

* : nitrogen (N) phosphorus(P) potassium(K)
** : Different characters in the same column show significant difference ($P<0.05$).
*** : Fresh weight
**** : Coefficient of variability; (standard deviation /mean) × 100
***** : Mean ± standard deviation of 3 replicates.

was nearly same, but the mean number on 'NPK' was significantly more than the other 3 treatments. On the other hand there was a wide variation of the (root + stubble) yield within same treatment, it was considered to the difference of the soil fertility (Fisher, 1920). The root weights on 'Alum' and on 'Alum+NPK' had smaller variations than that on 'Control' when compared with coefficient variability (CV). But alum sludge might not be recommended to apply with NPK. Because the weight of underground part was less on 'Alum+NPK' than that on 'NPK only', and the biggest CV for root number appeared on 'Alum'.

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