

Effect of the Application of Sucrose on Rapid Decrease of Soil Inorganic Nitrogen

Hyun-Hwoi Ku, Woo-Jin Lim, and Sang-Eun Lee*

Climate Change Research Center, Hankyong National University, Anseong, 456-749, Korea

To solve the problems with excessive accumulation of soil inorganic N and resulting saline soils from overuse of nitrogen fertilizer, the effect of sucrose application on decrease of soil inorganic N content and electrical conductivity (EC) was studied. Sucrose treatment greatly reduced NH_4^+ -N content in soil. The amount of reduction was greater as the amount of sucrose treatment was increased. When NH_4^+ -N content was reached the lowest point (about 10 mg kg^{-1} or lower), the C/N ratio, which determines the amount of sucrose treatment, was around 10 regardless of initial NH_4^+ -N content. For the rate of NH_4^+ -N reduction 15~36 hours was required to reduce the initial NH_4^+ -N content to half, and 36~69 hours to lower NH_4^+ -N content to the lowest point (about 10 mg kg^{-1} or lower). In addition, sucrose treatment greatly lowered NO_3^- -N content. In case of C/N ratio above 10, initial NO_3^- -N content of 348 mg kg^{-1} was reduced to the lowest of $14\sim 21 \text{ mg kg}^{-1}$. As for the rate of NO_3^- -N reduction by sucrose treatment, it took 36~60 hours for NO_3^- -N content to reach the lowest point for C/N ratio of 10 or higher; and it took 3 weeks, comparably longer time, for C/N ratio of 5. Lowering soil EC from sucrose treatment showed the same trend as NO_3^- -N content. As an important energy and carbon source for humankind, sugar should not be wasted and must be carefully applied to soil. In principle, the best way of preventing salt accumulation in soil is to optimize the fertilizer input. However, when over-fertilization should be dealt with, the sucrose treatment would be a possible and effective counter-measure to reduce overdosed nitrogen sources in soil.

Key words: Inorganic nitrogen, NH_4^+ -N, NO_3^- -N, Sucrose, C/N ratio

Introduction

In Korean agriculture, a greenhouse built with plastic film is very popular facility for the production of vegetable crops and flowers. It makes all-year-round cultivation of crops possible due to temperature control and gives a lot of benefits to farmers. However, chemical fertilizer and manures which are easily obtained from livestock industry are frequently over-applied into the field with a hope to maximize the productivity, which have actually increased accumulation of nutrients in soils. This unnecessary accumulation of nutrients not only causes a problem of salt accumulation but also decreases crop production. In addition, the excessive salts accumulated in soil moves downward along with irrigation water and has been found to cause underground water pollution (Spalding et al., 1993;

Jemison et al., 1994). When salts are accumulated in soil, hindrance in absorption of nutrient by elevated osmotic pressure of soil solution, unbalance among mineral elements, hampering of metabolism by excessiveness of specific salt, and hindered growth of plants by soil's physicochemical property deterioration are well known to be present (Bernstein, 1975 ; Van, 1984 ; Yun et al., 2010).

Hwang et al. (1993) suggested various methods for mitigating salinity of greenhouse soil, such as, washing method from flooding, diluting method by adding other fresh soil, method of removing soil nutrient by planting highly scavenging crops, and method using organic matter with high C/N ratio such as rice straw. However, every method suggested has some complication. The washing can cause groundwater pollution as a side effect. The dilution with addition of other soil is too laborious and expensive. The cultivation of scavenging crops is not economical to farmers. The application of organic matter with high C/N ratio is environmental-friendly method. However, the effect is quite slow due to slow digestion by microbes.

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*Corresponding author : Phone: +82316705085

E-mail: selee@hknu.ac.kr

Jung et al. (1994) presented, when organic matter with high C/N ratio is supplied in salt accumulated soil, soil microbe absorbs large amount of NO_3^- -N, which in turn has effect of reducing EC. Soil microbe is a living part inside of soil. It takes part in metabolism in soil by mineralization and immobilization of soil microbe. It is also a supplier and a storage of soil nutrients (Coleman et al., 1983 ; Paul et al., 1980). Inorganic-N in soil is important not only to plants but also in forming soil microbe's body.

In soil, plants and microbes absorb nitrogen in two forms, NH_4^+ -N or NO_3^- -N. Among them NH_4^+ -N is absorbed by plants faster compared to NO_3^- -N. However, when the concentration exceeds a certain level, it causes ammonium toxicity which is critically harmful to plant growth and this symptoms are reported to hinder water absorption when not fully decomposed organic matters or urea fertilizer are supplied in great order (Lee, 1984). Unfortunately, satisfactory methods for quickly recovering plants, damaged from ammonium toxicity, are unknown. Only the method is waiting for NH_4^+ -N concentration in rhizosphere to gradually drop caused by nitrification of nitrifier.

The purpose of this research is to identify a method to reduce excessively accumulated inorganic nitrogen and electrical conductivity of greenhouse soil by supplying sucrose that has advantageous characteristics, i.e., easy decomposability and thus better carbon and energy source for microbes than rice straw.

Materials and Methods

The effect of sucrose treatment on NH_4^+ -N in soil
Laboratory experiment was implemented to understand the change of soil NH_4^+ -N level from treatment of sucrose, which is easily decomposable and has high C content. Nitrogen was treated in 4 levels, NH_4^+ -N 50, 100, 150, and 250 mg kg^{-1} using NH_4Cl . Under each N level, C/N ratio was set according to Table 1, applying sucrose as carbon source. 60 g of sandy loam soil was placed in 100 ml plastic beaker. Solution of NH_4Cl and sucrose was applied to the soils according to table 1, together with distilled water which corresponds to 90% of field moisture capacity. Soils were well mixed and incubated for 4 days in 25°C incubator. Samples were collected in 2, 4, 8, 12, 18, 24, 36, 48, 72, and 96 hours respectively and NH_4^+ -N was analyzed. The experiment was conducted

Table 1. Treatment.

Rates of NH_4^+ -N (mg kg^{-1})	C/N ratio
50	Control, 5, 10, 20, 40, 80
100	Control, 5, 6, 8, 10, 12, 15, 20, 30
150	Control, 6, 8, 10, 12, 15, 20, 30
250	Control, 2, 4, 6, 16, 32

with 3 replicates.

The effect of sucrose treatment on NO_3^- -N and EC value of salt-accumulated soil
The content of NO_3^- -N in greenhouse sandy loam soil used in this experiment was 348 mg kg^{-1} and EC value was 5.03 dS m^{-1} , indicating salt accumulated soil. 550 g of soil was placed in 1000 mL plastic beakers and sucrose stock solution was applied to the soil in each beaker according to the treatment levels of C/N ratio which were control, 5, 10, 15, 20, and 30, together with distilled water which corresponds to 90% of field moisture capacity. They were placed in 25°C incubator for 5 weeks. During the incubation, water loss was replenished every week by weighing the amount lost and adding the exact amount of water. The soil was analyzed for NO_3^- -N, pH, and EC by taking samples from the soil incubated over 12, 18, 24, 36, 60, 72, and 96 hours, and also 1, 2, 3, 4 and 5 weeks. All the experiments were conducted with 3 replicates.

NH_4^+ -N and NO_3^- -N of soil were extracted by 2M-KCl. NH_4^+ was analyzed using spectrophotometer by Indophenol blue method (Aminot et al., 1997). NO_3^- -N was analyzed with U/V visible spectrophotometer.

Results and Discussion

The effect of sucrose treatment on NH_4^+ -N reduction
Without sucrose treatment (control), the reduction of NH_4^+ -N content was negligible over the experimental period. However, in the case of sucrose treatment, NH_4^+ -N content rapidly and significantly dropped compared to control. The rate of NH_4^+ -N reduction was very fast. It took for treated NH_4^+ -N content to drop to half of the original level were only 15, 18, and 36 hours respectively in 50, 100, 150, and 250 mg NH_4^+ -N kg^{-1} treatment levels. Also, the times for NH_4^+ -N content to reach the lowest point were only 36, 48, 72, and 96 hours respectively, in 50, 100, 150, and 250 mg NH_4^+ -N kg^{-1} treatment levels

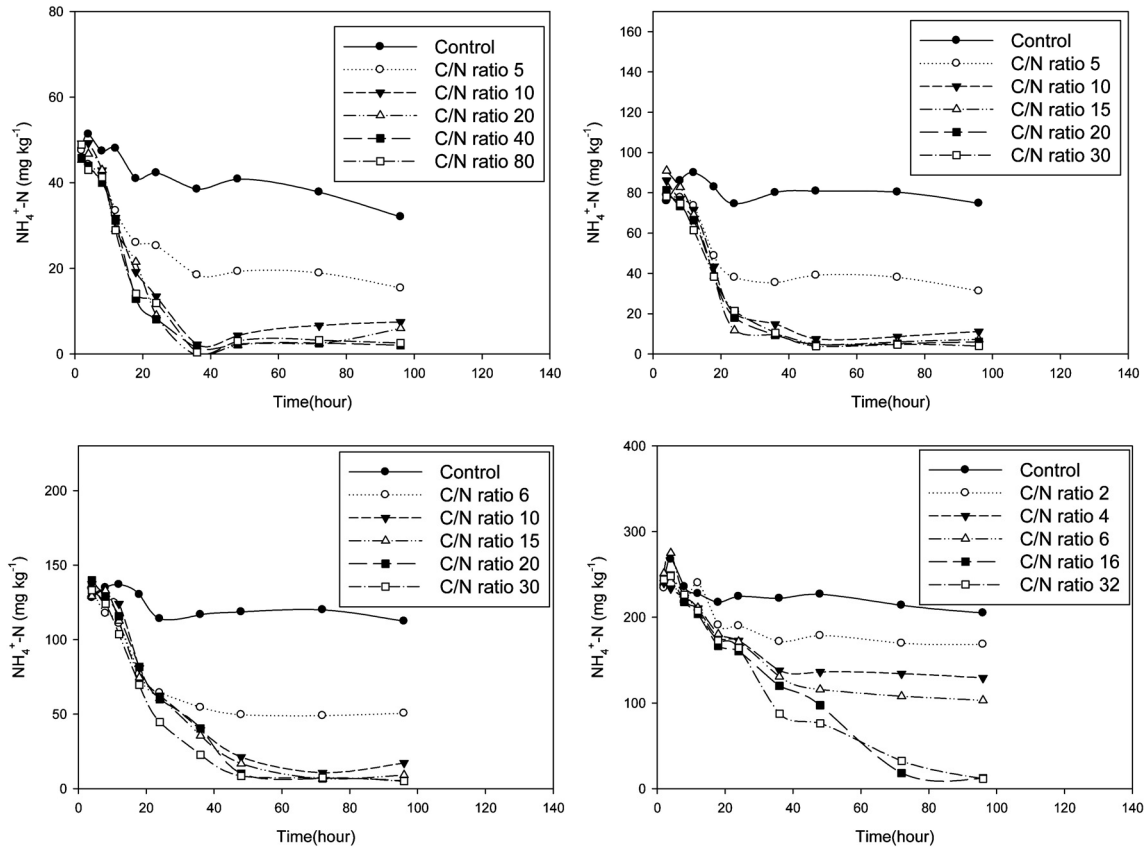


Fig. 1. Effect of sucrose treatment on rapid decrease in soil ammonia contents.

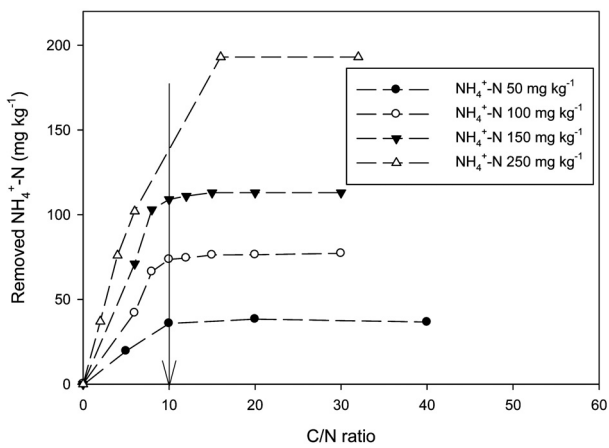


Fig. 2. Effects of C/N ratio on the removal of $\text{NH}_4^+\text{-N}$ from soil. C/N ratio was adjusted by the application of sugar. The arrow indicates that the threshold value of C/N ratio, which showed the largest $\text{NH}_4^+\text{-N}$ removal, was around 10.

(Fig. 1). The effect of decrease was greater as sucrose treatment level was greater, meaning high C/N ratio treatment. From the overall $\text{NH}_4^+\text{-N}$ levels, the lowest $\text{NH}_4^+\text{-N}$ content reachable by sucrose treatment was less than 10 mg kg^{-1} in general. The threshold value of C/N ratio, which showed the largest $\text{NH}_4^+\text{-N}$ removal was

around 10 (Fig. 2). It is very interesting to notice that this value coincides with C/N ratio of microbe used as a parameter among N simulation models (Jung et al., 1994).

These observations strongly indicate that supplying carbon source, which is easily decomposable and exploited by soil microbe such as sucrose, to soil reduces inorganic N content in soil rapidly in indirect manner. The reason why the term ‘indirect manner’ is used is because soil microbes swiftly absorb soil inorganic N into their bodies for their growth and indirectly resulted in the decrease of inorganic N in the soil. Soil microbes essentially need a certain level of inorganic N for the rapid synthesis of metabolites, triggered by the supply of good carbon source.

The effect of sucrose treatment on the reduction of $\text{NO}_3^-\text{-N}$ contents and EC value of salt-accumulated soil
 Without sucrose treatment, the soil $\text{NO}_3^-\text{-N}$ content was remained around 347~449 mg kg^{-1} throughout the experimental period and this value was rather higher than 348 mg kg^{-1} of original soil before incubation (Fig. 3). However, with sucrose treatment, $\text{NO}_3^-\text{-N}$ content rapidly dropped and the amount removed was greater as the amount of sucrose treatment was greater.

Meanwhile, the time NO_3^- -N content took to reach the lowest point was different depending on the sucrose treatment. That is, it took 36–60 hours to record comparably low lowest point of 14–21 mg kg^{-1} when sucrose treatment was higher than C/N ratio 10, while more than 3 weeks were taken to record comparably high lowest point of 66 mg kg^{-1} in case of treatment of C/N ratio 5. Looking back at the results from experiment, C/N ratio under 10 reaching a stable level before 96 hours, implies that it is not a good idea to assume it will reach the lowest point rapidly and stay this way for certain period of time.

Meantime, NO_3^- -N content, reduced temporarily by sucrose treatment, gradually increased after around 3 weeks, regardless of the amount of sucrose treatment. Microbes' vigorous growth continued for 3 weeks and thereafter growth could no longer continue and become extinct due to exhaustion of carbon or nitrogen nutrition. NO_3^- -N was again produced from microbe's autolysis and this seems to be the reason for specific change in NO_3^- -N content in soil.

Rapid decrease of NO_3^- -N in soil from sucrose treatment is the results of the process where soil microbe acquires inorganic-N, required in great amount for microbe growth, from soil when easily decomposable carbohydrates (EDC) is supplied to soil. This can be seen by the same mechanism of rapid decrease of soil NH_4^+ -N content explained in previous chapter, because soil microbes' main nitrogen sources are NH_4^+ and NO_3^- ions.

Without sucrose treatment, soil EC maintained high level of 4.0–5.5 dS m^{-1} , while sucrose treatment rapidly decreased EC value and recorded low level of 2.2–2.8 dS m^{-1} at 5 weeks after start of the experiment (Fig. 4). The greater amount of sucrose treatment was implemented, the greater was the effect of EC decreased. That is, while it took only 60 hours to reach 1.8–1.9 dS m^{-1} for C/N ratio of 10 or above, it took 3 weeks for C/N ratio of 5 to reach the lowest point of 2.1 dS m^{-1} .

Meanwhile, the trend in change of soil's EC depending on sucrose treatment followed exactly that of NO_3^- -N's trend. This observation is in agreement with previous works reporting that NO_3^- -N content is closely related to EC value in Korean greenhouse soil (Jung et al., 1998 ; Kowalenko, 1980). To conclude from the above results, it is easy to say sucrose treatment is an effective measure to lower soil EC.

Hence, when EDC like sucrose is incorporated to soil, soil microbes rapidly absorb soil NO_3^- -N for growth, resulting in quickly lowering NO_3^- -N content and therefore

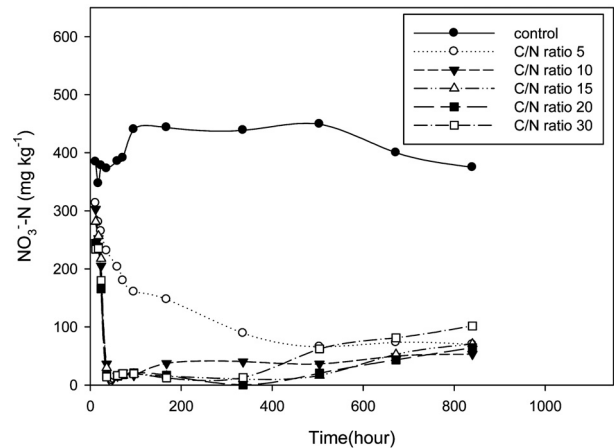


Fig. 3. Effect of sucrose on nitrate decrease in saline soil.

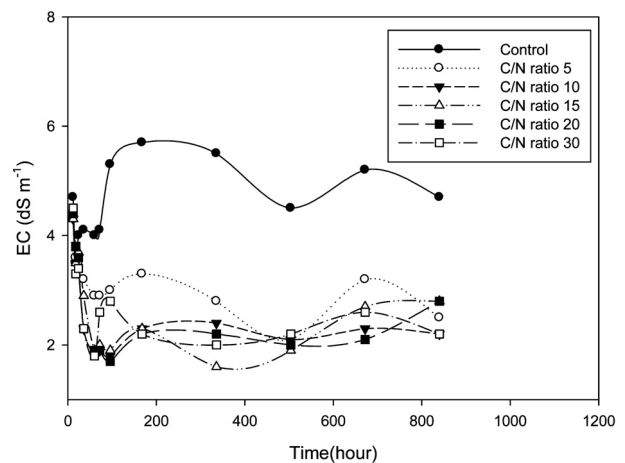


Fig. 4. Effect of sucrose on rapid decrease in electrical conductivity (EC).

indirect effect of soil EC reduction was achieved in correlation with reduction of NO_3^- -N content. For this reason, EDC treatment such as sucrose can be a fast and economical measure to reduce EC in greenhouse salt-accumulated soil that shows great correlation between NO_3^- -N content and EC. However, as pointed earlier, the fact that NO_3^- -N content and EC start to increase 3 weeks after the treatment from microbe autolysis. This implies that sucrose treatment is a temporary measure of locking NO_3^- -N inside of microbe rather than complete removal of NO_3^- -N.

Hence, taking this property of EDC treatment effect into account, an efficient treatment measure needs to be studied. That is, to maintain appropriate level of NO_3^- -N content and EC in soils with high NO_3^- -N content and EC, periodic EDC treatment over certain period is required and the amount of treatment and time for this purpose need to be set up well.

As a matter of fact, the authors have hesitated to publish the results that application of sugar could effectively reduce the inorganic N contents and EC value in salt-accumulated soil. The reason is that the sugar is an important energy and carbon source for humankind and it should not be wasted by applying to soil except special case. The best way of preventing salt accumulation in soil is to decrease the fertilizer input rather than implementing various counter-measures to deal with already accumulated salts in soil from over-fertilization. The excessive accumulation of inorganic N in soils can be avoided by proper application of inorganic and organic N fertilizers through soil diagnosis. However, in a case that an inevitable treatment is required to reduce nitrogen level in soil, the sucrose treatment would be an efficient measure.

Conclusion

In Korea, greenhouse built with plastic film is a very popular facility for the production of vegetable crops because of cold winter season of the country. However, soils isolated from outdoors are easy to accumulate salts, especially inorganic nitrogen, by excessive use of chemical fertilizers and manure. Various methods for mitigating salinity of greenhouse soils have been suggested, but not so satisfactory. Therefore, still alternate method to solve the problem that is economical and environment-friendly, is urgently needed.

From this study, sucrose application was found to be an effective measure in speed and extent to reduce the inorganic nitrogen contents and EC of salt accumulated soils. The C/N ratio was considered to be a standard to determine the rate of sucrose application. The critical level of C/N ratio was 10, above which no further effect was expected. Sucrose is one of easily decomposable carbohydrates (EDC) that are nice carbon sources for microbes. There are many kinds of EDC in the world. In future, more economical EDC substances than sucrose are needed to be examined. Because sugar is an important energy and carbon source for humankind and it should not be wasted by applying to soil. The best way of preventing salt accumulation in soil is to decrease the fertilizer input by soil diagnosis rather than implementing various counter-measures to deal with already accumulated salts in soil from over-fertilization.

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Sucrose 처리가 토양 무기태질소의 신속 감소에 미치는 영향

구현회 · 임우진 · 이상은*

한경대학교 기후변화연구센터

질소 비료 과용에 의한 토양 무기태 질소의 과다 축적과 그에 따른 염류 집적이 심각한 시설원에 토양의 문제점을 해결하기 위하여, C/N율이 높은 이분해성 탄수화물의 사용이 토양 무기태 질소 함량과 전기전도도 감소에 미치는 영향을 실내 실험을 통하여 검토하였다. sucrose의 처리는 토양 NH_4^+ -N 함량을 크게 감소시켰는데, 감소량은 sucrose 처리량이 많을수록 컸으며, NH_4^+ -N 함량을 최저점 (약 10 mg kg^{-1} 이하)에 도달하게 할 수 있는 sucrose 처리량은 최초의 NH_4^+ -N 함량에 관계없이 C/N율로 약 10부근이었다. sucrose 처리는 토양 NH_4^+ -N 함량을 매우 빠르게 감소시켰는데, 최초 NH_4^+ -N 함량 $50\sim 250 \text{ mg kg}^{-1}$ 을 $1/2$ 로 감소시키는데 $15\sim 36$ 시간이 걸렸으며, 최저점 (약 10 mg kg^{-1} 이하)으로 감소시키는 데에는 $36\sim 69$ 시간이 걸렸다. sucrose 처리는 토양 NO_3^- -N 함량을 큰 폭으로 감소시켰는데, 감소량은 처리량이 많을수록 컸으며, sucrose 처리량이 C/N율로 10 이상인 경우에는 최초 348 mg kg^{-1} 이었던 NO_3^- -N 함량이 최저 $14\sim 21 \text{ mg kg}^{-1}$ 으로 감소하였다. sucrose 처리는 토양 NO_3^- -N 함량을 매우 빠르게 감소시켰는데, 토양 NO_3^- -N 함량을 최저점으로 감소시키는데 걸리는 시간은 sucrose 처리량이 C/N율로 10이상인 경우에는 $36\sim 60$ 시간이 걸렸으며, 처리량이 C/N율 5로 적었던 경우에는 3주로서 상대적으로 긴 시간이 걸렸다. sucrose 처리에 의한 토양 EC의 감소는 NO_3^- -N 함량의 감소와 같은 양상을 보였다. 이 논문의 결과를 응용함에 있어서 명심해야될 사항이 있다. 설탕은 인류에게 에너지와 탄소 원(原)을 공급하는 매우 중요한 자원이므로 특별한 경우가 아니면 토양에 사용하는 것을 피해야 한다. 토양의 염류집적을 막는 최선의 방법은 시비량을 줄이는 일이며, 염류가 집적된 후에 여러 대응방안을 강구하는 것은 사후약방문(死後藥方文)에 불과하다.