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Influence of K^+、Na^+ and HCO_3^- on Photosynthesis of Soybean Seedlings

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Strictly as per the compliance and regulations of :

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I. Introduction

CO_2 is the raw material of photosynthesis, the optimal concentration of plant photosynthesis is about 1000 μ l/l, but the C3 plants need a concentration of 800μ l/l to1600 μ l/l. The main source of carbon of Terrestrial plants are from the CO_2 in the air ; the CO_2 content is about 360 μ l/l in the air and it cannot meet the need of plant photosynthesis, so improve the CO_2 content will increase Plant photosynthesis rate obviously. Now the atmospheric CO_2 concentration is too high, has brought all kinds of destruction to the human environment. It is a subject of realistic meaning and theoretical significance, that how to increase the carbon sources scientifically and avoid the side effects to the environment. In recent years, a lot of reports in the literature use soybean (Han Wang, et al., 2008), rice (Liying Zhang, et al.,2007) and cucumber (Yanan Xing, et al.,2006) seedlings as test materials, $KHCO_3$ is sprayed on the leaves of them and increased Plant photosynthesis rate. The test is based on the work of Han Wang et al. (2008), explore the influence of K^+ and Na^+ on soybean seedlings photosynthesis, Rubisco content, PEPC vigor and electronic transfer from ion level, and provide the theoretical bases for the application of $KHCO_3$ in soybean production.

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II. Material And Method

a) Experiment Design

Experimental product is "Tie feng 31" soybean seedlings. Firstly clean the seeds, then soak seeds and evenly tiles them in big petri dishes (two layer of wet gauze are laid in the bottom and top), the sprout will be expedited in incubator having 30℃ constant temperature. About two days later, choose seeds with the same length of bud, plant them in lymph plate which has many holes cultivate them in the artificial incubator. When the soybean seedlings grows to the first pair leaves expand, divide the seedling plate and transplant them into larger flowerpot, until the the second piece ternate leaves expand that can be used as experimental material.

The experiment has three treatments (act three times): No.1, clear water comparison treatment;No.2, 1500mg/L $KHCO_3$ water-soluble fluid treatment; No.3, 1500mg/L $NaHCO_3$ water-soluble fluid treatment. To spray on the leaves of the first and the second period of soybean separately with watering can (causing solution to form even and close distribution on leaf blade surface), when the second piece ternate leaves expand. Process-time is 4 PM around. Six days later, using the first and second piece ternate leaves as the experimental materials to mensurate photosynthetic physiology indexes. The $KHCO_3$ and $NaHCO_3$ both produced in shenyang chemical reagent factory.

b) Measuring Items and Method

Determine photosynthetic rate by Oxygen electrode. The equipment of dissolved oxygen is that domestic CY-Ⅱ of measuring oxygen gauge as host, matched with reaction cup, magnetic mixer, the constant temperature water-bath water, automatic recorder, light source etc. Soluble sugar content refers refers to the methods of Xianzheng Zhang (1992), that Anthracene ketone method. Chlorophyll a (Chla), chlorophyll b (Chlb), chlorophyll total amount (Chl a + b) and carotenoids (CTK) use Arnon method. Photosynthetic electron transfer rate refers to the methods of Qilin Chen et al. (2000) and Chunmei Wang et al. (2000). ATP enzyme activity refers to the methods of HeshengLi (2000). Rubisco enzyme content is Determined by MaSiLiang LAN G-250 method. PEPC activity refers to the methods of Fusheng Feng et al. (1992) and Yonghua Dong et al. (1995).

Global Journal of Science Frontier Research (C) Volume XIII Issue III Version I Year 2013

c) Data Analysis

Using the Excel 2003 and SPSS 13.0 analyze data.

III. Result And Analysis

a) Soluble Sugar Content

From Figure 1, we can obtain that $KHCO_3$ treatment and $NaHCO_3$ treatment both increase the soluble sugar content of soybean seedlings. Among them, compared with CK, $KHCO_3$ treatment and $NaHCO_3$ treatment were increased by 74.65% and 38.03% respectively. It show that their joint HCO_3^- have increased the soluble sugar content, and the promoting function of K^+ is higher than Na^+.

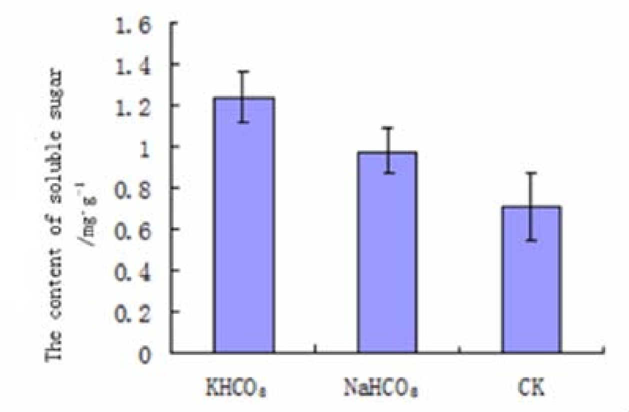

Figure 1 : Effects of Na^+, K^+ and HCO_3^- on soluble sugar content of soybean seedlings leaves

b) Photosynthetic Pigment Content

From Figure 1, we can obtain that $KHCO_3$ treatment and $NaHCO_3$ treatment both increased the Chla, Chlb, Chl a + b and CTK content. Compared with CK, $KHCO_3$ treatment and $NaHCO_3$ treatment result in the Chla increased by 4.63% and 0.94%, the Chlb increased by 21.86% and 4.33%. It shows that the promoting function of K^+ is higher than Na^+.

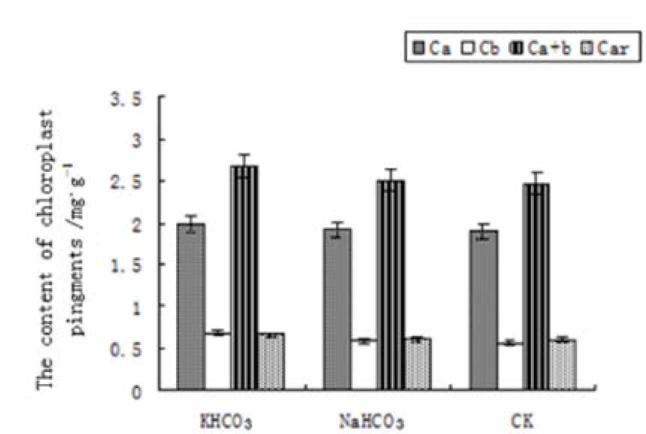

Figure 2 : Effects of Na^+, K^+ and HCO_3^- on photosynthetic pigments content of soybean seedlings leaves

c) Photosynthetic Electron Transport Rate

From Figure 3, we can obtain that $KHCO_3$ treatment and $NaHCO_3$ treatment both increased photosynthetic electron transport rate of soybean seedlings from different degree. Compared with CK, $KHCO_3$ treatment and $NaHCO_3$ treatment were increased by 23.66% and 20.1% respectively. It show that their joint HCO_3^- have increased the photosynthetic electron transport rate and the promoting function of K^+ is higher than Na^+.

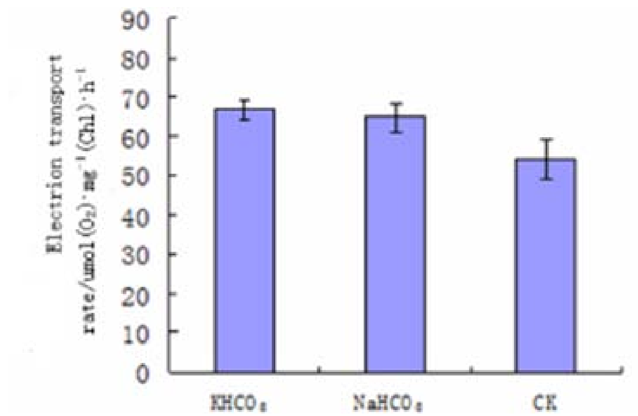

Figure 3 : Effect of Na^+, K^+ and HCO_3^- on the electron transport rate of soybean seedlings leaves

d) ATP-Enzyme Activity

From Figure 4, we can obtain that $KHCO_3$ treatment and $NaHCO_3$ treatment both increased ATP-enzyme activity of soybean seedlings, it show that $KHCO_3$ and $NaHCO_3$ have the function of acceleration. The function of acceleration of $KHCO_3$ is more than $NaHCO_3$, it means that $HCO_3^-$is the main factor and the next is K^+. In addition, $KHCO_3$ can increase the level of photophosphorylation, promote the photosynthetic electron transport.

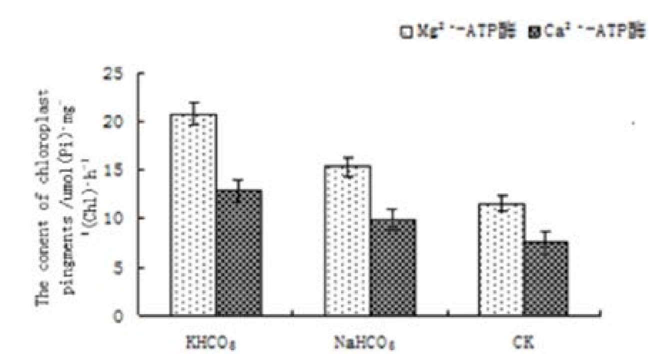

Figure 4 : Effects of Na^+, K^+ and HCO- on ATP-enzyme activity of soybean seedlings leaves

e) Rubisco Content

According to Table 1, compared with CK, $KHCO_3$ treatment made the Rubisco content decreased by 5.17% and $NaHCO_3$ treatment made the Rubisco content increased by 30.02%, it means that K^+ may have the inhibition to Rubisco biosynthesis. Compared with CK, $KHCO_3$ treatment causes the Rubisco containing in the soluble protein to reduce 18.06%, and reduce 28.21% compared with $NaHCO_3$ treatment. From the above statement we can obtain that K^+ can increase the soluble protein, it has a effection on Rubisco biosynthesis but possibly increases other protein synthesis, decrease the Rubisco percentage in the soluble protein.

Table 1 : Effects of Na^+, K^+ and HCO_3^- on content of Rubisco of soybean seedlings leaves

Treatment	Rubisco content	Δ%	RubiscoOccupies soluble protein the percentage（%）	Δ%
$KHCO_3$	5.9270±1.1030	-5.17	35.29	-18.06
$NaHCO_3$	8.1260±2.2016*	30.02	49.16	14.14
CK	6.2500±1.1450	-----	43.07	-----

* means significant difference compared with CK ($P<0.05$), the same below

f) PEPC-Enzyme Activity

According to Table 2, $KHCO_3$ treatment and $NaHCO_3$ treatment both increased PEPC-enzyme activity and PEPC-enzyme specific activity obviously. Compared with CK, the PEPC-enzyme activity increased by 45.60% and 36.99% respectively, the PEPC-enzyme specific activity increased by 44.38% and 33.16% respectively. It means that their joint HCO_3^- have increased PEPC-enzyme activity and PEPC-enzyme specific activity obviously, and the promoting function of K^+ is higher than Na^+.

Table 2 : Effects of Na^+, K^+ and HCO_3^- on PEPC enzyme activities of soybean seedlings leaves

Treatment	Enzyme activity/nmol·mL^{-1}·min^{-1}	Increment/%	Enzyme specific activity/nmol·μg^{-1}·min^{-1}	Δ%
$KHCO_3$	7.1200±1.0274*	45.60	5.3700±0.6588*	36.99
$NaHCO_3$	7.0600±0.8326*	44.38	5.2200±0.8532*	33.16
CK	4.8900±0.9266	--------	3.9200±0.6285	-------

g) Photosynthetic Rate

According to Table 3, compared with CK, $KHCO_3$ treatment and $NaHCO_3$ treatment both increased photosynthetic rate. The acceleration of $KHCO_3$ treatment on soybean seedlings photosynthetic rate is the highest, it increased by 13.20% compared with CK and 6.85% compared with $NaHCO_3$. It indicates that the promoting function of K^+ is higher than Na^+, their joint HCO_3^- plays the main role, HCO_3^- can promote the photosynthesis for that reason that as a carbon source in photosynthetic carbon cycle.

Table 3 : Effects of Na^+、K^+和HCO_3^- on photosynthetic rate of the leaf of soybean seedlings

Treatment	photosynthetic rate/μmol.m^{-2}s^{-1}	Δ%
$KHCO_3$	9.5200±0.3233*	13.20
$NaHCO_3$	8.9100±0.1386	5.95
CK	8.4100±0.1848	——

IV. Conclusion and Discussion

Potassium can promote chlorophyll biosynthesis effectively (Bingsong Zheng, 2002), $KHCO_3$ can also improve plant chlorophyll content (YingchangLi, et al., 2006). The study shows that, HCO_3^- and K^+ both can improve the Chla, Chlb and Chl a + b content, and improve the primary reaction of photosynthesis. According to the rearch of Lihua Rao et al. (1989), it will reduce the speed of photosynthetic product output, photosynthesis and lower yields, Damaged chloroplasts, when the potassium is excessive. This study did not appear this phenomenon, the reason maybe that the potassium is not excessive, that is to say the concentration of $KHCO_3$ is the optimal and reduce the damage of chloroplasts greatly.

According to the rearch of Bingsong Zheng (2006), spraying appropriate concentration of potassium can increase Chloroplast grana, photosynthetic electron transport, photophosphorylation, photosynthesis, activate the Rubisco activate enzymes, Rubisco activity. The study shows that, HCO_3^- and K^+ both can significantly improve soybean seedlings photosynthetic electron transport rate, ATP-enzyme activity, and speed up the process of the photophosphorylation .

According to the rearch of Camp et al. (1982), in the C_3 plants, PEPC added C4 organic acid biosynthesis, It is a key enzyme of the "back to fill the metabolic" pathway, is the speed limit enzymes of C4 microcirculation. The study shows that, soybean seedlings leaves contain PEPC, spraying $KHCO_3$ on the leaf increased soybean seedlings leaves PEPC-enzyme activity and PEPC-enzyme specific activity, the reason maybe that HCO_3^- can be used as the substrate of carboxylase PEP to promote its carboxy reaction, HCO_3^- and K^+ both can speed up the process of the photosynthetic dark reactions by by improving Rubisco activity, content and activity of PEPcase. K^+ affected Rubisco biosynthesis, increased its PEPC protein biosynthesis at the same time.

In this experiment，$KHCO_3$ treatment decreased Rubisco content, there are maybe some reasons：Rubisco content and air CO_2 are related. The air CO_2 density ascension causes the plant of Rubisco content reduce (Chen G-Y,2005; Spencer W, Bowes G,1986)，this possibly is the adjustment of plant to Rubisco content in the process of adapting to external environment, so CO_2 assimilation and the electron transfering ability become balanced. In this experiment, HCO_3^- was spurted on the leaf, which increases CO_2 density indirectly, thus the Rubisco content dropped. In addition, K^+ possibly increases others protein biosynthesis while suppresses the Rubisco biosynthesis in the translation level.

In this experiment, Na^+ in the $NaHCO_3$ aqueous solution has little influence on soybean seedlings photosynthesis.

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