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Research Article

Effect of Seed Spray Treatment by DCPTA on Plant Growth and Yield of Soybean (Glycine max L.)

Jong-U Ri[†], Kwang-Il To[*, †], Chung-Il Ri, Sok-Chol Ri, Hung-Man Jong, Son-Hyok Jo, Su-Chol Rim

Institute of Chemistry and Biology, University of Sciences, Pyongyang, DPR Korea

Abstract

DCPTA (2-diethylaminoethyl-3,4-dichlorophenylether) is one of the most representative tertiary compounds and appears to have the potential for biochemical manipulation of plant growth. Here we presented effective spray treatment method to soybean (Glycine max L.) seeds and revealed that DCPTA spray treatment influenced plant growth and increased the yield of soybean. The suitable concentration of DCPTA was 10 mg/L. 60~70 kg of soybean seeds was evenly sprayed with 1 L amount of DCPTA diluent and covered with plastic sheet for 0.5~1 h. After soybean seeds absorbed DCPTA diluent sufficiently, they were dried under the shade condition and sowed. Compared with the control, application of 10 mg/L DCPTA seed spray treatment increased significantly the length of primary shoot and root of germinated seeds, and shoot dry weight, root dry weight, the number of nodules, weight of nodules were enhanced 110.5%, 111.9%, 132.8%, 119.2%, respectively at the vegetative growth stage. During a period between the ending of vegetative growth and the beginning of reproductive growth stage, the height of soybean was decreased and the numbers of branches were increased clearly. DCPTA spray treatment clearly increased the yield of soybeans, especially the highest yield (2475 kg) of seeds was observed in the treatment of 10 mg/L DCPTA compared with the control. The yield of soybean increased to 128%, thus, we confirmed that seed spray treatment by DCPTA is effective, eco-friendly and successful way in order to increase the soybean yield.

Keywords

DCPTA, 2-Diethylaminoethyl-3,4-Dichlorophenylether, Soybean, Seed Spray Treatment, Yield

1. Introduction

DCPTA is a new plant growth regulator which is widely used to regulate the growth and development of crops in the world. DCPTA is one of the most representative tertiary compounds and has strong abilities to regulate photosynthesis of the plants and the activity of relative enzymes [2, 10, 11]. DCPTA treatment can speed up seedling growth, chlorophyll content increase, and the ability of photosynthesis in different plants, which indicates that DCPTA may be involved in the regulation of some photosynthetic reactions [1, 3, 16].

DCPTA treatment results in greater biomass accumulation, increased plant height, fruit yield, etc. in cotton, sugar beet, tomato, eggplant, etc. In cotton (*Gossypium hirsutum*), DCPTA appears to have the potential for biochemical ma-

[*]Corresponding author: tki1982@star-co.net.kp (Kwang-Il To)

† Jong-U Ri and Kwang-Il To are co-first authors.

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nipulation of plant growth. As compared with the control plants, photosynthesis of DCPTA-treated plants was increased by 21%, and biomass was almost doubled [3]. Moreover, DCPTA-treated plants had earlier flowering and more squares and bolls than the control plants. Foliar application of DCPTA significantly increased the taproot development, leaf development, and the photosynthetic productivity of sugar beet (*Beta vulgaris*) [9].

In tomato (*Lycopersicon esculentum*) application of 30 μM (10 mg/L) DCPTA as a pre-germination seed treatment increased the mean relative growth rates of leaves, stems, and roots, 37%, 16%, and 20%, respectively, during vegetative growth [8]. In eggplant (*Solanum melongena*) harvested 107 days after seed planting, the total fruits per plant, harvestable yield, and harvest index (dry weight basis) of 3 and 30 μM DCPTA-treated plants were increased significantly ($p<0.05$) when compared with the control [10].

Studies on horticultural crops and other plants were reported. A 26 μM DCPTA seed treatment for guayule *(Parthenium argentatum* Gray) was studied [4]. They obtained a 23% increase in germination rate and exhibited a 22% increase in dry weight and a 95% increase in survival rate under water-limiting conditions. Application of DCPTA to seedling Phalaenopsis plants increased seeding survival, long-term vegetative plant growth, and greatly accelerated flowering when compared to controls [7]. Shoot growth, root: shoot ratio, and the survival of DCPTA-treated transplanted Orchid were increased significantly. After 3 to 6 months of greenhouse growth, plants treated with 30 μM DCPTA produced a 2- to 3-fold increase in root growth compared to the controls [6].

DCPTA stimulated growth on red pine *(Pinus resinosa* L.) germinant and one and two-year-old seedlings, mainly to foliage and stems at 10 mg/L [13].

DCPTA application significantly increased the grain number of grains per ear and thousand-kernel weight in maize, and contributed to the increase in yield. This effect may have occurred because DCPTA improves canopy function and delays leaf senescence to support grain filling and increases the kernel number per ear and grain weight [5, 12]. Some studies showed that DCPTA could speed up seedling growth, increase chlorophyll content and improve photosynthesis in different plants, which indicated that DCPTA participated in regulation of photosynthetic reaction [15]. Together, exogenous DCPTA improved plant growth and drought tolerance by regulating N-mechanism enzymatic activities involved in transcription and enzymatic protein synthesis. And DCPTA-treated maize seedlings caused an increase of soluble sugar, which gave a good foundation for the higher dry matter accumulation and transportation [14].

The crop plant soybean is one of the main sources of vegetable oil and protein, and ranks first in the world in vegetable oil production. The legume species soybean (*Glycine max* L.) originated in East Asia, and is now widely grown, being the primary oilseed crop in the world, with the Brazil, Argentina, India and China being the main soybean-growing countries. The area where soybean is grown has increased significantly in recent years [17]. However, it is noteworthy that, despite this, demand for plant protein, oil and food are increasing in the world, and further improvements in soybean production are essential.

Application of DCPTA increased the soybean yield and caused significant increases in lipid (triglyceride) and protein content of soybean [16]. DCPTA was applied at concentration levels of 80 mg/L and 120 mg/L to the developing plants initially at the first leaf stage and again at the four-leaf stage. At the lower concentration level (80 mg/L) DCPTA caused a more significant response pattern than the higher concentration level (120 mg/L). They observed a 68% increase in protein content, accompanied by a 20% increase in lipid content. At the same time, DCPTA caused a significant increase (35%) in the yield of seeds. At the higher concentration level of 120 mg/L DCPTA affected only protein accumulation, and no effect was observed on lipid content and yield of soybean. So the more appropriate concentration level for DCPTA appears possibly to be in the still lower range with 80 mg/L at the upper end.

In the above studies, DCPTA was applied as either a seed treatment or as a foliar spray to early seedling plants just after they emerged from the seed. Also there were a few documents that DCPTA applied on soybean and foliar spray methods were used mainly. Foliar applications require a great volume of water and agrochemicals and expensive labors. It is important to establish the application method of DCPTA because of economic effectiveness of the investment.

Based on the previous data that DCPTA influenced growth, development and yield of plants, we suggested seed treatment methods. However, soaking treatment couldn't apply to soybean seeds. Because soybean seeds, which are treated by soaking and absorb a great deal of water, result in some problems in dealing and seedling of seeds.

Thus, we suggested newly spray treatment of soybean seeds, not soaking treatment method and also examined the effects of seed spray treatment with DCPTA on the growth and yield of soybean.

2. Materials and Methods

2.1. Materials

The soybean cultivar "Kong 24", widely grown in DPRK, was employed in this study. DCPTA was obtained from China Zhengzhou Zhengshi Chemical Company, Ltd. Then DCPTA was diluted with distilled water containing 0.02% (v/v) Tween-20 in different concentration (0, 5, 10, 20 mg/L).

2.2. Spray Treatment of Soybean Seeds

60~70 kg of soybean seeds were evenly sprayed with the amount of 1 L DCPTA diluent and covered with plastic sheet

for 0.5~1 h. After soybean seeds absorbed DCPTA diluent sufficiently, they were dried under the shade condition and sowed.

2.3. Measurement of Seed Germination and Seedling Growth Index (SDI)

The elite soybean seeds treated were incubated in Petri dishes on two layers of filter paper and 20 ml of distilled water was added. The germination experiments were performed at 15, 25 ℃ and 60% relative humidity under dark conditions; the germination rates were recorded every day for 6 days. For each germination test, 100 soybean seeds were used, and three experimental replications were performed.

After 6d of incubation, primary root and shoot length of the germinated seeds were measured.

The germinated soybean seeds were transferred into pots and grown in greenhouses under 25 ℃ with 16 h light and 8 h dark conditions. Subsequently, the primary seedling establishment rate, height, shoots dry weight, roots length, roots dry weight and number of nodule were determined after seedling for 25 days, and the dry weights were taken after the samples were oven-dried at 80 ℃ for 48 h. The plant pots were placed in a completely randomized design with three replicates.

2.4. Plot Experiment

Plot Experiments were replicated four times in two field locations. Plants were cultivated using conventional furrow irrigation and N-P-K application methods for commercial soybean production according to concerned area.

All the planting, maintenance, and harvesting operations were carried out according to the concerned area technical instructions issued by the Juche farming methods. Necessary data taken included the number of pods, the number of seeds in pods, 1000 seed weight, and seed yield (obtained by excepting the boundary effects and through taking samples from the remaining part of each plot).

2.5. Statistical Analysis

The experiments were repeated four times. The experimental data was analyzed with SPSS (Statistical Package for the Social Sciences) statistical package. Then all the data were subject to ANOVA (Analysis of Variance), and average values were compared using the appropriate Fisher's protected LSD (Least Significant Difference) ($p<0.05$).

3. Result

3.1. Effect of DCPTA on Seed Germination of Soybean

Agricultural weather conditions are different at every area, so the effect of DCPTA spray treatment on germination of soybean was investigated at two temperature conditions (low and normal).

3.1.1. Effect of DCPTA on Germination of Soybean at Low Temperature

Table 1. *Effect of DCPTA on germination rates of soybean at low temperature.*

treatments	germination rates (%)					
	1d	2d	3d	4d	5d	6d
control	3.9	14.0	34.1	73.3	88.7	94.7
5 mg/L	4.7	27.3	53.5	75.2	90.1	94.5
10 mg/L	5.7	34.0	60.4	83.8	95.1	95.3
20 mg/L	5.2	34.5	58.5	79.8	94.5	94.3

(temperature: 19±1 ℃)

Table 1 showed the effect of DCPTA on germination rates of soybean at low temperature. The results indicated that DCPTA spray treatment influenced germination rates of soybean at low temperature. Especially 10 mg/L and 20 mg/L DCPTA spray treatment significantly prompted compared with the control. And DCPTA spray treatment at low temperature advanced the date to germinate 1d approximately.

Table 2. *Effect of DCPTA on plumule and radicle length of soybean at low temperature.*

treatments	plumule length (cm)	radicle length (cm)
control	5.60±0.25	4.82±0.51
5 mg/L	5.96±0.32	5.75±0.52
10 mg/L	6.02±0.35	6.45±0.48*
20 mg/L	6.14±0.28	6.51±0.50*

temperature: 19±1 ℃, *: $p<0.05$ (compared with the control)

Table 2 indicated the radicle and plumule length of the germinated seeds after 6d of seed incubation at low temperature. As shown in Table 2, all of DCPTA spray treatment (5, 10, 20 mg/L) increased the shoot length of the germinated seeds, but not significantly. However primary root length was increased significantly by the application of 10, 20 mg/L DCPTA.

These results of the experiment indicated that DCPTA spray treatment influenced the root length of soybean importantly at low temperature during germination.

3.1.2. Effect of DCPTA on Germination of Soybean at Normal Temperature

Table 3 showed the Effect of DCPTA on germination rates of soybean at normal temperature.

At the normal temperature, 10 mg/L and 20 mg/L DCPTA spray treatment slightly increased germinating ability compared with the control but among the treatment plots there was not a significant difference on germination rate and date of germinating. And after 5 days germination rate didn't increase more.

Table 3. *Effect of DCPTA on germination rates of soybean at normal temperature.*

treatments	germination rate (%)					
	1d	2d	3d	4d	5d	6d
control	4.8	15.4	39.3	76.6	92.3	93.0
5 mg/L	5.7	24.3	52.5	78.2	93.1	93.5
10 mg/L	5.5	34.2	55.4	81.9	94.5	94.8
20 mg/L	5.2	30.8	52.5	80.8	94.5	95.1

temperature: 25±1 ℃

And then at the upper conditions we discussed the radicle and plumule length of the germinated seeds after 6d of seed incubation (Table 4). As shown in Table 4, 10 mg/L and 20 mg/L DCPTA spray treatment significantly increased the radicle and plumule length of the germinated seeds compared with the control.

The results revealed that at normal temperature DCPTA spray treatment doesn't increase the germination rate and increased significantly the radicle length.

From above-mentioned results, DCPTA seed treatment enhanced germination of soybean and the optimum concentration of DCPTA was 10 mg/L.

Table 4. *Effect of DCPTA on plumule and radicle length of soybean at normal temperature.*

treatments	plumule length (cm)	radicle length (cm)
control	10.24±0.25	7.08±0.51
5 mg/L	10.63±0.32	8.47±0.52*
10 mg/L	11.52±0.35*	9.35±0.48*
20 mg/L	11.14±0.28*	9.40±0.50*

temperature: 25±1 ℃, *: $p<0.05$ (compared with the control)

3.2. Effect of DCPTA on Primary Growth of Soybean

Based on the fact that DCPTA increased germination soybean seeds, we then investigated the effects of DCPTA on the primary growth of soybean seeds. Table 5 showed the effect of DCPTA on primary growth of soybean.

A positive effect of DCPTA on seedling establishment rate of soybean seeds was also detected (Table 5). In the treated soybean, spray application of 10 mg/L, 20 mg/L DCPTA caused 10.8%, 7.5% increase of seedling establishment rate respectively more than the control. Also the number of leaf and shoot height tended to decrease compared with the control.

Table 5. *Effect of DCPTA on primary growth of soybean.*

treatments	seedling establishment rate (%)	number of leaf	shoot height (cm)	root length (cm)	number of nodule
control	81.7	2.5	26.75	24.85	10.6
10 mg/L	92.5*	2.4	25.48	26.54	12.7
20 mg/L	89.2*	2.4	25.77	26.73	12.9

(place: Pyongyang, seeding date: May 21, 2024, investigation date; June 15, 2024)

3.3. Effect of DCPTA on Growth of Soybean

In order to investigate the effects of DCPTA on soybean growth, we examined some growth index of soybean at an experimental plot (Table 6). There was a great difference between treated plants and controls at the concentration 10, 20 mg/L for soybean.

In the DCPTA spray treated soybeans, compared with the control, the treated seedling caused an increase in shoot dry weight, root dry weight and number of nodule, weight of nodule at the stage of vegetative growth. Specially the applications of 10 mg/L DCPTA increased number of nodule per plant to 32.8% and weight of nodule per plant to 19.2% in

comparison to the control.

Table 6. *Effect of DCPTA on some growth index of soybean.*

treatments	shoot dry wt.(g)	root dry wt.(g)	nodule number		nodule wt.	
			per plant	Percentage (%)	per plant (g)	Percentage (%)
control	5.52	1.35	49.56	100	1.59	100
10 mg/L	6.10	1.51	65.80*	132.8	1.90*	119.2
20 mg/L	5.64	1.45	61.01*	123.1	1.73	108.8

(nodule investigation date: June 30, dry wt. investigation date: July 13)

Next we investigated the effects of DCPTA on plant height and number of branches at the end of vegetative growth-early of reproductive growth stage. As shown in Table 7, at this stage the height of soybean was decreased clearly and the number of branches was increased.

Table 7. *Effect of DCPTA on plant height and the number of branches of soybean.*

treatments	plant height, (cm)	number of branch
control	137.7 ±5.2	4.0 ±0.3
10 mg/L	126.2 ±3.9*	5.2 ±0.4*
20 mg/L	127.4 ±4.1*	5.3 ±0.4*

(investigation date; August 27, *: $p < 0.05$ (compared with the control))

Generally, reproductive growth in soybean was progressed together with vegetative growth for a long time, so the decrease of height reflecting vegetative growth and the increase of number of branches showing reproductive growth are the main factors for the yield increase. These results also showed DCPTA was a plant growth regulator that contributed to controlling of hormones balance.

3.4. Effect of DCPTA on Yield Components and Yield of Soybean

Table 8 showed the effect of DCPTA on yield components of soybean.

Table 8. *Effect of DCPTA on yield components of soybean.*

treatments	plant per plot (%)	number of pod per plant	number of seeds per pod	number of seeds per plant	1 000 seed weight (g)
control	53.5	70.1	2.4	166.5	210.0
10 mg/L	62.3	102.4	2.5	251.2	208.5
20 mg/L	60.3	92.9	2.5	227.7	211.1

(investigation date; September 30, harvesting date; October 7)

Results of the experiment indicated the number of plant per plot, pod per plant, seed per pod and seed per plant were

increased in treated soybean. Difference in 1 000 seed weights was not statistically significant. And we investigated the effect of DCPTA on number of seeds per pod of soybean (Table 9). According to the results of the comparison of means, in DCPTA-treated soybean, the rate of 4 seeds per pod and 3 seeds per pod were increased, but the rate of 1 seed per pod and empty husk of soybean were reduced compared with the control.

Table 9. *Effect of DCPTA on number of seeds per pod of soybean.*

treatments	4 seeds per pod (%)	3 seeds per pod (%)	2 seeds per pod (%)	1 seed per pod (%)	0 seed per pod (%)
control	8.3	36.6	29.5	16.6	9.0
10 mg/L	9.2	38.3	32.5	14.2	5.8
20 mg/L	8.3	41.4	30.5	15.3	4.5

investigation date; September 30

Table 10. *Effect of DCPTA on yield of soybean.*

treatments	yield per plot (kg)	yield per ha (kg)	increased yield (kg)	Percentage (%)
control	1.932	1 932	-	100
10 mg/L	2.475	2 475	543	128.1
20 mg/L	2.264	2 264	332	117.2

(harvesting date; October 7, $LSD_{0.05}$=420 kg)

And we investigated the effect of DCPTA on yield of soybean. DCPTA spray treatment clearly increased the yield of soybeans, especially the highest yield (2 475 kg) of seeds was observed in the treatment of 10 mg/L DCPTA compared with the control (1,932 kg).

The results obtained suggested that spray treatment of DCPTA was one of effective ways in order to increase the soybean yield.

4. Conclusion

In the study, we presented effective spray treatment method to soybean seeds and revealed that DCPTA spray treatment increased the growth and yield of soybean.

The suitable concentration of DCPTA was 10 mg/L, 60~70 kg of bean seeds was evenly sprayed with the amount of 1L DCPTA diluent and covered with plastic sheet for 0.5~1 h. After soybean seeds absorbed DCPTA diluent sufficiently, they were dried under the shade condition and sowed.

DCPTA spray treatment influenced germination rates of soybean. The results of the experiment indicated that 10 mg/L DCPTA spray treatment influenced germination rate and root length of soybean importantly at low temperature, and showed no increase of the germination rate and increased significantly the primary root and shoot length of the germinated seeds at normal temperature (Tables 1-4).

Compared with the controls, application of 10 mg/L DCPTA seed spray treatment increased the growth of soybean, so that shoot dry weight, root dry weight and number of nodules, weight of nodules was enhanced 110.5%, 111.9%, 132.8%, 119.2%, respectively at the stage of vegetative growth (Tables 5, 6).

During a period between the ending of vegetative growth and the beginning of reproductive growth stage, the height of soybean was decreased and the number of branches were increased clearly (Tables 7-9). These results showed that DCPTA enhanced reproductive growth.

DCPTA spray treatment clearly increased the yield of soybeans, especially the highest yield (2475 kg) of seeds was observed in the treatment of 10 mg/L DCPTA compared with the control (1932 kg) (Table 10). In conclusion, we confirmed that seed spray treatment by DCPTA is effective, eco-friendly and successful way in order to increase the soybean yield.

Abbreviations

DCPTA	2-Diethylaminoethyl-3,4-Dichlorophenylether
SPSS	Statistical Package for the Social Sciences
ANOVA	Analysis of Variance
LSD	Least Significant Difference
SDI	Seedling Growth Index

Author Contributions

Jong-U Ri: Project administration, editing.
Kwang-Il To: Data interpretation, Manuscript revision.
Chung-Il Ri: Experimental design.
Sok-Chol Ri: Synthesis of DCPTA, Validation.

Hung-Man Jong: Software, Data analysis.
Son-Hyok Jo: Software, Data analysis.
Su-Chol Rim: Wrote manuscript.

All the authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

References

[1] Borras, L., G. A. Slafer, and M. E. Otegui (2004) Seed dry weight response to source-sink manipulations in wheat, maize and soybean: A quantitative reappraisal. Field Crops Res. 86: 131-146. https://doi.org/10.1016/j.fcr.2003.08.002

[2] Cheng, X. C. (2002) Application of a new plant growth regulator (PGR). Chem. Eng. 2: 62-63. https://doi.org/10.16247/j.cnki.23-1171/tq.2002.02.031

[3] Gausman HW, Burd JD, Quisenberry J, Yokoyama H, Dilbeck R, Benedict CR (1985) Effect of 2-diethylaminoethyl-3,4-dichlorophenylether (DCPTA) on cotton plant (Gossypium hirsutum) growth and phenology. Biotechnology. 3: 255-257. https://doi.org/10.1038/nbt0385-255

[4] Mar çal H. A. Jorge, Maren E. Veatch-Blohm, Dennis T. Ray et al (2006) Guayule seed germination under different conditioning treatments. Industrial Crops and Products. 1(24). 60-65. https://doi.org/10.1016/j.indcrop.2006.02.002

[5] Huang. Z. H., S. Y. Wang, Y. Bao, X. H. Liang, G. Sun, L. Shen et al (2007) Studies on dry matter accumulation and distributive characteristic in super high-yield maize. Yumi Kexue 15: 95-98. https://doi.org/10.13597/j.cnki.maize.science.2007.03.023

[6] Songjun Zeng, Kunlin Wu, Jaime A. Teixeira da Silva et al (2012) Asymbiotic seed germination, seedling development and reintroduction of Paphiopedilum wardii Sumerh., an endangered terrestrial orchid. Scientia Horticulturae. 138. 198-209. https://doi.org/10.1016/j.scienta.2012.02.026

[7] Keithly JH, Yokoyama H (1990a) Regulation of plant productivity. 1: Improved seedling vigor and floral performance of Phalaenopsis by 2-(3,4-dichlorophenoxy) triethylamine (DCPTA). Plant Growth Regulation (Netherlands). 9: 19-26. https://doi.org/10.1007/BF00025275

[8] Keithly JH， Yokoyama H，Gausman HW (1990b) Enhanced yield of tomato in response to 2-(3,4-dichlorophenoxy)-triethylamine (DCPTA). Plant Growth Regulation. 9: 127-136. https://doi.org/10.1007/BF00027440

[9] Keithly JH, Yokoyama H, Gausman HW (1990c) Effect of 2-(3,4-dichorophenoxy) triethylamine (DCPTA) on the growth and development of sugarbeet. Plant Science. 68: 57-64. https://doi.org/10.1016/0168-9452(90)90152-E

[10] Kobayashi H, Keithly JH, Yokoyama H (1991) Improvements in the fruit set and harvest index of eggplant [Solanum melongena] by 2-(3,4-dichlorophenoxy) triethylamine hydrochloride [DCPTA]. J. Japan. Soc. Hort. Sci. 60: 77-81.

[11] Li. L. L., W. R. Gu, C. F. Li, Y. Meng, J. Y. Mu, Y. L. Guo, L. Li, and S. Wei (2016) Effect of DCPTA on antioxidant system and osmotic adjustment substance in leaves of maize seedlings under low temperature stress. Chih Wu Sheng Li Hsueh T'ung Hsun 52: 1829-1841. https://doi.org/10.13592/j.cnki.ppj.2016.0138

[12] L. L. Li, W. R. Gu, C. F. Li, W. H. Li, X. C. Chen, L. G. Zhang, and S. Wei (2019) Dual Application of Ethephon and DCPTA Increases Maize Yield and Stalk Strength, Crop Ecology And physiology, Agronomy Journal, 111, 1-16. https://doi.org/10.2134/agronj2018.06.0363

[13] Richter DD, Ramseyer LJ, Johnson JR, Olson CE, Zhu Z (1987) Growth responses of red pine seedlings to the chemical bioregulator, DCPTA. New Forests. 4: 301-309. https://doi.org/10.1007/BF00031740

[14] Tenglong Xie, Wanrong Gu et al. (2019) Exogenous DCPTA Increases the Tolerance of Maize Seedlings to PEG-Simulated Drought by Regulating Nitrogen Metabolism-Related Enzymes. Agronomy 2019, 9, 676. https://doi.org/10.3390/agronomy9110676

[15] Wang Y, Gu W, Xie T, Li L, Sun Y, Zhang H et al. (2016) Mixed Compound of DCPTA and CCC Increases Maize Y ield by Improving Plant Morphology and Up-Regulating Photosynthetic Capacity and Antioxidants. PLoS ONE 11(2): e0149404. https://doi.org/10.1371/journal.pone.0149404

[16] Ling Hao, Yuqiong Wang, Juan Zhang, Yan Xie et al.(2013) Coronatine enhances drought tolerance via improving antioxidative capacity to maintaining higher photosynthetic performance in soybean. Plant Science. 210. 1-9. http://dx.doi.org/10.1016/j.plantsci.2013.05.006

[17] Zhou W, Chen F, Zhao S et al. (2019) DA-6 promotes germination and seedling establishment from aged soybean seeds by mediating fatty acid metabolism and glycometabolism. Journal of Experimental Botany. 70: 101-114. https://doi.org/10.1093/jxb/ery247