全国中文核心期刊
中国科技核心期刊
中国农业核心期刊
RCCSE中国核心学术期刊
中国科学引文数据库（CSCD）期刊
CAB International 收录期刊
美国《生物学文摘》收录期刊
美国《化学文摘》（CA）收录期刊

«上一篇 (DArticle.aspx?type=view&id=201506025)
下一篇 (DArticle.aspx?type=view&id=201506027)

PDF下载 (pdfdow.aspx?Sid=201506026)
+分享 (http://www.jiathis.com/share?uid=1541069)


微信公众号：大豆科学

[1]杨淞超,李彦生,刘晓冰,等.大气CO2升高对大豆生理指标及产量影响的研究进展[J].大豆科学,2015,34(06):1075-1080.[doi:10.11861/j.issn.1000-9841.2015.06.1075]
YANG Song-chao,LI Yan-sheng,LIU Xiao-bing,et al.Research Advances on Physiological Parameters and Yield of Soybean in Response to Elevated CO2[J].Soybean Science,2015,34(06):1075-1080.[doi:10.11861/j.issn.1000-9841.2015.06.1075]
点击复制

大气CO_2升高对大豆生理指标及产量影响的研究进展

《大豆科学》 [ISSN:1000-9841 /CN:23-1227/S] 卷： 第34卷 期数： 2015年06期 页码： 1075-1080 栏目： 出版日期： 2015-12-25

Title: Research Advances on Physiological Parameters and Yield of Soybean in Response to Elevated CO_2

作者：杨淞超[1] (KeySearch.aspx?type=Name&Sel=杨淞超)；[2] (KeySearch.aspx?type=Name&Sel=2</sup>) (KeySearch.aspx?type=Name&Sel=2</sup>)；李彦生[1] (KeySearch.aspx?type=Name&Sel=李彦生)；刘晓冰[1] (KeySearch.aspx?type=Name&Sel=刘晓冰)；王光华[1] (KeySearch.aspx?type=Name&Sel=王光华)；殷奎德[2] (KeySearch.aspx?type=Name&Sel=殷奎德)；金剑[1] (KeySearch.aspx?type=Name&Sel=金剑)
1.中国科学院 东北地理与农业生态研究所/中科院黑土区农业生态重点实验室，黑龙江 哈尔滨 150081；
2.黑龙江八一农垦大学 生命科学技术学院，黑龙江 大庆 163319

Author(s): YANG Song-chao[1] (KeySearch.aspx?type=Name&Sel=YANG Song-chao)；[2] (KeySearch.aspx?type=Name&Sel=2</sup>) (KeySearch.aspx?type=Name&Sel=</sup>) LI Yan-sheng[1] (KeySearch.aspx?type=Name&Sel=</sup>) LI Yan-sheng)； LIU Xiao-bing[1] (KeySearch.aspx?type=Name&Sel=LIU Xiao-bing)；[3] (KeySearch.aspx?type=Name&Sel=</sup>) WANG Guang-hua[1] (KeySearch.aspx?type=Name&Sel=</sup>) WANG Guang-hua)； YIN Kui-de[2] (KeySearch.aspx?type=Name&Sel=YIN Kui-de)； JIN Jian[1] (KeySearch.aspx?type=Name&Sel=JIN Jian)
1.Key Laboratory of Mollisols Agroecology, Northeast Insitute of Geography and Agroecology, Chinese Academy of Sciences, Harbin 150081, China;
2.College of Life and Sci-technology, Heilongjiang BaYi Agricultural University, Daqing 163319, China

关键词：CO_2升高 (KeySearch.aspx?type=KeyWord&Sel=CO₂升高)；大豆产量 (KeySearch.aspx?type=KeyWord&Sel=大豆产量)；光合速率 (KeySearch.aspx?type=KeyWord&Sel=光合速率)；生物固氮 (KeySearch.aspx?type=KeyWord&Sel=生物固氮)；根系 (KeySearch.aspx?type=KeyWord&Sel=根系)

Keywords: Elevated CO_2 (KeySearch.aspx?type=KeyWord&Sel=Elevated CO₂)； Soybean yield (KeySearch.aspx?type=KeyWord&Sel=Soybean yield)； Photosynthetic rate (KeySearch.aspx?type=KeyWord&Sel=Photosynthetic rate)； Symbiotic nitrogen fixation (KeySearch.aspx?type=KeyWord&Sel=Symbiotic nitrogen fixation)； Root (KeySearch.aspx?type=KeyWord&Sel=Root)

DOI: 10.11861/j.issn.1000-9841.2015.06.1075 (http://dx.doi.org/10.11861/j.issn.1000-9841.2015.06.1075)

文献标志码：A

摘要：在全球气候变化过程中，大气CO_2浓度不断升高，已从工业革命前的270 μmol·L^{-1}升高到2013年的390 μmol·L^{-1}，预计到本世纪末将达到700 μmol·L^{-1}，CO_2浓度的快速升高将对大豆生产产生重要影响。本文从光合速率、叶面积、叶绿素含量、共生固氮、内源激素、以及干物质积累和大豆产量等方面综述了大气CO_2浓度升高产生的影响。大多数研究发现，随着大气CO_2浓度升高，大豆光合速率随之升高，但少数研究发现，随大气CO_2浓度升高，光合速率反而降低，这可能与植物对CO_2浓度升高的光合适应反应有关；叶绿素含量随CO_2浓度升高呈现增加趋势，但对一些夏大豆研究发现，叶绿素含量无明显变化；叶面积、共生固氮、干物质积累和产量也都对CO_2升高产生不同程度的响应，但响应程度因CO_2升高幅度、大豆品种、生育时期和其他试验条件而有所差异；有关于CO_2升高对内源激素影响的研究报导较少。针对未来所需要开展的研究，我们提出与光合作用相关酶学生理、内源激素以及碳氮代谢角度对CO_2影响大豆产量机制进行深入解析，而且在不同品种之间对CO_2浓度升高的响应进行分析，明确品种之间是否存在差异。这将对未来大豆高产育种，提高大豆生长的环境适应性有重要的理论价值；并提出了今后的研究方向。

Abstract: During global climate change, the concentration of CO_2in the atmosphere has increased from 270 μmol?L^{-1}prior to the Industrial Revolution to 390 μmol·L^{-1} in 2013. It is expected that CO_2will increase to 700 μmol·L^{-1}?by the end of the century. The increase of atmospheric CO_2concentration is likely to affect soybean production. The impacts of elevated CO_2on photosynthetic rate, leaf area, chlorophyll content, phytohormones, nitrogen fixation, biomass accumulation and yield are reviewed. Many studies stated that photosynthetic rate of soybean had positive response to elevated CO_2, while a decrease trend was observed in other studies. This is likely due to photosynthetic acclimation in response to elevated CO_2.?Elevated CO_2generally facilitates the accumulation of the chlorophyll content, but there was no response in some summer-sowing cultivars of soybean. The magnitude of leaf area, nitrogen fixation, biomass and yield in response to elevated CO_2varied depending on the extent of CO_2rise, cultivars, growth stages and other experimental conditions. The information on the effect of elevated CO_2on phytohormones is very rare to our knowledge. It is worth further investigating on the mechanisms of yield in response to elevated CO_2, including enzyme activities in relevant photosynthetic physiology, and metabolisms of carbon and nitrogen etc. Such work is fundamental to the high-yield breeding and the improvement of environmental adaptability in soybean in the future.

参考文献/References:

[1] Stocker T F, Qin D, Plattner G K, et al. The Physical Science Basis Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [R]. IPCC: Climate Change, 2013

[2] Wieser G, Gruber A, Bahn M, et al. Respiratory fluxes in a Canary Islands pine forest [J].Tree Physiology, 2009, 29(3): 457-466

[3] Leakey A D, Ainsworth E A, Bernacchi C J, et al. Elevated CO_2?effects on plant carbon, nitrogen, and water relations: six important lessons from FACE [J]. Journal of Experimental Botany, 2009, 60(10): 2859-2876

[4] Pagani M, Freeman K H, Arthur M A. Late Miocene atmospheric CO_2concentrations and the expansion of C4 grasses [J]. United States Science, 1999, 285(5429): 876-879

[5] Pearson P N, Palmer M R. Atmospheric carbon dioxide concentrations over the past 60 million years [J]. Nature, 2000, 406(6797): 695-699

[6] Prentice I C, Farquhar G D, Fasham M J R, et al. The carbon cycle and atmospheric carbon dioxide [M] //Houghton J T, Ding Y, Griggs D J, et al.Climate Change 2001: The Scientific Basis- Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change Cambridge: Cambridge University Press, 2001:183-237

[7] Dyson T.On development, demography and climate change: The end of the world as we know it [J].Population and Environment, 2005, 27(2): 117-149

[8] Canadell J G, Quere C L, Raupach M R, et al. Contributions to accelerating atmospheric CO_2?growth from economic activity, carbon intensity, and efficiency of natural sinks [J]. Proceedings of the National Academy of Sciences, 2007, 104(47): 18866-18870

[9] Hansen J, Sato M, Kharecha P, et al. Target atmospheric CO_2: Where should humanity aim [J].The Open Atmospheric Science Journal, 2008, 2: 217-231

[10] Ainsworth E A, Yendrek C R, Skoneczka J A, et al. Accelerating yield potential in soybean: potential targets for biotechnological improvement [J]. Plant, Cell & Environment, 2012, 35(1): 38-52.

[11] 中华人民共和国国家统计局.中国统计年鉴 [M].北京：中国统计出版社，2011: 473-476.(National Bureau of Statistics of the People's Republic of China China Statistical Yearbook [M]. Beijing: China Statistics Press, 2011: 473-476.)

[12] McGrath J M, Lobell D B. An independent method of deriving the carbon dioxide fertilization effect in dry conditions using historical yield data from wet and dry years [J]. Global Change Biology, 2011, 17(8): 2689-2696.

[13] Heinemann A B, Dourado Neto D, Ingram K T, et al.Soybean (Glycine max (L) Merr) growth and development response to CO_2?enrichment under different temperature regimes [J]. European Journal of Agronomy, 2006, 24(1): 52-61.

[14] Kumagai E, Tacarindua C P, Homma K, et al. Effects of elevated CO_2concentration and temperature on seed production and nitrogen concentration in soybean [J]. Journal of Agricultural Meteorology, 2012, 68(1): 1-13.

[15] 张建平，赵艳霞，王春乙，等. 气候变化情景下东北地区玉米产量变化模拟 [J].中国生态农业学报，2008，16(6): 1448-1452.(Zhang J P, Zhao Y X, Wang C J, et al. Simulation of maize production under climate change scenario in Northeast China [J].Chinese Journal of Eco-Agriculture, 2008, 16(6): 1448-1452.)

[16] 张建平，李永华，高阳华，等. 未来气候变化对重庆地区冬小麦产量的影响 [J]. 中国农业气象，2007，28(3): 268-270.(Zhang J P, Li Y H, Gao Y H, et al. Impacts of future climate change on yields of winter wheat in Chongqing [J].Chinese Journal of Agrometeorology, 2007, 28(3): 268-270.)

[17] 吴杏春，林文雄，郭玉春，等.未来气候变化对福建省水稻生产的影响及其对策 [J].福建农业大学学报，2001，30(2): 148-152.(Wu X C, Lin W X, Guo Y C, et al. Effect of the coming climatic change on the growth of rice in Fujian and its counter measures [J]. Journal of Fujian Agricultural University, 2001, 30(2): 148-152.)

[18] 陈超，潘学标，张立祯，等.气候变化对石羊河流域棉花生产和耗水的影响 [J]. 农业工程学报，2011，27(1): 57-65. (Chen C, Pan X B, Zhang L Z, et al. Impact of climate change on cotton production and water consumption in Shiyang River Basin [J]. Transactions of the Chinese Society of Agricultural Engineering, 2011, 27(1): 57-65.)

[19] Ainsworth E A, Long S P.What have we learned from 15 years of free-air CO_2enrichment (FACE) A meta-analytic review of the responses of photosynthesis, canopy properties and plant production to rising CO_2 [J]. New Phytologist, 2005, 165 (2): 351-372.

[20] Hao X Y, Han X, Lam S K, et al. Effects of fully open-air [CO_2] elevation on leaf ultrastructure, photosynthesis, and yield of two soybean cultivars [J]. Photosynthetica, 2012, 50(3): 362-370.

[21] Ruiz-Vera U M, Siebers M, Gray S, et al.Global warming can negate the expected CO_2?stimulation in photosynthesis and productivity for soybean grown in the Midwestern United States [J]. Plant Physiology, 2013, 162(1): 410-423.

[22] 张彤，胡楠，王磊. CO_2浓度增高对大豆光合生理的影响 [J] 河南大学学报(自然科学版)，2006，36(2): 68-70. (Zhang T, Hu N, Wang L. Effects of CO_2enrichment on photosynthetic physiology of soybean [J].Journal of Henan University (Natural Science), 2006, 36(2): 68-70.)

[23] 高霁，郝兴宇，居煇，等. 自由大气CO_2浓度升高对夏大豆光合色素含量和光合作用的影响 [J]. 中国农学通报，2012，28(6): 47-52. (Gao J, Hao X Y, Ju H, et al Effect of elevated [CO_2] on photosynthetic pigment contents and photosynthesis of summer soybean [J].Chinese Agricultural Science Bulletin, 2012, 28(6): 47-52.)

[24] 岳伟.大气CO_2浓度升高对大豆生育生理及产量品质影响的研究 [D].合肥：安徽农业大学，2007.(Yue W. Study on the effect of growth, physiology, yield and quality of soybean to increasing CO_2concentration [D]. Hefei: Anhui Agricultural University, 2007.)

[25] Rosenthal D M, Ruiz-Vera U M, Siebers M H, et al.Biochemical acclimation, stomatal limitation and precipitation patterns underlie decreases in photosynthetic stimulation of soybean(Glycine max) at elevated [CO_2] and temperatures under fully open air field conditions [J]. Plant Science, 2014, 226: 136-146.

[26] Gesch R W, Pennanen A H, Hartwell L A, et al.Soybean photosynthesis, Rubisco, and carbohydrate enzymes function at supraoptimal temperatures in elevated CO_2 [J]. Plant Physiology, 2001, 158(3): 295-307.

[27] Ainsworth E A,Rogers A. The response of photosynthesis and stomatal conductance to rising [CO_2]: Mechanisms and environmental interactions [J]. Plant, Cell and Environment, 2007, 30(3): 258-270.

[28] Bernacchi C J, Morgan P B, Ort D R, et al.The growth of soybean under free air [CO_2] enrichment (FACE) stimulates photosynthesis while decreasing in vivo Rubisco capacity [J] Planta, 2005, 220(3): 434-446.

[29] 李小溪，武建军，吕爱锋，等. 不同CO_2浓度变化下干旱对冬小麦叶面积指数的影响差异 [J].生态学报，2013，33(9): 2936-2943. (Li X H, Wu J J, Lyu A F, et al.The difference of drought impacts on winter wheat leaf area index under different CO_2?concentration [J].Acta Ecologica Sinica, 2013, 33(9): 2936-2943.)

[30] Dermody O, Long S P, Mcconnaugay K, et al. How do elevated CO_2?and O_3 affect the interception and utilization of radiation by soybean canopy [J]. Global Change Biology, 2008, 14(3): 556-564.

[31] Twine T E, Bryant J J, Richter K T, et al. Impacts of elevated CO_2concentration on the productivity and surface energy budget of the soybean and maize agroecosystem in the Midwest USA [J].Global Change Biology, 2013, 19(9): 2838 -2852.[32] Oikawa S, Okada M, Hikosaka K. Effects of elevated CO_2?on leaf area dynamics in nodulating and non-nodulating soybean stands [J]. Plant and Soil, 2013, 373(1-2): 627-639

[33] 蒋跃林，张庆国，张仕定，等. 大豆根系生理特性对大气二氧化碳浓度升高的反应 [J]. 作物杂志，2006(2): 40-43.(Jiang Y L, Zhang Q G, Zhang S D, et al. The physiological characteristics of soybean root response to elevated atmospheric CO_2concentration [J]. Crops, 2006(2): 40-43.)

［34］杨江龙.大气CO_2与植物氮素营养的关系［J］.土壤与环境，2002，11(2)：163 -166.(Yang J L.The relationship between atmospheric $CO_2$and plant nitrogen nutrition ［J］.Soil and Environmental Sciences，2002，11(2)：163-166.)
［35］Salvagiotti F，Cassman K G，Specht J E，et al. Nitrogen uptake，fixation and response to fertilizer N in soybeans：A review ［J］. Field Crops Research，2008，108(1)：1-13.
［36］Miyagi K M，Kinugasa T，Hirose T,et al.Elevated CO_2?concentration，nitrogen use，and seed production in annual plants ［J］.Global Change Biology，2007，13(10)：2161-2170.
［37］Hikosaka K，Kinugasa T，Oikawa S，et al. Effects of elevated CO_2concentration on seed production in C_3annual plants ［J］. Journal of Experimental Botany，2011，62(4)：1523-1530.
［38］蒋跃林，张庆国，张仕定，等. 大气CO_2浓度升高对大豆根瘤量及其固氮活性的影响 ［J］.大豆科学，2006，25(1)：53-57.(Jiang Y L，Zhang Q G，Zhang S D，et al. Effect of elevated atmospheric CO_2concentration on root nodules and nitrogenase activity soybean ［J］.Soybean Science，2006，25(1)：53-57.)
［39］Lam S K，Hao X Y，Lin E，et al. Effect of elevated carbon dioxide on growth and nitrogen fixation of two soybean cultivars in northern China ［J］. Biology and Fertility of Soils，2012，48(5)：603-606.
［40］董志新，莫庸，陈新红. 多效唑对大豆化学调控诱导效应研究 ［J］. 石河子农学院学报，1996，14(2)：7-12.(Dong Z X，Mo Y，Chen X H. Study pacolobutrazol chemical regulating effect on soybean［J］.Shihezi Agricultural University，1996，14(2)：7-12.)
［41］Liu B，Liu X B，Wang C，et al. Endogenous hormones in seed，leaf，and pod wall and their relationship to seed filling in soybeans ［J］. Crop and Pasture Science，2010，61(2)：103-110.
［42］Young T E，Gallie D R. Regulation of programmed cell death in maize endosperm by abscisic acid ［J］.Plant Molecular Biology，2000，42(2)：397-414.［43］Jin J，Watt M，Mathesius U.The autoregulation gene SUNN mediates changes in root organ formation in response to nitrogen through alteration of shoot-to-root auxin transport ［J］. Plant Physiology，2012，159(1)：489-500.
［44］王修兰，徐师华 CO_2浓度倍增对大豆各生育期阶段的光合作用及干物质积累的影响 ［J］. 作物学报，1994，20(5)：520-527.(Wang X L，Xue S H. Eeffet of CO_2concentration doubling on photosynthesis and dry matter production in different growth stages of soybean plant［J］. Acta Agronomic Sinica，1994，20(5)：520-527.)
［45］郭建平，王春乙，白月明，等 CO_2和O_3浓度倍增对作物影响的研究进展 ［J］.气象学报，2004，62(5)：875-881.(Guo J P，Wang C Y，Bai Y M，et al. An experiment study of the impacts of CO_2concentration doubling on soybean growth［J］ Acta Meteorologica Sinica，2004，62(5)：875-881.)
［46］张庆国，岳伟，陈庭甫，等. 大气二氧化碳浓度升高条件下大豆光合色素含量的变化 ［J］.作物研究，2006(2)：144-146.(Zhang Q G，Yue W，Chen T P，et al. Changes of photosynthetic pigment contents in soybean under elevated atmospheric CO_2concentrations［J］. Crop Research，2006(2)：144-146.)
［47］Kimball B A. Cost comparisons among free-air CO2 environment，open-top chamber，and sunlit controlled-environment chamber methods of CO_2exposure［J］ Critical Reviews in Plant Sciences，1992，11：265-270.
［48］Bishop K A，Betzelberger A M，Long S P，et al.Is there potential to adapt soybean (Glycine max Merr) to future［CO_2］ An analysis of the yield response of 18 genotypes in free air CO_2enrichment［J］. Plant，Cell & Environment，2014
［49］Sakurai G，Iizumi T，Nishimori M，et al. How much has the increase in atmospheric CO_2directly affected past soybean production［J］.Scientific Reports，2014，4：4978
［50］Morgan P，Bollero G A，Nelson R L，et al. Smaller than predicted increase in aboveground net primary production and yield of field-grown soybean under fully open-air ［CO_2］ elevation ［J］.Global Change Biology，2005，11(10)：1856-1865
［51］Southworth J，Pfeifer R A，Habeck M，et al.Changes in soybean yields in the Midwestern united states as a result of future changes in climate，climate variability，and CO_2fertilization ［J］. Climatic Change，2002，53(4)：447-475.
［52］郝兴宇，林而达，杨锦忠，等. 自由大气CO_2浓度升高对夏大豆生长与产量的影响［J］. 生态学报，2009，29(9)：4595-4603.(Hao X Y，Lin E D，Yang J Z，et al. Effects of free air CO_2enrichment on growth and yield of summer soybean ［J］. Acta Ecologica Sinica，2009，29(9)：4595-4603.)
［53］Ziska L H，Bunce J A，Caulfield F A. Rising atmospheric carbon dioxide and seed yield of soybean genotypes［J］.Crop Science，2001，41：385-391
［54］Lee E H，Pausch R C，Rowland R A，et al. Responses of field-grown soybean to elevated SO_2under two atmospheric CO_2concentrations ［J］. Environmental and Experimental Botany，1997，37：85-93.
［55］刘丹.外源激素对油菜光合特性及产量构成因素的影响［D］. 北京：中国农业科学院，2008.(Liu D. Effects of exogenous hormones on photosynthesis characteristics and yield components in rapeseed［D］.Beijing:Chinese Academy of Agricultural Sciences，2008.)

相似文献/References:

[1]杨继学,黄珊珊,杨明亮,等.密度和施肥量对不同分枝类型大豆产量的影响[J]. (darticle.aspx?type=view&id=201203009)大豆科学,2012,31(03):381.[doi:10.3969/j.issn.1000-9841.2012.03.009]
YANG Ji-xue,HUANG Shan-shan,YANG Ming-liang,et al.Effect of Density and Fertilizer Amount on Yield of Different Branching Types of Soybeans[J].Soybean Science,2012,31(06):381.[doi:10.3969/j.issn.1000-9841.2012.03.009]
[2]崔喜安,姜宇,米刚,等.长期麦秸还田对暗棕壤土壤肥力和大豆产量的影响[J]. (darticle.aspx?type=view&id=201106019)大豆科学,2011,30(06):976.[doi:10.11861/j.issn.1000-9841.2011.06.0976]
CUI Xi-an,JIANG Yu,MI Gang,et al.Effect of Long-term Application of Wheat Straw on Fertility of Dark Brown Soil and Yield of Soybean[J].Soybean Science,2011,30(06):976.[doi:10.11861/j.issn.1000-9841.2011.06.0976]
[3]周克琴,韩秉进,张秋英,等.生防菌BRF-1和BRF-2对大豆根腐病和产量的影响[J]. (darticle.aspx?type=view&id=201205024)大豆科学,2012,31(05):801.[doi:10.3969/j.issn.1000-9841.2012.05.024]
ZHOU Ke-qin,HAN Bing-jin,ZHANG Qiu-ying,et al.Effect of BRF-1 and BRF-2 on Root Rot and Seed Yield in Soybean[J].Soybean Science,2012,31(06):801.[doi:10.3969/j.issn.1000-9841.2012.05.024]
[4]林磨刚,吴俊江,刘丽君,等.保护性耕作对土壤部分物理特性及大豆产量的影响[J]. (darticle.aspx?type=view&id=201002013)大豆科学,2010,29(02):238.[doi:10.11861/j.issn.1000-9841.2010.02.0238]
LIN Wei-gang,WU Jun-jiang,LIU Li-jun,et al.Impact of Conservation Tillage on Some Soil Physical Properties and Soybean Yields (Glycine max L. Merrill) [J].Soybean Science,2010,29(06):238.[doi:10.11861/j.issn.1000-9841.2010.02.0238]
[5]宿庆瑞,迟凤琴,张久明,等.不同耕作技术模式对土壤理化性状及大豆产量的影响[J]. (darticle.aspx?type=view&id=201003021)大豆科学,2010,29(03):453.[doi:10.11861/j.issn.1000-9841.2010.03.0453]
SU Qing-rui,CHI Feng-qin,ZHANG Jiu-ming,et al.Effects of Different Cultivation Technique Patterns on Soil Physical-Chemical Properties and Yield of Soybean[J].Soybean Science,2010,29(06):453.[doi:10.11861/j.issn.1000-9841.2010.03.0453]
[6]姜丽霞,那济海,朱海霞,等.基于Logistic方程的大豆产量预报方法[J]. (darticle.aspx?type=view&id=20080301l)大豆科学,2008,27(03):414.[doi:10.11861/j.issn.1000-9841.2008.03.0414]
JIANG Li-xia,NA Ji-hai,ZHU Hai-xia,et al.Method for Forecasting Soybean Yield Based on Logistic Equation[J].Soybean Science,2008,27(06):414.[doi:10.11861/j.issn.1000-9841.2008.03.0414]
[7]姜佰文,赵赛东,魏丹,等.坡度和耕作措施对土壤侵蚀及大豆产量的影响[J]. (darticle.aspx?type=view&id=201502011)大豆科学,2015,34(02):238.[doi:10.11861/j.issn.1000-9841.2015.02.0238]
JIANG Bai-wen,ZHAO Sai-dong,WEI Dan,et al.Effect of Slope and Tillage Measures on Soil Erosion and Yield of

Soybean[J]. Soybean Science, 2015, 34(06):238. [doi:10.11861/j.issn.1000-9841.2015.02.0238]
[8 郭 玉 刘龙军. 垄底垄沟超深松对土壤含水量及大豆产量影响的研究*[J]. (darticle.aspx?type=view&id=200603026)大豆科学, 2006, 25(03):333. [doi:10.11861/j.issn.1000-9841.2006.03.0333]
Guo Yu Liu Longjun. STUDY ON RIDGE AND FURROW DEEP-TILLAGETO HOLARD AND SOYBEAN YIELD[J]. Soybean Science, 2006, 25(06):333. [doi:10.11861/j.issn.1000-9841.2006.03.0333]
[9.刘晓冰宋春雨Stephen J.Herber.美国大豆产量生理研究的进展[J]. (darticle.aspx?type=view&id=200102015)大豆科学, 2001, 20(02):141. [doi:10.11861/j.issn.1000-9841.2001.02.0141]
Liu XiaobingSong ChunyuStephen J .Herbert.SOME BRIEF ASPECTS OF YIELD PHYSIOLOGY RESEARCH IN SOYBEAN IN USA [J]. Soybean Science, 2001, 20(06):141. [doi:10.11861/j.issn.1000-9841.2001.02.0141]
[10]韩晓增 乔云发 张秋英 王守宇 宋春雨.不同土壤水分条件对大豆产量的影响[J]. (darticle.aspx?type=view&id=200304007)大豆科学, 2003, 22(04):269. [doi:10.11861/j.issn.1000-9841.2003.04.0269]
Han Xiaozeng Qiao Yunfa Zhang Qiuying Wang Shouyu Song Chunyu. EFFECTS OF VARIOUS SOIL MOISTURE ON THE YIELD OF SOYBEAN[J]. Soybean Science, 2003, 22(06):269. [doi:10.11861/j.issn.1000-9841.2003.04.0269]
[11]杨淞超, 李彦生, 刘长锴, 等. 大豆产量形成对大气CO2浓度升高响应的基因型差异[J]. (darticle.aspx?type=view&id=201505011)大豆科学, 2015, 34(05):819. [doi:10.11861/j.issn.1000-9841.2015.05.0819]
YANG Song-chao, LI Yan-sheng, LIU Chang-kai, et al. The Response of Yield Formation to Elevated Atmospheric CO 2 in Different Soybean Cultivars[J]. Soybean Science, 2015, 34(06):819. [doi:10.11861/j.issn.1000-9841.2015.05.0819]

备注/Memo 基金项目：国家自然科学基金（41271261）；黑龙江省杰出青年基金（JC201413）；国家“十二五”科技支撑（2014BAD11B01-A01）。

第一作者简介：杨淞超（1989-），男，硕士，主要从事作物生理研究。E-mail: yangsongchao_1989@126.com。
通讯作者：金剑（1974-），男，博士，研究员，主要从事作物生理生态研究。E-mail: jinjian@iga.ac.cn。nitrogen fixation; Root

更新日期/Last Update: 2016-01-07