J. BIOL. ENVIRON. SCI.,
2019, 13(38), 71-78

Original Research Article

Sustainable Agriculture and Soybean, a Legume in Traditional Chinese Medicine with Great Biological Nitrogen Fixation

Mohamad Hesam Shahrajabian[1,2*], Wenli Sun [1,2] and Qi Cheng[1,2]
[1]Biotechnology Research Institute, Chinese Academy of Agricultural Sciences, Beijing 100081, CHINA
[2]Nitrogen Fixation Laboratory, Qi Institute, Building C4, No.555 Chuangye, Jiaxing 314000, Zhejiang, CHINA

Received: 28.05.2019; Accepted: 10.06.2019; Published Online: 31.10.2019

ABSTRACT

China is the home of the soybean. Traditional Chinese Medicine is a natural and organic health care system which view the body as a complex network of interconnected parts. The most important health benefits of soybeans are improving metabolic activity, health weight gain, anti-cancer potential, boost heart health, relieve menopausal symptoms, boost digestion, improve bone health, prevent birth defects, improve circulation, control diabetes and relieve sleep disorders. Soybeans can clear heat, detoxify, ease urination, lubricate lungs and intestine, provides an excellent protein food. In soybean, atmospheric nitrogen (N_2) fixation happens in the nodules, nodules grow in the roots that are produced by N_2-fixing rhizobial bacterias and most of these bacteria belong to the genera of *Bradyrhizobium*, *Mesorhizobium*, *Rhizobium* and *Sinorhizobium*. With the world's increasing dependence on agriculture to feed its population, the use of reduced nitrogen derived from energy provided by fossil fuels is not likely to be sustainable. The key to future sustainable agriculture is to utilize the fundamental knowledge of the process of symbiotic nitrogen fixation in association with other agricultural crops to benefits an increasing world population. Food therapy of traditional Chinese medicine aims to maintain balanced nutrition through diet.

Keywords: Soybean, Traditional Chinese Medicine, Biological Nitrogen Fixation, Sustainable Agriculture

INTRODUCTION

Nutrition therapy on the basis of traditional Chinese medicine (TCM) is quite effective at treating common diseases. China is the home of the soybean. It was domesticated in the eastern half of north China around 11th century BCE. In terms of traditional Chinese medicine (TCM), soybeans are known for their ability to tonify qi and blood. They also help to clear heat and eliminate toxins from the body (Soleymani and Shahrajabian 2012a, Ogabi *et al.* 2013, Young and Shahrajabian 2017, Ogbaji *et al.* 2017, Ogbaji *et al.* 2018, Shahrajabian *et al.* 2018, Soleyman and Shahrajabian 2018; Young *et al.* 2018, Shahrajabian *et al.* 2019a,b,c,d). In Chinese medicine soybeans have long been known as an herb capable of healing many diseases including edema, common cold, skin sores, diarrhea, habitual constipation, iron-deficiency anemia, leg ulcers and complications of pregnancy such as vomiting, atrophy of the liver and renal failure. Chinese farmer also feed soybeans to cow to promote lactation, and humans may benefit frying soybeans and then steaming them with turnips and fresh ginger to promote lactation (Sun *et al.*, 2018). In Traditional Chinese Medicine (TCM), fermented soybeans are plants that belong to the 'Cool/Acrid herbs that release the Exterior' category. Herbs that release the Exterior aim to to treat the early stages of diseases that affect the upper respiratory tract, the eyes, the ears, the nose, the throat or the skin. TCM believes that External diseases such as colds or allergies can only invade the body if the External environment overwhelms our Wei Qi (the TCM version of the immune system). In order to counteract this invasion Cool/Acrid herbs aim to induce sweating by dilating our capillary pores so that they release more sweat. The belief is that this will expel the disease from the body and stop it from invading further (Xu *et al.* 2012).

Table 1. A list of some key nutrients currently under investigation in soybeans.

Nutrient		
Flavonoids and Isoflavonoids	1.	Daidzein
	2.	Genistein
	3.	Malonylgenistin
	4.	Malonyldaidzin
Phenolic Acids	1.	Caffeic acid
	2.	Coumaric acid
	3.	Ferulic acid
	4.	Gallic acid
	5.	Sinapic acid
Phytoalexins	1.	Glyceollin I

* Corresponding author: hesamshahrajabian@gmail.com

	2.	Glyceollin II
	3.	Glyceollin III
Phytosterols	1.	Beta-sitosterol
	2.	Betal-stigmasterol
	3.	Campestrol
Proteins and Peptides	1.	Defensins
	2.	Glycinin
	3.	Conglycinin
	4.	Lunacin
Saponins	1.	Soyasaponins (group A and group B)
	2.	Soyasapogenols

Table 2. The most important health benefits of soybeans.

1-	Improve metabolic activity
2-	Healthy weight gain
3-	Anti-cancer potential
4-	Boost heart health
5-	Relieve menopausal symptoms
6-	Boost digestion
7-	Improve bone health
8-	Prevent birth defects
9-	Improve circulation
10-	Control diabetes
11-	Relieve sleep disorders

Table 3. The most important health benefits of soybean milk.

1-	Helps to lower levels of cholesterol.
2-	Beneficial in providing relief from osteoporosis.
3-	Helps to prevent liver damage caused by oxidative stress.
4-	Provides relief from many postmenopausal health issues.
5-	Aids in maintaining optimal blood pressure in diabetic patients.
6-	Helps in maintaining optimal estrogen levels in menopausal women.
7-	Good remedy for managing weight and improving cardiovascular health.

Greater amounts of potassium, nitrogen and phosphorus were taken up from intercropping soil than from the monoculture (Soleymani *et al.* 2011a, Soleymani *et al.* 2011b, Soleymani *et al.* 2011c, Soleymani and Shahrajabian 2012b, Shahrajabian *et al.* 2017, Lian *et al.*, 2018). Gao *et al.* (2015) reported that soil nitrification was the main way of N_2O emission in intercropped field in the experimental zone. Nitrogen is one of the primary limiting nutrients for plant growth in agriculture, and the productivity of many agricultural ecosystems is controlled by nitrogen availability (Broumand *et al.* 2010, Khoshkharam *et al.* 2010, Shahrajabian *et al.* 2011, Soleymani and Shahrajabian 2011, Soleymani *et al.*, 2011d, Soleymani and Shahraiabian 2012c, Soleymani *et al.* 2012a, b, c, Shahrajabian *et al.* 2013, Soleymani *et al.* 2013, Soleymani *et al.* 2016, Shahrajabian and Soleymani 2017a, b, Abdollahi *et al.* 2018). The value of fixed nitrogen depends on its capacity to generate farm profits, economic value of the fixation agent (typically a legume) and its place in the farming system, on the proportion of fixed and applied nitrogen in the system, and on the bio-economic interactions between the two forms of nitrogen. Also, soil type and climate also affect the value of nitrogen, but so do fertilizer and crop and animal prices as well as their seasonal variability (Schilizzi and Pannell 2011).

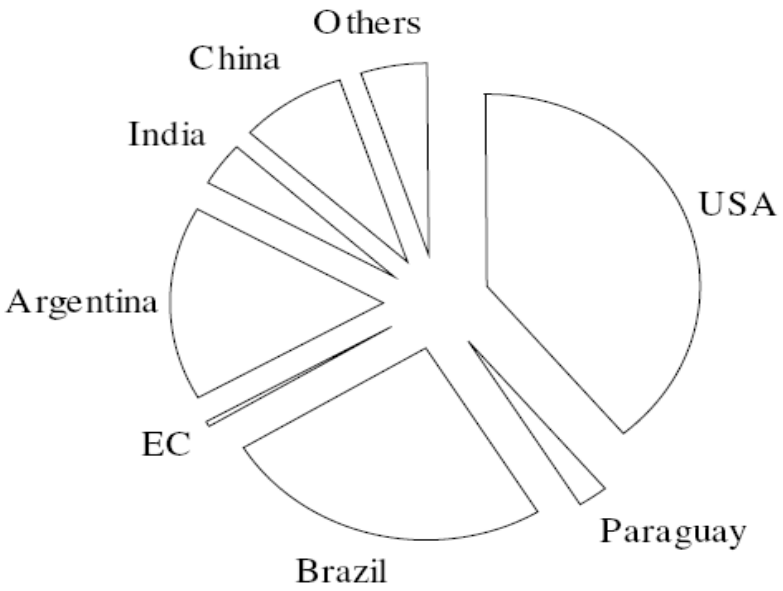

Figure 1. Contribution of different countries to world soybean production (estimated as 183.28 Tg) in 2002/2003 (CONAB 2002).

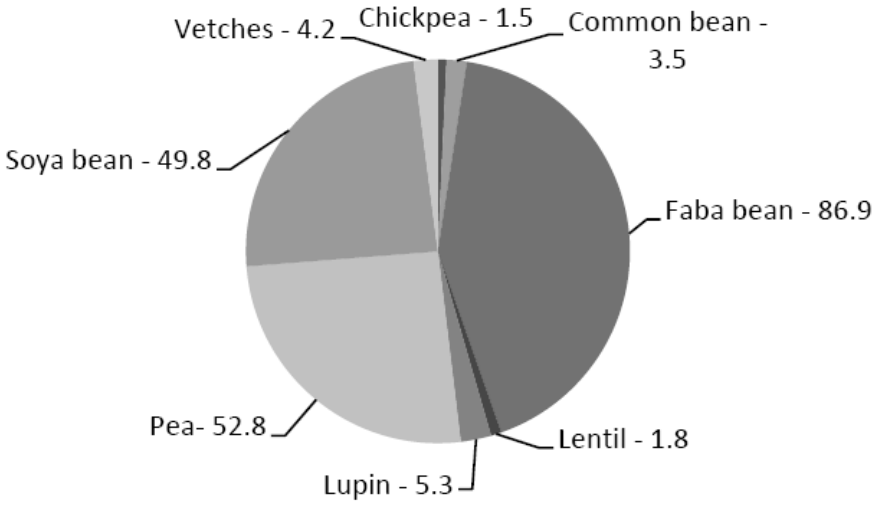

Figure 2. Total N fixed (10^3 tons) by grain legume crops in Europe (EU27 countries in 2009) (Soares *et al.* 2016).

Soybean nodule is classified to as a determinate type nodule, which has a spherical from. The cell divisions and nodule development is completed at the initial stage of nodule growth, when the nodule size is as small as about 1 mm diameter, and the nodule growth thereafter is mainly due to cell expansion. The soybean nodule has the symbiotic region (infected region) in the center, which consists of the mosaic of large infected cells and small uninfected cells. The nitrogenase, an enzyme to fix N_2 in bacteroid, is very susceptible to free O_2 and irreversibly destroyed by O_2. Therefore, free O_2 concentration should be kept at very low levels in a symbiotic region of nodules. On the other hand, nitrogen fixation and its assimilation processes require a large amount of energy and reductant produced through O_2 respiration. Therefore, nodule respiration is about four times higher than that of

roots based on dry weight. To suppor active respiration, abundant supply of O_2 is essential.

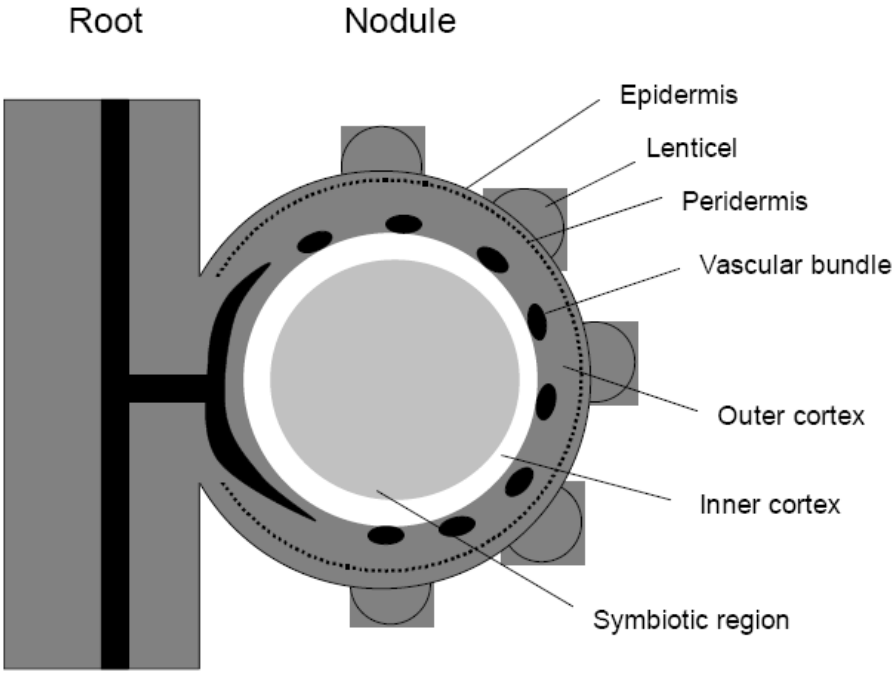

Figure 3. Structure of soybean root nodule.

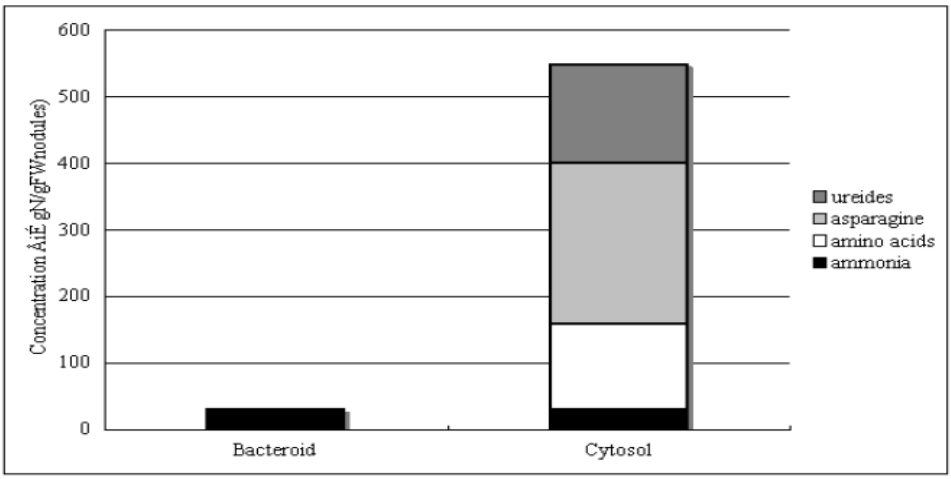

Figure 4. Major nitrogen constituents in bacteroid and cytosol fractions of soybean nodules.

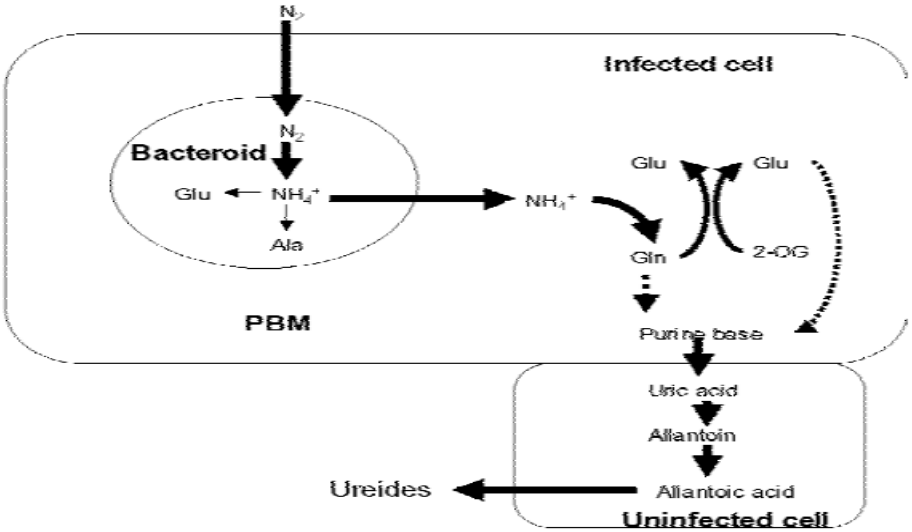

Figure 5. A model of nitrogen metabolism and transport in a soybean nodule.

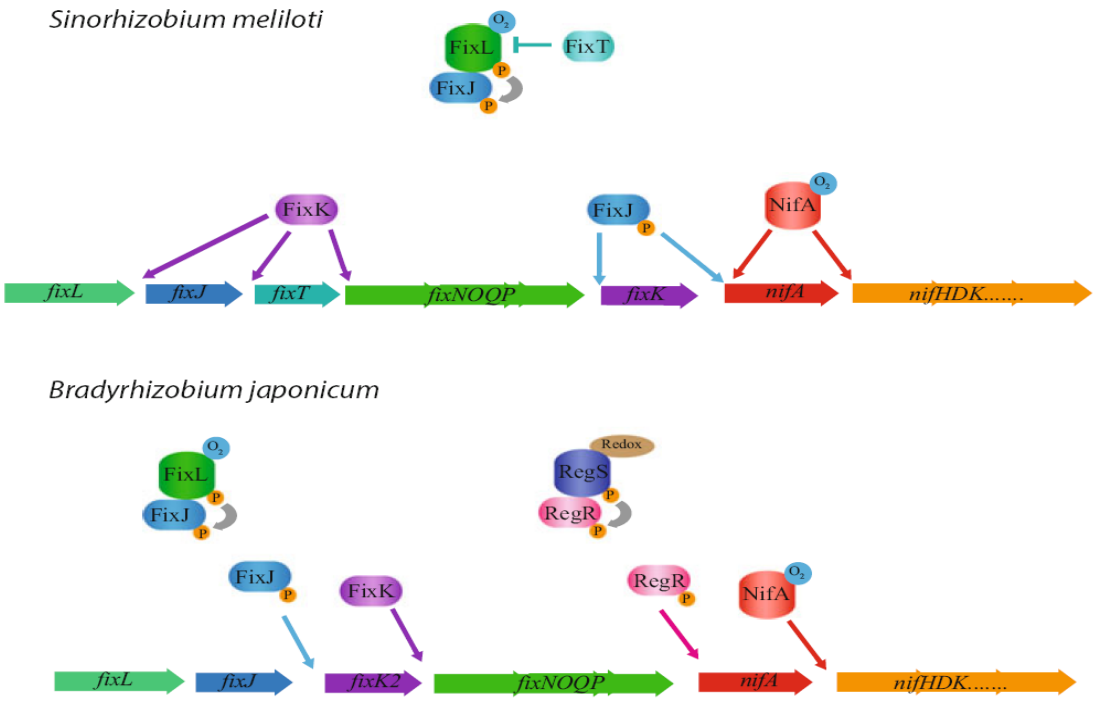

Figure 6. The mechanism of symbiotic nitrogen fixation.

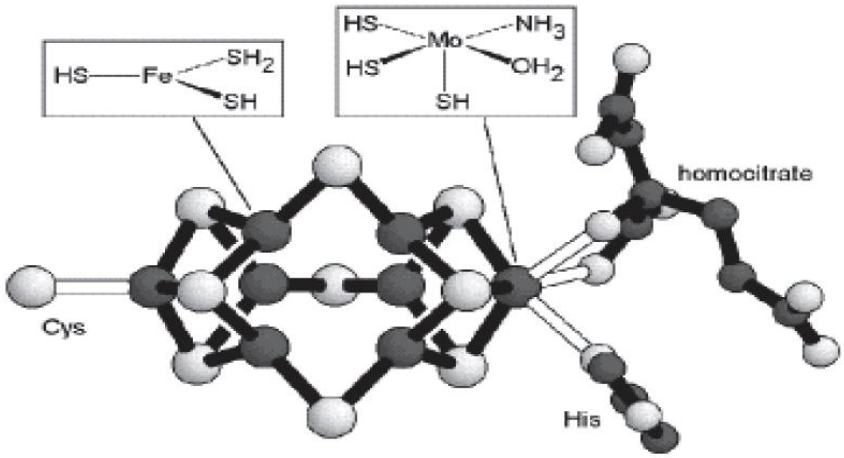

Figure 7. Structure of nitrogenase enzyme (Durrant 2011).

Ohyama *et al.* (2010) indicated that the major part of fixed ammonia in bacteroid (a symbiotic state of rhizobia) is rapidly excreted to the cytosol of infected cells in nodules, then the ammonia is assimilated into amino acids via glutamine synthetase/glutamate synthase (GS/GOGAT) pathway. Then the fixed nitrogen is then assimilated into ureides, allantoin and allantoate through de novo purine synthesis and degradation, followed by transporting ureides to the shoots via xylem vessels. Combined nitrogen especially nitrate rapidly and reversibly inhibits the nodule growth and nitrogen fixation activity, possible due to changes in photo assimilate supply to the nodules. In soybean, atmospheric nitrogen (N_2) fixation happens in the nodules, nodules grow in the roots that are produced by N2-fixing rhizobial bacterias and most of these bacteria belong to the genera of *Bradyrhizobium*, *Mesorhizobium*, *Rhizobium* and *Sinorhizobium*. Santachiara *et al.* (2018) found that the atmospheric N concentration curve might indicate an upper benchmark for evaluating symbiosis performance during crop development. Second, the concentration pattern observed for biological nitrogen fixation could potentially help to reverse the decline in seed protein concentration in modern soybean cultivars. And, the N concentration/dilution curves for the individual nitrogen sources could be incorporated into crop models for estimating nitrogen biological fixation at different crop biomass levels during soybean development. Schipanski *et al.* (2010) mentioned that soil N availability is often considered to be acentral factor affecting biological nitrogen fixation. They have also found that soil N uptake by N_2-fixing soybeans relative to the non-nodulating isoline increased as soil N decreased, suggesting that N_2 fixation increased soil N scavenging in low fertility fields.

CONCLUSIONS

Traditional Chinese medicine (TCM) is a system of healing that is thousands of years old. When used in traditional Chinese medicine, fermented soybeans are affiliated with the stomach and lung meridians and are used to aid digestion and relieve stuffiness and congestion in the chest. Fermented soybeans are used in the treatment of cancer-related symptoms including reducing the risk of prostate, stomach, and breast cancer and for counteracting the effects of chemotherapy and other forms of radiation. They are also used as a calming agent and help treat restlessness, irritability, and vexation. Fermented soybeans are used to help improve sleep. Other conditions treated with fermented soybeans include fevers and menopausal symptoms. Biological nitrogen fixation (BNF) is mediated by diazotrophic microorganisms that are capable of fixing atmospheric nitrogen using the enzyme nitrogenase. Nitrogenase catalyzes the reduction of N2 to ammonia (NH3) in the energetically expensive reaction: $N_2 + 8H^+ + 8e^- + 16ATP \rightarrow 2NH_3 + H_2 + 16ADP + 16P_i$. In soybean, atmospheric nitrogen (N_2) fixation happens in the nodules, nodules grow in the roots that are produced by N_2-fixing rhizobial bacterias and most of these bacteria belong to the genera of *Bradyrhizobium*, *Mesorhizobium*, *Rhizobium* and *Sinorhizobium*. The natural process of symbiotic nitrogen fixation, whereby plants such as legumes fix atmospheric nitrogen gas to ammonia, usable by plants can have a substantial impact as it is found in nature, has low environmental and economic costs and is croadly established.

REFERENCES

Abdollahi, M., Soleymani, A., and Shahrajabian, M. H. (2018). Evaluation of yield and some physiological indices of potato cultivars in relation to chemical, biological and manure fertilizers. Cercetari Agronomice in Moldova. 2(174):53-66.

Broumand, P., Rezaei, A., Soleymani, A., Shahrajabian, M. H., and Noory, A. (2010). Influence of forage clipping and top dressing of nitrogen fertilizer on grain yield of cereal crops in dual purpose cultivation system. Research on Crops. 11(3):603-613.

CONAB (Companhia Nacional de Abstercimento). (2002). Retrieved December 10, 2002,fromhttp//www.conab.gov.br/politica_agricola/ConjunturaSemanal?Semana19a2308/Soja-19a2308.doc.

Durrant, M. C. (2001). Controlled protonation of iron-molybdenum cofactor by nitrogenase: a structural and theoretical analysis. Biochemistry Journal. 355: 569-576.

Gao, Y., Li, X., Shen, X., Sun, J., and Duan, A. (2015). Soil respiration and nitrification-denitrification in maize/soybean intercropping system. Oxidation Communications. 38 (No 1A):357-366.

Khoshkharam, M., Rezaei, A., Soleymani, A., and Shahrajabian, M. H. (2010). Effects of tillage and residue management on yield components and yield of maize in second cropping after barley. Research on Crops. 11(3):659-666.

Lian, T., Mu, Y., Ma, Q., Cheng, Y., Gao, R., Cai, Z., Jiang, B., and Nian, H. (2018). Use of sugarcane-soybean intercropping in acid soil impacts the structure of the soil fungal community. Scientific Reports. 8:14488.

Ogbaji, P. O., Shahrajabian, M. H., and Xue, X. (2013). Changes in germination and primarily growth of three cultivars of tomato under diatomite and soil materials in auto-irrigation system. International Journal of Biology. 5(3):80.

Ogbaji, P. O., Li, J., Xue, X., Shahrajabian, M. H., and Egrinya, E. A. (2017). Survey yield components of spinach under influence of biofertilizer and nutrient solution in soils of Chengdu, Hunan, Shannxi and Xiaotanshan, China. Research on Crop Ecophysiology. 12(1):1-8.

Ogbaji, P. O., Li, J., Xue, X., Shahrajabian, M. H., and Egrinya, E. A. (2018). Impact of bio-fertilizer or nutrient solution on Spinach (*Spinacea Oleracea*) growth and yield in some province soils of P.R. China. Cercetari Agronomics in Moldova. 2(174):43-52.

Ohyama, T., Ito, S., Nagumo, Y., Ohtake, N., Sueyoshi, K., Takahashi, Y., and Sato, T. (2010). Symbiotic nitrogen fixation and its assimilation in soybean. Nitrogen Assimilation in Plants. ISBN: 978-81-308-0406-4.

Santachiara, G., Salvagiotti, Gerde, J. A., and Rotundo, J. L. (2018). Does biological nitrogen fixation modify soybean nitrogen dilution curves? Filed Crops Research. 223:171-178.

Schilizzi, S., and Pannell, D. J. (2011). The economics of nitrogen fixation. Agronomie. 21:527-537.

Schipanski, M. E., Drinkwater, L. E., and Russelle, M. P. (2010). Understanding the variability in soybean nitrogen fixation across agro ecosystems. Plant Soil. 329:379-397.

Shahrajabian, M. H., Soleymani, A., and Naranjani, L. (2011). Grain and forage characteristics of forage sorghum under different plant densities and nitrogen levels in second cropping after barley in Isfahan, Iran. Research on Crops. 12(1):68-78.

Shahrajabian, M. H., Xue, X., Soleymani, A., Ogbaji, P. O., and Hu, Y. (2013). Evaluation of physiological indices of winter wheat under different irrigation treatments using weighing lysimeter. International Journal of Farmiing and Allied Sciences. 2(24):1192-1197.

Shahrajabian, M. H., and Soleymani, A. (2017a). A lysimeter study, a unique tool for botanists, agronomists and other plant scientists. Asian Research Journal of Agriculture. 4(2):1-9.

Shahrajabian, M. H., and Soleymani, A. (2017b). Responses of physiological indices of forage sorghum under different plant populations in various nitrogen fertilizer treatments. International Journal of Plant & Soil Science. 15(2):1-8.

Shahrajabian, M. H., Soleymani, A., and Khoshkharam, M. (2017). Influence of green manuring from different cover crops and farm yard manures on quantitative and qualitative characteristics of forage corn in low input farming. Research on Crop Ecophysiology. 12(2):62-68.

Shahrajabian, M. H., Wenli, S., and Qi, C. (2018). A review of goji berry (*Lycium barbarum*) in traditional Chinese medicine as a promising organic superfood and superfruit in modern industry. Academia Journal of Medicinal Plants. 6(12):437-445.

Shahrajabian, M. H., Wenli, S., and Qi, C. (2019a). The power of natural Chinese medicine, ginger and ginseng root in an organic life. Middle-East Journal of Scientific Research. 27(1):64-71.

Shahrajabian, M. H., Wenli, S., and Qi, C. (2019b). Clinical aspects and health benefits of ginger (*Zingiber officinale*) in both traditional Chinese medicine and modern industry. Acta Agriculturae Scandinavica, Section B-Soil & Plant Science. 1-11.

Shahrajabian, M. H., Wenli, S., and Qi, C. (2019c). Traditional Chinese medicine and agriculture; organic life and sustainability for future. GSC Biological and Pharmaceutical Sciences. 7(01):091-095.

Shahrajabian, M. H., Khoshkharam, M., Wenli, S., and Qi, C. (2019d). Germination and seedlings growth of corn (*Zea mays L.*) to allelopathic effects of rice (*Oryza sativa L.*). Tropical Plant Research. 6(1):152-156.

Soares, R., Trejo, J., Veloso, M. M., and Castro, I. V. (2016). Biological nitrogen fixation by *Phaseolus vulgaris*. Revista de Ciencias Agrarias. 39(4):526-537.

Soleymani, A., and Shahrajabian, M. H. (2011). The influence of different planting dates, plant densities on yield and yield components of rice on the basis of different nitrogen levels. International Journal of Agronomy and Plant Production. 2(2):80-83.

Soleymani, A., Shahrajabian, M. H., and Naranjani, L. (2011a). The effects of nitrogen as starter fertilizer on ash percentage, important elements and solar radiation absorption of berseem clover cultivars intercropped by corn. Journal of Food, Agriculture and Environment. 9(1):342-344.

Soleymani, A., Shahrajabian, M. H., and Naranjani, L. (2011b). Yield and yield components of berseem clover cultivars in low nitrogen fertilizer input farming. Journal of Food, Agriculture and Environment. 9(2 part 1):281-283.

Soleymani, A., Shahrajabian, M. H., and Naranjani, L. (2011c). Changes in qualitative characteristics and yield of three cultivars of berseem clover intercropped with forage corn in low input farming system. Journal of Food, Agriculture and Environment. 9(1):345-347.

Soleymani, A., Shahrajabian, M. H., and Naranjani, L. (2011d). The effect of plant density and nitrogen fertilization on yield and yield components and grain protein of grain sorghum. Journal of Food, Agriculture and Environment. 9(3):244-246.

Soleymani, A., and Shahrajabian, M. H. (2012a). Response of different cultivars of fennel (*Foeniculum vulgare*) to irrigation and planting dates in Isfahan, Iran. Research on Crops. 13(2):656-660.

Soleymani, A., and Shahrajabian, M. H. (2012b). Forage yield and quality in intercropping of forage corn with different cultivars of berseem clover in different levels of nitrogen fertilizer. Journal of Food, Agriculture and Environment. 10(1 part 2):602-604.

Soleymani, A., and Shahrajabian, M. H. (2012c). Effects of different levels of nitrogen on yield and nitrate content of four spring oion genotypes. International Journal of Agriculture and Crop Sciences. 4(4):179-182.

Soleymani, A., Shahrajabian, M. H., and Khoshkharam, M. (2012c). Effect of different fertility systems on fresh forage yield and qualitative

traits of forage corn. Research on Crops. 13(3):861-865.
Soleymani, A., and Shahrajabian, M. H. (2012c). Effect of nitrogen fertilizer on ash, nitrate, organic carbon, protein and total yield of forage maize in semi arid region of Iran. Research on Crops. 13(3):1030-1034.
Soleymani, A., Khoshkharam, M., and Shahrajabian, M. H. (2012a). Germination rate and initial growth of silage corn grown under various fertility systems. Research on Crops. 13(3):1035-1038.
Soleymani, A., Khoshkharam, M., and Shahrajabian, M. H. (2012b). Influence of green manures and crop residue management on yield and yield components of silage corn. Research on Crops. 13(3):871-876.
Soleymani, A., Shahrajabian, M. H., and Naranjani, L. (2013). Effect of planting dates and different levels of nitrogen on seed yield and yield components of nuts sunflower (*Helianthus annus L.*). African Journal of Agricultural Research. 8(46):5802-5805.
Soleymani, A., Shahrajabian, M. H., and Khoshkharam, M. (2016). The impact of barley residue management and tillage on forage maize. Romanian Agricultural Research. 33:161-167.
Soleymani, A., and Shahrajabian, M. H. (2018). Changes in germination and seedling growth of different cultivars of cumin to drought stress. Cercetari Agronomics in Moldova. 1(173):91-100.
Sun, Y., Bi, H., Xu, H., Duan, H., Peng, R., and Wang, J. (2018). Variation of fine roots distribution in apple (*Malus pumila M.*)-Crop intercropping systems on the Loess Plateau of China. Agronomy. 8:280.
Xu, L.W., Jia, M., Salchow, R., Kentsch, M., Cui, X. J., Deng, H. Y., Sun, Z. J., and Kluwe, L. (2012). Efficacy and side effects of Chinese herbal medicine for menopausal symptoms: a critical review. Evidence-Based Complementary and Alternative Medicine. Article ID: 568106. 19 pages.
Young, Y., and Shahrajabian, M. H. (2017). Effects of intercropping and rotation on forage yield and quality of oat and common vetch in Jilin province. Research on Crop Ecophysiology. 12(1):9-23.
Young, Y., Hu, Y., Shahrajabian, M. H., Ren, C., Guo, L., Wang, C., and Zeng, Z. (2018). Changes in dry matter, protein percentage and organic matter of soybean-oat and groundnut-oat intercropping in different growth stages in Jilin province, China. Acta Agriculturae Slovenica. 111(1):1-7.