Research Assessment Exercise 2020

Impact Case Study

University: The Chinese University of Hong Kong
Unit of Assessment (UoA): 01 Biological Sciences

Title of case study: Developing stress tolerant soybeans for sustainable agriculture on marginal lands

1. Summary of the impact (indicative maximum 100 words)

Pioneering research led by Prof. Hon-Ming Lam decoded wild and cultivated soybeans genome and developed 3 new salinity and drought tolerant soybeans. Economic and social welfare impacts have exerted on smallholder farmers in NW China through collaboration with local institutes, international food companies and charities. The research continues to have a direct impact on sustainable crop production and profitability of farming nationally and internationally, with additional environmental impact by reduction of fertilizer use and thus CO_2 emission. This project has also been used to promote public awareness of sustainable agriculture via STEAM education programs, media interviews, talks, exhibitions etc.

2. Underpinning research (indicative maximum 500 words)

Soybean is an important cash crop as food and feed due to its excellent nutritional value, contributing ~70% and 30%, respectively dietary protein and oil of global supplies. Besides, soybean is also a natural fertilizer that can fix atmospheric nitrogen in quantities of in average 100kg/ha/year. Although soybean originated in China, the domestic supply of soybean can only meet one-third of its demand, making China the world's largest soybean importer. A comprehensive analysis was performed and concluded that environment constraints pose a severe challenge to the food supply in China and the world (3.1). Prof. Lam (School of Life Science, CUHK [1997-]) began his underpinning soybean genomic research since 1997 to ultimately increase the non-GM soybean production on marginal land in China. In 2010, 31 wild and cultivated soybean genomes were decoded and published in *Nature Genetics* that revealed much higher biodiversity in the wild soybean (3.2) and confirmed that wild soybean is valuable genetic resources for crop improvement. In 2019, Lam's team published the world's first high-quality reference genome of wild soybean in *Nature Communications* to facilitate soybean scientists to mine the gene resources entrapped in wild soybeans (3.3).

In further investigation of Ref 3.2, Lam's team successfully mapped several major quantitative trait loci (QTLs) with whole-genome-sequencing for important agronomic traits, including salt tolerance QTL with a causal gene cloned in 2014 (3.4). The research findings have been used in national projects to expedite the screening of new stress-tolerant soybean cultivars. With marker-assisted selection for the salt tolerance gene and field performance for drought tolerance, Lam's team successfully developed 3 new salt and drought-tolerant soybean cultivars, namely Longhuang 1, 2, and 3. These new cultivars have passed a 3-year regional test and are now using by farmers in Gansu Province with accumulative acreage exceeding 12,400 hectares since 2016 (detailed in Section 4).

Using advanced computer models, DNDC and GEOS-Chem, Lam's team found that total replacement of the traditional monoculture with intercropping soybean and maize enables higher productivity in crops with less synthetic fertilizers and hence reduces ammonia being volatilized from the cropland soil. This sustainable farming practice may help maintain a stable food supply and mitigate the air pollution problem in China (3.5).

Most recent work by Lam's team has also focused on international collaboration with South African plant scientists for the future development of soybean in there. South Africa has the highest potential to increase soybean acreage in a simulation modelling (3.6) and yet 87% arable lands of this country are suffered from drought. A local academic society for crop breeding was established under Lam's effort. A joint breeding program has been launched to develop new stress soybean cultivars. (detailed in Section 4)

3. References to the research (indicative maximum of six references)

(3.1) **H.-M. Lam**, J. Remais, M.-C. Fung, L. Xu, S.S.-M. Sun. 2013. Food supply and food safety issues in China. *Lancet* **381**:2044-2053.

(3.2) **H.-M. Lam**, X. Xu, X. Liu, W. Chen, G. Yang, F.-L. Wong, M.-W. Li, W. He, N. Qin, B. Wang, J. Li, M. Jian, J. Wang, G. Shao, J. Wang, S.S.-M. Sun, and G. Zhang. 2010. Resequencing of 31 wild and cultivated soybean genomes identifies patterns of genetic diversity and selection. *Nat. Genet.* **42**:1053-1059. (cover story)

(3.3) M. Xie, C.Y.-L. Chung, M.-W. Li, F.-L. Wong, X. Wang, A. Liu, Z. Wang, A.K.-Y. Leung, T.-H. Wong, S.-W. Tong, Z. Xiao, K. Fan, M.-S. Ng, X. Qi, L. Yang, T. Deng, L. He, L. Chen, A. Fu, Q. Ding, J. He, G. Chung, S. Isobe, T. Tanabata, B. Valliyodan, H.T. Nguyen, S.B. Cannon, C.H. Foyer, T.-F. Chan, **H.-M. Lam**. 2019. A reference-grade wild soybean genome. *Nat. Commun.* **10**:1216.

(3.4) X. Qi, M.-W. Li, M. Xie, X. Liu, M. Ni, G. Shao, C. Song, A.K.-Y. Yim, Y. Tao, F.-L. Wong, S. Isobe, C.-F. Wong, K.-S. Wong, C. Xu, C. Li, Y. Wang, R. Guan, F. Sun, G. Fan, Z. Xiao, F. Zhou, T.-H. Phang, X. Liu, S.-W. Tong, T.-F. Chan, S.-M. Yiu, S. Tabata. J. Wang, X. Xu, **H.-M. Lam**. 2014. Identification of a novel salt tolerance gene in wild soybean by whole-genome sequencing. *Nat. Commun.* **5**:4340.

(3.5) K.-M. Fung, A. P.-K. Tai, T. Yong, X. Liu, **H.-M. Lam**. 2019. Co-benefits of intercropping as a sustainable farming method for safeguarding both food security and air quality. *Environ Res Lett.* **14:** 044011.

(3.6) C.H. Foyer, K.H.M. Siddique, A.P.K. Tai, S. Anders, N. Fodor, F.-L. Wong, N. Ludidi, M.A. Chapman, B.J. Fergusson, M.J. Considine, F. Zabel, P.V.V. Prasad, R.K. Varshney, H.T. Nguyen, **H.-M. Lam**. 2019. Modelling predicts that soybean is poised to dominate crop production across Africa. *Plant Cell Environ*. **42**:373-385.

4. Details of the impact (indicative maximum 750 words)

Since the first milestone publication in 2010, Lam's soybean research has successfully translated basic scientific research to agricultural applications, producing diverse impacts:

Impact on national and international agriculture

Improved crop yield from arid farmlands

Gansu Province is in northwestern China, where precipitation is scanty and unpredictable year-round. From 2016 to 2018, three non-genetically modified soybean cultivars, Longhuang 1, 2, and 3 developed by Lam's team were approved by the Gansu authority as certified cultivars (5.1). These cultivars were distributed to local subsistence farmers working on semi-arid or arid region of Gansu Province. The estimated accumulated acreages of Longhuang 1, 2 and 3 in total have exceeded 12,400 hectares (2016-2019) with an estimated financial benefit of RMB 3.12 million (2016-2018) (5.2). These new cultivars were successfully used in intercropping (e.g. with maize, flax, wheat, trees, etc.), restoration of abandoned arid lands, soybean production, and soil replenishment in remote villages of high altitude.

Developing special soybean seeds for environmental sustainability in South Africa

Lam's team has started to collaborate with South Africa where 87% of her arable lands are suffered from drought. Scientists from South Africa have indicated strong interest to reanimate Prof. Lam's successful story in their country. Soybean seeds were sent to South Africa for developing adaptive soybean cultivars in 2016 (5.3). The impact of the soybean research has gone beyond China to other part of the globe. Inspired by the research of Prof. Lam, the establishment of South Africa Society for Crop Breeding and Research has been initiated in 2019 to collaborate with Lam's team on a project named "Climate-Smart Soybean Cultivation" (5.4), with the ultimate goal to empower underprivileged smallholder local farmers by providing new stress tolerant soybean seeds.

Influence on public welfare
The value of Longhuang 1 and Longhuang 3 was recognized by a famous international food company, Lee Kum Kee (LKK), which had hired 50 farmers in Gansu base to grow 20 hectares of in 2019 (5.5). LKK estimated this project will bring RMB 500,000 additional income to local farmers. Since 2016, Yellow Earth Foundation (YEF), has acquired the seeds of Longhuang 2 and distributed to over 150 underprivileged families in Gansu, *"….your seeds enabled them to make a successful harvest in over 20 hectares of land in remote mountainous villages which exerted impacts on their livelihoods"* (5.6).

Impact on Environment
Since 2016, over 12,400 hectares accumulated acreages of Longhuang 1, 2 and 3 in Gansu implied that 1,240 tones nitrogen were fixed. The same amount of ammonia nitrogen fertilizer will release 11,532 tones CO_2 (3.6 kg, 0.1 kg, and 5.6 kg CO_2 equivalence per kg of nitrogen production, transportation, and usage, respectively). Environmental impact was also revealed in the letters from LKK (5.5), *"…protecting the environment by replenishing the soil with nitrogen"* and YEF (5.6) *"The nature of the crop will help improve the quality of soil …… improve yield of other crops"*.

Influence on global policy
Prof. Lam is one of the key players of the World Universities Network (WUN) legume research team which collaboratively formulated a policy paper submitted to the United Nations in 2015 (5.7), to deliver a strong message to world leaders and policy makers the unique importance of legume cultivation in human health and sustainable food production.

Impacts on promoting public understanding of science and STEAM education
Prof. Lam's soybean research featured prominently in the local and international press, including Reuters in 2010. Prof. Lam has given numerous invited talks on soybean research in Hong Kong, to both specialist and lay audiences. The attendance of a 3-month special exhibition, "Soybean Homecoming" at Hong Kong Science Museum in 2013 was 483,920 (5.8). Besides, his story was also included in featured RTHK TV programme, "Our Scientists" (2017) to be broadcasted to the public. Apart from public lectures and media, Prof. Lam also initiated a STEAM programme since March 2018, targeting secondary school students and teachers. Total 732 participants from 25 schools have joined the "STEAM@soybean" activities (STEAM = science, technology, engineering, liberal arts, and mathematics). This programme broadened students' horizon with sophisticated scientific concepts and humanistic values (5.9). A quote from the principal of the Carmel Alison Lam Foundation Secondary School summarized the educational impact of the project, *"Through this activity, students have enhanced their awareness of food security, strengthened the concept of sustainable agriculture, and benefited from broadening their horizons and life planning."* (5.10). Efforts from Prof. Lam has improved public awareness and understanding on the significance of soybean in sustainable agriculture and promoting STEAM education in Hong Kong.

5. Sources to corroborate the impact (indicative maximum of 10 references)
(5.1) Certificate of three new soybean cultivars approved by Gansu Agriculture and Livestock Bureau (2016 - 2018).
(5.2) Certificate of three new soybean cultivar applications and acreage issued by Gansu Seed Administrative Bureau (2019)
(5.3) Material Transfer Agreement between CUHK and the University of Western Cape (2016)
(5.4) Letter from University of Western Cape (UWC), "Intention to form the South Africa Society for Crop Breeding and Research" (2019)
(5.5) Letter from Lee Kum Kee, "Cultivation of Soybean Seeds in Gaotao, Gansu" (2019)
(5.6) Letter from Yellow Earth Foundation, "Soybean Seeds Donation Programme in Gansu" (2018-2019)

(5.7) A policy paper sent from the World University Network to the United Nations. (2015)
(5.8) Letter from Hong Kong Science Museum (2019)
(5.9) STEAM@Soybean participating statistics (2019)
(5.10) Examples of appreciation letters from high schools (2019)