Transcript: Plant Breeding Stories Podcast
S3E5 - Professor Tifeng Shan

[Theme music plays]

Hannah Senior: Welcome to this episode of the Plant Breeding Stories Podcast, where I talk to leading lights in plant breeding, asking what they do, what makes them tick and what fascinates them about the world of plants. I'm your host, Hannah Senior of PBS International, world leaders in pollination control. We design and produce specialist pollination bags and tents used by plant breeders and seed producers all around the world. And through this, I've been privileged to get a unique perspective on how plant breeding globally affects our diets, farming systems and the environment. I'm excited to share a little of this with you. As we meet some of the amazing people who make plant breeding their life's work.

Hannah Senior: Today, I'm talking to Dr. Tifeng Shan, associate professor at the Institute of Oceanology, at the Chinese Academy of Sciences. Whereas normally we talk about terrestrial plants, today, we're talking about seaweed and focusing on brown algae, which technically are not plants at all, however, I think you'll agree, it's a really fascinating conversation. We'll be getting to grips with the macroalgae life cycle and how directed breeding happens in an aquatic environment. The related goals of intellectual property protection and preventing genetic pollution of natural varieties of seaweed, and why the future of algae looks bright. Transcripts of this episode and all our podcasts are available at PBSInternational.com/podcast. I hope you enjoy it.

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Hannah Senior: So to kick things off, would you like to introduce yourself?

Dr. Tifeng Shan: Thank you, my name is Tifeng, I'm from China. I have been working in the Marine Institute for 12 years. My research field includes seaweed cultural collection and conservation, genetic breeding, and population genetics. My career has been focusing on brown algae, especially kelp species.

Hannah Senior: A place I like to start these conversations is to understand a bit about your background, so how did you grow up and how did that lead into what you're doing today?

Dr. Tifeng Shan: Okay, I was born in the city of Zibo, another city very near Qingdao, in Shandong province, in the north of China. I almost never left the city until I went to university, I studied biology in a Yunomi university. I was supposed to be a teacher, teaching biology in high school. But before my graduation, I thought I should try something more challenging as I would like to do scientific research. Fortunately, I passed the graduate entrance examination and from 2004 I began to study marine biology at the Institute of Oceanology, and got my PhD degree in 2009. My path to my current role is very simple, after getting my PhD degree, I stayed in my mentor's laboratory as a researcher, until now.

Hannah Senior: So, you did marine biology at masters level, before that, did you have any interest in the sea or in marine life?

Dr. Tifeng Shan: Not always. I grew up in the city, I never saw live seaweed in the early days except for some dry kelp products in the market. But like many other children, I always had a dream to see and feel the big ocean, and also the marine life. I remember I watched a documentary film and I'm fascinated by the amazing, beautiful, and diverse marine organisms. Also, I think I cultivated my interest in seaweed gradually with my research. Now, I feel I am very lucky because I'm doing what I'm interested in.

Hannah Senior: Yes, so it sounds like it was an interest that you had in theory, but you were very lucky when you got into the role, you discovered you really loved it, it wasn't just a childhood idea, it was-

Dr. Tifeng Shan: Yeah.

Hannah Senior: It was actually a good idea.

Dr. Tifeng Shan: Yeah, you're right.

Hannah Senior: As I mentioned at the beginning, we focus mostly on terrestrial plants, and seaweed is a completely different thing. So, maybe we could just start by asking you to give us a little explanation of how are seaweeds and terrestrial plants related, are they even in the same taxonomic kingdom?

Dr. Tifeng Shan: Yeah, I will give a quick overview of the similarity and difference between them. Seaweeds or macroalgae can generally be divided into red, green, and brown categories, green algae and land plants are very close in evolution, and we can call them green plants. Although red seaweed is a little bit distant, they and green plants belong to the same kingdom, *archaeplastida*. In comparison, brown algae are very different, they belong to *Stramenopiles* or *Heterokonts*. In this sense, we should not call brown algae plants. They share some similarities to land plants, for example, they are both photosynthetic and multicellular, while the differences include the carbon storage metabolism, a cell wall component among others.

Hannah Senior: Many of the people listening will have eaten seaweed maybe in sushi or as a bit of garnish, but not really thought of it being something that's harvested or eaten in large quantities. So, can you tell me about the seaweed industry in China? What kind of seaweeds? How is it used? Could you give me an overview?

Dr. Tifeng Shan: Definitely. China has a very giant seaweed cultivation industry, with a total production of about 2.5 million tons.

Hannah Senior: Is that dry weight or harvested weight?

Dr. Tifeng Shan: This is dry weight. Commercially important, brown seaweed mainly includes two kinds of species, the Latin name, *Saccharina japonica* and *undaria*, their Japanese name, maybe people are more familiar, kombu and wakame. The red commercial seaweeds mainly include *Pyropia* and *Gracilariopsis*. We cultivate kelp on

long lines, *Saccharina japonica* is mainly farmed in three provinces, Fujian, Shandong, and Liaoning. *Undaria pinnatifida* is mainly cultivated in Liaoning and the Shandong province. *Saccharina japonica* is mainly consumed as food, not only due to the supplements of iodine in earlier days, which is indispensable for thyroid function, but also due to its flavor and other nutrients in general. Strikingly, a large portion is also used to feed abalone.

Hannah Senior: Oh, seafood delicacy!

Dr. Tifeng Shan: Yeah, which also has a big market in China. A small fraction is used for extraction of alginate, fucoidan, and other compounds, and chemicals, which can be applied in pharmaceutical and the cosmetic industry. *Undaria* used to be export oriented products, mainly exported to Japan, but now it has become more popular in China because of its tasty flavor, and benefits to human health.

Hannah Senior: You said that there were three types of seaweed, red, green, and brown. And today, we're going to focus mainly on kelp, which is a brown algae, and specifically *Saccharina japonica* and *Undaria pinnatifida.* But before we do, are green and red algae commercially used at the moment as well? I know that red algae is being investigated as a feed additive for livestock to reduce methane emissions, but I don't know whether there are other uses for red or green algae, commercially.

Dr. Tifeng Shan: Yeah, for red algae, there are a lot of commercial use. As you have said, sushi. Sushi is a product of *Pyropia*, it is the most valuable red seaweed in the world, I think. There are other red algae, for example, *Gracilaria*, they are used for extraction of phycocolloids, for example, agar or carrageen. There's a country producing a large quantity of red seaweed, this country is Indonesia. The production of tropical red seaweed is very huge in this country.

Hannah Senior: And is the majority of global seaweed production and consumption in Northeast and East Asian countries?

Dr. Tifeng Shan: Yeah, in fact, there's a large scale commercial seaweed production in Japan, Korea, and China. And the commercial seaweed in these three countries are almost the same because of the overlapping latitudes, intimate culture, and economic exchange between these countries.

Hannah Senior: And all being produced in the same way with these long lines, or is that just for kelp?

Dr. Tifeng Shan: Just for kelp, because *Pyropia*, the seaweed used for producing sushi, they are cultivated on a different system. We use nets to cultivate this kind of seaweed.

Hannah Senior: Thank you, that's really helpful to get a good overview of where seaweed is being grown and consumed and why. So the two species that we're talking about, I'm curious about how you go about breeding them. So for starters, what is the life cycle of kelp? How do they go about reproducing? What does that mean for breeding? So, let's start with, what is the life cycle?

Dr. Tifeng Shan: Yeah, the life cycle is very important, before we conduct breeding, we must know exactly what the life cycle of the seaweed is. So, the kelp has a biphasic life cycle, alternating between separate and free living diploid sporophytes, and haploid gametophytes. Sporophytes are what we can see in the wild with big steles and the gametophytes are very tiny filaments, we can only see them under a microscope. When sporophytes become mature, they go through meiosis and they release zoospores. The zoospores attach to hard substrates and germinate to form gametophytes. Males and the females are half and half, they produce sperms and eggs, respectively. After the eggs are fertilized by sperm, young sporophytes are produced, this is the life cycle of kelp species.

Hannah Senior: And I understand they can also reproduce asexually, is that correct?

Dr. Tifeng Shan: Yeah, but usually reproduce sexually. Under some stressful condition, if the female cannot find a male counterpart, they go through asexual life cycle, like parthenogenesis, but asexual life cycle is not very usual in nature.

Hannah Senior: Many of our listeners will be familiar with the process of plant breeding on the land, but how do you go about collecting the gametophytes and ensuring you get a controlled cross when you're dealing with plants in the water?

Dr. Tifeng Shan: Similar to land plants, there are two major breeding methods of kelp, selection and cross of hybridization. For selection breeding methods, we don't need to collect gametophyte first, we just perform selection by choosing parental sporophytes with desirable traits, and getting the next generation just through mixing the spores. With regard to cross of hybridization, we must first establish gametophyte clone cultures, then we are able to cross between a pair of male and female gametophytes. In this way, we can fully take advantage of hybrid vigor, that is heterosis in biological term.

Hannah Senior: And how do you isolate those gametophytes? Do you have to literally use a microscope to do it, or can you collect them in a net, or a bag, or something?

Dr. Tifeng Shan: Yes, we must complete this job at the lab, after sporophytes mature, we collect them and take them back to our lab, and release zoospores, and we usually use petri dishes in the lab to collect zoospores. And we collect them in low density, and after they become gametophytes we can select them individually so we can take them out and put every single one into a tube. So every single one is called a gametophyte clone, because they come from the one single zoospore.

Hannah Senior: So it's quite labor intensive, it needs a lot of work, a lot of specialists.

Dr. Tifeng Shan: Yeah, it's a lot of work.

Hannah Senior: Who is doing this breeding? You're a researcher, but are private companies doing the breeding? And do you work with other organizations?

Dr. Tifeng Shan: For cultivation, usually the private companies will do this job. For breeding varieties, I think it's cooperation between private companies and breeding scientists from universities or institutes. I think this is similar in Japan, Korea and China.

[Theme music plays]

Hannah Senior: You're listening to plant breeding stories brought to you by PBS International, world leaders in pollination control. We're exploring the personal stories behind people, who've dedicated their careers to plant breeding, helping us to well productive plants, greater food security, and more sustainable agriculture. Now back to the podcast.

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Hannah Senior: You painted a picture of these very early crosses happening in petri dishes. But then in terrestrial plants, you would go from a single plant to maybe a plot trial, to maybe a field, so you have to do the process of scaling up. How does that work in these kelps? How do you scale up from a single plant that looks promising, to larger quantities for trials, for testing?

Dr. Tifeng Shan: There are two ways to breed and cultivate individuals, one way is from gametophytes, as you have said, it is very laborious. We must select different gametophyte clone cultures, and then propagate in order to get enough by a mass quantity. And after that we cross female and male gametophytes to get enough individuals for cultivation. But there's another simple way, and that is what we usually do nowadays - we usually just release the zoospores. We attach to the collection, the collection is a kind of system, it's a frame wrapped up with strings, so the zoospores will attach to the strings, and they grow into gametophytes, just on the strings. And after that, male and the female gametophytes just cross and generate the next generation of sporophytes. This is a much easier way to do breeding and the cultivation subsequently.

Hannah Senior: Okay, it's blowing my mind! There's so many similarities, but so many differences! [Hannah laughs]

Dr. Tifeng Shan: Yeah it's!

Hannah Senior: The important question I haven't asked so far is what traits are you breeding for? We understand a little bit about the mechanics, but what are the goals of your breeding program?

Dr. Tifeng Shan: The breeding purpose, mostly for higher biomass and a larger size. In addition, chemical composition, stress tolerance, and later maturity are also targeted. For *Undaria*, we're also breeding for small and flexible fronds because this kind of individual is of high commercial value in the markets.

Hannah Senior: Why is late maturity something that's important?

Dr. Tifeng Shan: I think late maturity is related to yeild, if the seaweed can grow for long periods, their biomass is kind of higher.

Hannah Senior: And also stress tolerance you mentioned, one of the things I imagine that might be a growing challenge is the consequence of climate change, having warmer oceans, perhaps more acid or a lower pH in the ocean. Is that the kind of stress tolerance that you're thinking of?

Dr. Tifeng Shan: Yeah, I mean stress tolerance by tolerance to high temperature, low pH or changing environment across different kinds of environmental conditions. Yeah, all kinds of stress tolerance.

Hannah Senior: All kinds of stress. Do you ever take account of the taste? Some breeding programs like for berries or things like that, which are for human consumption, they have tasting panels and people are feeding back about the flavor or the texture. Is that something that ever features into your breeding programs?

Dr. Tifeng Shan: The taste, I think, is too complicated for seaweed breeding now because there's a very short breeding history for seaweed. Maybe this is the next target of our breeding, but now it is too complicated. [He laughs.]

Hannah Senior: There's lots of work to do without worrying about that.

Dr. Tifeng Shan: Yeah.

Hannah Senior: One of the things that I was thinking about is when you have these improved varieties that you're putting out into commercial production, they're going out on these long lines. I wondered if there was any risk to those improved genetics escaping into the wild, into the natural environment. Is it a problem? Is it something that people think about or is it actually of no consequence?

Dr. Tifeng Shan: Yeah, good question. I think there's a possible risk if the variety escapes from the farm to nature. In China, few people consider this question because I think we don't have the protection standpoint now. But for western people and especially for Japanese people, they protect the natural populations, very strictly. They cannot transplant a natural population to another population, and they avoid the variety escaping from the farm to the wild. I think the risk exists, for instance, if the varieties grow faster, once they escape to the wild, it may out-compete the natural population. This will threaten the existence of natural population. And it will also homogenize genetic variations and reduce genetic diversity of the species. I think there's a risk of escaping of the variety.

Hannah Senior: But how do you control that? Being in the sea, surely a lot is washing in and out with the currents, is it actually possible to control an introduced variety?

Dr. Tifeng Shan: Yeah, as I have mentioned, in Europe, I think there are some regulations. If they conduct cultivation, they must cultivate the local population. They cannot introduce another population for cultivation, so I think this is a method to avoid

genetic pollution. Another more feasible way is to expand the use of hybrid varieties because some hybrid varieties cannot reproduce in nature, so we can widen hybridization between varieties and natural populations.

Hannah Senior: And moving from that ecological risk of hybrids escaping into the wild, what about intellectual property risk? If a lot of time, money, and energy has gone into developing a variety, and then that just spreads on the current, how do you control the intellectual property rights in it? Are there intellectual property rights in these varieties that you're developing?

Dr. Tifeng Shan: Yeah, there are intellectual property, and the people in China realize the importance of intellectual property. So, when we successfully bred a new variety, we get a certificate from the Chinese agriculture ministry. But in spite of that, people usually don't comply with the regulations, so by this way, we cannot protect intellectual property very efficiently. I think the most feasible or efficient way to protect intellectual properties is to expand the use of hybrid varieties. As I have mentioned, we can just protect the male and female parental gametophytes of the hybrid variety, just like the elite seeds of maize or rice. Seaweed growers must come back to us for the original F1 hybrid seedlings because only the F1 hybrid seedlings are superior.

Hannah Senior: Okay, so every year they have to come back for…. A bit like a grower of hybrid corn has to come back for the seed every year, it's the same principle for the hybrid seaweeds.

Dr. Tifeng Shan: You're right.

Hannah Senior: Interesting, yeah. And that leads on to whether you see any crossovers with the terrestrial plant breeding world, whether you think there are any opportunities for collaboration between breeders on the land and breeders in the sea.

Dr. Tifeng Shan: Yes, absolutely. In fact, seaweed breeding is at its infancy, if compared to land crop breeding. In fact, we learn a lot of breeding strategies and

methods from land plants. We learn directly from the land crops in fact. I think we should look for more opportunities for collaboration with land crop breeding scientists.

Hannah Senior: What do you think of the big trends in seaweed breeding that you anticipate?

Dr. Tifeng Shan: Well, I think genomic selection and gene editing are two big trends for seaweed. Fortunately, genomes of several seaweeds have been sequenced, and this is an important step towards exploring genomic information for more efficient breeding in seaweed.

Hannah Senior: Is that something that your lab is doing or is that something for the future?

Dr. Tifeng Shan: I think it's for the future, but we just sequenced a genome of *Undaria pinnatifida* last year.

Hannah Senior: So not too far in the future then.

Dr. Tifeng Shan: Not too far, but difficult.

Hannah Senior: Yes. You've given me a really good overview of this whole world that I knew nothing about prior to our conversation, and so it's been really interesting. But just circling back to you and your motivations, I'm wondering when you have difficult times, what is it that keeps you going, when you hit a problem, when things go wrong, tell me about that, what keeps you going?

Dr. Tifeng Shan: Because I'm interested in what I'm doing, and I have passion, when things gets tough I believe things are going to be fine if I persist. Also, interest is the best teacher, so I think passion, belief, and interests are the motivations that drives me through the tough things.

Hannah Senior: Do you think that the future of seaweed as a crop is bright? Do you think there's a good future? Because if nothing else, I understand the nutrition value is very high, the carbon sequestration value is very high, it feels like it should have a big growth future.

Dr. Tifeng Shan: Yeah, I think the future of seaweed is bright. In early days only Asian countries focused on the cultivation industry of seaweed, but now more and more people from Europe, from America, they realize the value of cultivating seaweed. Because seaweed, just as you have mentioned, have a lot of benefits, nutrition, carbon sequestration. I think that's it.

Hannah Senior: So my final question to ask you, do you have any messages for the terrestrial plant breeding world, anything you want to share with, or make sure that the terrestrial plant breeding world knows about marine plants?

Dr. Tifeng Shan: [He laughs] Seaweed breeding is very young, it is a young subject, so I know some very excellent breeding scientists of land crops, and in fact, our teachers in breeding subjects. So I think I just look forward to more collaborations with land crop breeding scientists. I think your program is mainly focused on terrestrial plant breeding. Maybe very few people are interested in seaweed, but I suggest people focus more on this kind of amazing marine life. They are very beautiful and diverse. I suggest more people came in contact with seaweed.

Hannah Senior: Excellent. This has been such an interesting conversation. Thank you very much for your time today, associate professor of marine biology, Tifeng Shan of the Chinese Academy of Sciences. Thank you very much indeed.

My pleasure. It’s really my honour to share what I know about seaweeds.

[Theme music plays]

Hannah Senior: You've been listening to plant breeding stories by PBS International and I'm your host Hannah Senior. Plant breeding is a pretty specialist podcast topic, which can make it difficult for people who share our interest in this kind of thing to find it. So if you've enjoyed the podcast, recommend it to your friends and colleagues and please help others in the plant science community to find it by rating this episode and subscribing to the series. I'd love to hear from you if you want to suggest people you'd like me to interview, you can contact me on Twitter @PBSInt or on Instagram at @PBS_Int. Until next time stay well.

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