Transcript: Plant Breeding Stories Podcast
S4 E7 Dr Girish Chowdhary

[Theme tune 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: Series 4 will be the last in this podcast. And it has been the most incredible experience to dig into so many different aspects of the plant-breeding world. And literally the world. If you're listening to this, you're part of a community that spans the globe from Albania to Zambia, Adelaide, Australia and Ames, Iowa, to Zurich.

Hannah Senior: This is one of those episodes of plant breeding stories, where we talk to someone who is not exactly a plant breeder, but whose work is super relevant to our field. Professor Girish Chowdhary is an expert in robotics, who's taken his expertise and applied it to the needs of plant breeders in setting up a company called EarthSense. In this episode, we talk about how EarthSense uses robotics to speed up and enhance the collection of phenotyping data during plot trials, making it almost ten times faster, and providing a much richer data set. We talk about the difference between academia and industry, using plant breeding as a route into agriculture more widely, and how to train the next generation of students in AI and robotics to see a wider range of industry applications than the tech industry.

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Hannah Senior: It's a pleasure to have you here today, Professor Girish Chowdhary. So we'll start with an easy question. Can you please introduce yourself?

Girish Chowdhary: Sure, yeah, so. So I'm a professor of Ag and bioengineering and computer science at the University of Illinois at Urbana Champaign, and also the co founder and CTO, Chief Technology Officer at EarthSense Inc, which is a company that I co founded about four years ago with my very good friend, Chinmay Soman. My formal training is actually in aerospace engineering in Australia. So 2003 is when I graduated. But I've always been working in robotics, Field Robotics. It started with drones. When I was done with my undergraduate degree, I started working at the German Aerospace Center, working on unmanned aircraft, as we call them then. And then that led to an interest in robotics and mobile robotics overall, and in particular field robotics, robots that are not in indoor environments that are outdoors that are doing things in the real world. Then I did my PhD in this area at Georgia Tech, and then spent some time at MIT doing a postdoc and then started faculty positions.

Girish Chowdhary: And I was always interested in creating robots that make an impact on the real world. Robots that are designed to help people. I really strongly believe and even when I teach robotics, I always tell students that one of the things that roboticist have to do is, you know, we write papers, and that's great and we create technology, that's great. But we should really ask ourselves, where are the robots? Where is the impact? You see R2D2 and C3PO from Star Wars. And that's where most of us got into this stuff, right? Robots that can actually be useful to people. But then if you look outside today, robotics is not maybe as widely adopted as it should have been. I would say that the best working robot that I know of is an elevator. I mean, it's a robot, you don't even know that it's one. So we need something more. I was always focused on trying to create systems that have an impact in the real world. And about four or five years ago, having done lots of defense projects with aerial robots, ground robots, I got very interested in this, this idea of agricultural robotics.

Hannah Senior: Did you have any connection to plants or agriculture. Was there any particular reason that the lights went on with “Aha! This thing that I'm interested in with robotics could be usefully applied in this space!”

Girish Chowdhary: The school that I was in, with my very good friend Chinmay, who also went to the same school, we had a lot of interactions with farmers in India. There's a lot of disparity between cities and villages. And so we would go out into these villages to meet with farmers and the problems that they were facing were just momentous, they were just huge. So Chinmay and I started chatting together after a long time of having gone our own way. He was starting to get back into agriculture after having done a PhD in nano tech and just felt really moved about some of the issues that farmers are facing around In the world. And I was looking for an impactful application of robotics. Like defense is great. But the impact is not always something that you can write home about, right? I just started looking into this. And it felt like field robotics would have a tremendous application in agriculture. And it would really be valuable. So that's how it kind of came together.

Hannah Senior: And it was through that, that you got involved with a program in sorghum breeding. And that's when you had a lightbulb moment about plant breeding. Is that right?

Girish Chowdhary: Yeah, through that program, I got exposed to this wonderful world of plant breeding. It just hit me so hard that this foundation of agriculture is the seeds, it's the program that we install in the soil - that's how I think of it. And there's a lot of value in making that work better. So if I can make a plant that's resistant to diseases and to insects, then I don't need to spray. It's such a more foundational attempt at improving sustainability. So how can plants be more resilient 40 years from now when the planet is expected to be a lot warmer?

Hannah Senior: You've been developing a robot that can help plant breeders gather data on their plot trials. But before we dive into that, could you tell me what the key issues are, or differences are, between field robotics versus other kinds of robotics?

Girish Chowdhary: In a nutshell, it's because the field environment is surprising. It's unstructured. You really have not a lot of control. And anything and everything that you can imagine will happen. Murphy's Law is active - full on big time! So I would say of course, we all know about the fixed robots that make your cars, right. So they are all programmed, they basically just orchestrate their movements extremely precisely. But mobile robots that go around and move carts around, those robots use a lot of navigation aids that are already embedded in the floor. They will put some markers in the environment, they can also control who is where, at what time. So you don't have that control when you're in the field, you're literally in the wild. Sensors crapping out, it gets cloudy and some GPS doesn't work or some broadcast station in Oklahoma is down so you don't have RTK precision anymore. There's also ditches and holes and all kinds of things just combined together. The other part that's also challenging about field robotics is that the applications typically demand that you deliver value at reasonable cost. You're going to a farm where the amount that you can get from the farm is kind of set. So cost becomes a pretty big challenge. And just like computers and other industries have done well, we have to deliver it at cost. It's not just about how fancy my robot is, and how many hundreds of thousands of dollars of sensors I have. But can I make a good robot? That doesn't cost an arm and a leg. So that's what makes field robotics really hard.

Hannah Senior: It also needs to be more robust. I mean, it's not just, to your point, not just unexpected things happen in the environment, but it's subject to more damage and dirt.

Girish Chowdhary: Subject to the elements, right? So harsh, uncertain and changing environments, that's what we say. So it's like some of our really early robots that we were when we were just prototyping with 3d printing, we sent them to Australia, and they melted! They literally melted in the sun. Today, of course, we have robots now deployed all over the world,

and you can kick them, you can sit on them, and they don't break. But that's absolutely true. So the system itself has to be very rugged, very self contained, easy to move around, waterproof, and things like that.

Hannah Senior: So tell me a bit more about your company EarthSense? What are your goals, where are you based, and so on?

Girish Chowdhary: Our slogan is agricultural intelligence. And we believe very strongly that AI and robotics will provide new options for farmers that are foundationally and fundamentally more sustainable. In the long term, why we founded EarthSense was to heal the planet.

We wanted to create technologies that will make sustainable management a reality. So we've just, we've just been growing and you know, and accelerating at really fast speeds. And we're very fortunate to be in the Urbana Champaign area, which is so conducive to this type of entrepreneurship, especially in agriculture - a confluence of agriculture and technology. So we founded it in 2016. It was me and Chinmay, the two musketeers in our garage, I would say. Now we're 25 people strong full time, and we have two offices, one in Champaign Urbana, and the other in Pune, India. We have basically worked with many of the top breeding companies. In total, we made about 130, 140 robots and by design and a little bit by luck our robots have been fairly reliable compared to the ones that we started with at the lab. Now they're really super reliable, and we're really proud and happy with what we do.

Hannah Senior: Why did you choose a plant breeding application for your first field robot? What was the problem that you set out to solve?

Girish Chowdhary: They were limited by data, they couldn't collect all the data that they wanted. So we crystallized around that and we said, “Okay, well, this is the place to start.” I mean, an issue with agricultural robotics, in any robotics, is that they try to go after the big one, you know, and the big path is far away .You have to establish the market first. So this was the place to start and then it had all the impact and there was a clear need, and we had a product that we could make that could actually help these people.

Hannah Senior: Mmmhmm [affirmative] And your robot is designed to help plant breeders with phenotyping. Is that right?

Girish Chowdhary: Absolutely. Yeah. So it's about helping plant breeders understand the physiology of the plants so that they can downselect better and earlier in a more efficient way, so that they can… If you're a scientific academic reader, you can get your research and your experiments done efficiently and in a more meaningful and confident way. And if you're a commercial breeder, you can bring products that farmers actually like that are predictable, to market earlier than your competition. And that's the true value proposition.

Hannah Senior: So what kinds of characteristics can your robot recognize in the field, what's being measured?

Girish Chowdhary: There are things that plant scientists measure today that drive their decisions on selections. And then there are things that they would like to measure. So let me start with the things that they do measure. So depending on what the growth target is, so if you're doing for example, sorghum, which is where we had started with the TERRA-MEPP project, that was all biomass. It was bio energy sorghum. So it was about height, and it was about leaf index and stem width. Now that we're more into corn or maize, it's all about the yield, right? So one of the key phenotypes of interest right now is the height of the plant versus the height of the ear, the corn ear. Corn yields pretty well today, compared to what it used to. But it's tall, right? And it's subject to lots of wind damage. One question could be “can we breed shorter corn that is equally productive?” and then it will be less susceptible to wind damage. Another example, if you move away from the commodities into the specialty crops - say papaya, right? So papaya, the trees can be taller, harder to get to. Can we breed a papaya that is a dwarf papaya, so it's easier to pick? Can we build a papaya that's resistant to, let's say, different kinds of diseases. So I think each breeding program would have a different target. And then they're looking for data and then they measure… So in maize, they measure

height, they measure Leaf Area Index, which is kind of a measure of how much sunlight is penetrating through the canopy. They measure stem width, they measure ear height, which we mentioned, talked about. So these are just some basic phenotype things. And then there's things that they don't measure today that they would really like to know. Like leaf angle. Leaf angle is a great one. It's like a dream trait for some breeders, because the angle of the leaf depends on how much energy it can capture. It's nearly impossible to measure that in a field setting. So you'd have to walk around with a protractor, bending in front of every plant… [they both laugh]

Hannah Senior: [laughing] In the wind!

Girish Chowdhary: [laughing] put that protractor there, in the wind in the 90 degrees Fahrenheit, temperature, right? And nobody wants to do this job!

[they both laugh]

Hannah Senior: [sarcastically] I can't imagine why!

Girish Chowdhary: You can't measure everything today. That's what happened. So what breeders do is they say, “Okay, we're gonna measure three plants from this one plot”. Because that's all the time we can afford. So right there, when that person goes in and picks the plants, there's already a bias. Which plants did they pick? And again, like I said, it's hard to find that labor, it's hard to train that labor. So you kind of are getting really variable data. What I think the robots do really well is give you consistent data. Robots could make that possible. We could actually measure high throughput.

Hannah Senior: Is it the sensing and imaging technology that's novel? Or is it the fact that it's then automated and can just head off into the field and do its thing?

Girish Chowdhary: Yeah, it's a confluence of three things that I think EarthSense has managed to put together. So the first is the platform itself, this idea of a compact agricultural robot, specifically designed for phenotyping. So we designed this form factor that was

specifically designed for breeders. It was a small robot that will fit in the plant canopy. So width was just right, the cameras were positioned perfectly - they are inset into the robot so that they get the longest view to the plant so that the plant images are not blurry. The little details on the camera we've got figured out like they all have exposure control, they have gimbal stabilizers, the robot has independent suspension, has a brushless DC motor so it can go into waters. Before us there isn't a smaller robot than ours that actually is rugged and has been deployed and you can kick around and throw around in the field. The second is this autonomy, so being able to be autonomous under the plant canopy. So under the plant canopy GNSS, or GPS isn't as accurate as it is outside. It's still usable for identifying the plot. So you can get an accuracy of up to 10 centimeters, 40 centimeters. But you can't rely on it to navigate under the canopy like a tractor does. So we had to create technologies that we're basically reactive to the plants, We sense the plants around us using either lidars or camera vision, and then keep the robot in the center of the road with that. So that was another big set of innovations. And the third one was this whole sensing, like data analysis. So we take the camera data from these specifically calibrated cameras, combine that with the GPS, and inertial and robot other data, and then create these measurements of STEM width. It's a geometric measurement. It's not just how many things I see, but what is the width of it. Ear height - so first, you have to find the ear and then find its height. Then plant height, plant count, all of these things. And we deliver them at scale. And we guarantee that when you collect data, over 1000 plots, or 100,000 plots, in the case of one of our customers, our data is attributed to that plot which you collected the data from. Because if it gets messed up, then it's completely useless to them, right! [He laughs].

Girish Chowdhary: So we guarantee that and there's a whole process. Part of that is the fancy, shiny, whatever algorithms that we use for computer vision. And large datasets that we use to train those algorithms. But the other part of it is the meticulous pipeline, that picks up that data from the field on crappy internet connections, moves it to the cloud, verifies it automatically, there's even a human verification process in place that we can get done at high scale, and then delivers the traits back to the breeder, you know, in 48 hours.

[Theme tune 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 more productive plants, greater food security and more sustainable agriculture. Now back to the podcast.

[Theme tune fades out]

Hannah Senior: We've been talking about your phenotyping field robot and how it gathers all sorts of data on plants in the field. But I wonder, there are so many different crops out there, do you need to reconfigure or redesign the robot for each new crops that you work on?

Girish Chowdhary: So almost, but not entirely. It's about the infrastructure. So when we were a young company, it was a big deal for us, because we had to create that key IP. And then we were really early in the field too. But now we're at a point where I think what's more important is the rest of the thing, like the robot doesn't change, the sensors don't always change as much. But the all of that pipeline of moving that data, cleaning it up and putting it in the place where our developers can go at it is figured out. So we can now do traits, like change from one crop to the other in weeks. And also our models are getting better, because we have, you know, the last we counted, 5 million annotated images, annotations from under the plant canopy. Nobody has this kind of data! [He laughs] With that kind of data, we can pre train, we can do unsupervised learning, we can do all kinds of the top tray tools in the market. That's where I'm fortunate to have this connection to academia where I actually teach AI and teach robotics. So I know what's going on over there. And with our AIFarms is the National Center for AI, one of the National Centers for AI and agriculture at UIUC, so I'm involved with that. So there's a lot of these new AI methods that are coming out, they're applied to something totally different, right? Mostly like these autonomous driving things. But we're pretty aware of those so we can leverage those and speed up how fast we can move from one plant or one trade to other.

Hannah Senior: What made you choose to go for a ground based robot rather than something that goes overhead?

Girish Chowdhary: Yeah. In fact, we started there. We started with drones. So when EarthSense was founded, we were like, “Let's make drones a reality in ag” and we went through this National Science Foundation program called I-Corps™. By the way, this is, again wearing quickly my slightly more academic hat, for any entrepreneur who is interested, a science entrepreneur and if you're in the United States, you should definitely spend some time with the NSF I-Corps™ program. They get you to get out of the building and talk to real people, people who are going to be your customers, to figure out the value proposition. And so we did that and we went out and we talked to a very large number of agronomists, crop breeders and other stakeholders, farmers. And the thing we kept hearing over and over again, is people were excited about drones, they had tried them out, but the drones weren't giving them the information that they wanted. So they wanted data that was under the plant canopy, which is simply not visible to drones, and not visible to satellites. So that's how we got into this whole idea of, “okay, well customers kept asking ‘can you get me a drone that flies between the plants?’” and I was like, “Well, then let's just roll in between the plants it's just better.” And the other thing they were not happy about is the battery life and all. Our robots have a four hour to three hour, four hour battery life, depending on sensor configuration, which is a lot.

Hannah Senior: And I know, it's a common complaint from people in agriculture towards ag tech companies in general, this idea of “Data is great, but what's the application of that data? How does it really help me?” So can you talk to me a bit more about how that data is being applied?

Girish Chowdhary: You're absolutely right. The raw data that is from our robots, is basically camera data, and the LIDAR data and other data, that's not directly useful to the breeders. So what I mean by data is actually the processed traits. So breeders, who are measuring, for example, ear height today. It takes them a long time to measure ear height, they have to go

out there with the stick or some other tool, push it through the crop, measure the ear height recorded down somewhere. We do that at least 10 times faster, right, at least. And I think it's a fairly big understatement, we probably do it much faster than 10 times what a human would do. And then we get them a lot more data, we get them data for pretty much every single plant that is in the field. So 100 times more data, 10 times faster, that is our clear value proposition for these breeders. So all the measured, counted traits. Because at the end of the day, breeders are only interested in the CSV file, or whatever file that we give them, that says, their field map. They're like, “Okay, here's my field and here's how each plot did in terms of ear height, or height or width” and it's basically a heat map. And that's what they get.

Hannah Senior: So tell me, what are your ambitions for the company? Where do you see things going from here?

Girish Chowdhary: The next immediate thing that we're very interested in right now is taking this technology, and continuing to help the breeders continuing to… Using that as our foundation, as our starting point, but bringing it to farmers, that's the thing that we want to do. So we're working on cover crop planting robots. So robots that can go… Again using the same idea of going under the canopy and planting cover crops. So we can plant cover crops much earlier in the season, we can plant them in standing corn. Basically, remove the hassle of planting cover crops, we can do that at a much more attractive value proposition for the farmers. And that is good for the planet because they can sequester carbon, they also reduce the need for herbicides and for nitrogen. So that's our next big ambition.

Hannah Senior: So the direction of travel is to use the robotics capability and all that knowledge around how do you make it robust in an agricultural setting, but then whether it's with sensing or with imaging or with some other planting technology, that's where you have the scope to diversify. Is that right?

Girish Chowdhary: Yeah, I mean, labor is a big issue in agriculture. And it's a tricky issue. It's labor that nobody wants to work in, right? If given a choice, everybody would prefer a job.

That's not in the field. And we've seen this, our parents have done the same. If you go to places like India, that's what you see in the villages, right? Nobody wants to have their children continue to work in the farms. So labor is challenging. And so what happens is this crunch of labor is resulting in unsustainable ways in which we do farming today. So you know, we tried to replace labor with chemicals. That's what we're doing in the Midwest. And pretty much everywhere. So just spray, spray spray, you know, pre emergent, post emergent, just spray as insurance, chemicals as an insurance. This is not sustainable. So we need a much more sustainable way of replacing labor. And that is where we really strongly believe that robots come in. So mechanical weeding is a great example.

Hannah Senior: is that the application that brought you to the AgLaunch business accelerator, because of course, that's focused on companies developing technologies that meet the needs of farmers, not really plant breeders. So tell me more about your involvement with them.

Girish Chowdhary: So AgLaunch was one of our early partners, they saw the value in what we were doing really early on. And they were really aligned with our mission that eventually we want to help farmers but we only want to bring farmers technology that's vetted and ready for them to deploy at scale, because ag robotics is not a new idea. I mean, people have been talking about ag robotics for, I don't know, since robots have been around. The issue is that people are not able to deliver it at scale and at cost, because farming is such a cost sensitive market and the robots actually have to do their job. So the place where we started was this idea of “what can robots do in the farm?” The eventual goal is mechanical weeding, because there's this huge crisis with herbicide resistance in weeds. So mechanical weeding would be great but in order to get there, we need to be able to be autonomous, reliable, operational. In large field settings, the smaller robots that are a lot more dexterous, then larger tractors need to go in there and get their job done.

Girish Chowdhary: And to go there, we need to master these steps. So the first is let's make robots that understand their environment, and deliver high quality data and then maybe… Actually, what happens is that we make the most complex robot first. So the next thing is cover

crops. We actually don't need all that data, we just need the robot to be autonomous. And then from mechanical reading, you don't even need to carry payload, it just has to carry things that you know, disturb the soil. So we take this body of technology, this IP, and then you create this, this corpus of knowledge and skill sets and technology that you can then focus and make more efficient and skill and bring costs down and then bring it to farmers.

Hannah Senior: But in theory, this technology could be used in breeding for any kind of system. So you know, whether it's using biotechnology techniques, or organic breeding, you know, breeding for organic systems, it's the same principles of just collecting the data to make better decisions.

Girish Chowdhary: Absolutely. It's about collecting high throughput data that is reliable, verifiable, and accountable in the sense that you know where that data belongs.

Hannah Senior: Throughout your career, you've been walking that line between academia and industry. How do you think that has influenced your thinking?

Girish Chowdhary: I think the biggest thing that I've learned is that in academia, we are so focused on novelty, right, and originality and “how do we solve a problem in a different way than somebody else?” And in industry we’re focused on “Did you solve the problem?”

[Hannah laughs]

Hannah Senior: And is it a good solution?

[they both laugh]

Girish Chowdhary: Yeah, the outcome is pretty predictable in that way, actually. So every time I write a paper, I'm always worried about what my reviewers are going to say. Whereas in industry, it's like, “I made something that you wanted, and it works now” Today, what I really like about academia is that it has a focus on novelty, it has a focus on “where do we go into the future?” But in some cases, “where do we go into the future?” is so far away from where we

are today. And it seems like people lose interest in actually taking “where do we go” and bringing that back, and then actually moving that state of the art forward. And specifically, roboticists have always insisted on this, like “the proof is in the pudding”. We insist on actually taking stuff back from the theory and making it really happen. So I think this path of it being between academia and industry - (for) startups specifically - is a really rewarding and necessary path. Because for technologies like Field Robotics it's not like you get some open source software and make it work. There is a lot of innovation that has to go through it. And you need people who are thinking ahead, not just the mechanic… The mechanical robot is the easiest part of it. Its all the software and the algorithms that are hard. So having that connection in academia has really helped with that.

Hannah Senior: Changing gears then, you've you've been through this career, which has got many different aspects to it, most recently, one of which is EarthSense. I'm wondering what you found hardest so far in your career?

Girish Chowdhary: The thing that comes to my mind is, it's about the people, it's about building teams and having a vision, and then motivating or leading teams towards that vision. So that's hard I think. [He laughs] What I find difficult in telling some of my new younger generation students is that they are all going after the hotness, the attractiveness, the flashiness of the algorithm, and not so much on the use. But are you asking the next question; “Okay, now that it works here, can I now actually make something useful, that affects somebody's life in a meaningful way?”

Hannah Senior: And last question from me, what opportunities excite you for the future?

Girish Chowdhary: Well I absolutely think that robotics and agriculture are really going to hit it off together. I think we're going to have some meaningful impact of robotics and agriculture. I feel that agriculture is going to be the cradle for field robotics, it's going to be where some of these new technologies will really make an impact. And I also really strongly believe that we

can heal the planet, we can use AI. It's time for AI, which is the pinnacle of our, like, you know, we figured out food and we did agriculture, we created society. If you go all the way back 10,000 BC, right. And then we paid for it with freedom, we paid for it with diseases. And finally, now we are at a point where AI and technology is at a point where it can go back and give back to agriculture. Like my dream, my ultimate dream, and this is a dream that I share with my co-founder at EarthSense is that we can do polycultures with robots. We can go back to the way Native American farmers were farming in these large food forests. We can bring that back with robots. I mean, that would be the utopia. So I really strongly believe we can get there. I think it's very ambitious. But you know, you got to have a good dream.

Hannah Senior: Excellent. Well, it has been really interesting. It's a really exciting future that we're talking about here. So thank you very much for your time. Today, Professor Girish Chowdhary:

Girish Chowdhary: Thank you so much.

[Theme tune plays]

Hannah Senior: You've been listening to plant breeding stories by PBS International, and I'm your host, Hannah Senior. If this episode has got you thinking about how we bring new technologies into agriculture, you should check out my new podcast documentary, Innovating AgTech. It explores the world of agricultural technology startups, and you can find it on all the usual podcasting channels. 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 @PBS_Int. Until next time, stay well

[Theme tune fades]