2013 THE "BORLAUG DIALOGUE"
October 18, 2013 – 12:30 p.m.
Laureate Luncheon Panel: Mary-Dell Chilton, Robert Fraley, Marc Van Montagu

Introduction:

Ambassador Kenneth M. Quinn
President – The World Food Prize Foundation

Now I want to turn to the real dessert for this meal, and that is the panel discussion by our three laureates for this year, Dr. Fraley, Dr. Van Montagu, Dr. Chilton. And I said, who can we have that can keep them under control and yet have a lively discussion? And sitting there thinking, and I said, the only one who can do it is our council member, Margaret Catley-Carlson. So, Maggie, the herding of the laureates is over to you.

PANEL:

LOOKING AHEAD: A CONVERSATION WITH THE LAUREATES

Panel Moderator:

Margaret Catley-Carlson
Chair, Global Crop Diversity Trust
Member, Council of Advisors – World Food Prize

Panel Members:

Mary-Dell Chilton	2013 World Food Prize Laureate
Robert Fraley	2013 World Food Prize Laureate
Marc Van Montagu	2013 World Food Prize Laureate

Margaret Catley-Carlson

Welcome, and this is going to be a really nice event, because you've got these really fabulous people that we've been celebrating all week. We've celebrated also the amazing Ken Quinn and his magic staff that put all of this together. So this is a time to sit back and to have some reflections on what's really important about the work that you've done and the way we've looked at these issues this week. So we can go on all afternoon, but we lose our audience at 2:30, so that shouldn't stop us. We can go on a very long time, as long as we don't mind not having an audience.

PANEL DISCUSSION

Margaret So anyway, Marc Van Montagu, who I've known for many years, Mary-Dell, if I may, Chilton, and Rob Fraley, Rob B-B – he's got to B's in the Fraley, he says.

Rob In the Robb.

Margaret Yes, exactly, okay. Well, as I say, we've had a marvelous lead-in to this meeting in the panels this morning. And I think that what those panels covered gave us the ability here not to talk about a number of subjects, what could-have, should-have, might-have-been, where the current priorities meet ethical imperatives, how to meet the campaign of misunderstandings, half-truth, some truth, no truth, regulation by superstition – all this kind of leads to gloom, even though it gets punctuated by little rays of sunshine such as we have this morning from the Philippine announcement.

But I thought it would be a good thing, as we move on, to celebrate the amazing science and the amazing scientists that we're honoring, rather than going into these issues. If we get into them, we do, but I wanted to start by really finding out a little bit more about some of the science that we're talking about here. And I wanted to start with the idea that great science is a springboard for a lot of things other than the products that we have spent a good deal talking about.

And we have here three great scientists, whether you're looking at the T cells, whether you're looking at the idea that bacterium can be used to move one characteristic into another plant, whether you're looking at the idea that once you can take one characteristic, you might even transfer that to something as astonishing as pesticide resistance.

So this is more than the trail that leads to a product; it's opening a whole door on a new place that wasn't there before. So I'd like to hear from each one of you. Tell me about those, the science and the people that have used your science, that have moved from the springboard that you've created, to go in the most interesting places and the places that you're most proud of, and if you've got a couple of examples… Mary-Dell, you look like you might have one that you could share with us.

Mary-Dell My interest has been in the beginning, the science of gene transfer. We began this as a study in pure science. We were interested in how a bacterium could cause a tumor, a gall, on a plant. And as we began our studies, there was some literature on it that seemed to show that that might be caused by gene transfer, but there wasn't any direct evidence. And our team at the University of Washington in Seattle was able to show that indeed there is a tiny piece, a part of bacterial DNA, that went from the pathogen into those plant cells.

Margaret Now, I know that what you've done personally with your team has affected the lives of millions and millions of farmers, particularly in the corn area. What else

took off from that science? There must have been all sorts of interesting things that took off from that bacterium development.

Mary-Dell All of these people, of course, most of them, probably are on the agriculture side and interested in the gene in the products and the plants that have been produced. But I would like to recall one other thing that has come as a consequence of gene transfer to plants. We can use these tools to understand how plants work and understand the… The tools have been extremely valuable in basic science in understanding how plants work and in helping us to identify the plant genes that will give tolerance to drought. It's a tool not only for making products but for making new science, which in turn will likely lead to new kinds of science.

Margaret So the whole idea of marker assistance selection where you can go in and you can look and you determine what gene is going to do what, this also came out, very much out of those initial explorations.

Mary-Dell Not exactly, but when by marker assistance you find a gene, we are able now to pick that gene up and change it, put it back and prove what the function of the gene is.

Margaret Us non-scientists, try and imagine a pair of tweezers that are small enough to reach it and do that. And then when I learn… It's called "gene expression," which doesn't help non-scientists at all. Robb, who used your science as a springboard to go in interesting places?

Rob Well, let me reflect on a couple things that I think, you know, happened so fast that we take for granted. But I think really one of the really exciting things that happened is after a lot of these basic tools were developed in the early eighties, it really just drove a phenomenal amount of reinvestment in scientific and human capital across the plant sciences across the world.

You can look at the publications, and Marc used that in a slide. But I can remember back when I was looking for my job in 1980 and trying to find locations where you could do plant molecular biology research – you had to look pretty hard across universities and companies. And for me what's so exciting is you can go anywhere now. I mean, the phenomenal institutes in Beijing. We were just talking about the scientific capital that's now being developed across Africa. For me what's so exciting is we are seeing that next generation of knowledge explode, and I think it's in part been to the tools, the excitement, the ability to both invest. And that's cool.

The other one that I always like to emphasize, and I start a lot of talks like this, because it's one of the folks who helped really pioneer transgenics and GMOs in this tool… I always tell folks, for me, really the most remarkable transformation in science that's going on is plant breeding. I mean, these tools have fundamentally changed how we breed crops. I mean, once the complete genomes were sequenced and mapped and breeders had that ability to understand exactly the combinations that were being created. It has changed how you breed. I mean, we can now… A

breeder can find a new disease trait in Brazil, mapped and tagged, make your crosses, do your markers, and within a year you've got a Brazilian gene in a U.S. germplasm. If you tried to do that 10 years ago, it would have been virtually impossible. And that's what's changing the game.

And that leads then to a whole new wave of gene identification, the ability to pyramid genes, which is going to be so important for resistance management. And I think, particularly when we think about being prepared for the future, you know, climate change and rapidly evolving dynamics in pest populations, these are going to provide really important tools. And I always use the expression that today every breeder has the potential to be a molecular breeder because they can literally breed gene by gene.

And I really think when you kind of reel this all the way back and you look forward, the investment in the sequencing, the markers, the information technology – it will change breeding. I mean, we've done a couple of estimates that the ability to precisely pick that seed off of an ear of corn, the right brother and the right sister – you know, we have good kids and bad kids; you know how that works – but to pick the right one precisely that you want that has that combination, can improve the efficiency of a breeding cycle by thousands of fold, and that's not…

Margaret So your answer to the springboard is more money, more interest in agriculture, which is a really good thing, and really opening the door in a totally new way.

Rob And a real plea that molecular breeding… Breeding is going through a renaissance, and the ability to apply that technology, not only to the large-acre crops but to smaller crops and orphan crops, is enormous. And it's happening at the same time that the cost per data point makes this applicable to virtually every crop in the world.

Margaret Yes, astonishing…

Rob And we don't want to give that one up.

Margaret Robb, I have to get over to Marc. Marc, what springboard action are you really happy about that was a result of your work, which got to amazing places, not only- I liked the pulping of poplars – I thought that was great.

Marc Well, that's in the application, but still for us the fundamental science was so fantastic. When we started, nothing was known in the molecular genetics of plants; we had not the slightest information. Now we are, as Robb said, yes, that we have so many sequences that this aspect can be done within fundamental science. There's still so much to do, and we hope that there is good funding for that, because now we realize you may know the genes, but the way they are expressed, the opening of the chromogene, what we start calling now more and more epigenetics – it's still to be found. The role of the small RNAs, it's the same technology of making transgenics in the laboratory on the model system like

arabidopsis - we will bring us this information. But we badly need it, because we cannot without. Everybody knows that identical twins, if it was the same DNA, the same gene, the same order, that during development so many characteristics change, physically a bit less, but the susceptibility to disease and character and way of behaving. So what's the difference in some types of tissues that came. Can it be reset, because we will learn it in plants? It's not only how it works, but mostly can we reset? If a plant that is germinating has a certain stress but somehow overcoming, others are not overcoming… They were sometimes identical genetically. But it is parts that have been stressed out, can we reset them so that they now don't remember the stress they went through and can go, that is crucial for trees. Because you cannot, if you have to make crosses every 30, 40 years.

Margaret That's the fascinating, that you have to try and…

Marc …That's the science I am waiting for, and that's what…

Margaret Sounds more like science fiction – erasing the memory of a tree about the stress it's been through. That sounds absolutely fascinating.

Marc When we started doing the sequence, was also science fiction. Like my colleague, Walter Fiers, when he started sequencing RNA chemically, he did it: "Four nucleotides, now I have five, and now I can separate the piece of ten nucleotides…" And that's what makes then the possibilities that we know today.

Margaret It's very interesting. All three of you basically said, okay, the event was important, but you immediately went to an enormously broad canvas, because of course that has been exactly the implication of what you've done, is to move from a particular discovery. And very, very quickly it moved to a very broad canvas indeed. So thank you for those glimpses.

Now, we've got a lot of young people in the room, and I hope that some of them are going to leave this event deciding that, "Hey, I want some of that excitement, and I want to feel that way about having really changed the world and removing the stress memory of trees, and doing some really exciting things."

And I want to know - take yourself back to the time when you really… When I read the bios, when you were sitting in the labs and you were working presumably… Like before you discovered what you discovered, can you remember the moment or the event that made you turn a certain corner to find out what you found out? Because you've got people here who are wondering how, how does that happen? How does that magic actually happen? Is it just that you do it 195 times and the 196th time something turns out differently? Is it an inspiration? Is it a moonbeam that comes in through the window? What happens to turn you from a very good scientist into the great scientists making great changes that you made? Robb, what happens?

Rob It's real easy in my case. We had a phenomenal team that I joined when I went to Monsanto. And Rob Horsch and Steve Rogers and the chemistry and the ability to

link in one place with kind of one thought process the expertise from Rob's magic fingers with the tissue culture and he knew to regenerate plants from cells. Steve Rogers, a vector wizard, and I worked a lot with agrobacterium. And it was that teamwork that just was phenomenal.

Margaret But tell the young people – When you were trying to find out what you found out, do you keep going in a straight line? Do you make a list of all the things you're going to try? Give them some idea of what's involved in making the kind of breakthrough that…

Rob Well, as you all know, it's only a straight line when you look backwards, whether you're talking about your career or your science. I am famous for – we try everything we can possibly think of, and we try to design really, really good experiments. So sometimes the most important answer is "no." But you have to have "no" in a way that you can go forward with something else and make decisions. And I think I would recommend doing that on your careers, and I'd recommend you do that on your science.

Margaret Mary-Dell, when you finally convinced that bacterium to do what it didn't know it could do, was this a straight line, or was this magic, moonbeams?

Mary-Dell I want to go back to the first time, the first experiment we did that showed that there was gene transfer from agrobacterium to the plant cells. We recognized that this would be an extremely unusual thing if it were correct. So we designed the experiment in a way that, if it said yes, there would be no argument. Okay, we did all the controls. And as an example, all the glassware that we used in handling the various solutions was either brand new, or, if it had been used before, it was fired. We bought a self-cleaning oven at the Sears Roebuck store, and it was all fired in the self-cleaning oven. The reason is we wanted to be sure that when we found the DNA in the plant cell, if we did, we wanted to be sure that there wasn't contamination. So when I was at home in my kitchen after the boys were put to bed, calculating the results of our experiment, and saw that we had wiggle in the curve that showed the DNA had been transferred to the plant cells, I knew right then that it was right, no argument.

Margaret So was that inspiration – did you know it was going to turn out that way? Did you hope…?

Mary-Dell On the contrary, I expected it to be the other way. I was sure that bacteria couldn't put their genes into a plant and have them work – good heavens!

Margaret So that's an interesting piece of advice to young people.

Mary-Dell But the lesson is – we designed the experiment in a way that we would know definitively yes or no. We could stop working on this if it said no, or we could…

Margaret Or go on to the more profitable ways of looking at it.

Mary-Dell Exactly, exactly.

Margaret So contest everything, but don't contest gravity from too high a level. Marc, the moment that it all started to happen, what was happening to you, for you in your minds and your team…?

Marc The history is that we just, by looking what other people did, we were convinced that it should be genetic transfer, because these tissues, you could not think how in those days, surely, how a plant could start making these, all the amino acids if there was no genetic information for doing it. So we were convinced, and then I think one of the approaches is…

Well, there were maybe two things. First is Jeff Schell likes sports, and if he is doing sports, he likes to win. So he just could give the motivation. And it was teamwork indeed. But Jeff had been in the UK with Bill Hayes. He thought systematic supply, bacteria that he had to do for his PhD, he didn't like that at all – he wanted to do genetics, and he went to the UK. And there he said, "I learned something. In the UK you look how you can do the experiment, and then you say, 'Ooh, but that will take a whole week of work. Maybe we go for a cup of tea and think it over.' And the experiment can be done in an afternoon – yeah, then we will do it." And that created another atmosphere… I think it was important.

Margaret So your lessons were – Don't stay in the UK if you want to do a particular kind of science.

Marc No, absolutely not, absolutely not. I think it's a good approach, but think it over and discuss, and mostly look what others are doing. And also for the technologies, look as broad as possible at what is around. Now today with Mr. or Mrs. Google you can do it, but in our days it was slightly more difficult.

Margaret What would I do without Mr. Google, yes. Did you two know – Marc and Mary-Dell – did you know each other?

Mary-Dell Oh, yes, yes.

Margaret At the time that these discoveries came out?

Mary-Dell We were archrivals in fact.

Marc And we were working… We were telling the results to each other.

Margaret So you were rivals?

Marc Sure…

Margaret But you were also sharing information.

Marc …we have to win.

Mary-Dell We were archrivals and at the same time pretty good friends.

Margaret And do archrivals share information, some information, a lot of information.

Mary-Dell Well…

Rob I'm glad I'm in between here. We collaborated with both of them. I don't know about you guys.

Mary-Dell That's right, yes.

Marc Well, I remember the story that the T-DNA was one piece of DNA, that you said, "Oh, nonsense," and then you said, "Oh, you were right! My article is ready."

Mary-Dell But you have to recall that when the article was published, it was back-to-back with yours.

Marc Yeah, sure, sure, sure. Otherwise, we would have been angry, but now you were absolutely a good sport.

Rob I think, though, that's for me one of the parts of that period that were so magical, was there was a good-natured competition with a lot of labs but really a remarkable exchange of information. I mean, the Gordon conferences back then, and the meetings we had were absolutely remarkable. And there was a sense of wanting to shoot that first goal, but there was a lot of cheering of the successes. Because I think what everybody felt – I know we felt this – was that if this could happen, it was going to be big and it was going to change how we think about crops. So you're always kind of hoping maybe they didn't make as progress, but you always wanted to see where they were going, because it was such an exciting time.

Mary-Dell I can remember the most fun of the Gordon conference one year was the time that we had just made a map of all the fragments of the whole Ti plasmid. And these plasmids were so much bigger than the ones people had worked with in the past that you couldn't map them; nobody knew how to map them. And I came to the conference and told Jeff Schell, "We have mapped the Ti plasmid." And Jeff said, "You can't do it."

Margaret That's his plasmid.

Rob Yeah, actually that wasn't the most fun, Mary-Dell. The most fun was when Mary-Dell was chairing the Gordon conference and she ordered somebody to break into the bar. That was the most fun.

Mary-Dell Well, I confess to a terrible thirst at times.

Margaret So the lessons are for young people: Be competitive – it's really important – be competitive, but remember to shake hands afterwards and be collaborative. And if

you break into the bar, don't get caught. And don't have friends with long memories that remember 30 years later who broke into the bar. This is terrible – it's a good thing the statute of limitations…

Let me circle around a little bit more, and I'm coming just to the edges of acceptability issues, which we I think said, I said, we weren't going to talk about very much.

When the Cardinal was talking yesterday, he was talking about the need for advancements and changes to be seen to be benefiting the whole gamut of players, companies, the academy, very poor people, all the rest of it. If you ask yourself – What kind of product or what kind of product line? Is there anything you can think of that would be likely to move the genetically modified plants into a greater level of acceptability because they would be appealing to, would find a place in the heart of just about everybody. Because it was a very good panel today talking about the… What was that word? Bias? Yes, confirmation bias. And we're really up against things that don't respond to evidence, and we've got to, if we're going to get over this, we've got to find things that change the emotional appeal of these products, so that finding something that people really feel emotionally – oh, we should have that, we should be working towards something like that, that would be so important. And it's really asking for a big leap to asking scientists, because we're saying the evidence is one thing, but we've got to fight this battle on more than just the evidentiary basis. What could be the kind of development that might move us in that direction?

Mary-Dell We've already done it. We've made golden rice. We have made a strain of rice that produces the precursor to vitamin A. It could be a great boon to African children. We lose a million children per year from this deficiency.

Margaret But that's out, and it hasn't done it.

Mary-Dell It hasn't been accepted.

Margaret No. It hasn't done that warm and fuzzy…

Marc It's not out. It's still blocked.

Margaret Well, it could be out in the Philippines…, yeah, exactly.

Mary-Dell Is it out? Where is it?

Marc No, no. I say it is not out. It's on the field trials that have been destroyed by activists who are afraid to do it.

Margaret Yes, and we got that in spades this morning. Can you think of any kind of product area that could change the emotional or change the way these are seen?

Marc Well, I think in the laboratories there are hundreds of examples that are ready. We have seen the papayas in Hawaii; they have been in the field, but still people are protesting against it. We have the potatoes that are resistant against potato disease. But all this is in laboratory, and nobody has the money with the regulations that are around, to bring it to the field.

And so the battle has to be at two levels. People have to realize that, okay, we know, due to the confirmation bias, the way we are thinking, people will see, will have the need for having the product. But you could already, by reasoning, say that all these things can be done, and they are really like… Just like in the old days in the 19th century when the Luddites were destroying the machines, you know that there will be a whole economy that the machines will really, the production system will be different, that so much will be changed. We remember in our area in Flanders in the beginning of the 20th century around 1910 people were living in shacks, were having ten, twelve children. At five, they had to contribute to the income. Nobody could go to school. But industrialization has all changed that. And for 1910, in 1950 it was completely different. Nevertheless, people started destroying the machines.

Margaret Well, people don't like change; there's no question about that.

Marc Yeah, so this aspect has to be considered. So we have already opened the arguments in the lab, and Greenpeace knows that they just have to see that they cannot reach the public. So it's not the science that is the block. The science has already…

Margaret No. That's what I started off by saying.

Marc And the products could go, but nobody gives them the authorization to go yet. You have the regulatory, you have the financial aspect, all the controls and the super-controls and the re-controls that one has to do. So that is where the block is. But indeed psychologically people need the product. So if we have to insist…

Margaret They don't think they need it, that's the problem.

Marc No they don't think, but once they use it, they will see. And we have to try to find… And the best example that they cannot revolt because agriculture is so essential that people try to… And the stresses have always been there, so we learn to work with the most essential things. But if we see a plantation forest, because plantation forests are all made from identical clones in cell culture - nothing to see with GMOs these clones - but these forests start; they are there in Oregon and they are there in the Seattle area. And there are some beetles coming in, and in record time can cross it out, then people can understand – we should have all the solutions.

Margaret Yes.

Marc But, okay, the streams will then also not be…

Margaret I apologize for these beetles – they came down from Canada. Robb, can you think of a product or something that could appeal to the emotional intelligence of people and try and get around some of these barriers? Because the panel this morning was very clear that the evidence is not the answer at the moment.

Rob We obviously haven't found that product yet, and we've had some pretty good ones that have increased yields, and we've had some now that are protecting crops from drought. What we haven't had is the product that has unambiguous benefit to the consumer without going through the dynamics of food security or production or yield or benefits that are generally targeted at the farmers.

My guess is, when you get into these consumer traits… And we've worked a lot on looking at vitamin enrichment and colors and pigments. I think a lot of that's going to come again from the molecular breeding area. And one of the areas I think we're going to see just a phenomenal set of advances in a few years is, you know, most now of the major vegetable crop species have been sequenced and mapped and all the genes for the nutrients, and the flavors and the consumer appeal have all been mapped and tagged. And what we'll see, I think, is just a phenomenal proliferation of fresh fruits and vegetables that have different appeal. They may not be GMO, but they're going to be some of the most remarkable products of genetic modification.

I always like to use the example of, when you walk into a grocery store today and the first thing you see is, generally the produce area is right in the front of the store. And when you walk in, the colors, the availability is remarkable; and that is all just phenomenal advances in genetic modification. And that seems to, I think in my mind, be the big winner.

It's hard to focus on something else. I mean, we've looked at amino acids and lysine. We've looked at putting omega-3 fatty acids into soybean. But there's always alternatives; there's different approaches. I haven't found the magic bullet yet.

Margaret No. I don't imagine so. You want to have the final word on that?

Mary-Dell Yeah, I think the initial products we made were ones you could create with transfer of a single gene – resistance to an herbicide; one gene. BT that makes it resistant to an insect, one gene. So the technology in the beginning enabled us to transfer one or two genes. We can transfer many now. We can transfer 10, 15, 20, and the number will rise. So I think we will see entire pathways that synthesize chemicals, new, useful chemical pathways.

Margaret Well, you're very much leading into my question. But before I leave this one, I'm going to give you this suggestion. I'd like a six-cheese lasagna with no calories.

Rob You know how much recombinant chymosin would be in there. I think one of the best chances for that kind of public awareness is going to be in the response to drought and some of the climate change. It may not be a direct consumer benefit,

but everybody in the world understands drought. And I think that has a lot of appeal to people.

Margaret Some of the things that M.S. Swaminathan is doing with really some of the poorest people in India that are being menaced by salt intrusion, and developing plants that will be able to stand up to that saline intrusion and even increase yields and increase the prosperity. I think that's the kind of thing that will grab hearts and minds in a way that other products don't yet.

You've started the next question that I was going to go, so I'm going to give the microphone back to you. Where do we go beyond the GM techniques that we are today? And you've both already started into that, so can you start painting your canvas about where we go from here and today's technology? What does the future technology in plant science look like?

Mary-Dell What I find interesting is that agrobacterium did more for us than just put genes into plant cells. It inspired us all across the science that if you could get a gene in there somehow, it would be able to get itself into the chromosome of the plant, and it could express to create the new trait. So people have developed different means of adding genetic information to plant cells, not just by agrobacterium.

I stand by agrobacterium – it's still the best way – but people coat DNA genes onto little bullets made of gold and fire them, shoot them with a gun into the plant cells; and that works. It gets you genes that are scattered across the genome of the plant in more complicated ways. Agrobacterium puts them in one place much more tidily usually. So anyway there are various ways to put genetic information into the plant cell, and I suppose some of those may be exploited in the future. And I think that strings of genes that have a whole pathway will be put in there. I think multiple single gene traits will be put in.

Margaret Give us a for instance.

Mary-Dell We need to have different active principles to combat the same insect so that it doesn't just mutate in one jump to be resistant to our plant, so that's one reason we need multiple traits. But then also we need an herbicide resistance. We need resistance to the fungus. We need resistance to all kinds of things in the same plant cell.

Margaret So you would just develop a whole string of resistances which could be put in by your…

Mary-Dell Yeah, we call that "stacking the traits."

Margaret Stacking the crates, yes, okay.

Mary-Dell Trait, traits.

Margaret Traits, crates, yes, okay.

Mary-Dell Whatever they are.

Rob Really high.

Mary-Dell And you can make a plant with multiple traits, either by making a plant with one trait and another one with another and crossing those together and finding the two of them. And you can do that with yet a third trait and a fourth trait, but when you do that, the traits are all over the genome; and so the breeder has a problem breeding with those. They want to separate into the progeny. So perhaps a better way is to stack the different genes into one construct, into one DNA molecule and put that in. So we've been asking agrobacterium whether it could put long stretches of DNA into the plant cells, and happily it says yes. It says, "I don't do it nearly as efficiently, but I do it."

Margaret I do it. See, you should never have doubted it 30 years ago.

Mary-Dell You're right, absolutely.

Margaret Marc, what's the future in post… sort of beyond GM plant science?

Marc Well, with all the technology that we have worked out to study the plants, now we can make that genomics from the micro-organisms, and all the plants grow the roots, the leaves, it's full of the bacteria that never have been studied. Now we can do delivery of products. Food is bacteria. We can study which one is the best to do that. We can use the metagenomics for making new soil much more rapidly. Areas, the problem is the soil, so the molecular biologists will in the future work much more closer with the soil scientists. Soil is not inorganic chemistry; soil is a living organism. So many organisms are there that never were studied. With all the technologies that we have used for the plant, we will start doing that, and then people will see also, rapidly, progress in agriculture if we can adapt the soils.

Margaret Robb? The future?

Rob I think one of the areas that is tantalizingly close, but we can't quite declare victory yet, is in this area of being able to use RNAI molecules to modulate plant activity. So that's a whole level of science. Back when Mary-Dell and I were learning about chemistry at the University of Illinois, the gene made the RNA, which was the intermediate that made the protein. But a few Nobel Prizes ago people discovered that that RNA itself was regulated by small, little molecules called RNAI. What we've found out is you can actually manufacture these RNAIs. They might only be 40 or 50 nucleotides long, and you can deliver them to plants and elicit very specific reduction expression of a target gene. And the beauty of it is it gives you a lot of the specificity of biotechnology without a transgenic organism.

And a couple of the examples that we've worked on: If we synthesize these small RNAIs to a plant virus, and you have a plant that actually even is undergoing virus infection, if you spray these RNAIs on the plant, it will cure the plant of the disease. And we've also been able to show that for a couple other areas. And one

that's close to my heart is in the 40 years that Roundup has been used as a herbicide, there's three or four weed species that have become resistant to it. And what we've been able to show is that we can sequence now the weed and understand the mechanism biochemically by which it created the resistance, and we can design an RNAI molecule that knocks out the resistance mechanism, and now the activity of the herbicide is restored. And that's pretty cool.

But the area that is really special is in, I think, this area that's really cool and the science is still preliminary yet, but everybody is very concerned about bee populations and Colony Collapse Disorder. And there's a lot of theories, but most of the scientific consensus points to the fact that the bee gets a mite infection, and the mite transmits several viruses into the bee. And we've seen that you can now design these RNAIs that can knock out the mite and start to knock out the replication of the viruses. It's still complex, because there's a lot of different virus strains, but this is pretty cool when you can use the power of very precise targeted gene expression with a naturally occurring molecule that can do some pretty neat things.

Margaret I think that's more important than a six-cheese lasagna, no calories even. Are you saying, though, that… What I hear you saying is that some of the things that are now being done through genetic gene transfer from one plant or one entity to another plant might be done in the future by another kind of science, another kind of technology, another kind of technique?

Rob Yeah, I think they build on that same knowledge, but they could be done with different approaches. I mean, the way I look at it – If there's any way I can solve a problem without spending $150 million of regulatory cost to develop a GMO product, I will try breeding, molecular breeding, anything else I can do. But there are just some things that GMO technology will do better. But there are these other areas where I think there are remarkable opportunities. I mentioned the breeding before, but the RNAI approach could be very useful for disease and insect and very specific regulation of genes that you may want to reduce for ripening. So one of the clear applications is relooking at the ripening response or the overripening response, and using these RNAIs to specifically knock out that ripening mechanism at the crucial time.

Margaret Exteriorly.

Rob Exteriorly.

Margaret Interesting.

Rob The way it works, just so… These are very small molecules, and you can formulate them that they will actually penetrate through the leaf. And there would be enough of that molecule to elicit the biological activity. But it's not a permanent gene transfer; it's a temporary effect – and it's really cool.

Margaret So that could be an interesting back door for some of the problems that we have been talking about.

Rob Uh huh, from both a cost and a market access.

Margaret We're going to be losing our audience to the soybean farms soon enough, so I want to give each of you, though, before we close this part of your amazing four days as being laureates and the chances that we've all had to get to know you better and the opportunities we've had to explore three of the very interesting minds of the 21st century, so I'll leave you a couple minutes to say what you'd like to say as we close this session of the World Food Prize dialogue and the Borlaug Dialogue.

Rob I'd like to just start, first of all, by thanking you, Ken, and your team. I've had the privilege of being part of a lot of cool events, but I don't think I have ever seen anything that's been so, not only extraordinarily well organized but the detail and the nuance and connectivity is really remarkable. I mean, it's really special, and I appreciate that. And I'd just like to thank everybody here. This is a remarkable experience. [Mic goes out, Mary-Dell hands him her microphone. Laughter.]

Margaret Collaboration.

Rob I told you – I collaborate with both these guys.

Robb And I just want to say thank you. Somebody has to put the first shot in the goal, I mean. But really appreciate it, and I have thoroughly enjoyed it. And my sense is that it's been a pivotal conversation in terms of shifting and rethinking views. And the thing I would ask is – the science is so important, it is so applicable to so many of the problems, and the barriers aren't the science. The barriers are the policies and the politics. And that is really, really worth rethinking. And I'm not going to debunk all those myths that have already been debunked. I thought the panelists did a great job. But we don't yet appreciate the power that this technology has for the future. And to think that we're either regulating, overregulating, or in some cases blocking the adoption of tools that are going to be utterly transformational, it is… I'm going to keep pushing. It is too exciting.

Margaret Well, we've got to work on all the barriers, including the emotional one – not necessarily for the scientists to tackle that one. You know, what is the emotional appeal that we could use that we're not using with sufficient clarity and force now? Because if the difficulties are emotional and nonrational, then we've got to put some of those in our armamentarium.

Robb Yup.

Margaret Absolutely. A last word, Mary-Dell, or a last several words?

Mary-Dell Well, I certainly echo the things that Robb has already articulated. We certainly thank you and Ken and the other organizers of the whole operation. It's been a joy to be here this week. I have never seen so many supporters of the technology in

one place. I think it's a wonderful technology, and I hope in my lifetime to see it not only accepted but embraced throughout the world. We need it. We really need it.

And I think we have our work cut out for us. Some of us – and I point to the gentlemen on my right especially – are good at talking with people, at persuading. We need to talk to some of the leaders of the organizations that seem to think they're opposed to us. For example, the Sierra Club – I'm shocked that the Sierra Club thinks that we're not green. We are, and someone needs to talk to them and get it across. I don't know what the problem is there. But there are more organizations that ought to be on board with us that just aren't. We need to talk to our schoolteachers, find out what they're teaching their kids in school. We need to do whatever we can to spread the word, and I'm speaking of course of what we can do in this country, but I think Marc will address what we need to do in Europe and worldwide also. And I want to just thank the audience for your wonderful enthusiasm. And thank you for your wonderful questions.

Margaret Marc - the one who gets to not just battle from the trenches but live in the trenches as you battle.

Rob That's not a comment on Belgium.

Marc First, an important point that Robb was saying and that maybe he was not really taking up directly. That is, a major company like Monsanto, for each trait they have to spend $150 million. They are not the machines of the earth. Why should major companies… They have to survive and have made their products. So we know that they have to organize that the public sector does it, but meanwhile since they have to look for alternatives. What they are doing is fantastic, and they're blocking with group force approaches that the public sector could do. The whole RNA technology, because it's at the basis also in genetics and in the gene silencing that was discovered in the 1990s period. So that it again comes all together so that what the public sector does and what the private sector then brings in as new technologies is fantastic. And that will make us progress in agriculture. But there is no way out. The DNA technology has to be used, because the problems will not be sufficient only, because breeding is slow, and a lot of the techniques are slow and still have to be applied, and there can be problems coming up.

So we urgently have to see how we can communicate to the society, saying that it is a bias on beliefs, what the rationality is. And again, since people don't listen always to rationality, you have to give the information at the same time the progress. So it's complex, and we'll see what we can do. [Applause]

Margaret Yes, indeed. How many of the young people in the room, the people who are just starting off on their careers have got their interest raised by this week's discussions on biogenetics? Hands way up. Hey, fantastic! Okay, great. I hope that the lesson that you might have got from it is that part of the battle has to be in laboratory, but part is also in media, exactly as has just been said, in teaching, in understanding what makes people form ideas, in looking at these. So if your answer to my

question was, “Well, I’m not that good at science. I couldn’t get in there,” – there’s a lot to be done that isn’t going to be done at a laboratory bench or at a test tube. So therefore if you find the arguments compelling – and if you don’t, I don’t know what you’re doing here for lunch – but if you find the arguments compelling, remember there’s a role here for an awful lot of players. And you’ve got to shape the world. Because if you want these advantages that have been set out very eloquently as a very new kind of world, if you want these advantages in your world, you’re going to have to battle for them. And the battle has to be fought on a lot of fronts. So what a good thing that the initial warriors are as wonderful as they are and that they’ve been with us today. So thank you very much.