

An aerial photograph of a vast, green agricultural field, likely corn, with a winding lake or reservoir in the background. The field is divided into sections by rows of crops, and the lake reflects the sky. The overall scene is bright and clear, suggesting a sunny day.

Groundwork BioAg's Environmental Impact

Dan Grotsky, Chief Growth Officer
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The Groundwork BioAg team innovatively produces **highly-effective mycorrhizal inoculants**. We will not rest until every hectare of arable land is covered with mycorrhizae and every farmer benefits from higher crop yields and resilience to stress, while consuming less resources and regenerating the Earth's soil.

Rootella® – a cornerstone of regenerative agriculture

- Regenerative agriculture overview
- Groundwork BioAg's impact in numbers
- Yield increase
- Carbon sequestration
- Phosphorus savings
- Resistance to Stress
- Next Steps







Happy farmer in Rootella-treated soybean field in Mato Grosso, Brazil, 2019 (Rootella treatment on right). By adopting regenerative agriculture, his prosperity will not come on account of his successors'.

Groundwork BioAg's Impact in Numbers

Groundwork BioAg's Impact in Numbers



Groundwork BioAg directly addresses four UN Sustainable Development Goals:

	Rootella coverage expected in:	(acres) (year)	1M 2021	100M 2030
	Crop yield improvements equivalent to:	(kcal) (people fed)	750B 685K	75T 68M
	Carbon sequestration equivalent to:	(mtCO ₂ eq) (# cars)	55K 12K	5.5M 1.2M
	Phosphorus savings equivalent to:	(mt) (Caribbean Sea run-off)	1760 30%	176K 30x
	Climate resistance equivalent to:	(kcal) (people fed)	150B 137K	15T 14M

1M acres¹ covered with Groundwork BioAg's mycorrhizae in 2021 potentially translates to:



- 750B kcal in increased crop yields², or enough to **feed 685K people for a year**³, and
- 55K mtCO₂e directly sequestered by mycorrhizal fungi and roots⁴, the equivalent of **annual emissions from 12K cars**⁵, and
- 1,760 ton phosphorus fertilizer saved⁶, equivalent to **30% of the annual phosphorus run-off from land-based sources into the Caribbean Sea**⁷, and
- Resistance to climate stress (e.g. drought), equivalent to **1% of crop production**⁸, or **150B kcal**², enough to **feed 137K people for a year**³
- Additional benefits, e.g. plant health, soil remediation, and protection from desertification

1. Groundwork BioAg expects to cover 1M acres in 2021 with its mycorrhizal inoculant products.
2. Assuming 5% yield increase, all on corn in US (for simplification, though we sell to many crops at varying yield rates). In 2014, average yield in the United States was 171 bu/ac. Each bushel weighs 56 lb. and each pound yields ~1,566 kcal. That means corn averages roughly 15M kcal/ac (<https://www.mncorn.org/2015/07/16/corn-links-in-defense-of-corn-the-worlds-most-important-food-crop/>)
3. Assuming 3000 kcal/day per person (<http://www.fao.org/3/y4252e/y4252e04.htm>)
4. Assuming 132 kg/ha carbon sequestered annually (<https://www.oeaw.ac.at/forebiom/WS3lectures/IV-Ortas.pdf>)
5. A typical passenger vehicle emits 4.6 mtCO₂e per year (<https://www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle>)
6. Assuming 15% reduction of 29 kg/ha global annual average phosphate nutrient usage (<https://ourworldindata.org/fertilizers>)
7. Total estimated phosphorus nutrient load from land-based sources in the Caribbean Sea is 5.8K mt/yr (UNEP 2000). (<https://www.unep.org/cep/nutrients>)
8. Assuming 35% reduction of damage from drought, flooding, and extreme temperatures and 15% reduction of damage from storms and crop pests. Global disaster damage estimates from <https://reliefweb.int/sites/reliefweb.int/files/resources/cb3673en.pdf>

Groundwork BioAg's impact going forward potentially translates to:

Land Covered (annually)	1M acres ¹	50M acres	100M acres	4.3B acres ²
Yield Increase	750B kcal	37.5T kcal	75T kcal	3.23*10 ¹⁵ kcal
Carbon Sequestered	55K mtCO ₂ e	2.75M mtCO ₂ e	5.5M mtCO ₂ e	237M mtCO ₂ e
Phosphorus Saved	1,760 t	88K t	176K t	7.57M t
Crop Damage Averted	150B kcal	7.5T kcal	15T kcal	645T kcal

Based on the assumptions and references on the previous slide:

- When Groundwork BioAg covers 50M acres in a year, we will:
 - Increase crop yields enough to feed over 34M people for a year,
 - Sequester carbon equivalent to removing 600K cars from the road for a year, and
 - Save phosphorus equivalent to more than four times the entire phosphorus run-off of the Mississippi River in May 2020³, and
 - Reduce climate-related crop damage enough to feed 6.9M people for a year
- Our mission is to cover the world's agricultural land with mycorrhizae. That would:
 - Increase crop yields enough to feed 3B people for a year,
 - Sequester carbon equivalent to removing 52M cars from the road for a year, and
 - Save phosphorus equivalent to most of the world's phosphorus run-off⁴, and
 - Reduce climate-related crop damage enough to feed 593M people for a year

1. Groundwork BioAg expects to cover 1M acres in 2021 with its mycorrhizal inoculant products.

2. Total land harvested worldwide (FAOSTAT)

3. This larger-than average river discharge carried 21,400 tons of phosphorus into the Gulf of Mexico in May 2020 (<https://www.noaa.gov/media-release/larger-than-average-dead-zone-expected-for-gulf-of-mexico>)

4. 10.5-15.2M ton phosphorus annual run-off globally (UNEP 2005)

Crop Yield Increase



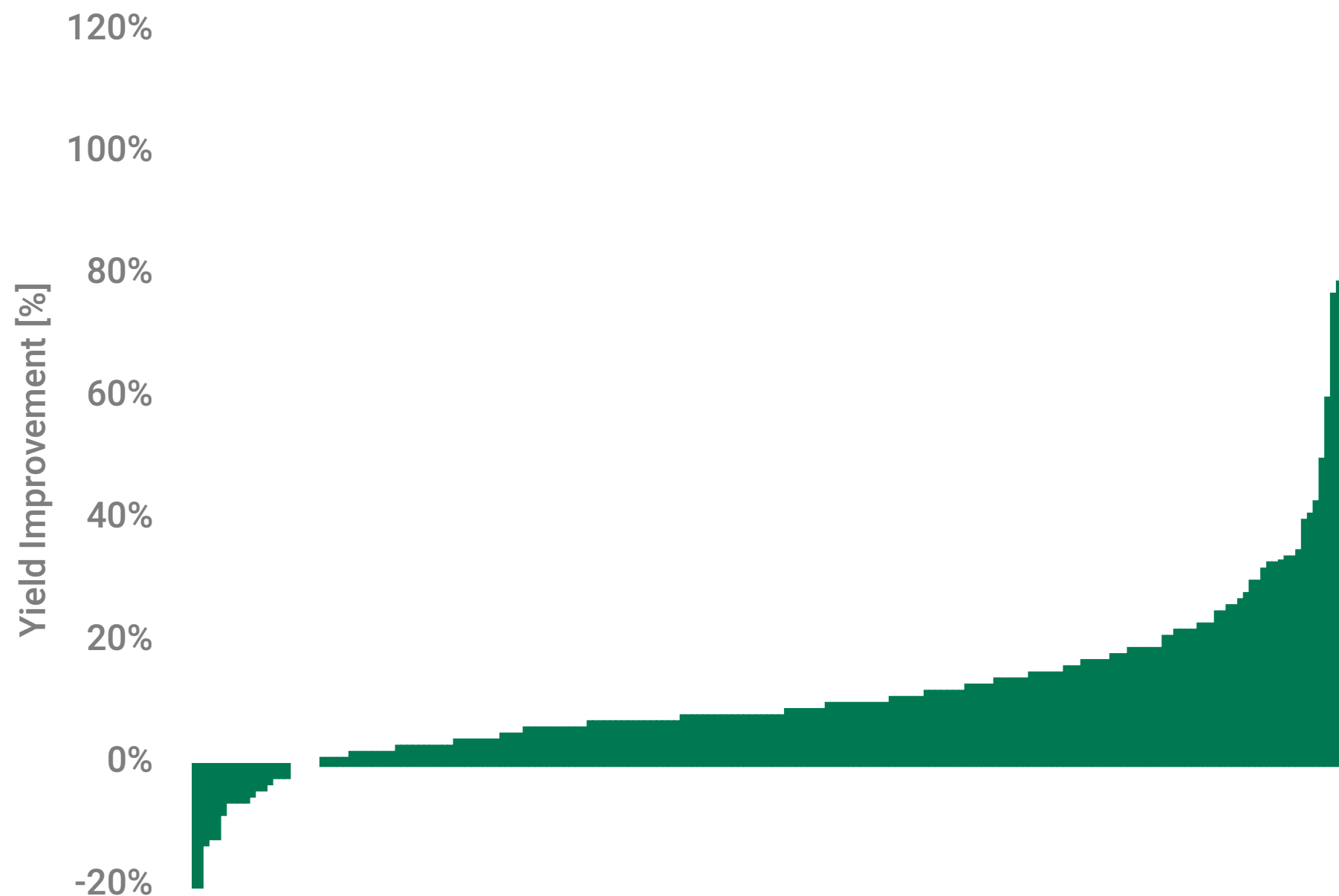
Groundwork BioAg's customers realize crop yield potential

- Better absorption of macro- and micro-nutrients
- Quicker establishment of seedlings and seeds
- Most effective in suboptimal soils (pH, salinity, organic matter)
- Higher yields translate directly to **SDG #2: Zero Hunger**



Right: Overall Rootella Yield Improvement Across Crops, Territories: Commercial Plots

Mean: 12%
Median: 8%
Win rate: 92%



Rootella increases crop yields to feed the world

Rootella Yield Increase	Base Yield	+2%	+5%	+10%	+12% (mean)	+20%
Corn Yield [bu/ac]	171	174	180	188	192	205
Caloric Yield [1000 kcal/ac]	14,996	15,296	15,746	16,496	16,796	17,995
Caloric Benefit [1000 kcal/ac]	-	300	750	1,500	1,800	2,999

- Groundwork BioAg expects to cover 1M acres in 2021 with its mycorrhizal inoculants.
- Calculations are made assuming corn in US¹, for simplification, though we sell to many crops at varying yield rates.
- Assuming 3000 kcal/day per person², and a mean yield increase of 12% (per our commercial results thus far), Groundwork BioAg's 2021 yield benefit is equivalent to feeding 1.64M people for an entire year.
- Conservatively assuming a 5% yield increase, the benefit would still feed 685K people.

1. In 2014, average yield in the United States was 171 bu/ac. Each bushel weighs 56 lb. and each pound yields ~1,566 kcal. That means corn averages roughly 15M kcal/ac (<https://www.mncorn.org/2015/07/16/corn-links-in-defense-of-corn-the-worlds-most-important-food-crop/>)

2. <http://www.fao.org/3/y4252e/y4252e04.htm>

Carbon Sequestration

Mycorrhizal fungi sequester carbon, and thus mitigate climate change

- Plant carbon allocation to mycorrhizal fungi are estimated to be 5-20% of total plant carbon uptake¹. Mycorrhizal biomass can be comparable to that of fine roots².
- Mycorrhizae have a major role in global carbon cycling because they consume up to 20% of plant assimilates and deposit slowly decomposing organic compounds in the soil, thus promoting soil carbon sequestration³.
- Mycorrhizal fungi consume 4% of fixed carbon, with 1% maintained in the fungal biomass and the remaining 3% exuded to the soil². This effect is more pronounced in deeper soils, i.e. the carbon is indeed sequestered (permanence achieved).
- Mycorrhizal carbon sequestration mitigates climate change (UN SDG #13), since CO₂ is a greenhouse gas.



1. <https://nph.onlinelibrary.wiley.com/doi/pdf/10.1111/j.1469-8137.1993.tb03839.x>
2. <https://www.oeaw.ac.at/forebiom/WS3lectures/IV-Ortas.pdf>
3. <https://www.ars.usda.gov/research/publications/publication/?seqNo115=279769>

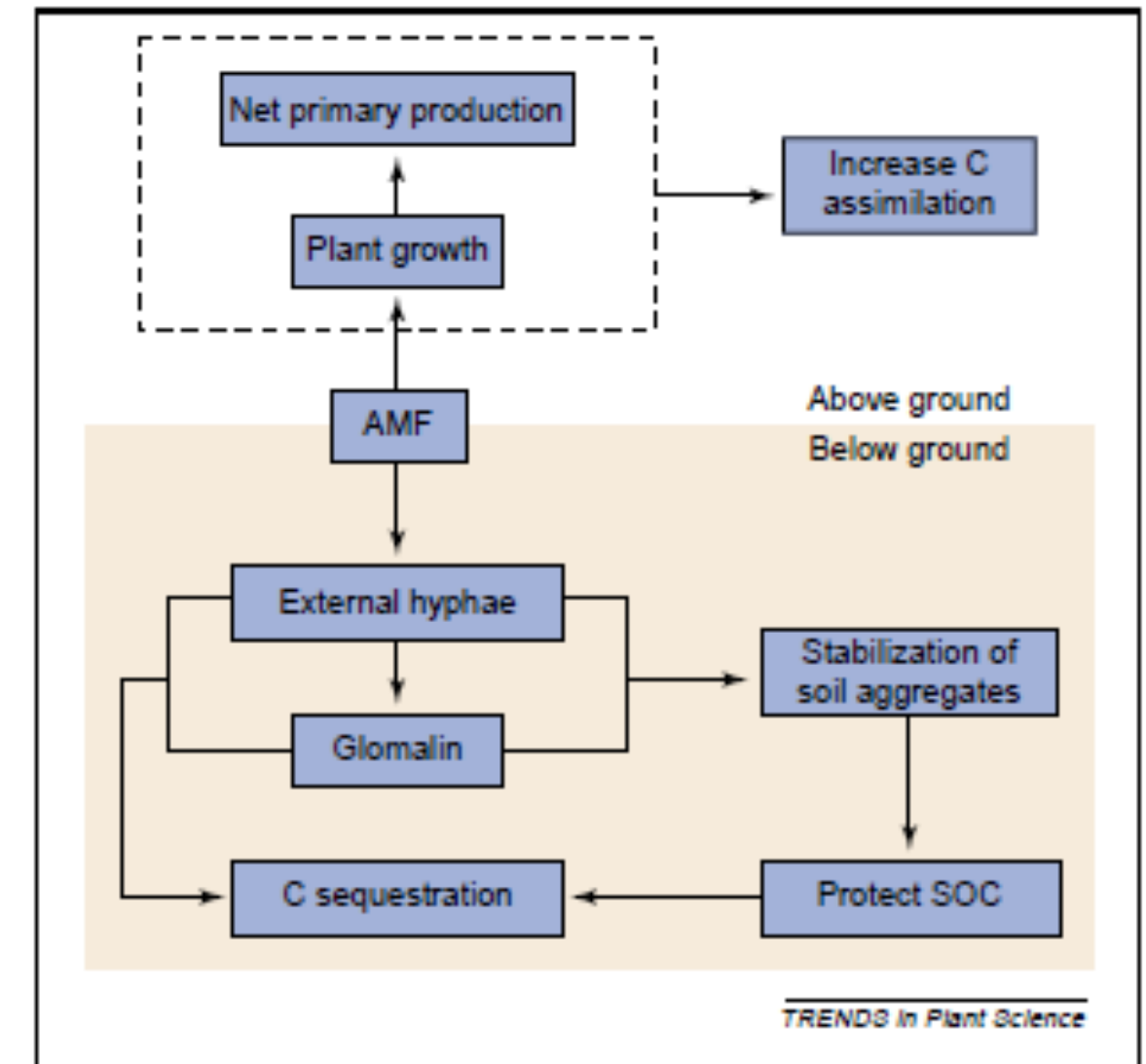
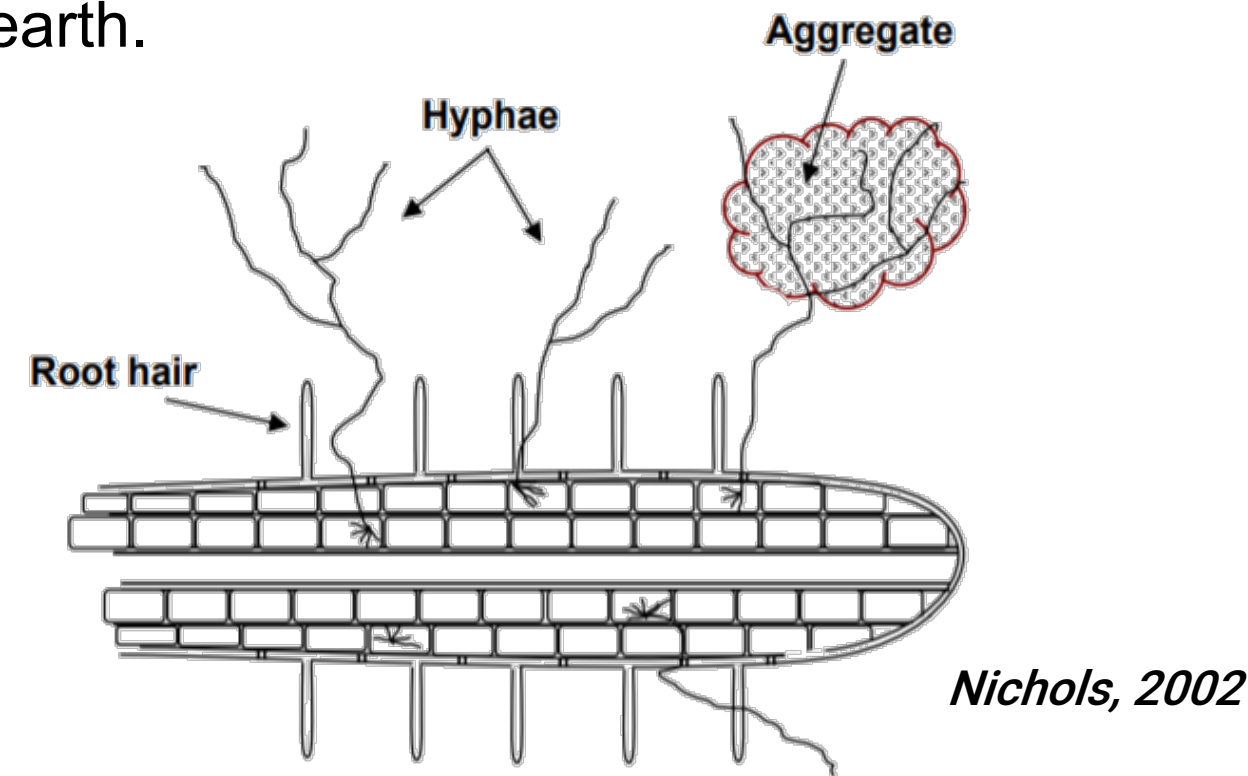
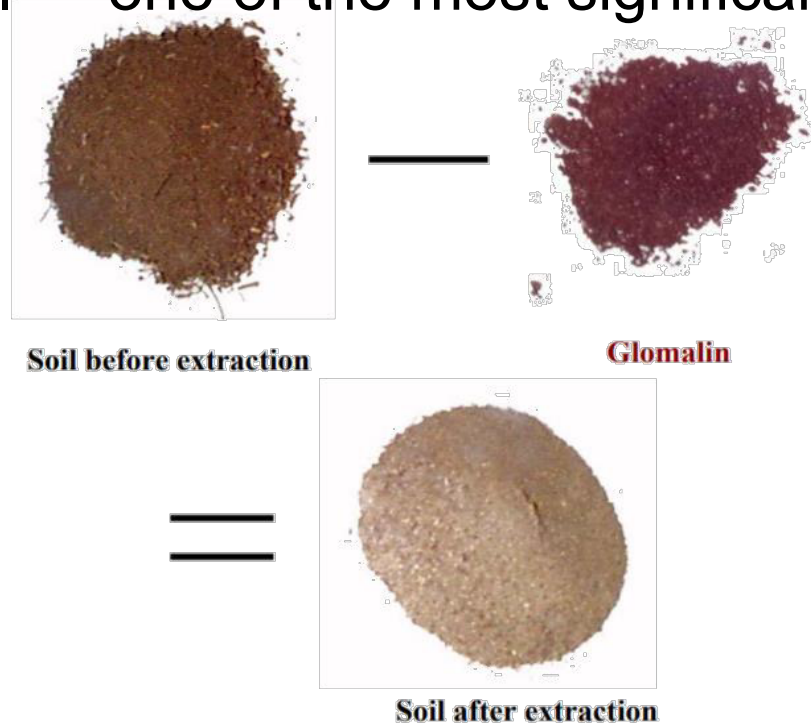


Fig. 1. Role played by arbuscular mycorrhizal fungi (AMF) in regulating carbon fluxes between the biosphere and the atmosphere. Abbreviation: SOC, soil organic carbon.

Zhu, Miller, 2003

Glomalin: glycoprotein soil adhesive produced by and named after *Glomus*, spp.

- Mycorrhizal fungi produce glomalin, a sticky substance that permeates organic matter and binds it to silt, sand and clay.
- Glomalin is what gives soil its tilth – that smooth granular texture of quality soil. It invigorates the soil and adds to soil structure. Soil aggregates protect soil organic carbon from reentering the atmosphere.
- Sequesters atmospheric carbon that is passed through symbiont plants. Glomalin accounts for 27% of carbon in soil¹ – one of the most significant carbon sinks on earth.



1. <https://agresearchmag.ars.usda.gov/2002/sep/soil>

Rootella sequesters carbon – and mitigates climate change

- Groundwork BioAg expects to cover 1M acres in 2021 with its mycorrhizal inoculants.
- Though it is known that mycorrhizae sequester carbon, actual measurements over the years are hard to come by and vary greatly. We used Prof. Ortas' comprehensive study¹ in Turkish soils for our calculations. Over Prof. Ortas' 15 year study, the top 30 cm of soil sequestered an additional 132 kg/ha of carbon in soils treated with compost and mycorrhizal inoculants, compared to compost only.
- Most Rootella is applied without compost, and thus we anticipate our actual contribution to be significantly greater. Under this conservative assumption, Groundwork BioAg should sequester 55K mtCO₂e, the equivalent of annual emissions from 12K cars².

1. <https://www.oeaw.ac.at/forebiom/WS3lectures/IV-Ortas.pdf>

2. A typical passenger vehicle emits 4.6 mtCO₂e per year (<https://www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle>)

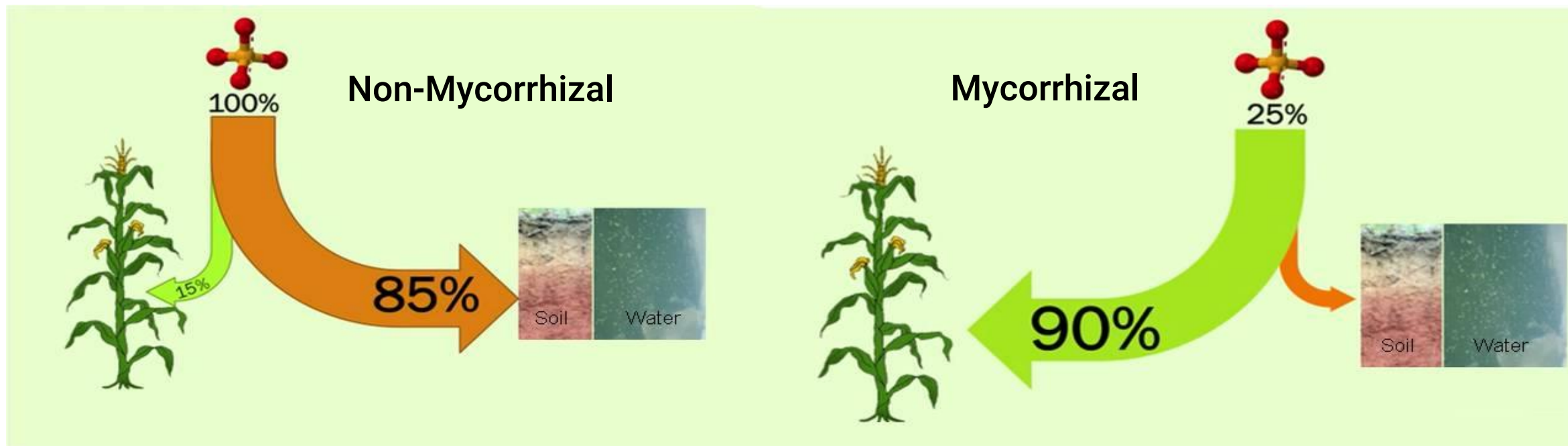
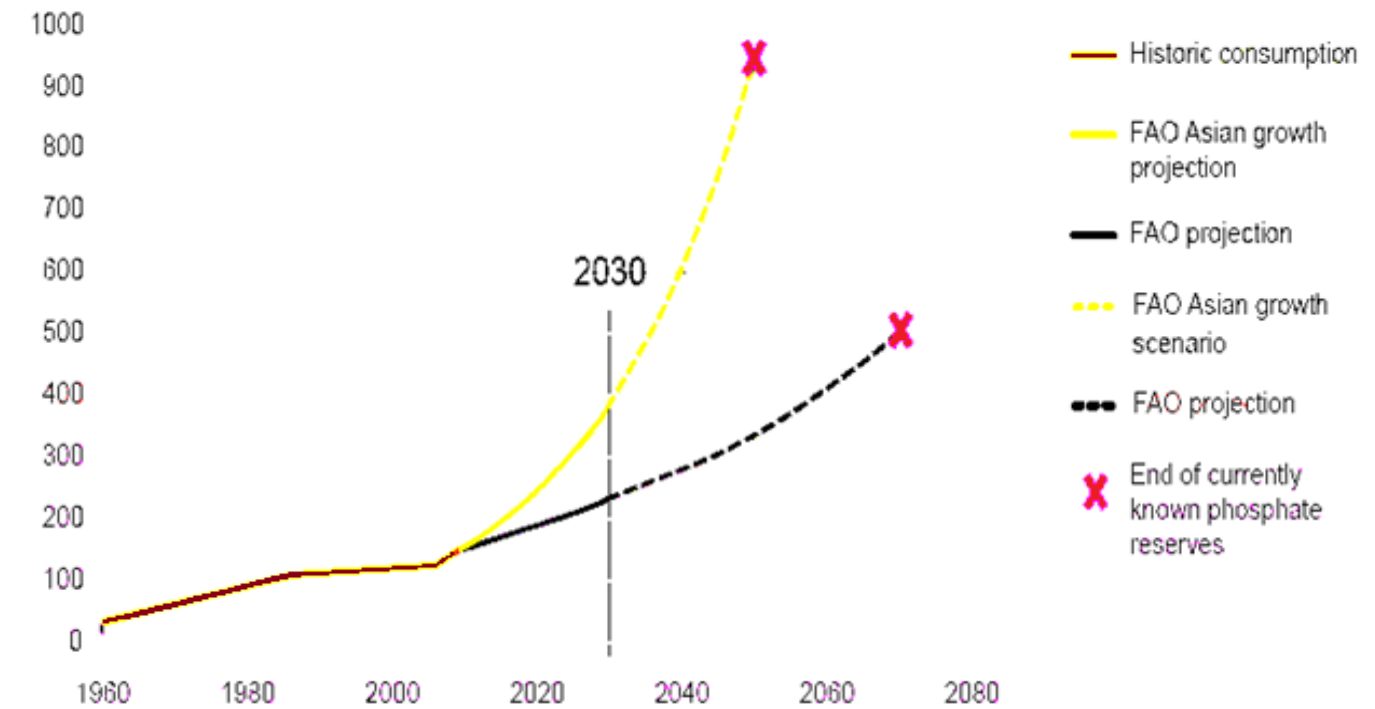
Phosphorus Savings

Phosphorus Savings

Mycorrhiza is a game-changer with phosphorus



- Phosphorus fertilizer run-off is a problem
- Phosphorus sources are running out
- Mycorrhiza can be a solution

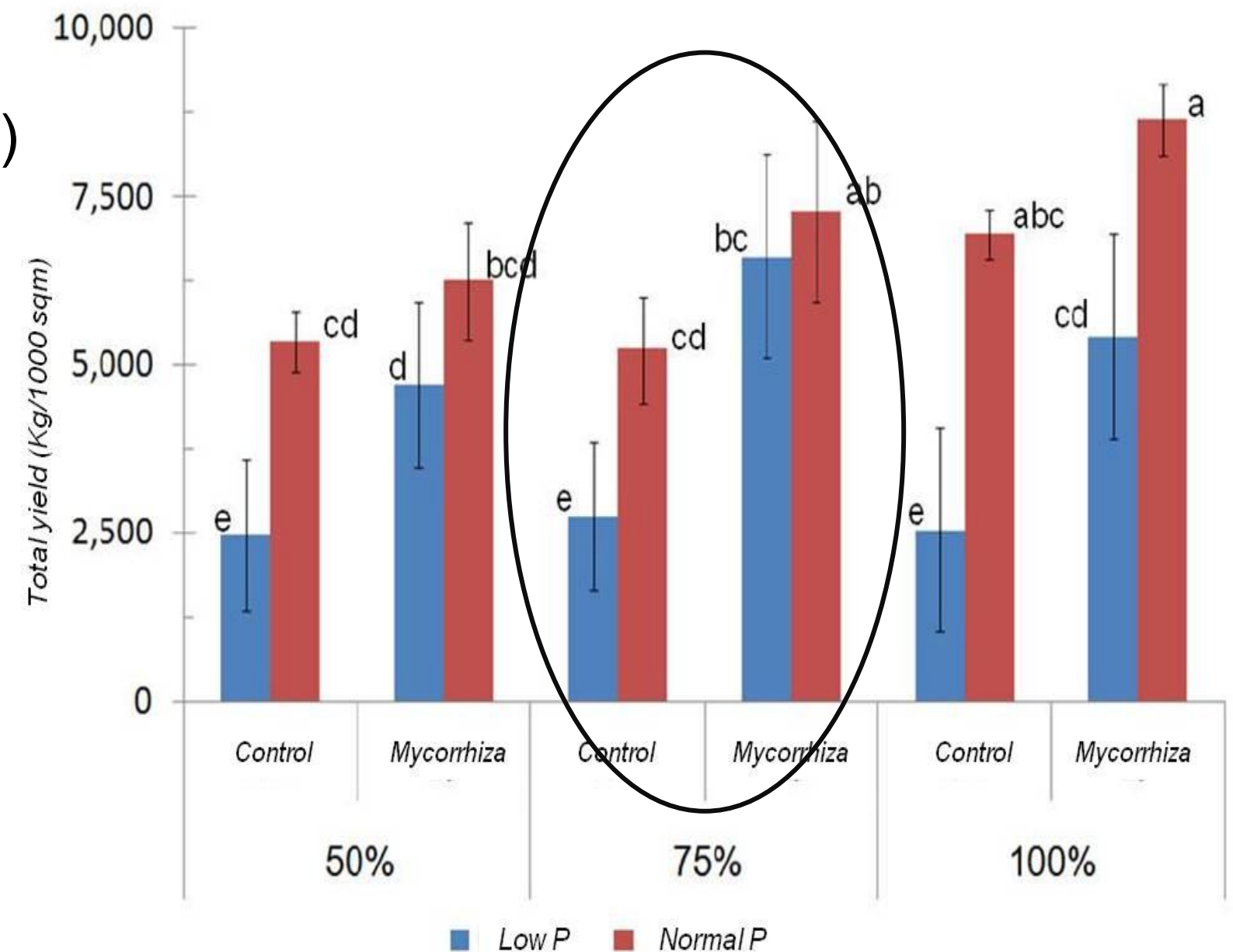


Above: Phosphorus sources are dwindling, with peak phosphorus expected in 2030 (Source: FAO)

Left: Non-mycorrhizal corn plants absorb only 15% of phosphorus fertilizer. Mycorrhizal corn plants absorb up to 90% (Source: Mohamed Hijri)

Bell peppers under several phosphorus and irrigation regimes (Hatzeva, Israel, 2008)

- Total yield from 1000 m²
- Red columns: normal phosphorous (100%)
- Blue columns: Low (20%) phosphorous
- Percentages represent level of irrigation applied
- Mycorrhiza with low P yields better than untreated with high P
- Mycorrhiza with low irrigation yields better than untreated with full irrigation



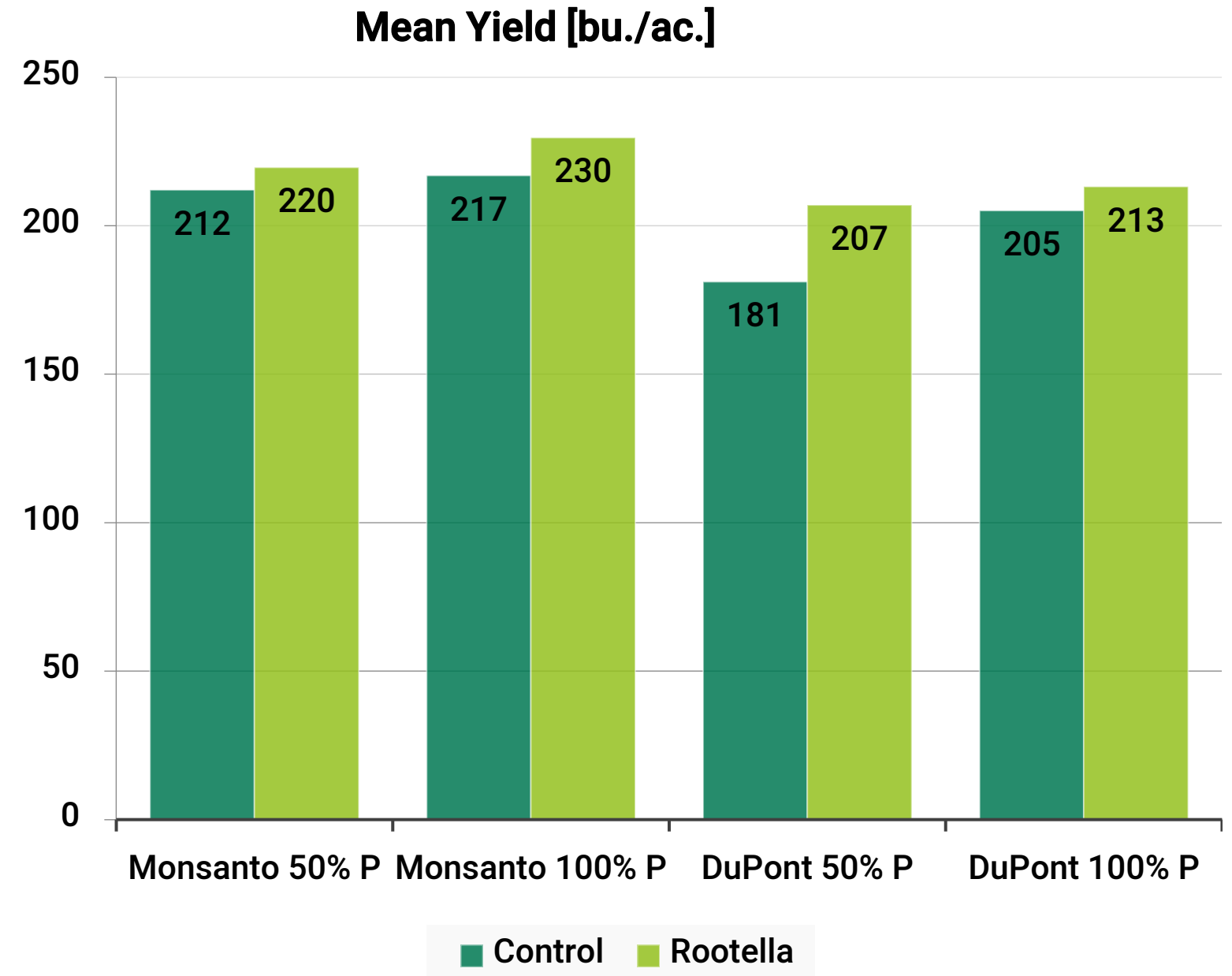
Phosphorus Savings

Rootella corn yields are better, even with only 50% Phosphorus

Seed Variety	P Rate*	Yield Improvement [bu./ac.]	Yield Improvement [%]
Monsanto Channel	50%	7.5	3.54
Monsanto Channel	100%	12.8	5.90
DuPont Pioneer	50%	25.9	14.30
DuPont Pioneer	100%	8.1	3.95

* 100% P = 140 lb. per acre

Rootella contract research corn trial, Iowa, US, 2015



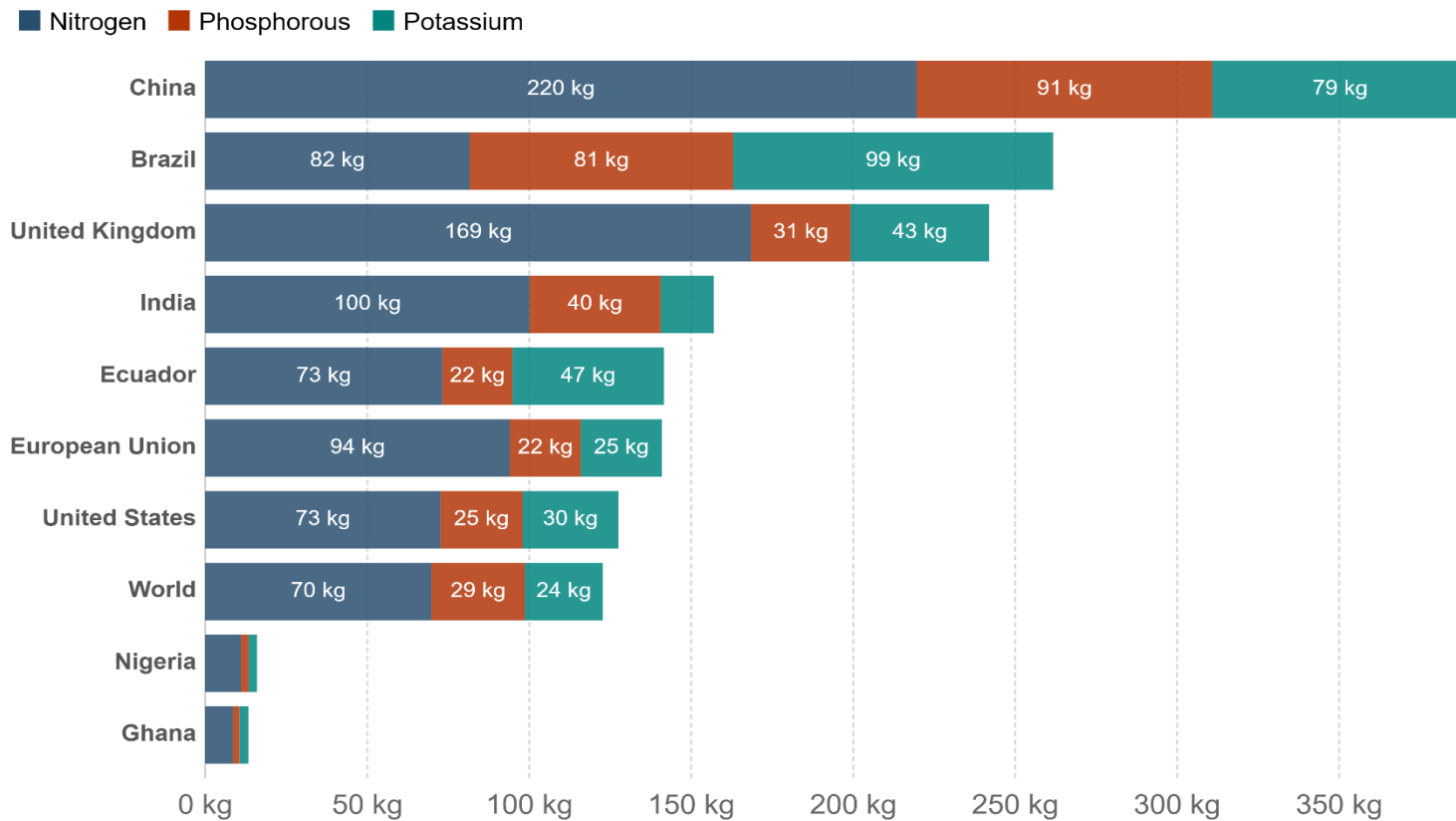
Rootella performs better under low phosphorus regimes

Crop	Phosphorus	Brazilian State						Average Yield Increase
		MT	PR	RS	GO	MG	SC	
Corn	0% P	105%	N/A	30%	32%	91%	93%	70%
	50% P	58%	N/A	12%	58%	138%	92%	72%
	100% P	81%	N/A	11%	26%	49%	11%	36%
Soybean	0% P	50%	65%	11%	6%	39%	N/A	34%
	50% P	29%	58%	11%	13%	57%	N/A	34%
	100% P	12%	23%	24%	24%	29%	N/A	22%

- Thorough trial report written by Dr. Admir Giachini, Federal University of Santa Catarina
- Rootella impact higher in low P
- Statistical significance at 26% yield increase

Phosphorus fertilizer is applied at high rates in our main markets (Brazil, India, US)

Fertilizer use per hectare of cropland, 2017



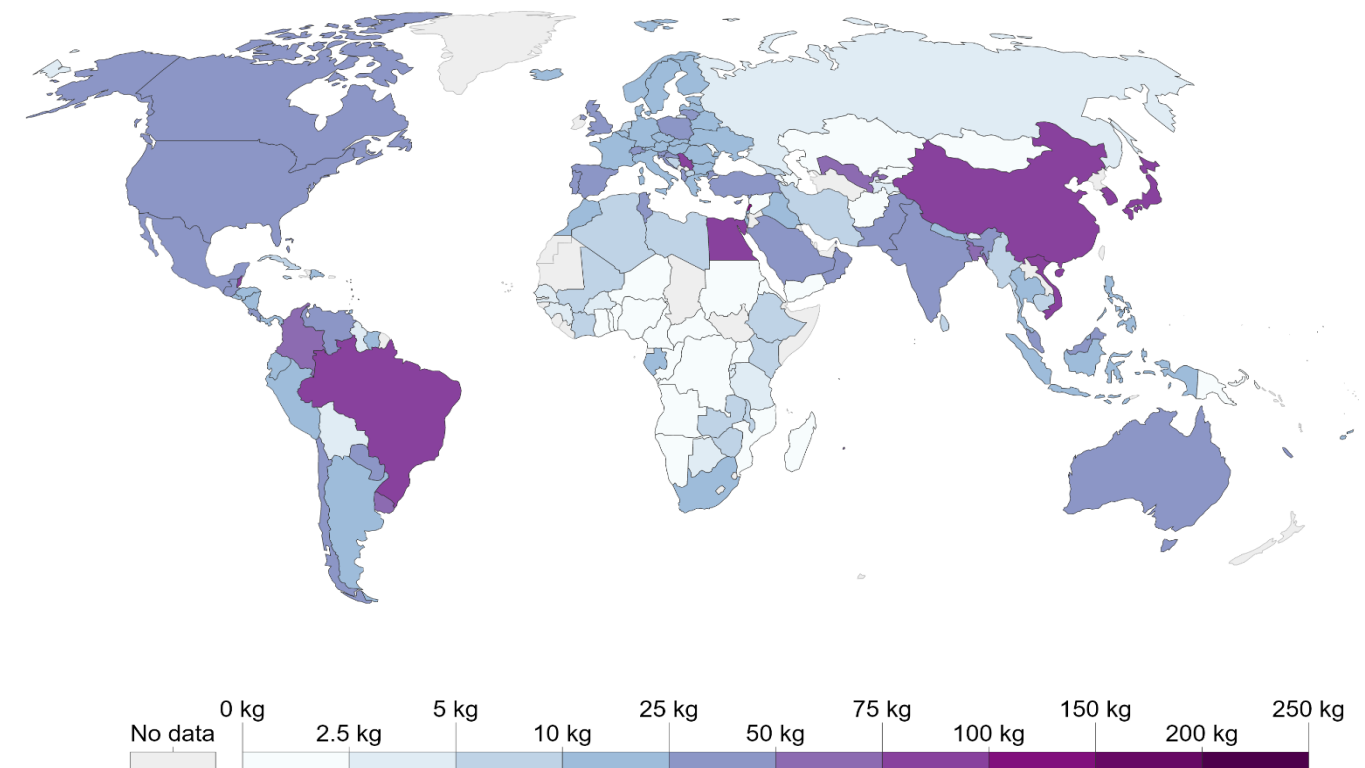
Source: Food and Agriculture Organization of the United Nations

OurWorldInData.org/fertilizers • CC BY

Phosphate fertilizer use per hectare of cropland, 2017



Application of phosphate fertilizer, measured in kilograms of total nutrient per hectare.



Source: UN Food and Agricultural Organization (FAO)

OurWorldInData.org/fertilizers • CC BY

- The global fertilizer market in 2019 was \$155.8B (Mordor Intelligence). Of this, phosphatic fertilizers comprised \$63.55B, or 40.7% of that market (MarketWatch).

Rootella can decrease phosphorus run-off pollution

Rootella Phosphorus Savings	Base Rate	-15%	-25%	-40%	-50%
P fertilizer application rate [kg/ha]	29 ¹	24.65	21.75	17.40	14.50

- Farmers are reluctant to change their fertility programs until they feel comfortable with a product. However, our trials show that with Rootella, similar yields may be achieved while applying significantly less phosphorus fertilizer. In addition, many territories (e.g. Europe, USA) have sanctioned limits on the amount of phosphorus farmers are allowed to apply. Ultimately, the application rate depends on the amount of unavailable phosphorus that is locked in the soil, as mycorrhizae break that down and avail it to the plant.
- Assuming a phosphorus application decrease of 50%, when Groundwork BioAg covers 50M acres, potential phosphorus savings would be equivalent to 293K tons.
- Conservatively assuming a 15% application decrease, savings would still be 88K tons, or 3.5X the amount of Phosphorus runoff pollution expected to be saved by all of the USEPA's Concentrated Animal Feeding Operations regulations³

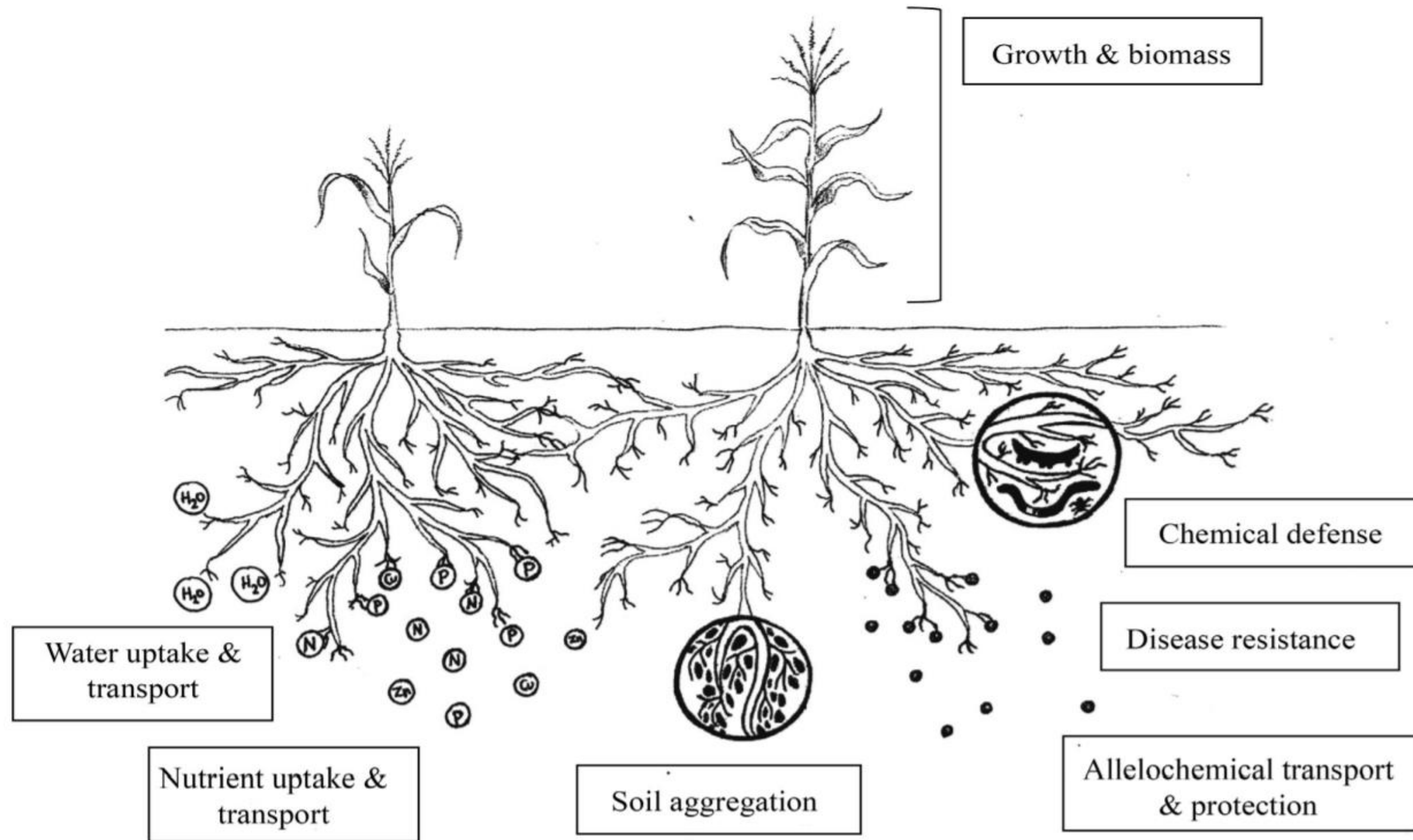
1. <https://ourworldindata.org/fertilizers>

2. Total estimated phosphorus nutrient load from land-based sources in the Caribbean Sea is 5.8K mt/yr (UNEP 2000). (<https://www.unep.org/cep/nutrients>)

3. <https://www.mdpi.com/2071-1050/13/12/6565/pdf>

Resistance to Climate-Related Stress

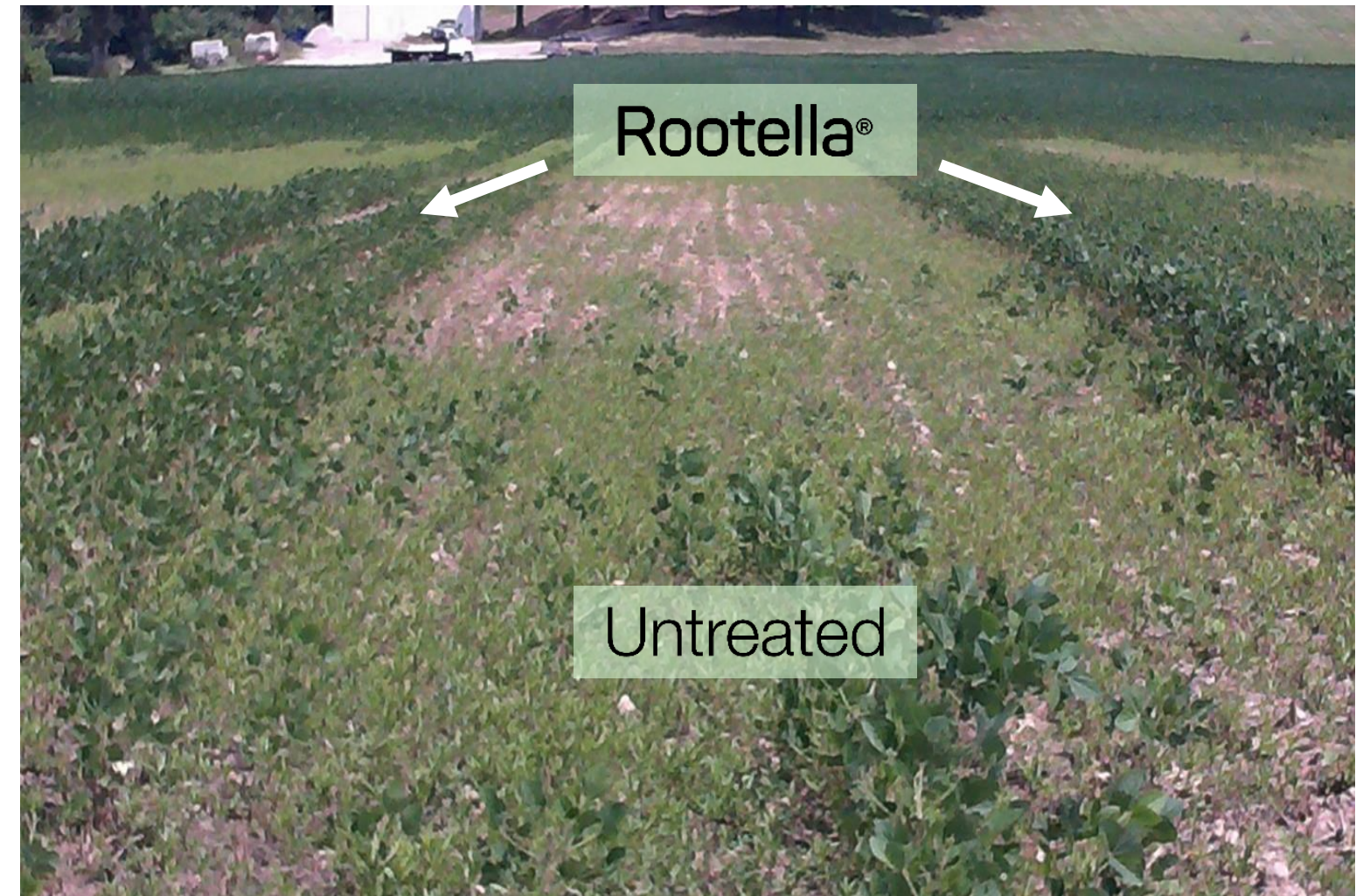
Resistance to Climate-Related Stress



Delavaux et al, 2017

Rootella improves water and nutrient absorption

- Mycorrhizal mycelia become “underground webs” that increase the root surface area by 10-100X and help plants absorb both water and nutrients
- Water accumulates on the mycelia, and ultimately reach plant roots
- Soils are held together by mycelia and glomalin, improving absorption capacity
- Mycorrhizal plants have better access to nutrients and can cope with stress
- Floods wash away nutrients, mycorrhizae help recover them when scarce



Flood stress, soybean, Indiana, US, 2016

Soybean Under Drought Conditions (Osvaldo Sacardo Farm, Goiás, Brazil, 2019)

- Despite 20 days without rain, Rootella[®] BR treated plot (36 ha) showed no signs of stress
- Rootella[®] BR increased yield by **21.6%** (70.28 treated vs. 57.1 untreated sacks/ha)



Resistance to Climate-Related Stress

Syngenta Foundation tomato trial endured drought and $>40^{\circ}\text{C}$ heat stress (India, 2019)



syngenta foundation
India



Organic corn Under Flood Conditions (Missouri, USA, 2016)

- Organic corn field suffered flooding right after seeding (crooked rows left, early in season)
- Field provided normal yields, despite nutrient wash-out (same mature field on right)



Rootella is a natural solution to climate-related plant stress

- Mycorrhizae help plants to resist several types of stress, through several modes of action:
 - Mycorrhizal plants are healthier plants. Healthier plants are more robust plants, able to withstand many of the stresses that climate change has created
 - Trials prove improved resistance to most abiotic stresses: water stress (drought and flooding), soil acidity (alkaline or acidic soils), salinity, and nutrient deficient soils
- Direct annual drought losses in the USA: \$6.4B¹. In the EU: €9 billion²
- Crop production accounts for 42% of all agricultural losses from large-scale disasters in developing countries, which comprise 84% of all climate-related disasters in these countries). 86% of this damage is due to drought¹
- Severe drought impacted 80 percent of US agricultural land in 2012, accounting for \$14.5B in federal crop insurance payments⁴
- In 2015, drought impacts to California's agricultural sector resulted in \$1.84B in direct costs⁵

1. NOAA-NCEI, 2021

2. Cammalleri et al., 2020; Naumann et al., forthcoming

3. FAO, 2015

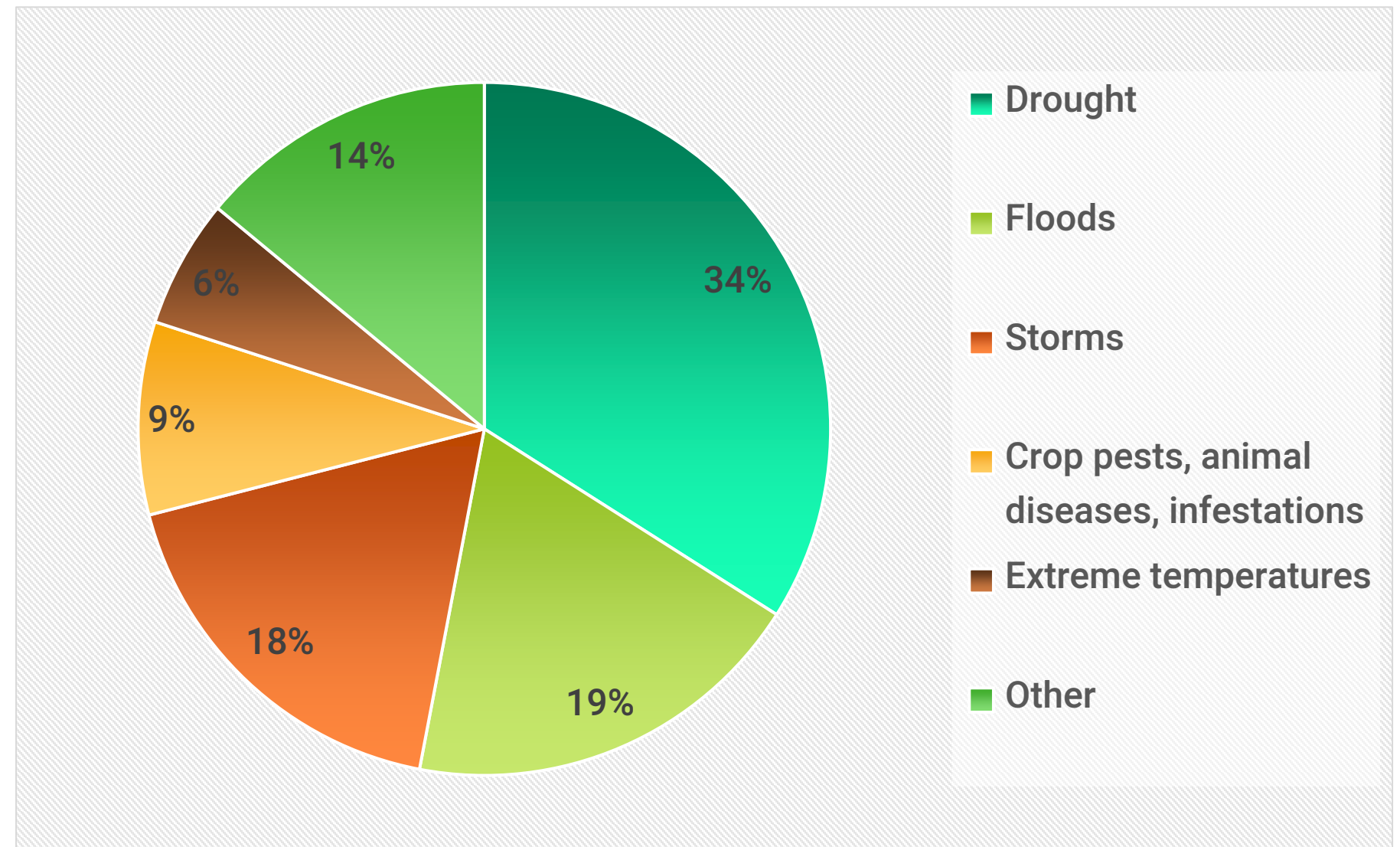
4. <https://nca2018.globalchange.gov/chapter/10/>

5. <https://www.ucdavis.edu/news/drought-costs-california-agriculture-184b-and-10100-jobs-2015/>

Rootella is a natural solution to climate-related plant stress

- Groundwork BioAg expects to cover 1M acres in 2021 with its mycorrhizal inoculants.
- 4% of global crop production is destroyed by natural disasters¹
- Rootella is effective in mitigating effects of all of the disaster types shown right, except for wildfires and earthquakes, to varying degrees
- For our calculations, we assume that Rootella provides a 35% reduction in damage from drought, flooding, and extreme temperatures, and a 15% reduction of damage from storms and crop pests

Total Crop and Livestock Production Loss Per Disaster Type, LDCs and LMICs, 2008-2018¹



1. <https://reliefweb.int/sites/reliefweb.int/files/resources/GAR%20Special%20Report%20on%20Drought%202021.pdf>

Summary and Next Steps

Rootella's impact is ground-breaking

- In summary, Groundwork BioAg has achieved real environmental impact already, and our accelerated growth will only fuel further impact.
- Though our impact will undoubtedly benefit generations to come, we want our current customers to benefit as well. To that extent, we intend to launch a carbon credit program, whereby farmers can be credited for their purchase of Rootella through carbon credits. Such programs are still in their infancy worldwide, and they require adoption of regenerative agriculture practices (e.g. low-till) in addition to adoption of products such as Rootella.
- More accurate quantification of our impact, whether for carbon credits or for estimating our double bottom line, requires more measurement of all our regenerative benefits: yield increase, phosphorus savings, carbon sequestration (soil organic carbon changes over time), and climate-related stress.



Thank you

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