Innovations in Berries Fertigation in Mexico and Peru

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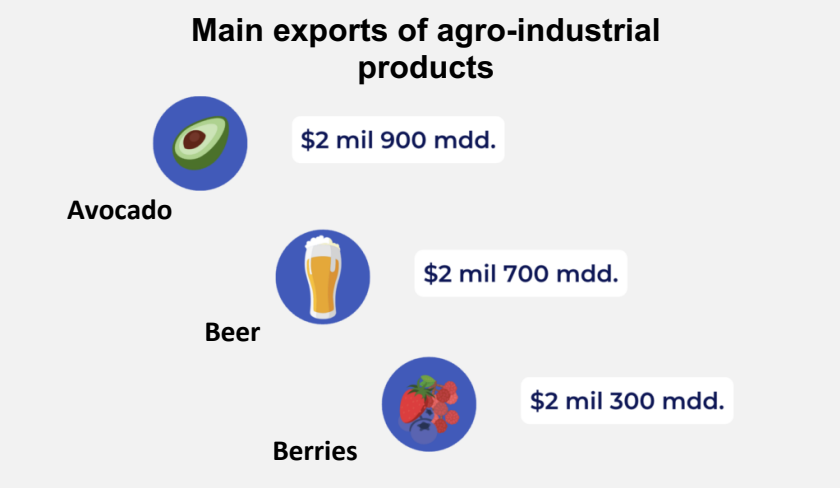
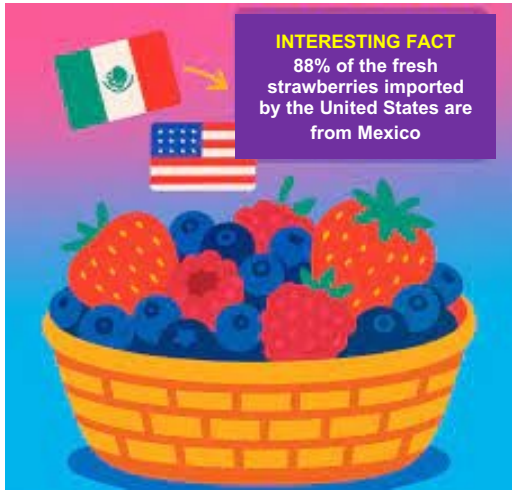
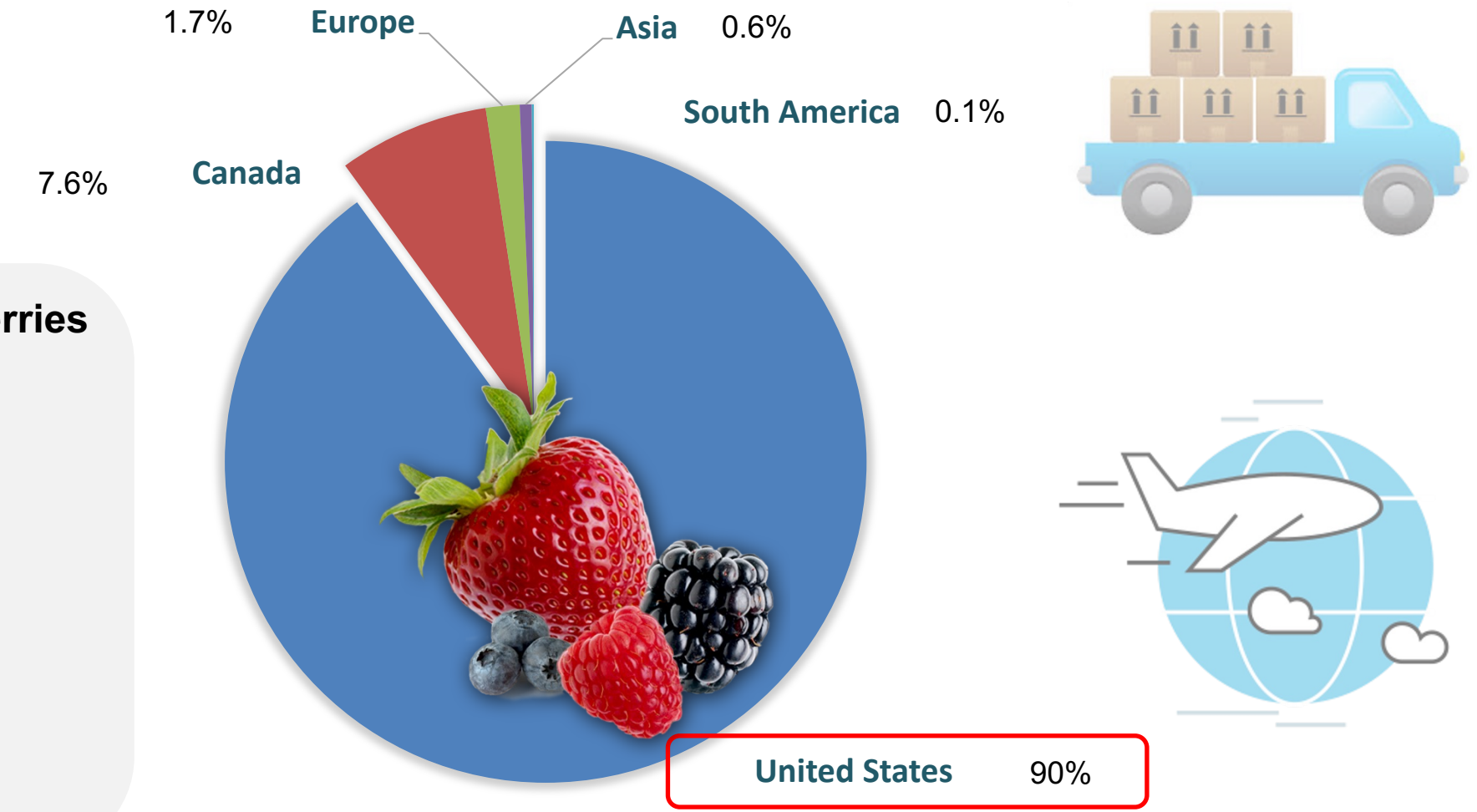
Mexico is a leader in berry production and export





Export markets for Mexican berries



Quality attributes of berries for export to USA:

- ✓ Brix degrees
- ✓ Firmness
- ✓ Color (appearance)
- ✓ Size
- ✓ “Bloom”
- ✓ Pesticide-free

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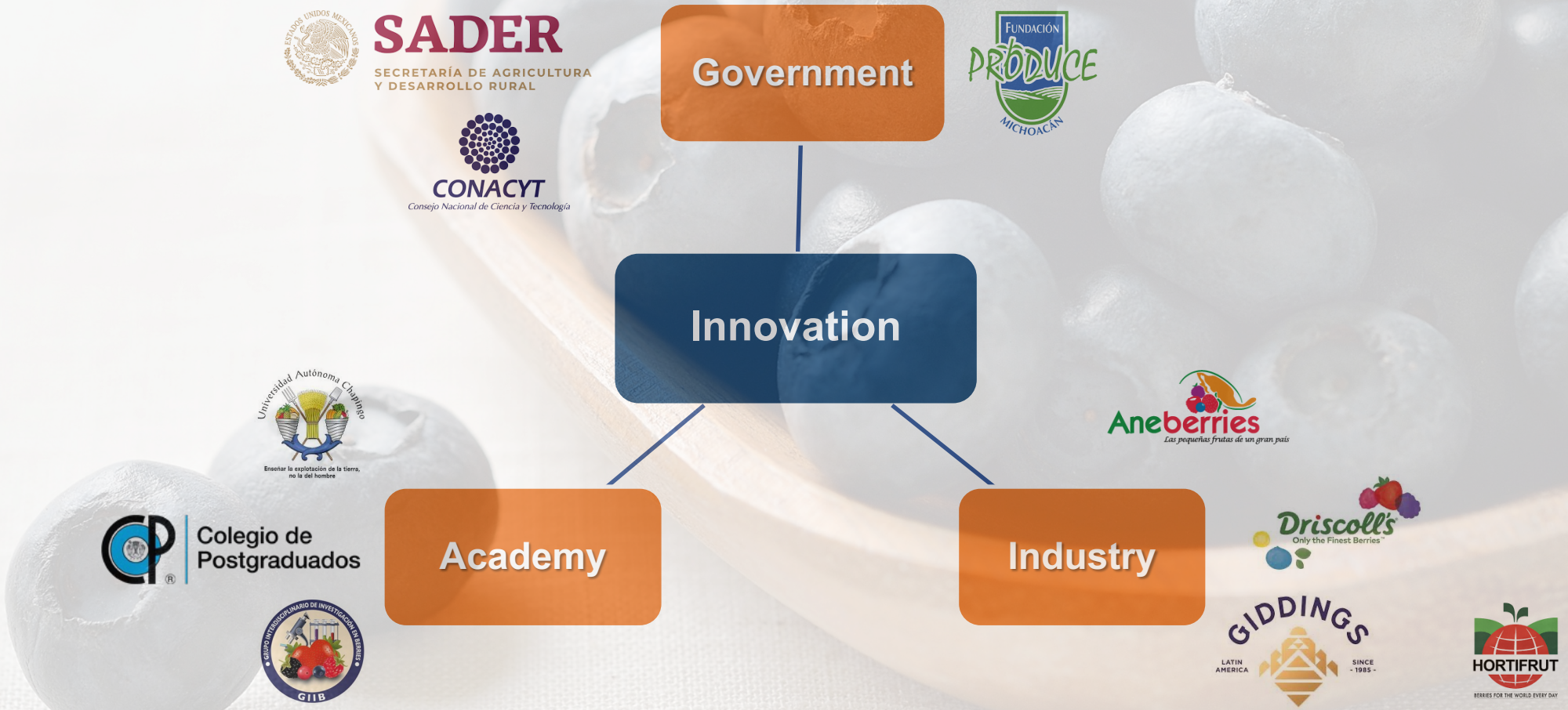
Innovation in Mexican berries is a pillar of the virtuous triangle Academy-Government-Industry



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Mexican berry export calendar to USA

CROPS	J	F	M	A	M	J	J	A	S	O	N	D
Blueberries												
Blackberries												
Raspberries												
Strawberries												

Berries production in Mexico covers approximately 50,000 hectares (2025)

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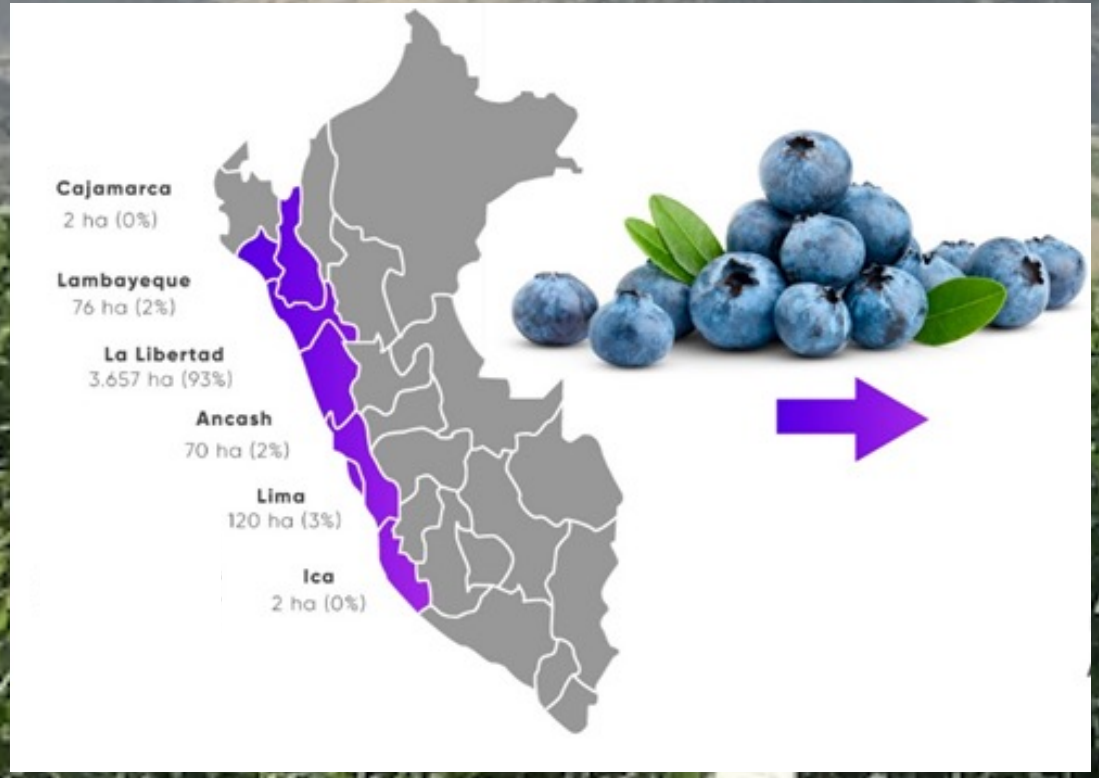
Peru, leader in blueberry production and exports

Peru currently has 26,600 hectares of blueberries



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Blueberries production in sandy soils in Peru and Northern Mexico

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Blueberry production in loamy soil in Central Mexico

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Blueberries production in protected structures (Central Mexico)

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Raspberry and strawberry production in Central Mexico

It is estimated that the total area of berries under protected agriculture (which includes macrotunnels, shade mesh and greenhouses) is close to 33,000 hectares

Production of blueberries in substrate (Mexico)

Dutch mix

1/3 peat
1/3 perlite
1/3 coconut fiber

*CEC > 100 cmol(+)/kg

*CEC = Cation Exchange Capacity

Production of blueberries in coconut fiber and chips (Mexico and Peru)

Coconut fiber

CEC > 50 cmol(+)/kg

Coconut chips

*CEC < 50 cmol(+)/kg

*CEC = Cation Exchange Capacity

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Production of blueberries and blackberries in volcanic gravel (Mexico)

Recommended
particle size
3-6 mm in diameter
CEC < 20 cmol(+)/kg

*CEC = Cation Exchange Capacity

Primocane raspberries production in Mexico

Primocane

Corresponds to the first year's growth (“suckers” or shoots)

Floricane

Corresponds to the second year's growth (canes)

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The largest area of raspberry plantations is in soil with a macrotunnel (Mexico)

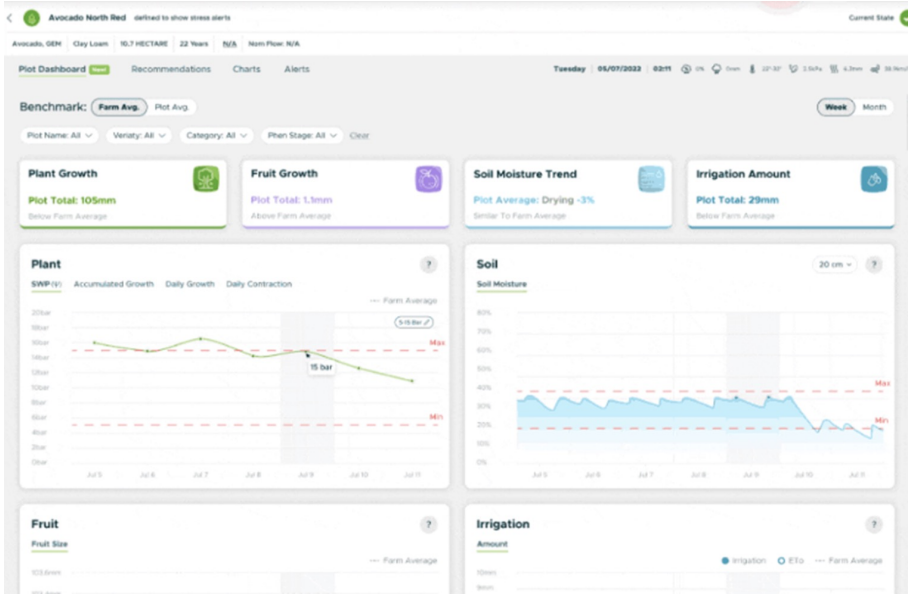
Rustic cultivation

Yields:
6-8 thousand
exportable boxes

Raspberry production in coconut fiber (pots with 7 liters of substrate)

Remote sensing to adjust irrigation and nutrition based on environmental conditions, in Peru

Advanced AI-Powered Precision Farming Platform



Use of remote sensors for soil moisture, pH and EC due to the large areas

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Use of soil profiles (“calicates”) and suction probes in Peru

The use of “calicates” allows to see the soil humidity and root development, and others

Result of a physicochemical analysis of a sample of suction probes in blueberry

INFORME DE SEGUIMIENTO NUTRICIONAL	TABLA DE DATOS ANALÍTICOS			13/08/2019
AGQ Labs	Cliente:	AGRICOLA COPACABANA DE CHINCHA S.A.	Cultivo:	ARANDANO
	Finca	FUNDO SAN LORENZO	Variedad:	ARANDANO
	Parcela	SECTOR A	Fenología	--
	Fecha:	01/08/2019		

P.A. CIP N° 221809

01/08/2019	pH	CE	H2PO4-	Cl-	SO4--	NO3-	NH4+	Ca++	Mg++	Na+	K+	B	Fe	Mn	Cu	Zn
		dS/m a 25° C	mg/L	meq/L	meq/L	meq/L	meq/L	meq/L	meq/L	meq/L	meq/L	mg/L	mg/L	mg/L	mg/L	mg/L
SFR	6,09	1,05	57,1	2,61	7,11	0,59	0,53	7,81	2,60	1,43	0,83	0,34	<0,05	<0,05	<0,05	14,4
SONDA 15 cm	6,84	1,82	36,0	1,41	12,0	6,50	<0,28	16,4	5,49	2,38	1,57	0,71	<0,05	<0,05	0,08	0,68
SONDA 30 cm	6,75	1,75	35,9	1,38	12,4	6,60	<0,28	17,0	5,67	2,46	1,62	0,74	<0,05	<0,05	0,08	0,61
SONDA 45 cm	7,58	2,01	3,93	0,87	19,2	4,31	<0,28	21,2	5,93	3,03	1,92	0,65	<0,05	<0,05	0,06	0,22
Índices		X1,8		X0,5		-1 004%				X1,8	-12,4%					

03/07/2019	pH	CE	H2PO4-	Cl-	SO4--	NO3-	NH4+	Ca++	Mg++	Na+	K+	B	Fe	Mn	Cu	Zn
		dS/m a 25° C	mg/L	meq/L	meq/L	meq/L	meq/L	meq/L	meq/L	meq/L	meq/L	mg/L	mg/L	mg/L	mg/L	mg/L
SFR	5,29	1,73	46,0	1,22	8,22	3,18	0,89	6,52	2,86	0,87	2,12	0,25	0,32	0,06	<0,05	34,6
SONDA 15 cm	6,59	2,23	27,4	1,22	12,1	4,97	<0,28	13,6	3,93	1,87	1,01	0,51	<0,05	<0,05	0,09	0,33
SONDA 30 cm	6,62	2,24	28,4	1,22	12,2	4,90	<0,28	13,9	3,98	1,86	1,01	0,52	<0,05	<0,05	0,09	0,29
SONDA 45 cm	7,09	2,30	15,1	0,99	13,8	3,65	<0,28	14,5	3,81	2,00	1,09	0,58	<0,05	<0,05	0,07	0,14
Índices		X1,3		X0,9		-18,0%				X2,2	77,6%					

HOJAS ARANDA N Total	P	K	Ca	Mg	S	Na	Cl	B	Fe	Mn	Cu	Zn	Mo
%	%	%	%	%	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
27/02/2019	3,24	0,04	0,71	0,56	0,20	0,33	1 479	333	157	258	249	7,44	91,7	0,69
29/03/2019	2,22	0,15	0,71	0,90	0,21	0,32	349	<250	138	270	210	41,7	64,5	1,59
29/04/2019	2,20	0,17	0,64	0,80	0,21	0,19	364	454	82,5	272	167	12,6	31,7	0,99
28/05/2019	2,07	0,13	0,61	1,20	0,20	0,32	486	<250	92,8	174	207	7,04	31,5	0,50
03/07/2019	2,08	0,11	0,84	1,12	0,17	0,40	788	441	148	326	238	13,0	42,8	1,05
01/08/2019	2,06	0,12	1,01	1,22	0,15	0,59	1 455	821	175	231	257	25,5	39,8	0,79

Suction probe analyses (soil or substrate) are used to adjust fertigation programs according to weather conditions and phenological stages.

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Nutrient solutions for blueberry production in different phenological stages

Phenological stage	Cations (meq/L)				Anions (meq/L)		
	NH_4^+	Ca^{+2}	Mg^{+2}	K^+	NO_3^-	$H_2PO_4^-$	SO_4^{-2}
Pruning - shoot formation	1-2	2-3	1-1.5	1-1.5	1.5-2	0.5-1	2-4
Shoot formation - bloom	2-3	3-4	1.5-2	1.5-2	1.5-2	0.5-1	2-4
Bloom - fruit set	1-2	4-5	2	3	3.5-4.5	1-1.5	2-4
Fruit set - harvest	1	4	2	5	2.5-3.5	0.5-1	2-4
Harvest - postharvest	2	2	1	1.5	2-2.5	0.5-1	2-4

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Monitoring strawberry nutrition using suction probes in clay soils

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Monitoring berry nutrition using sap analysis

Parameters	Phenological stages		
	Vegetative	Bloom	Fructification
	---------- mg/L ----------		
N-NO3	1000 - 1500	500 - 1000	100 - 500
P-PO4	250 - 300	200 - 250	100 - 200
K	2000 - 2500	1500 - 2000	1000 - 1500
Ca	50-100	50-100	50-100
Mg	60 - 100	40 - 60	50 - 100
S-SO4	700 - 800	550 - 700	450 - 550
Fe	0.09 - 0.15	0.08 – 0.15	0.1 – 0.13
Mn	1 - 3	0.5 - 1	0.2 – 0.5
B	3 - 5.5	1 - 3	0.1 - 1
Cu	4 - 6	1 - 4	0.5 - 1
Zn	1.5 - 2	1 – 1.5	0.5 - 1

Berries nutrition challenges: salty water management

Blueberry production in Baja California, Mexico (saline waters, *EC = 20 dS/m with reverse osmosis)

Cost of water: 1USD/m^3

*EC = electrical conductivity

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Berries nutrition challenges: saline coastal aquifers - Na^+ and Cl^- management

Strawberry production in sandy soils and salty waters in Baja California, Mexico (100 tons per hectare)

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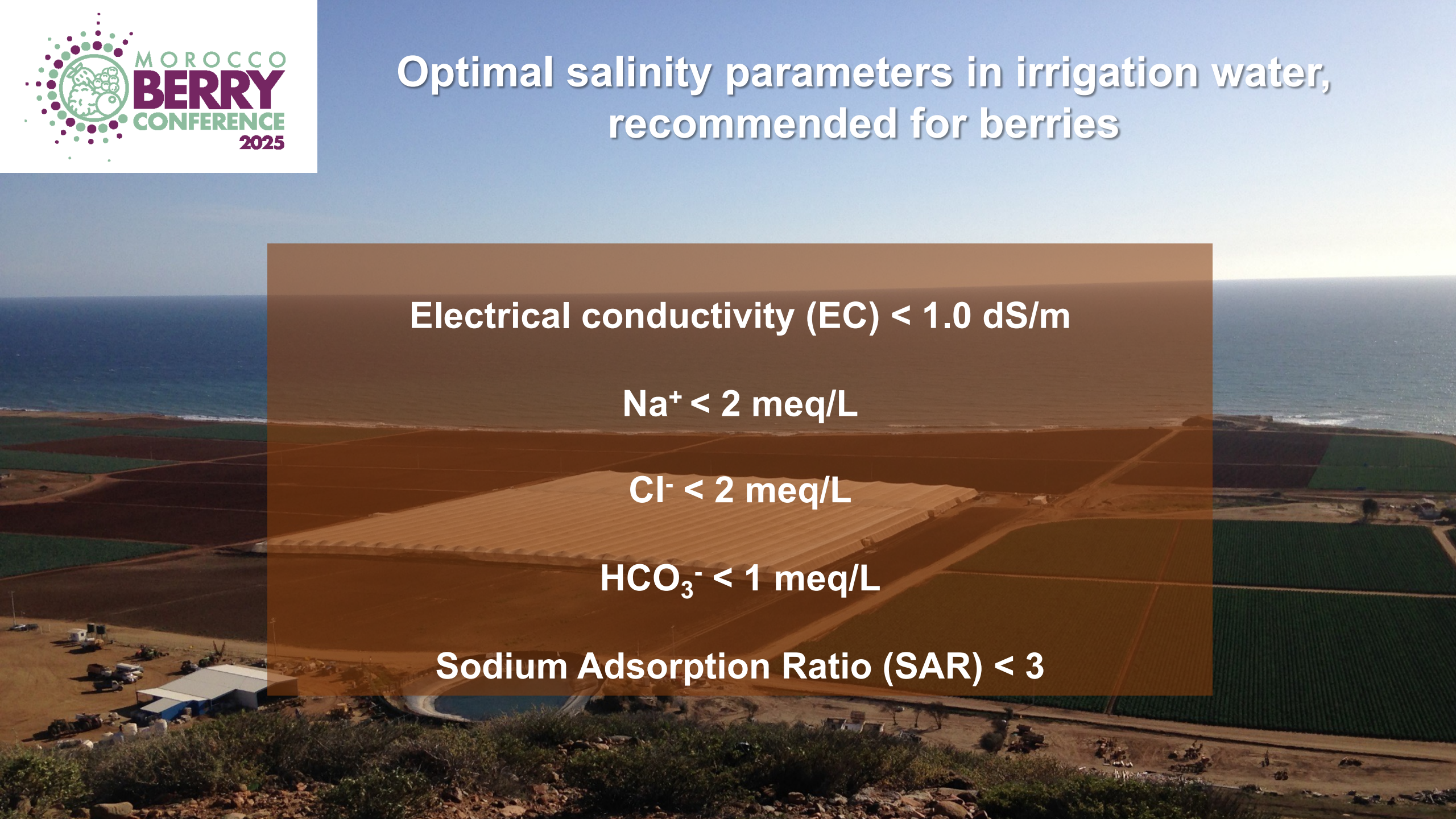
Optimal salinity parameters in irrigation water, recommended for berries



Electrical conductivity (EC) < 1.0 dS/m

Na^+ < 2 meq/L

Cl^- < 2 meq/L

HCO_3^- < 1 meq/L

Sodium Adsorption Ratio (SAR) < 3

Decreased berry yield as a function of irrigation water salinity

Crop	*EC (dS/m) at which performance decreases by:		
	10%	25%	50%
Blackberry	1.5	2.0	2.5
Blueberry	1.0	1.5	2.0
Raspberry	1.5	2.0	2.5
Strawberry	1.5	2.0	2.5

*EC – electrical conductivity

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Osmotic, ionic and oxidative stress in berries, generated by excess salts in the water

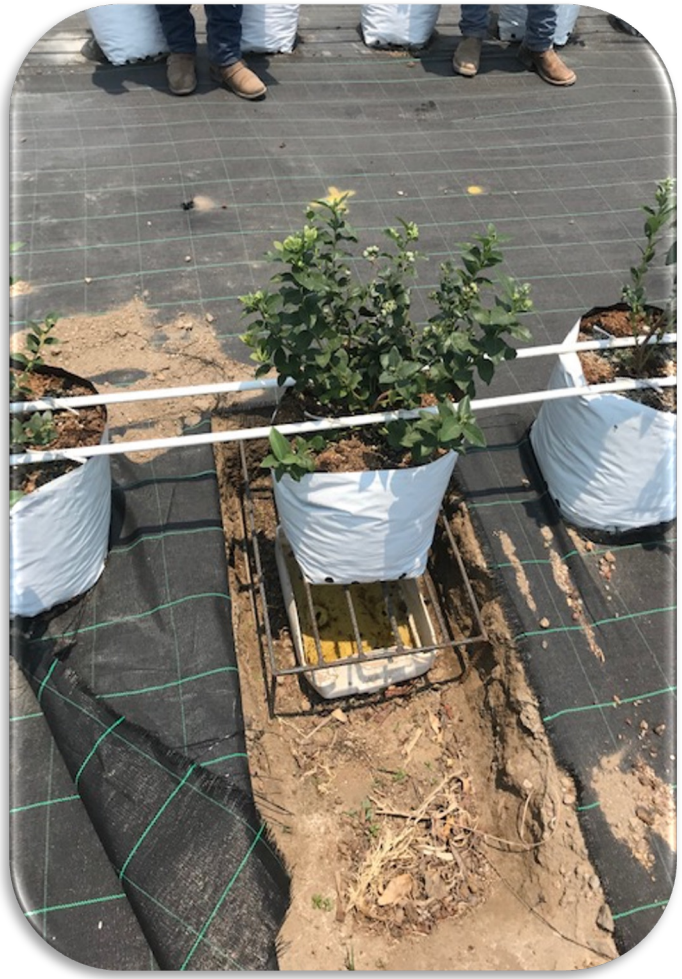
Excess sodium, chlorides and bicarbonates in blueberries

Excess chlorides in raspberries

Sodium chlorides in raspberries

Bluerries fertigation under saline conditions: fertigation keys

Irrigation and Drainage Management (Leaching)



Frequent and intermittent irrigation:

Because blueberries have shallow roots, they should be irrigated frequently and in short bursts (watering for 5 to 15 minutes, several times a day). This minimizes "jumps" in the Electrical Conductivity (EC) of the growing medium and prevents both drought and waterlogging.

Bluerries fertigation under saline conditions: fertigation keys

Increasing the leaching rate (Drainage):

To "wash" excess salts from the substrate, it is essential to maintain a drainage rate of more than 15% or 20% (it can reach 25% or more). This leachate discharges harmful salts (mainly chlorides and sodium) into the substrate.

% drainage = (drainage volume (leached)/ irrigation volume (applied)) ×100

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Bluerries fertigation under saline conditions: fertigation keys

Constant monitoring:

It is crucial to measure the EC and pH of the irrigation water (inlet) and the drainage solution (outlet). If the EC of the drainage is significantly higher than that of the irrigation, it indicates that salts are accumulating and drainage needs to be increased.

Bluerries fertigation under saline conditions: fertigation keys

Use of Pre- and Post-irrigation:

Some systems apply a small initial irrigation with water alone (or acidified water) to moisten the substrate, followed by the nutrient solution, and then a final irrigation with water to clean the lines and reduce salt concentrations at the end of the wet bulb.

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Constant monitoring of nutrient solution (inlet), saturated paste of the substrate and drainage (outlet): pH, EC, and ions

Use of synthetic acids for the management of alkaline waters

Main acids used in berries fertigation

Sulfuric acid

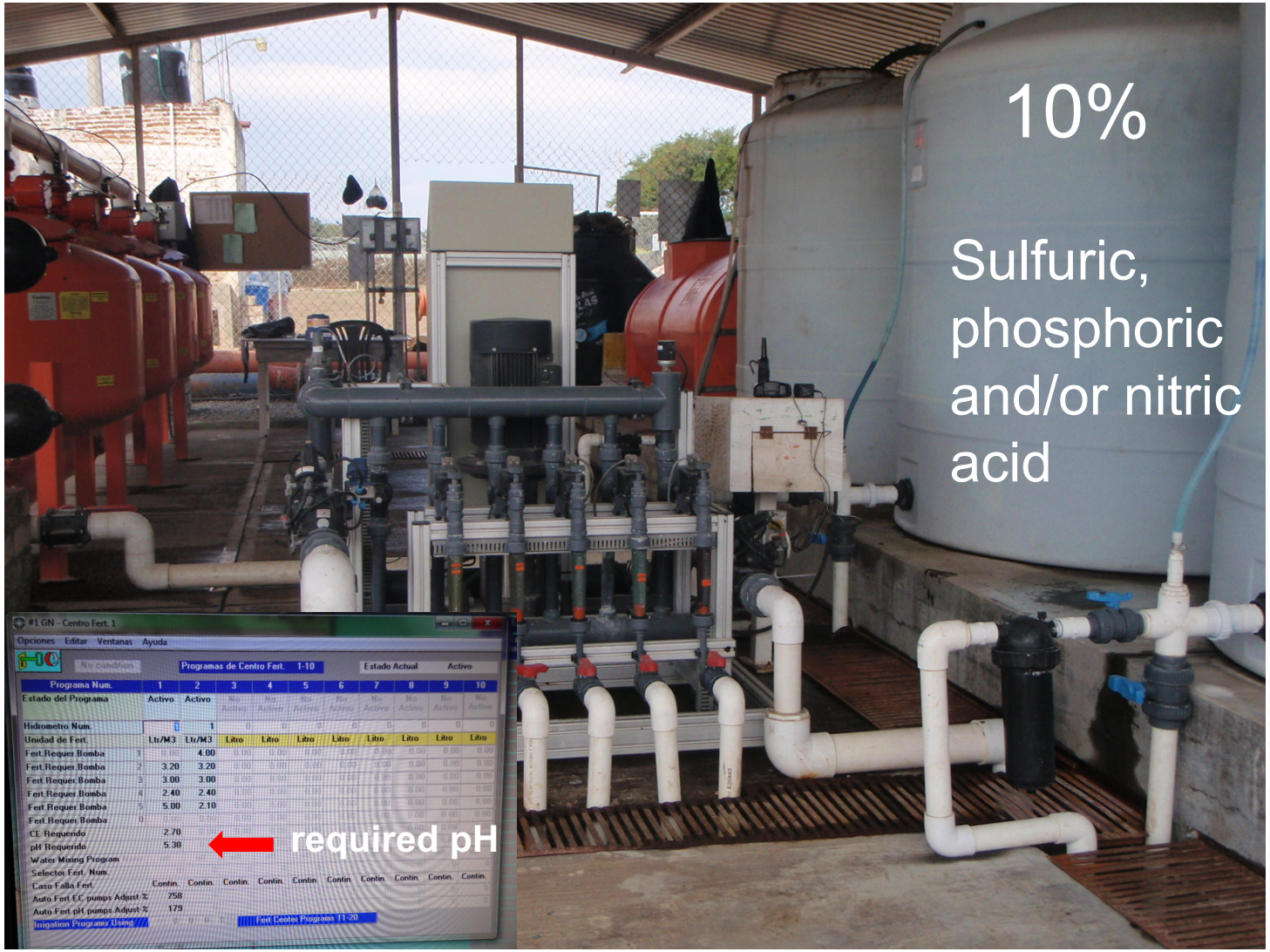
$$HCO_3^- + H_2SO_4 \longrightarrow H_2O + CO_2\uparrow + SO_4^{-2}$$

Phosphoric acid

$$HCO_3^- + H_3PO_4 \longrightarrow H_2O + CO_2\uparrow + H_2PO_4^-$$

Nitric acid

$$HCO_3^- + HNO_3 \longrightarrow H_2O + CO_2\uparrow + NO_3^-$$



Sulfur burner to acidify irrigation water with alkaline pH (>7)

The amount of sulfur to be burned depends on the volume of water, bicarbonates concentration and target pH.

Berries nutrition challenges: climate

Blueberry quality attributes affected by climate stress

Firmness

Brix

Size

Fruit dehydration

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Berries nutrition challenges: climate

Blueberries in Central Mexico and Peru, May 2024

(Low relative air humidity)

Berries nutrition challenges: climate

Central Mexico, December 2024
Blueberries in macrotunnel

Frost

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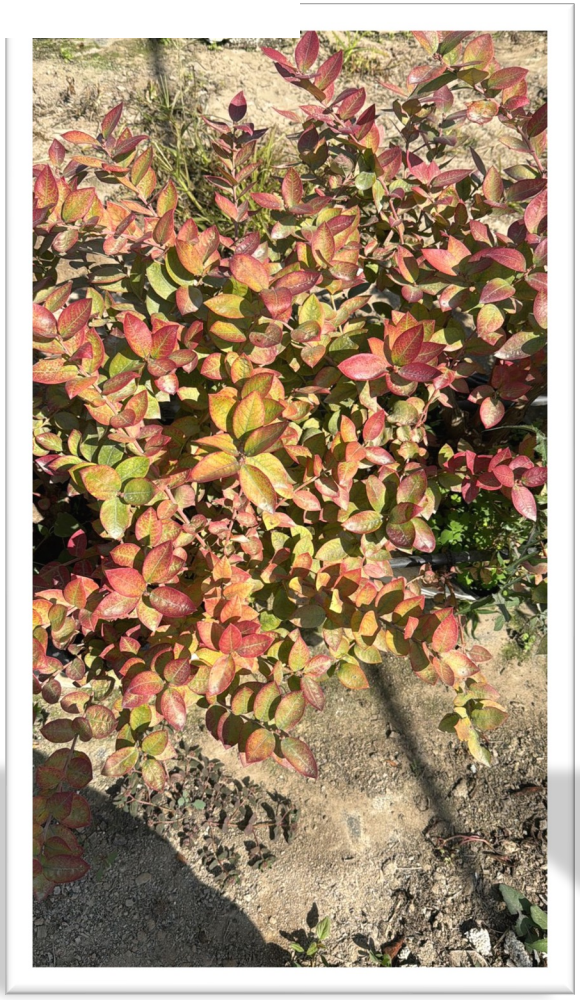
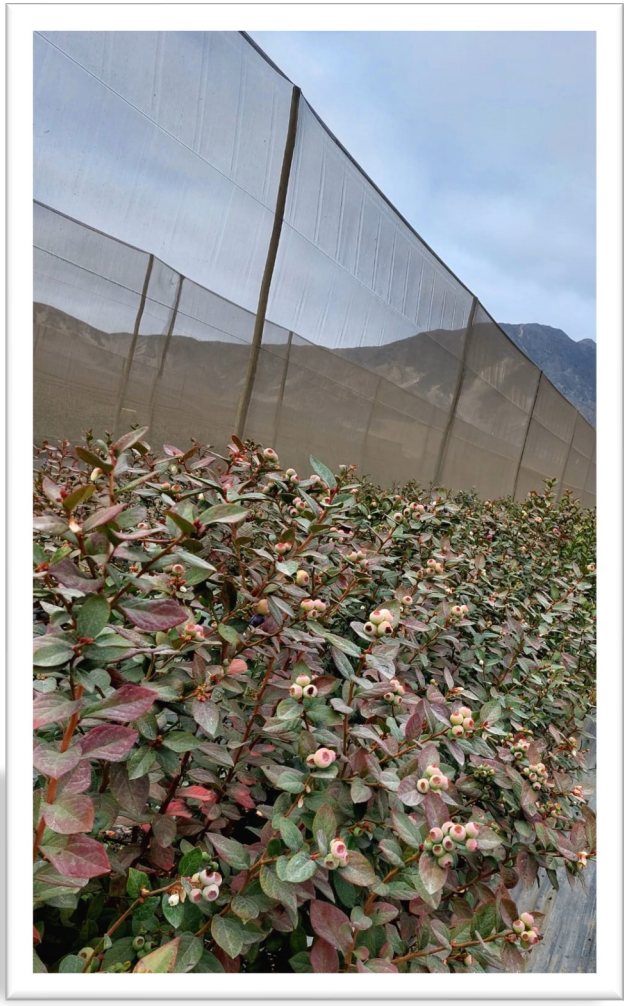
Berries nutrition challenges: climate





UV-B radiation effects on blueberries
(North Coast of Peru, August 2024)

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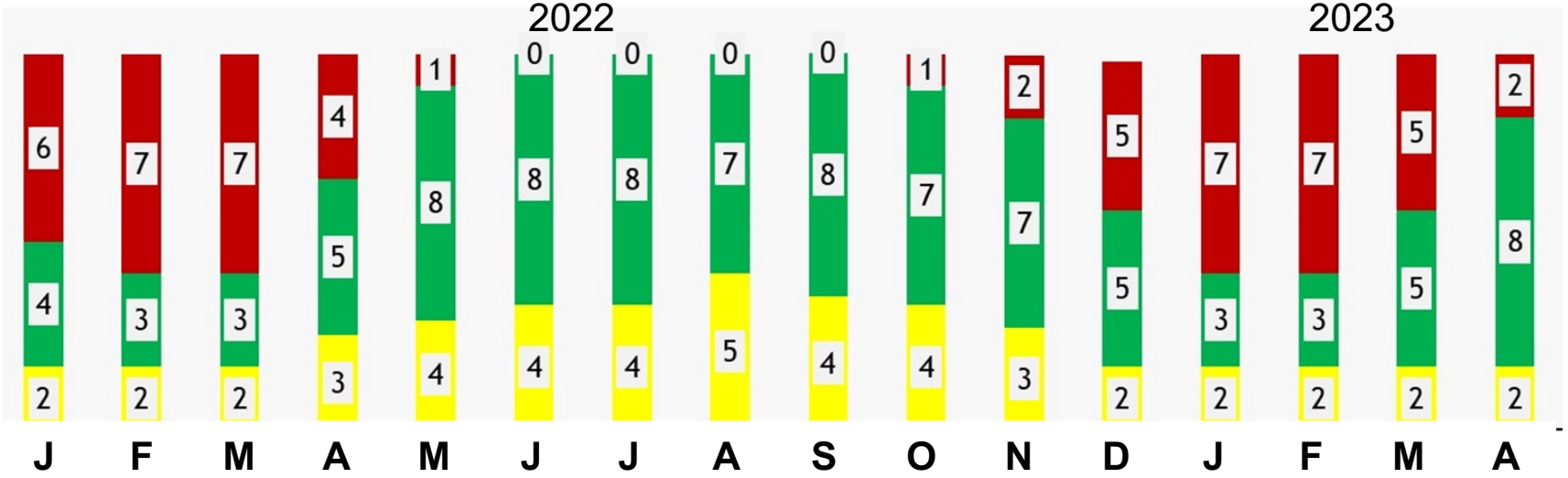
Design of a climate stress management program to improve the quantity and quality of berries

Weather station

Plant stressed by climate

The numbers in the red bars represent the number of stressful hours on average per day per month



Berries close stomata (dehydration) due to climatic stress when the VPD is below 0.5 and above 1.5 kPa

Conventional VPD values by phenological stages (Prenger and Ling, 2001)	VPD (kPa)
Low transpiration (propagation/beginning of vegetative growth)	0.5 – 0.8
Healthy transpiration (full vegetative growth/ beginning of flowering)	0.8 – 1.2
High transpiration (Medium flowering)	1.2 – 1.5
Dangerous area (decrease transpiration)	< 0.5 - > 1.5

VPD - vapor pressure deficit

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Measuring stomatal conductance in blueberries to determine stress levels using a portable porometer

Stomatal conductance level in blueberries	mmol $H_2O/m^2/s$
Low	< 200
Regular	200 - 400
High	> 400

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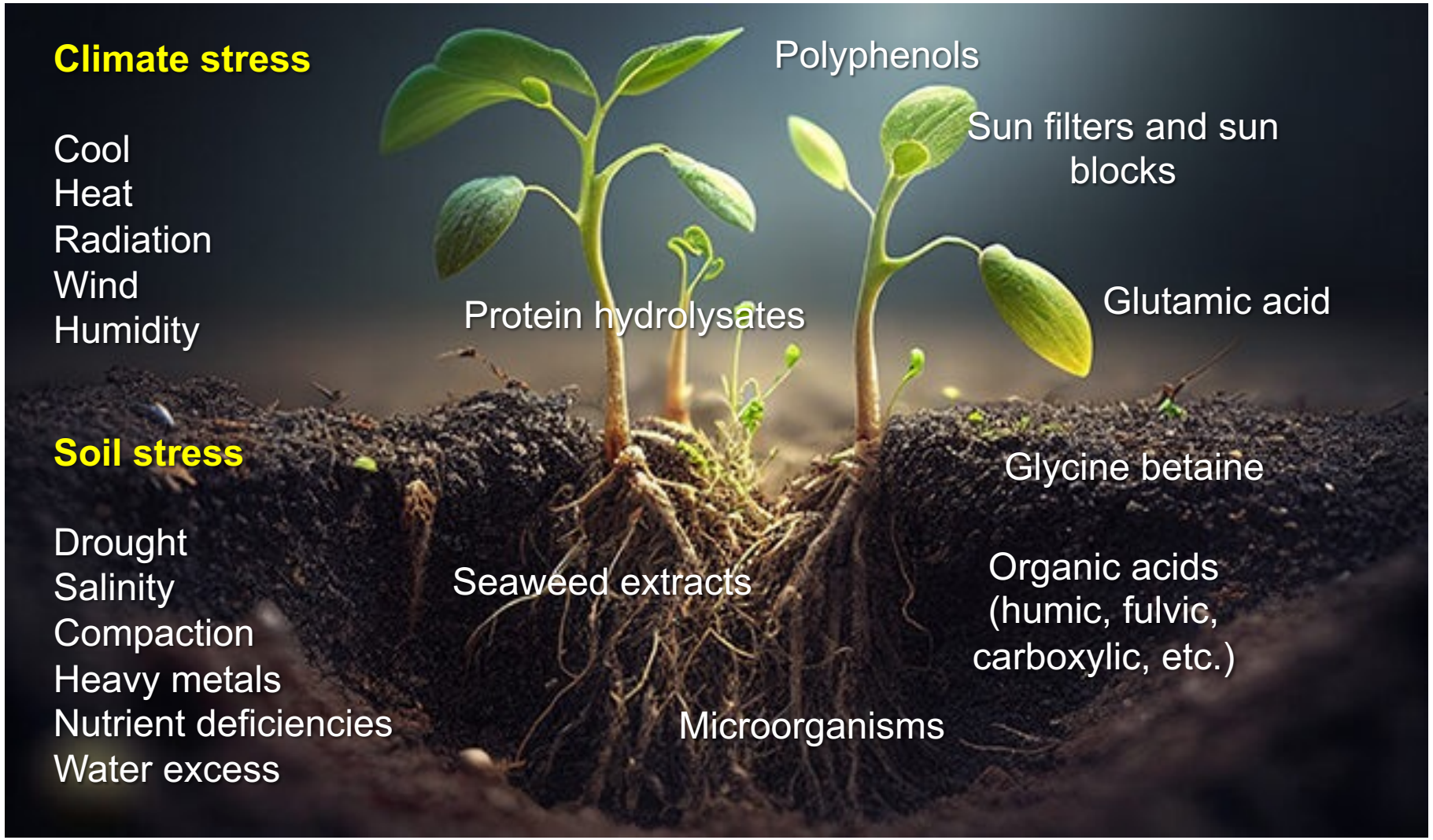
Biostimulation as a support for berry nutrition



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Evaluation of different biostimulant products to mitigate climate stress in blueberries (Piura, Peru)

Benefits of biostimulants:

- ✓ Improves fruit size
- ✓ Increases Brix levels
- ✓ Improves firmness
- ✓ Increased carbohydrate reserves
- ✓ Reduces carbon footprint
- ✓ Improves water use efficiency (WUE)

SPAD (chlorophyll) readings in blueberry leaves

DAA	Control	AA – Ext	Glycine betaine	Polyphenols	Ext AN	Ext L	Phyto hormones	AA
				---------- SPAD readings ----------				
2	40.3	40.5	40.5	44.8	41.0	43.6	43.2	40.9
16	41.3	41.1	41.9	50.5	43.2	42.8	45.5	-
24	50.1	44.8	45.5	52.9	47.4	44.2	42.8	43.9
34	41.1	42.5	42.7	52.6	41	43.4	42.5	41.6
41	41.3	45.8	51.7	67.8	53.6	54.7	53.2	53.1

DAA = days after application; AA = amino acids; Ext = seaweeds extract; AN = *Ascophyllum nodosum*; L = *Lithothamnium* sp.

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Take-Home Messages

The production of **export-quality berries** is possible even in extreme soil, water, and climate conditions.

To achieve these goals, it is necessary to use substrates such as coconut fiber and others, sulfur burners, reverse osmosis equipment, infrastructure, and biostimulants to mitigate salinity and climate stress.

Professional advice and nutritional monitoring are also necessary, using soil, substrate, water, and plant analysis, as well as the use of portable equipment and laboratories.

Thank you for your attention!!

For more information contact:

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