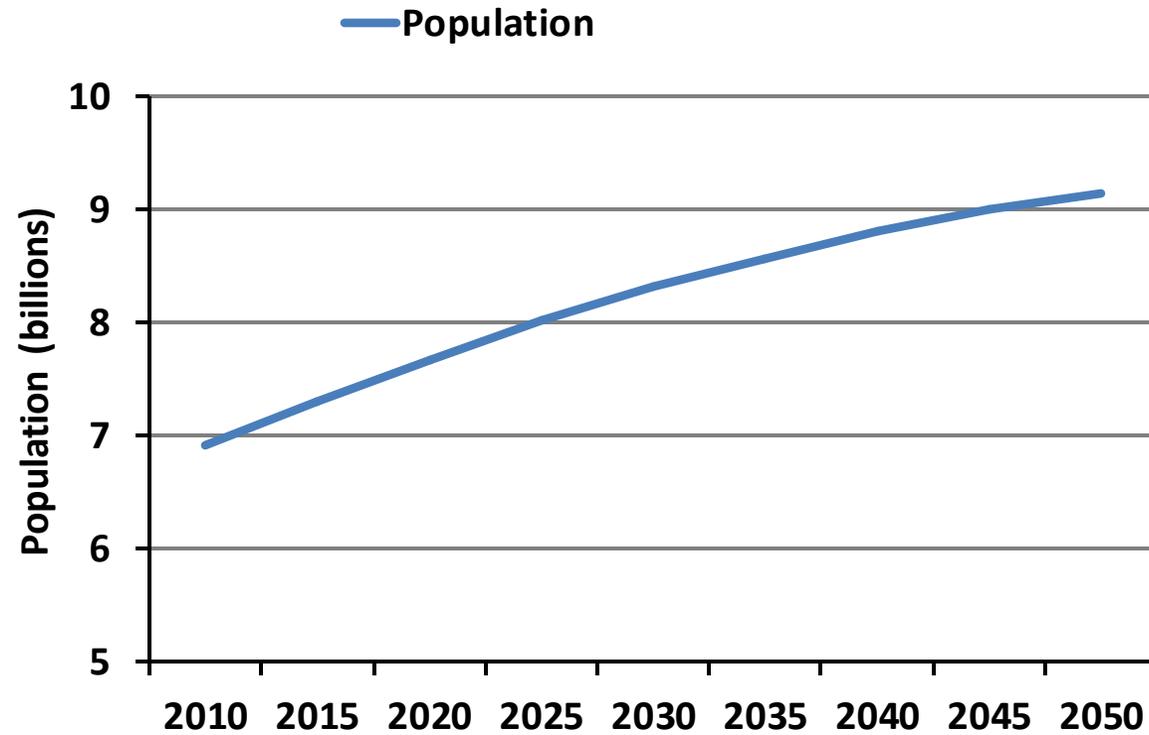


Improving quinoa through the development of genetic and genomic resources

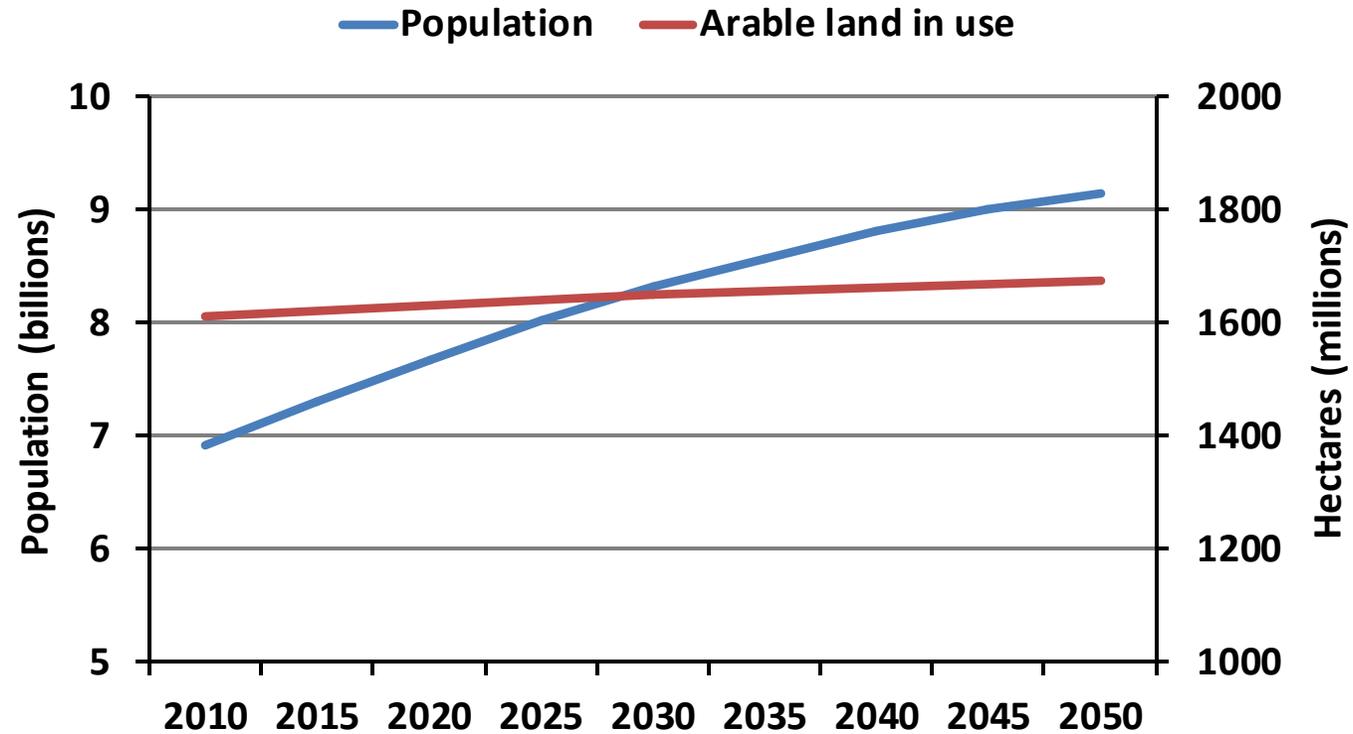
David Jarvis, Jeff Maughan, Rick Jellen



Feeding the world's growing population...



Feeding the world's growing population...



...will require plants that can grow on marginal lands

Feeding the world's growing population...

Plants account for over **80%** of the human diet

30 000 terrestrial plants are known to be edible

7 000 are cultivated or collected by humans for food

30 crops feed the world

5 cereal crops provide **60%** energy intake of the world population



Rice, wheat, maize, millet and sorghum

Some **7.4 million** samples of crop diversity are stored in **1 750 genebanks** around the world



PLANT

...will require new, highly nutritious crops

Quinoa can help improve global food security



Quinoa can grow on marginal lands



Quinoa is highly nutritious

	Quinoa	Maize	Rice	Wheat
Energy (Kcal/100g)	399	408	372	392
Protein (g/100g)	16.5	10.2	7.6	14.3
Fat (g/100g)	6.3	4.7	2.2	2.3
Total Carbohydrates (g/100g)	69.0	81.1	80.4	78.4

Source: Koziol (1992)

	FAO ^a	Quinoa ^b	Maize ^b	Rice ^b	Wheat ^b
Isoleucine	3.0	4.9	4.0	4.1	4.2
Leucine	6.1	6.6	12.5	8.2	6.8
Lysine	4.8	6.0	2.9	3.8	2.6
Methionine	2.3	5.3	4.0	3.6	3.7
Phenylalanine	4.1	6.9	8.6	10.5	8.2
Threonine	2.5	3.7	3.8	3.8	2.8
Tryptophan	0.66	0.9	0.7	1.1	1.2
Valine	4.0	4.5	5.0	6.1	4.4

^aAmino acid scoring patterns for 3 to 10 year old children, adapted from FAO (2013),
Dietary protein quality evaluation in human nutrition, Report of an FAO Expert Consultation, Rome.

^bKoziol (1992)

^cMethionine + cysteine

^dPhenylalanine + tyrosine

Quinoa is popular

Color: Quinoa



Feedback

\$19.99

Extra 30% Off Taken at Checkout



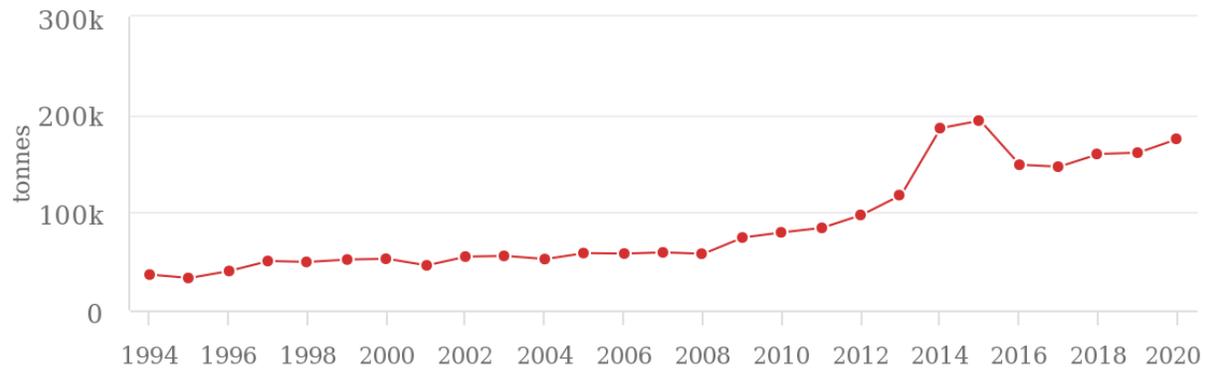
13 ratings

Color: Quinoa

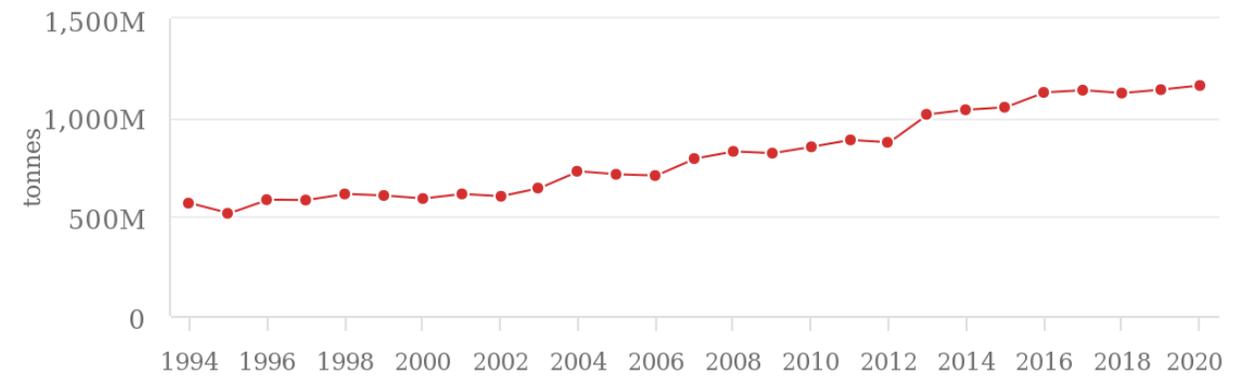
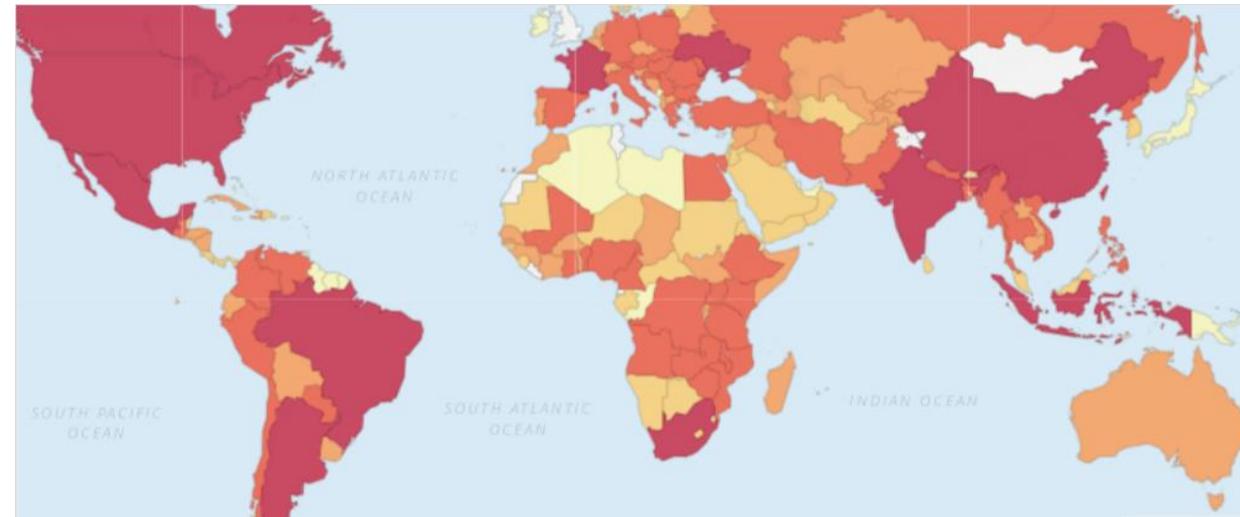


Quinoa production is low

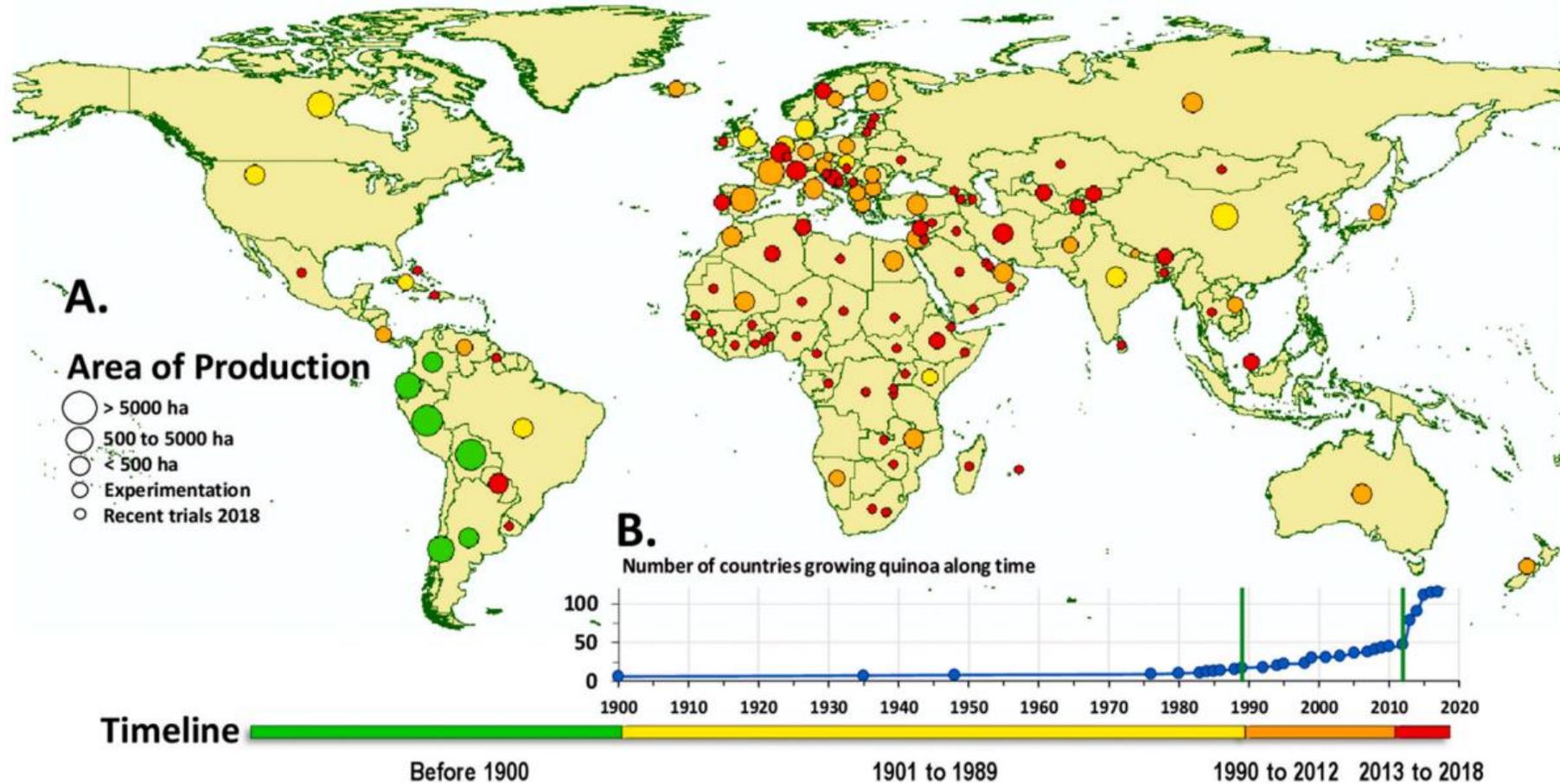
Global quinoa production



Global maize production



Quinoa production is expanding



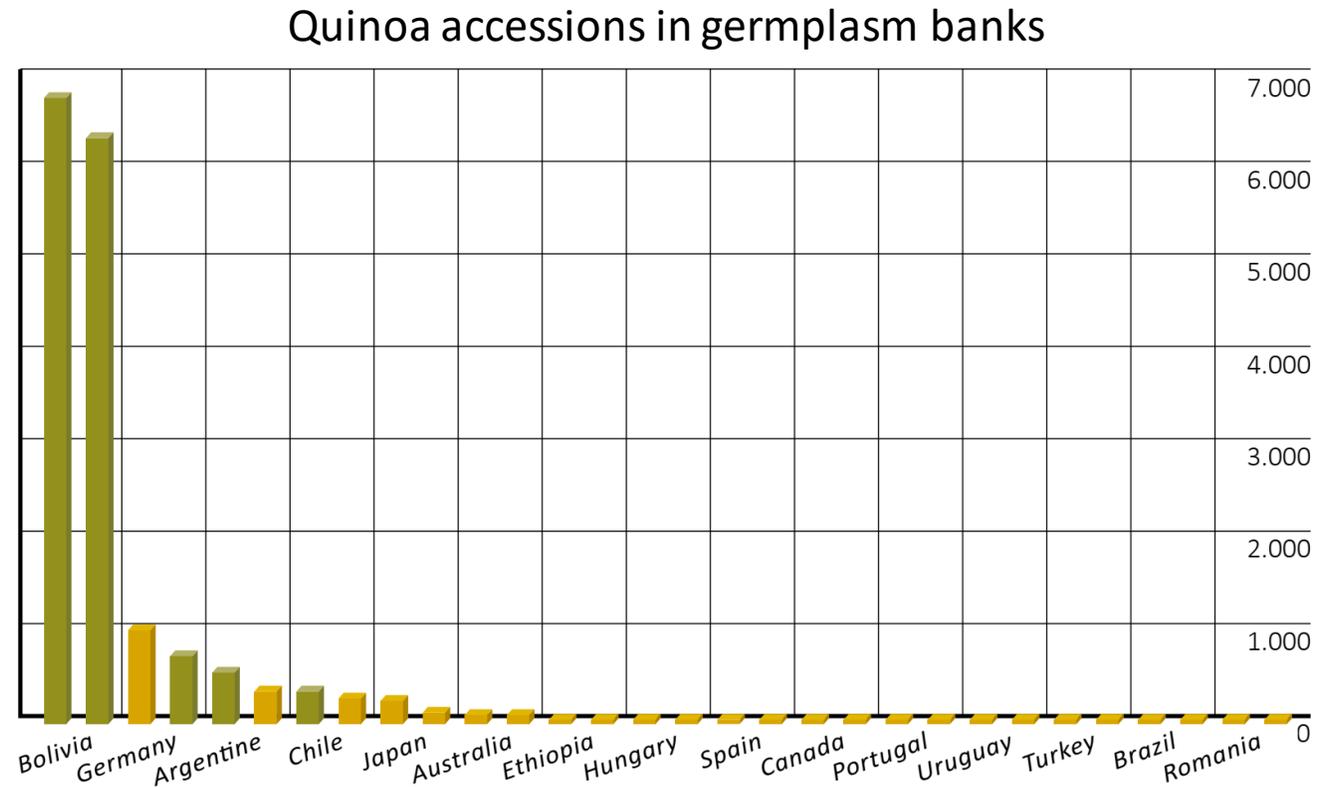
Quinoa isn't well adapted to new environments



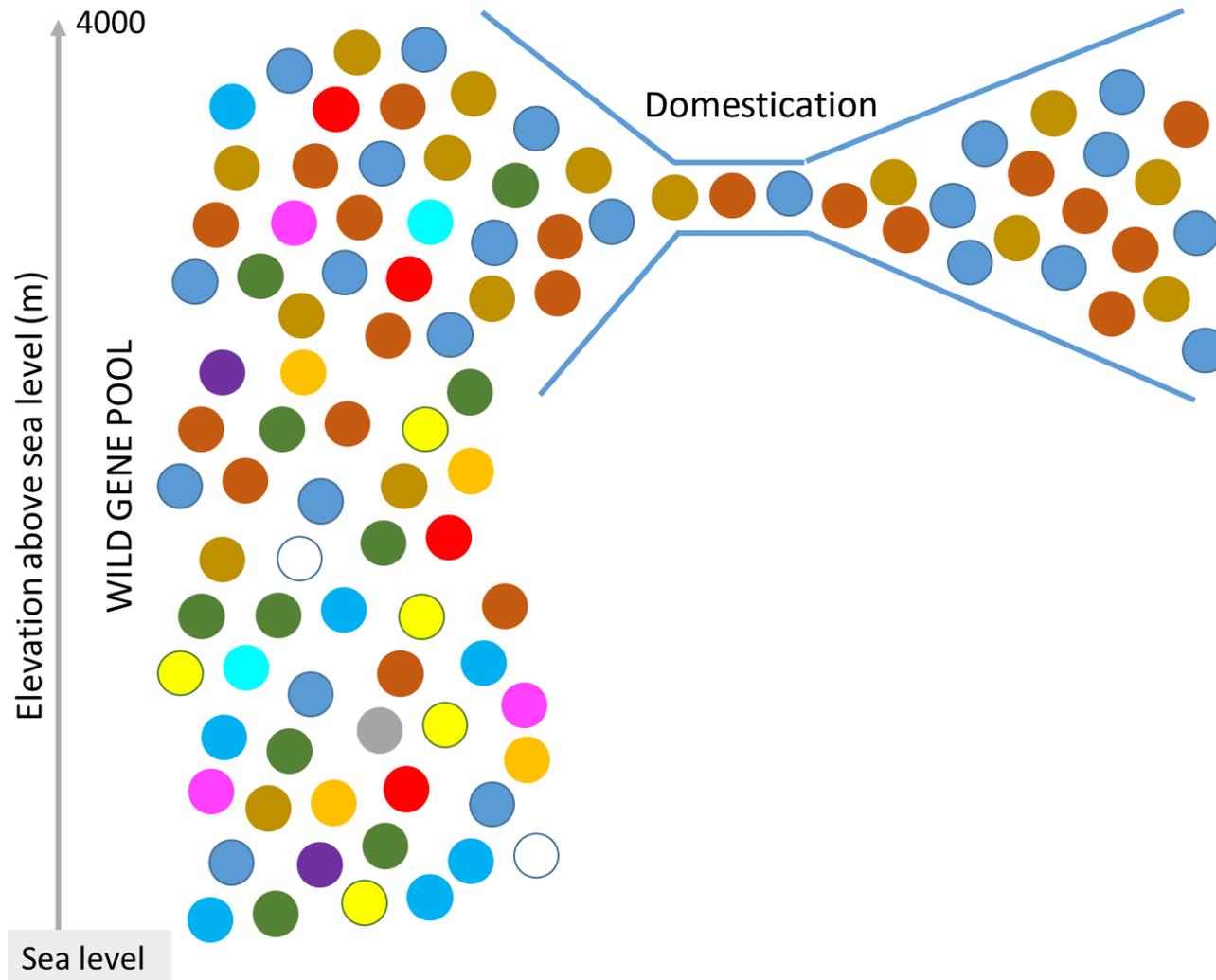
Quinoa isn't well adapted to new environments



Most quinoa genetic resources are not public



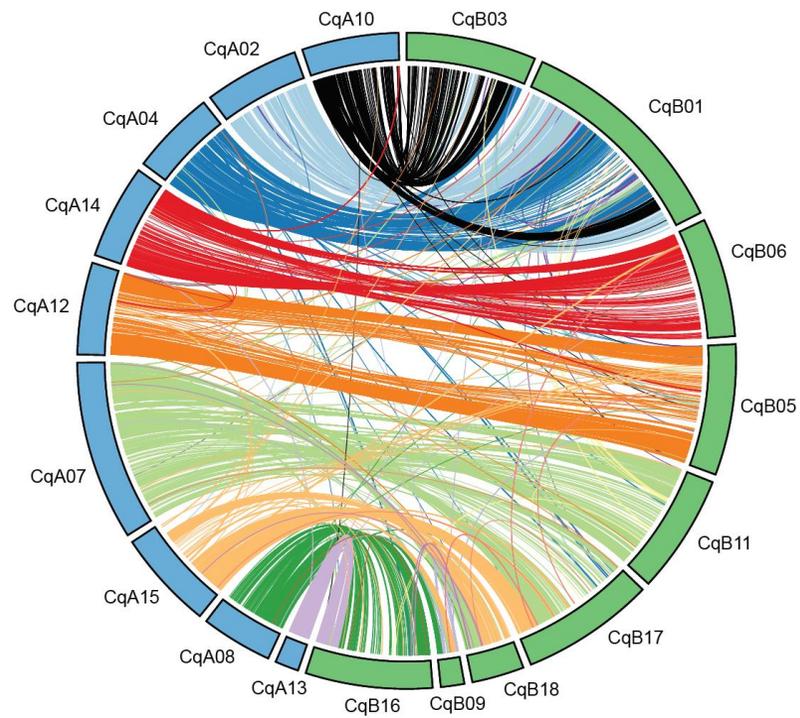
Quinoa has lost genetic diversity



Original domestication of Andean quinoa, ~5000 ybp:
Repeated selection for cold tolerance, drought tolerance, saline-soil tolerance at high altitudes

Can we improve quinoa production by increasing genetic diversity?

Genomic resources



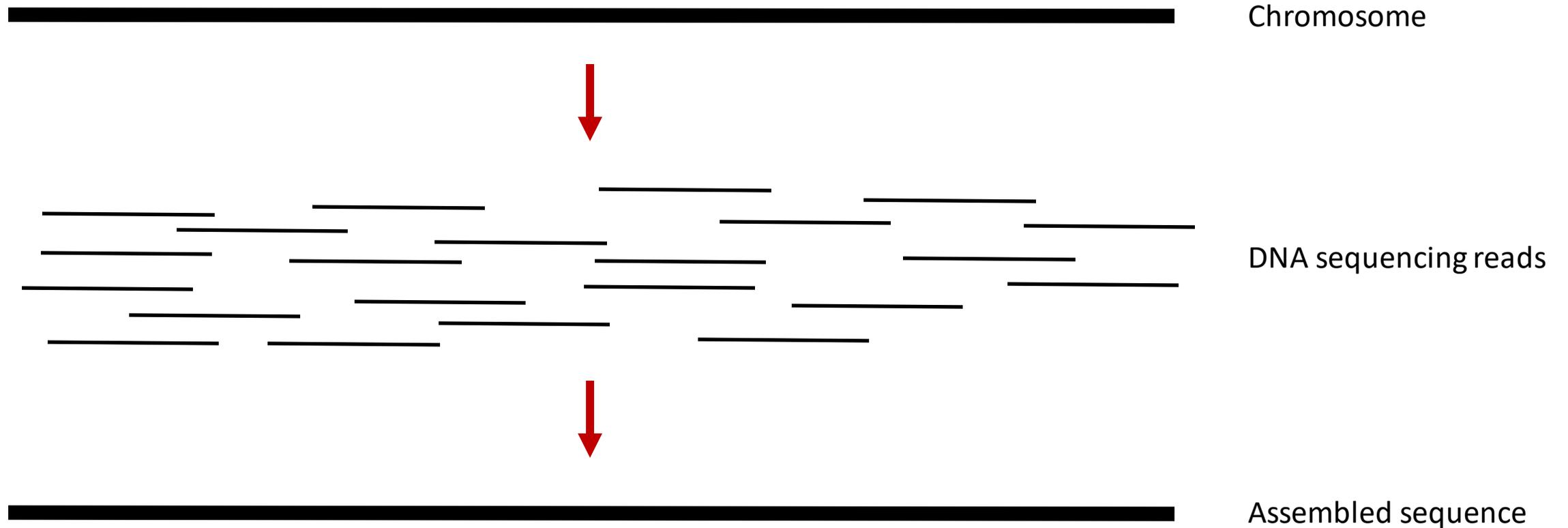
Genetic resources



Computational challenges of genome assembly

Sequence reads are shorter than chromosomes

Assembly is the process of putting reads back together



"All the News
That's Fit to Print"

The New York Times

Late Edition

Today, increasingly windy, heavy rain, coastal flooding, high 44. Tonight, windy, showers, low 40. Tomorrow, cloudy, windy, showers, high 41. Weather map, Page B14.

VOL. CLXIV . . . No. 56,710

© 2014 The New York Times

NEW YORK, TUESDAY, DECEMBER 9, 2014

\$2.50



Demonstrators seeking a new inquiry into Eric Garner's choking death staged a "die-in" on Monday at New York's City Hall. CHANG W. LEE/THE NEW YORK TIMES

White House and G.O.P. Clash Over Torture Report

Security Risks Seen as Senate Prepares to Release Details of Bush-Era Tactics

By MARK LANDLER and PETER BAKER

WASHINGTON — On the eve of a long-awaited Senate report on the use of torture by the United States government — a detailed account that will shed an unsparing light on the Central Intelligence Agency's darkest practices after the September 2001 terrorist attacks — the Obama administration and its Republican critics clashed on Monday over the wisdom of making it public, and the risk that it will set off a backlash overseas.

While the United States has put diplomatic facilities and military bases on alert for heightened security risks, administration officials said they do not expect the report — or rather the declassified executive summary of it that will be released Tuesday — to ignite the kind of violence that killed four Americans at a diplomatic outpost in Benghazi, Libya, in 2012. Such violent reprisals, they said, tend to be fueled more by perceived attacks against Islam as a religion than by violence against individual Muslims.

But some leading Republican lawmakers have warned against releasing the report, saying that domestic and foreign intelligence reports indicate that a detailed account of the brutal interrogation methods used by the C.I.A. during the George W. Bush administration could incite unrest and violence, even resulting in the deaths of Americans.

Former Vice President Dick Cheney added his voice to those of other Bush administration officials defending the C.I.A., declaring in an interview Monday that

its harsh interrogations a decade ago were "absolutely, totally justified," and dismissing allegations that the agency withheld information from the White House or inflated the value of its methods.

The White House acknowledged that the report could pose a "greater risk" to American installations and personnel in countries like Pakistan, Yemen, Egypt, Libya and Iraq. But it said that the government had months to plan for the reverberations from its report — indeed, years — and that those risks should not delay the release of the report by the Senate Intelligence Committee. "When would be a good time to release this report?" the White House press secretary, Josh Earnest, asked. "It's difficult to imagine one, particularly given the painful details that will be included."

But he added, "The president
Continued on Page A10

G.O.P. Donors Seek Early Call On '16 Nominee

By NICHOLAS CONFESSORE

Dozens of the Republican Party's leading presidential donors and fund-raisers have begun privately discussing how to clear the field for a single establishment candidate to carry the party's banner in 2016, fearing that a prolonged primary would bolster Hillary Rodham Clinton, the likely Democratic candidate.

The conversations, described in interviews with a variety of the Republican Party's most sought-after donors, are centered on the three potential candidates who have the largest existing base of major contributors and overlapping ties to the top tier of those who are uncommitted. Gov. . . .

Unrest Over Race Is Testing Obama's Legacy

By JULIE HIRSCHFELD DAVIS and MICHAEL D. SHEAR

WASHINGTON — As crowds of people staged "die-ins" across the country last week to protest the deaths of unarmed black men at the hands of police officers, young African-American activists were in the Oval Office lodging grievances with President Obama.

He of all people — the first black president of the United States — was in a position to testify to the sense of injustice that African-Americans feel in dealing with the police every day, the activists told him. During the unrest that began with a teenager's shooting in Ferguson, Mo., they hoped for a strong response. Why was he holding back?

Mr. Obama told the group that change is "hard and incremental," a participant said, while re-

Louis who attended the meeting, it was not enough. "It hurt that he didn't seem to want to go out there and acknowledge that he understands our pain," Mr. Aldridge said in an interview. "It would be a great mark on his presidential legacy if he would come out and touch an issue that everyone is scared to touch."

But Mr. Obama has not been the kind of champion for racial justice that many African-Americans say this moment demands. In the days since grand juries in Missouri and Staten Island decided not to bring charges against white police officers who

had killed unarmed black men, the president has not stood behind the protesters or linked arms with civil rights leaders. Although those closest to Mr. Obama insist that he feels a new urgency to capitalize on the attention to racial divisions, few dispute that he is personally conflicted and constrained by the position he holds.

"We are really on a precipice of either going in the right direction or entrenching a very perilous racial divide in this country, so I think he's trying to harness that and tread very carefully," said

Continued on Page A22

CHARGE IN DEATH AT RIKERS: LYING

Guard Is Said to Falsify Inmate Check Record

By MICHAEL SCHWITZ

A correction officer who was on duty when a homeless veteran died in an overheated cell at Rikers Island was charged on Monday with lying on jail records, falsely claiming she had checked on the inmate that night, according to prosecutors.

The charges against the officer.

"All the News That's Fit to Print"
VOL. CLXIV . . . No. 56,710



Demonstrators seeking a new inquiry into Eric

G.O.P. Donors Seek Early Call On '16 Nominee

By JULIE HIRSCH and MICHAEL D. SHEAR
WASHINGTON — Dozens of people staged a "die-in" in the country last week to protest the deaths of unarmed black men at the hands of police officers, young African-American activists were in the Oval Office leading grievances with President Obama.

Unrest

By JULIE HIRSCH and MICHAEL D. SHEAR
WASHINGTON — Dozens of people staged a "die-in" in the country last week to protest the deaths of unarmed black men at the hands of police officers, young African-American activists were in the Oval Office leading grievances with President Obama.

"All the News That's Fit to Print"
VOL. CLXIV . . . No. 56,710



Demonstrators seeking a new inquiry

G.O.P. Donors Seek Early Call On '16 Nominee

By JULIE HIRSCH and MICHAEL D. SHEAR
WASHINGTON — Dozens of people staged a "die-in" in the country last week to protest the deaths of unarmed black men at the hands of police officers, young African-American activists were in the Oval Office leading grievances with President Obama.

Unrest

By JULIE HIRSCH and MICHAEL D. SHEAR
WASHINGTON — Dozens of people staged a "die-in" in the country last week to protest the deaths of unarmed black men at the hands of police officers, young African-American activists were in the Oval Office leading grievances with President Obama.

"All the News That's Fit to Print"
VOL. CLXIV . . . No. 56,710



Demonstrators seeking a new inquiry into Eric

G.O.P. Donors Seek Early Call On '16 Nominee

By JULIE HIRSCH and MICHAEL D. SHEAR
WASHINGTON — Dozens of people staged a "die-in" in the country last week to protest the deaths of unarmed black men at the hands of police officers, young African-American activists were in the Oval Office leading grievances with President Obama.

Unrest

By JULIE HIRSCH and MICHAEL D. SHEAR
WASHINGTON — Dozens of people staged a "die-in" in the country last week to protest the deaths of unarmed black men at the hands of police officers, young African-American activists were in the Oval Office leading grievances with President Obama.

"All the News That's Fit to Print"
VOL. CLXIV . . . No. 56,710



Demonstrators seeking a new inquiry into Eric

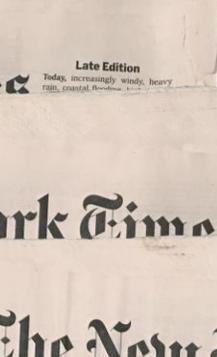
G.O.P. Donors Seek Early Call On '16 Nominee

By JULIE HIRSCH and MICHAEL D. SHEAR
WASHINGTON — Dozens of people staged a "die-in" in the country last week to protest the deaths of unarmed black men at the hands of police officers, young African-American activists were in the Oval Office leading grievances with President Obama.

Unrest

By JULIE HIRSCH and MICHAEL D. SHEAR
WASHINGTON — Dozens of people staged a "die-in" in the country last week to protest the deaths of unarmed black men at the hands of police officers, young African-American activists were in the Oval Office leading grievances with President Obama.

"All the News That's Fit to Print"
VOL. CLXIV . . . No. 56,710



Demonstrators seeking a new inquiry into Eric

G.O.P. Donors Seek Early Call On '16 Nominee

By JULIE HIRSCH and MICHAEL D. SHEAR
WASHINGTON — Dozens of people staged a "die-in" in the country last week to protest the deaths of unarmed black men at the hands of police officers, young African-American activists were in the Oval Office leading grievances with President Obama.

Unrest

By JULIE HIRSCH and MICHAEL D. SHEAR
WASHINGTON — Dozens of people staged a "die-in" in the country last week to protest the deaths of unarmed black men at the hands of police officers, young African-American activists were in the Oval Office leading grievances with President Obama.

"All the News That's Fit to Print"
VOL. CLXIV . . . No. 56,710



Demonstrators seeking a new inquiry into Eric

G.O.P. Donors Seek Early Call On '16 Nominee

By JULIE HIRSCH and MICHAEL D. SHEAR
WASHINGTON — Dozens of people staged a "die-in" in the country last week to protest the deaths of unarmed black men at the hands of police officers, young African-American activists were in the Oval Office leading grievances with President Obama.

Unrest

By JULIE HIRSCH and MICHAEL D. SHEAR
WASHINGTON — Dozens of people staged a "die-in" in the country last week to protest the deaths of unarmed black men at the hands of police officers, young African-American activists were in the Oval Office leading grievances with President Obama.

White House and G.O.P. Clash Over Torture Report

Security Risks Seen as Senate Prepares to Release Details of Bush-Era Tactics

By MARK LANDLER and PETER BAKER
WASHINGTON — On the eve of a long-awaited Senate report on the use of torture by the United States government — a detailed account that will shed an unflattering light on the Central Intelligence Agency's darkest practices after the September 2001 terrorist attacks — the Obama administration and its Republican critics clashed on Monday over the wisdom of making it public, and the risk that it will set off a backlash overseas.

White House officials have said that the government had months to plan for the reverberations from its report — indeed, years — and that those risks should not delay the release of the report by the Senate Intelligence Committee. "When would be a good time to release this report?" the White House press secretary, Josh Earnest, asked. "It's difficult to imagine one, particularly given the painful details that will be included."

But he added, "The president continued on Page A10



Demonstrators seeking a new inquiry into Eric Garner's choking death staged a "die-in" on Monday at New York's City Hall.

G.O.P. Donors Seek Early Call On '16 Nominee

By JULIE HIRSCH and MICHAEL D. SHEAR
WASHINGTON — Dozens of people staged a "die-in" in the country last week to protest the deaths of unarmed black men at the hands of police officers, young African-American activists were in the Oval Office leading grievances with President Obama.

He of all people — the first black president of the United States — was in a position to testify to the sense of injustice that African-Americans feel in dealing with the police every day, the activists told him. During the unrest that began with a teenager's shooting in Ferguson, Mo., they hoped for a strong response. Mr. Obama told the group that change is "hard and incremental," a participant said, while re-

Unrest Over Race Is Testing Obama's Legacy

By JULIE HIRSCH and MICHAEL D. SHEAR
WASHINGTON — As crowds of people staged "die-ins" across the country last week to protest the deaths of unarmed black men at the hands of police officers, young African-American activists were in the Oval Office leading grievances with President Obama.

He of all people — the first black president of the United States — was in a position to testify to the sense of injustice that African-Americans feel in dealing with the police every day, the activists told him. During the unrest that began with a teenager's shooting in Ferguson, Mo., they hoped for a strong response. Mr. Obama told the group that change is "hard and incremental," a participant said, while re-

CHARGE IN DEATH AT RIKERS: LYING

Guard Is Said to Falsify Inmate Check Record

By MICHAEL SCHWITZ
A correction officer who was on duty when a homeless veteran died in an overheated cell at Rikers Island was charged on Monday with lying on jail records, falsely claiming she had checked on the inmate that night, according to prosecutors.

"All the News
That's Fit to Print"

The New York Times

Late Edition

Today, increasingly windy, heavy rain, coastal flooding, high 44. Tonight, windy, showers, low 40. Tomorrow, cloudy, windy, showers, high 41. Weather map, Page B14.

VOL. CLXIV . . . No. 56,710

© 2014 The New York Times

NEW YORK, TUESDAY, DECEMBER 9, 2014

\$2.50



Demonstrators seeking a new inquiry into Eric Garner's choking death staged a "die-in" on Monday at New York's City Hall. CHANG W. LEE/THE NEW YORK TIMES

White House and G.O.P. Clash Over Torture Report

Security Risks Seen as Senate Prepares to Release Details of Bush-Era Tactics

By MARK LANDLER and PETER BAKER

WASHINGTON — On the eve of a long-awaited Senate report on the use of torture by the United States government — a detailed account that will shed an unsparing light on the Central Intelligence Agency's darkest practices after the September 2001 terrorist attacks — the Obama administration and its Republican critics clashed on Monday over the wisdom of making it public, and the risk that it will set off a backlash overseas.

While the United States has put diplomatic facilities and military bases on alert for heightened security risks, administration officials said they do not expect the report — or rather the declassified executive summary of it that will be released Tuesday — to ignite the kind of violence that killed four Americans at a diplomatic outpost in Benghazi, Libya, in 2012. Such violent reprisals, they said, tend to be fueled more by perceived attacks against Islam as a religion than by violence against individual Muslims.

But some leading Republican lawmakers have warned against releasing the report, saying that domestic and foreign intelligence reports indicate that a detailed account of the brutal interrogation methods used by the C.I.A. during the George W. Bush administration could incite unrest and violence, even resulting in the deaths of Americans.

Former Vice President Dick Cheney added his voice to those of other Bush administration officials defending the C.I.A., declaring in an interview Monday that

its harsh interrogations a decade ago were "absolutely, totally justified," and dismissing allegations that the agency withheld information from the White House or inflated the value of its methods.

The White House acknowledged that the report could pose a "greater risk" to American installations and personnel in countries like Pakistan, Yemen, Egypt, Libya and Iraq. But it said that the government had months to plan for the reverberations from its report — indeed, years — and that those risks should not delay the release of the report by the Senate Intelligence Committee. "When would be a good time to release this report?" the White House press secretary, Josh Earnest, asked. "It's difficult to imagine one, particularly given the painful details that will be included."

But he added, "The president
Continued on Page A10

CHARGE IN DEATH AT RIKERS: LYING

Guard Is Said to Falsify Inmate Check Record

By MICHAEL SCHWITZ

A correction officer who was on duty when a homeless veteran died in an overheated cell at Rikers Island was charged on Monday with lying on jail records, falsely claiming she had checked on the inmate that night, according to prosecutors.

The charges against the officer.

Unrest Over Race Is Testing Obama's Legacy

By JULIE HIRSCHFELD DAVIS
and MICHAEL D. SHEAR

WASHINGTON — As crowds of people staged "die-ins" across the country last week to protest the deaths of unarmed black men at the hands of police officers, young African-American activists were in the Oval Office lodging grievances with President Obama.

He of all people — the first black president of the United States — was in a position to testify to the sense of injustice that African-Americans feel in dealing with the police every day, the activists told him. During the unrest that began with a teenager's shooting in Ferguson, Mo., they hoped for a strong response. Why was he holding back?

Mr. Obama told the group that change is "hard and incremental," a participant said, while re-

Louis who attended the meeting, it was not enough. "It hurt that he didn't seem to want to go out there and acknowledge that he understands our pain," Mr. Aldridge said in an interview. "It would be a great mark on his presidential legacy if he would come out and touch an issue that everyone is scared to touch."

But Mr. Obama has not been the kind of champion for racial justice that many African-Americans say this moment demands. In the days since grand juries in Missouri and Staten Island decided not to bring charges against white police officers who

had killed unarmed black men, the president has not stood behind the protesters or linked arms with civil rights leaders. Although those closest to Mr. Obama insist that he feels a new urgency to capitalize on the attention to racial divisions, few dispute that he is personally conflicted and constrained by the position he holds.

"We are really on a precipice of either going in the right direction or entrenching a very perilous racial divide in this country, so I think he's trying to harness that and tread very carefully," said

Continued on Page A22

G.O.P. Donors Seek Early Call On '16 Nominee

By NICHOLAS CONFESSORE

Dozens of the Republican Party's leading presidential donors and fund-raisers have begun privately discussing how to clear the field for a single establishment candidate to carry the party's banner in 2016, fearing that a prolonged primary would bolster Hillary Rodham Clinton, the likely Democratic candidate.

The conversations, described in interviews with a variety of the Republican Party's most sought-after donors, are centered on the three potential candidates who have the largest existing base of major contributors and overlapping ties to the top tier of those who are uncommitted. Gov-

Computational challenges of genome assembly

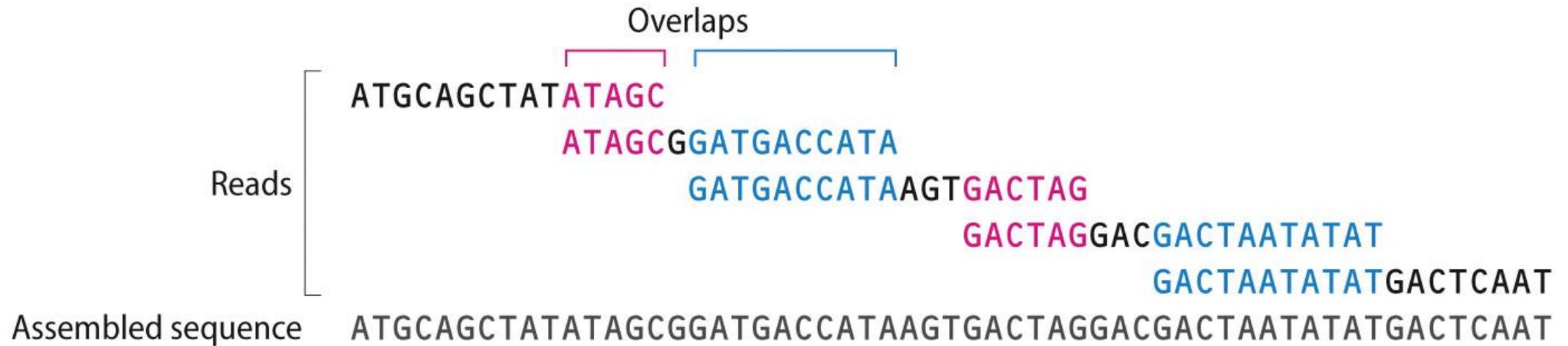
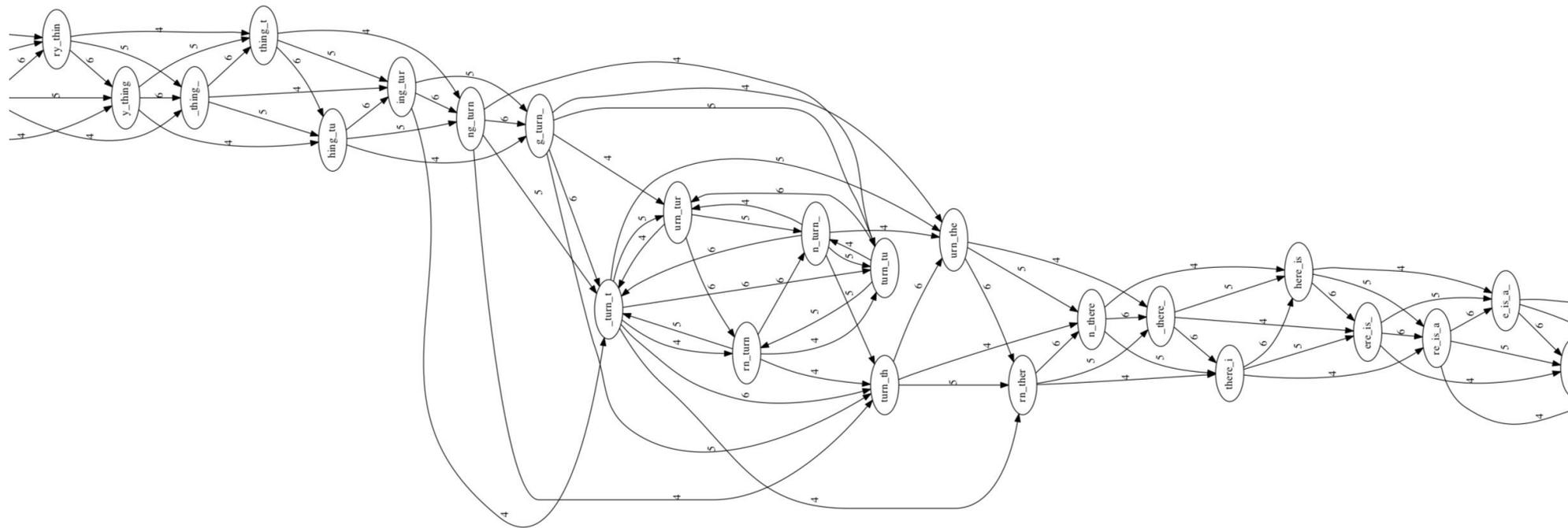


Figure 4.21 Genomes 4 (© Garland Science 2018)

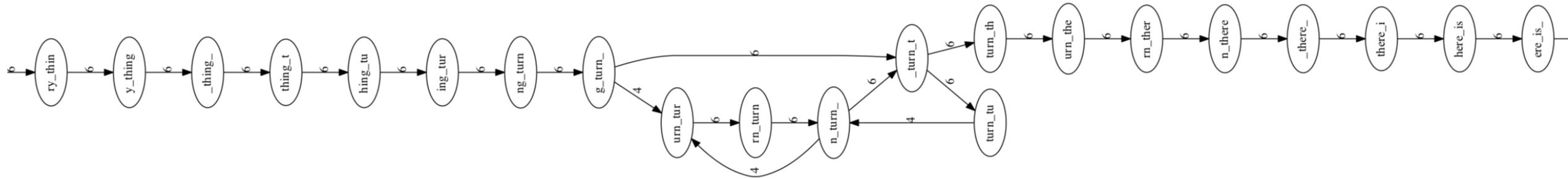
Computational challenges of genome assembly

to_every_thing_turn_turn_turn_there_is_a_season

$l = 4, k = 7$



Computational challenges of genome assembly



Computational challenges of genome assembly

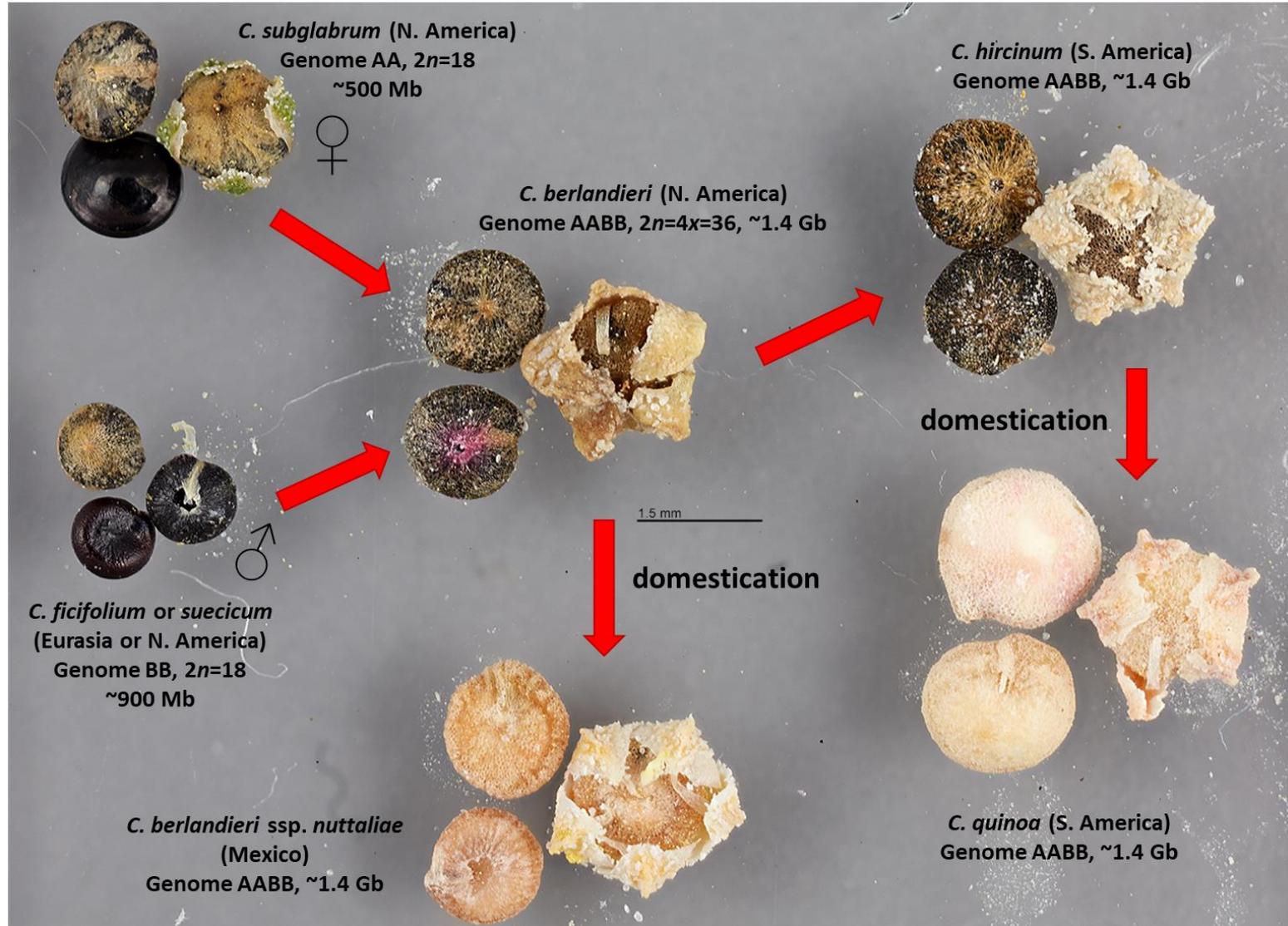
TAGATTACACAGATTACTGA TTGATGGCGTAA CTA
TAGATTACACAGATTACTGACTTTGATGGCGTAACTA
TAG TTACACAGATTA**T**TGACTT**C**ATGGCGTAA CTA
TAGATTACACAGATTACTGACTTTGATGGCGTAA CTA
TAGATTACACAGATTACTGACTTTGATGGCGTAA CTA

↓ ↓ ↓ ↓ ↓
TAGATTACACAGATTACTGACTTTGATGGCGTAA CTA

Take reads that make up a contig and line them up

Take *consensus*, i.e. majority vote

Quinoa and wild relatives genomic resources



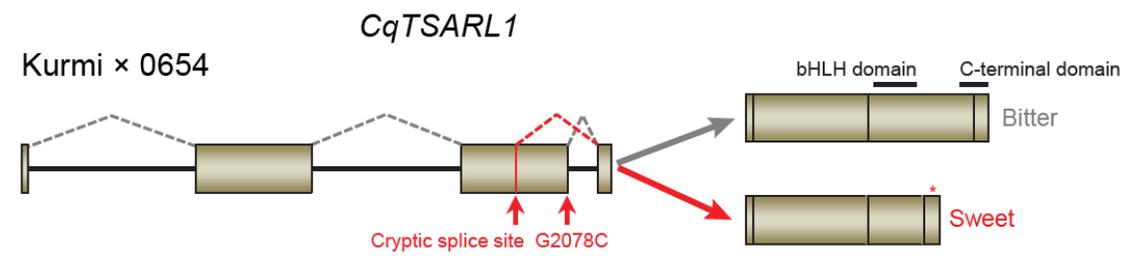
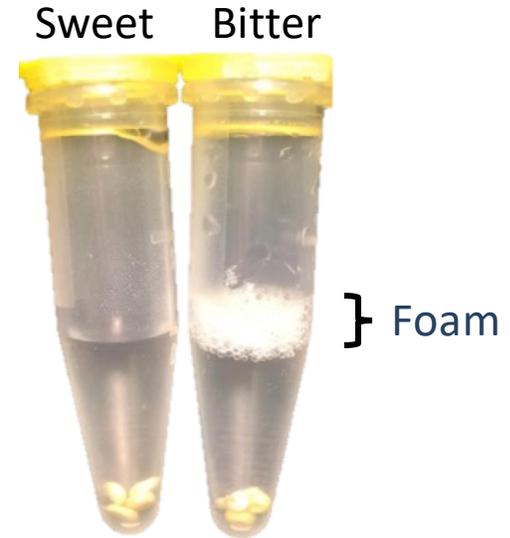
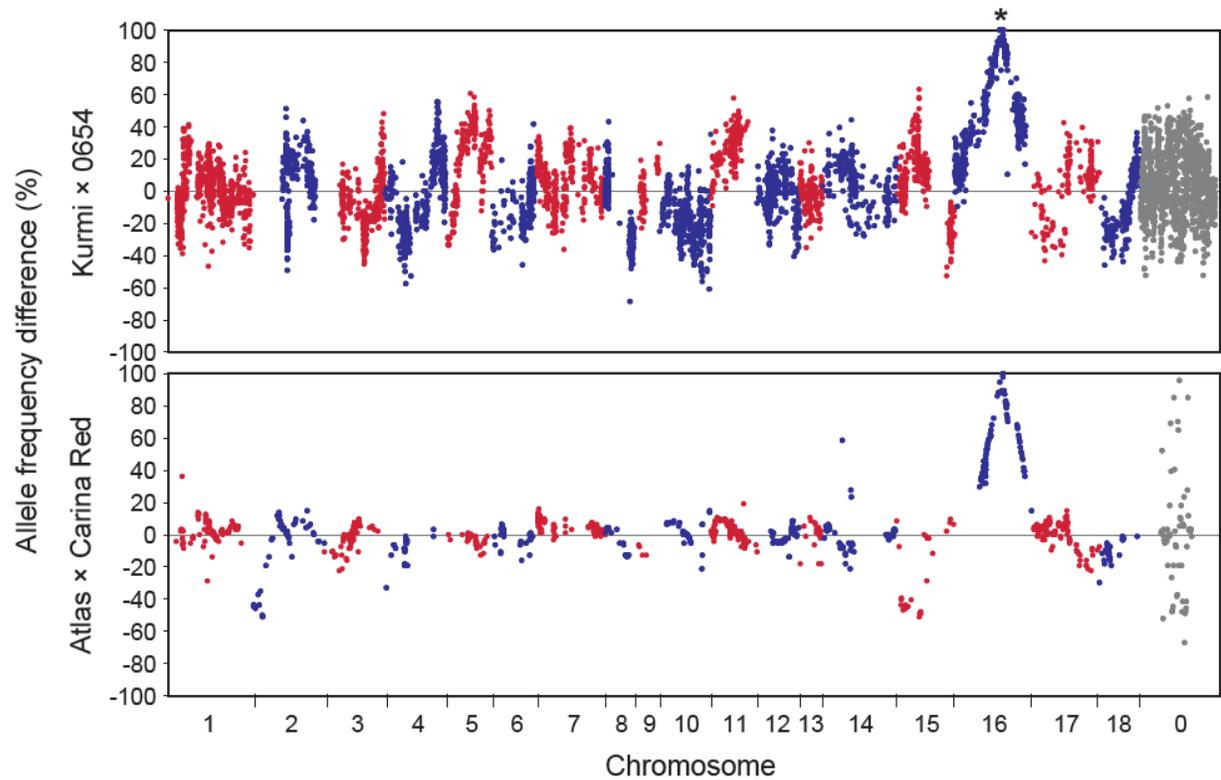
Application of quinoa genomic resources



Application of quinoa genomic resources

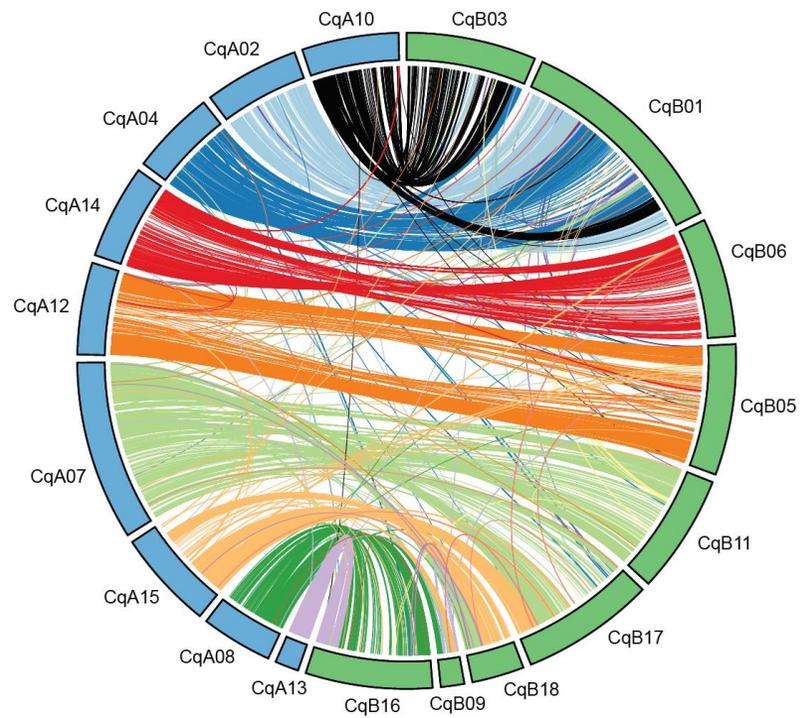


Application of quinoa genomic resources



Can we improve quinoa production by increasing genetic diversity?

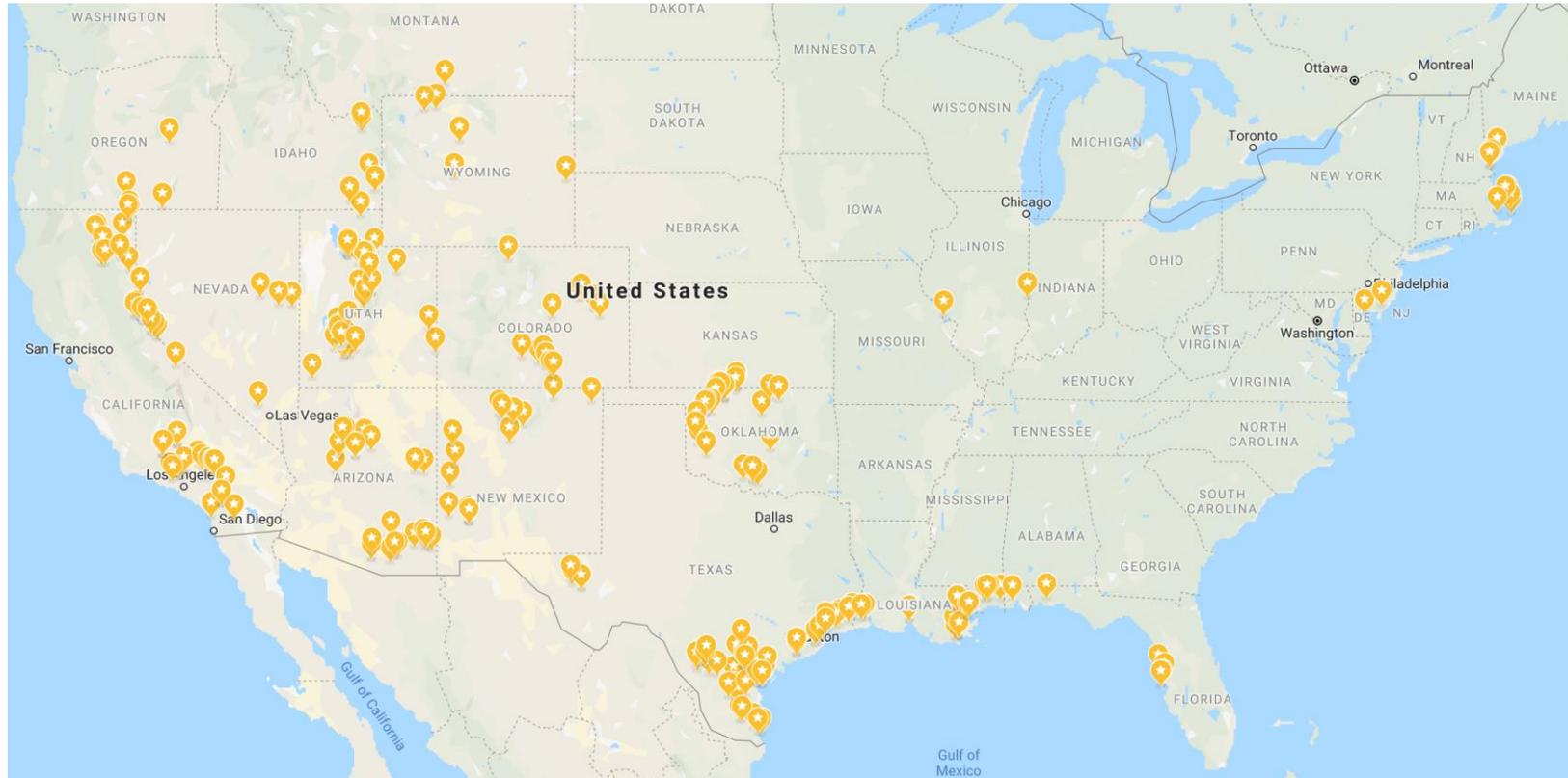
Genomic resources



Genetic resources



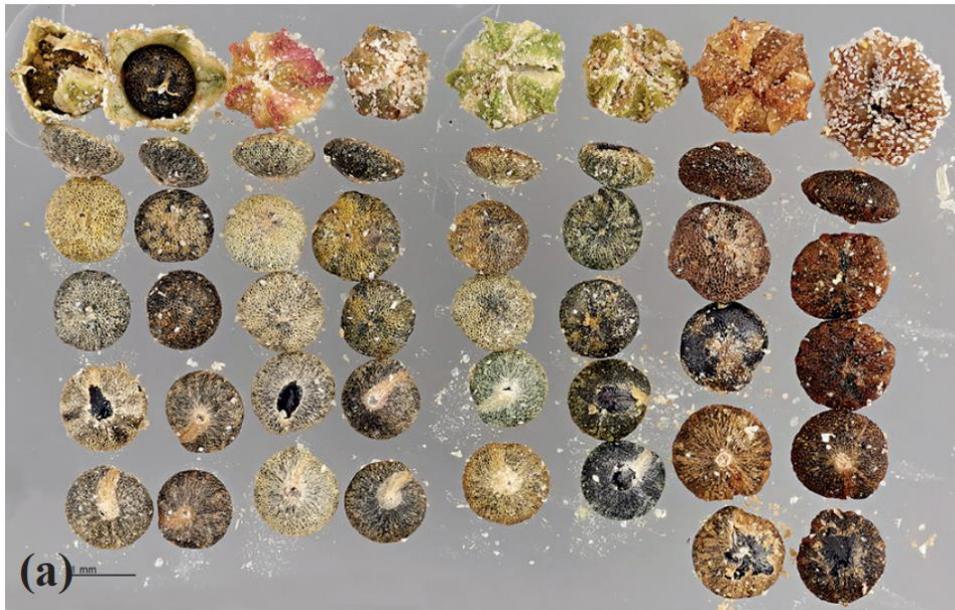
Increasing quinoa diversity with *C. berlandieri*



Increasing quinoa diversity with *C. berlandieri*

var. berlandieri

var. boscianum

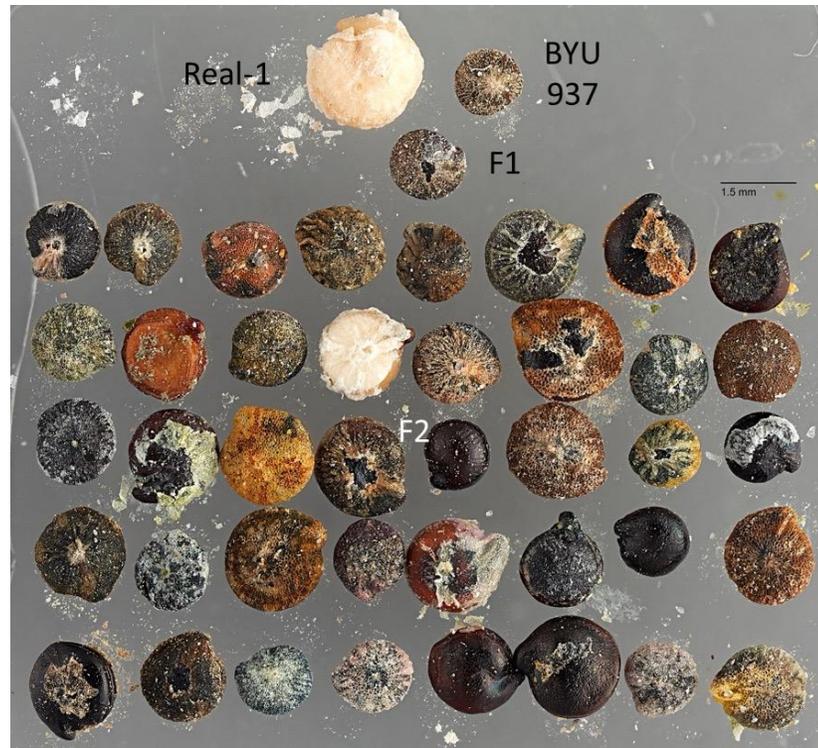


var. macrocalyrium



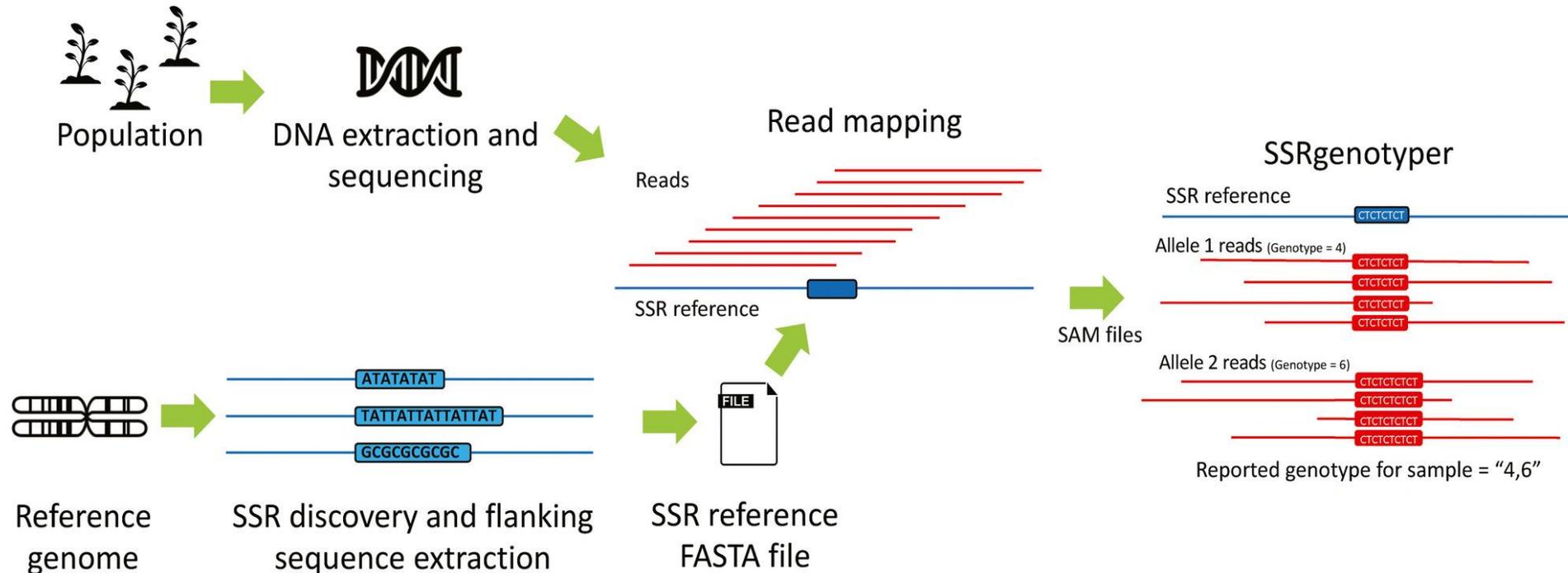
Increasing quinoa diversity with *C. berlandieri*

Generate interspecific quinoa \times *C. berlandieri* crosses



Increasing quinoa diversity with *C. berlandieri*

Identification of true hybrids using molecular markers

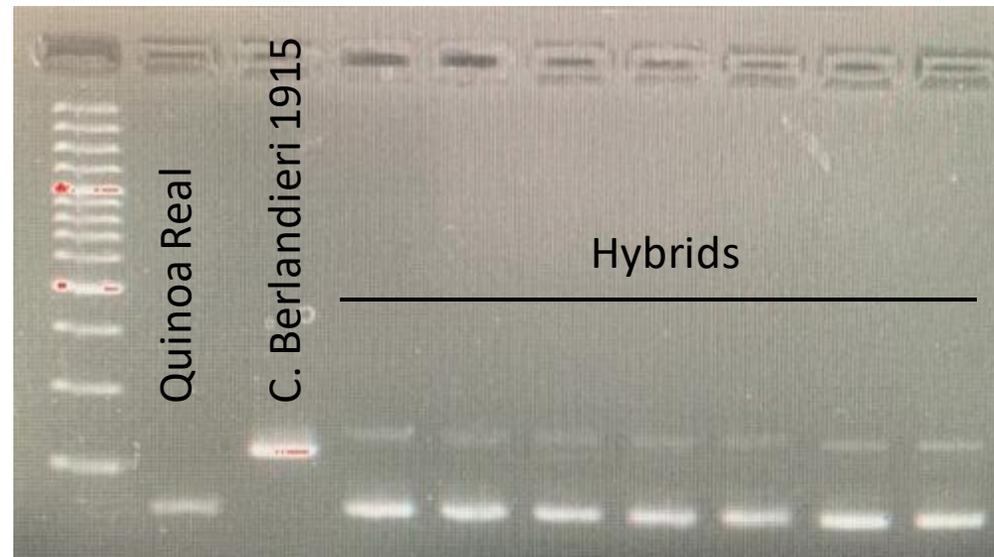


Increasing quinoa diversity with *C. berlandieri*

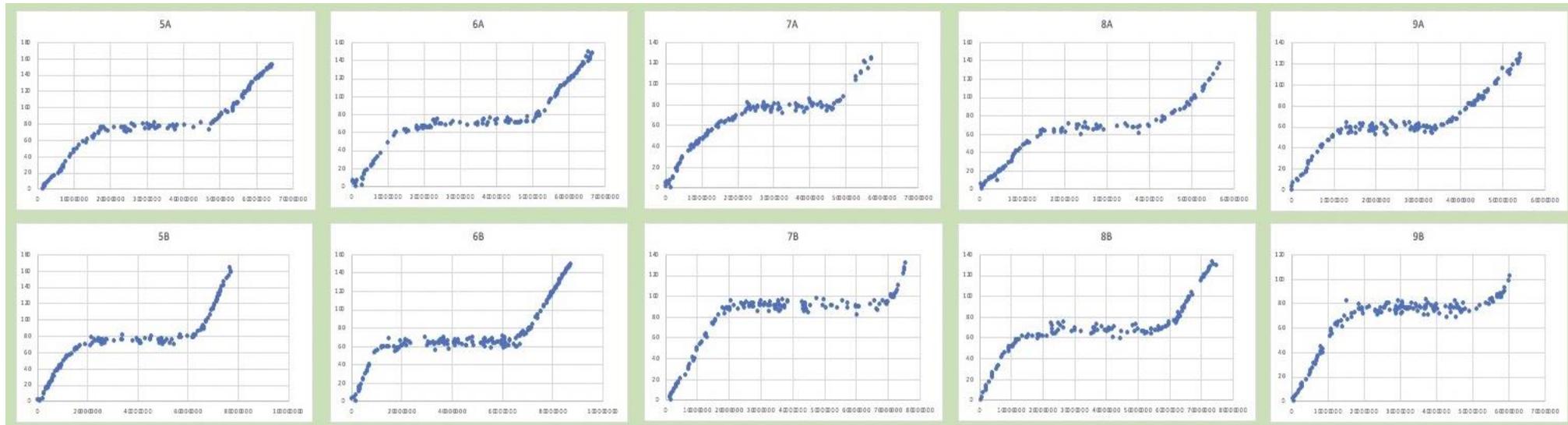
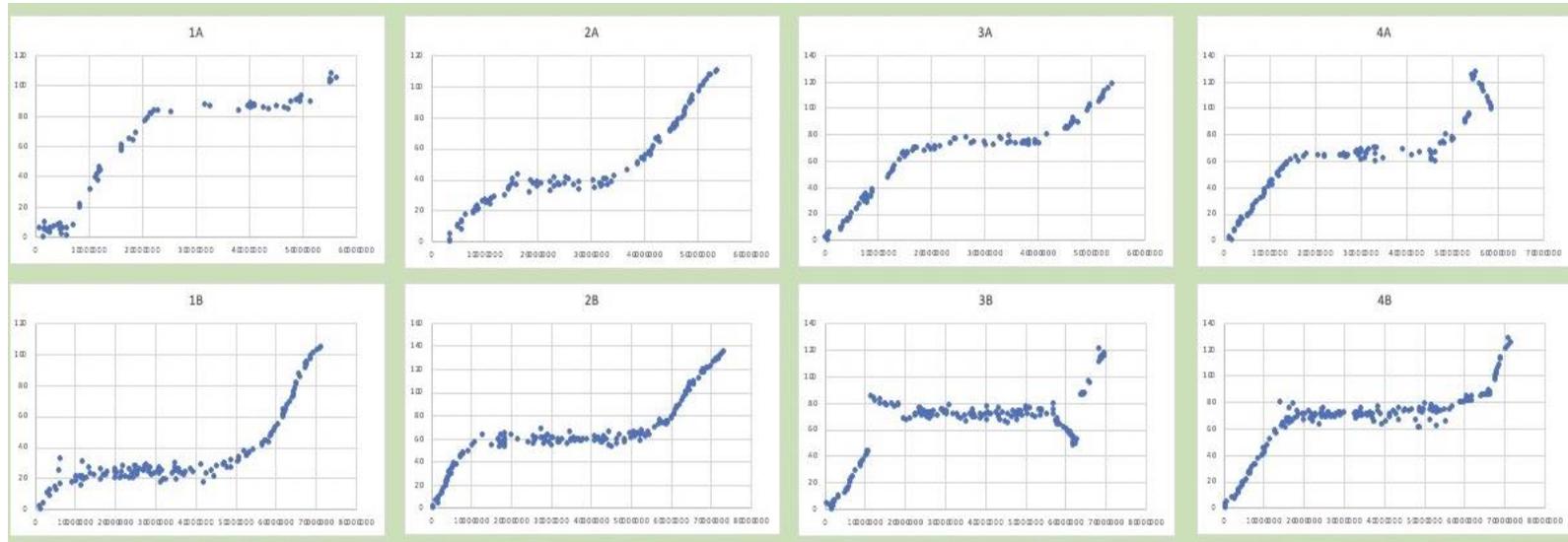
>Scaffold10:55985856-55986082

TTAATTTTTTAAACATCACAAACTCCGGGTTTCGTCCCTCCAAGTTCTTGTATCCTTCGCAAGAACATCTCCGGAATATTGGGTTCTACCAACGGCAGTT
GTGGTGGTGGTGGCGGGCGGGCGGGCGGGCGGGGGTGGTGGTGGCGTTCGAGGACGATCGACATTAATGATCTCATTAGTACGTTGTTGTTTGGGAAGTCGAAGGA
ATTGAGTTGGGATCAACATTGATAATCTTGTG

RefName	Ref	10175_Real	10177_Chir	10188_Cherr	BYU1312	BYU1856	BYU1904	BYU937
Scaffold10:55985856-55986082	5	5,5	0,-4	5,5	4,4	5,5	5,5	3,3



Increasing quinoa diversity with *C. berlandieri*

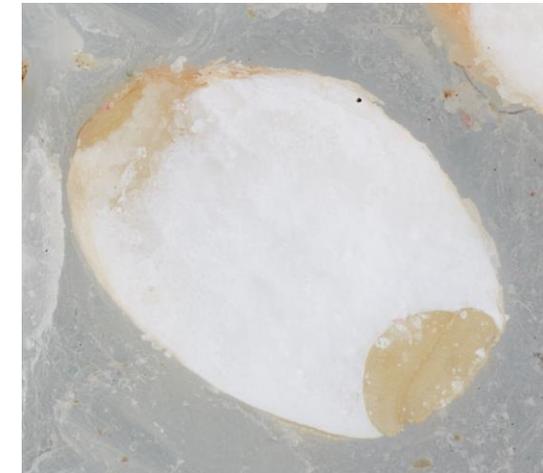
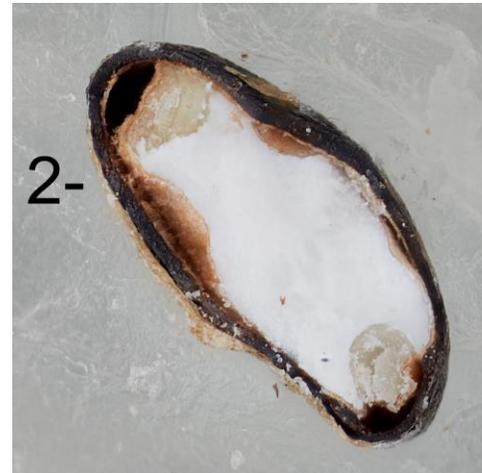


Increasing quinoa diversity with *C. berlandieri*

Perform crosses and advance populations

Quinoa	<i>C. berlandieri</i>	<i>C. berlandieri</i> ecotype	<i>C. berlandieri</i> origin
Real-1	BYU 937	var. boscianum	Galveston, TX (Gulf of Mexico Coast)
Surimi	BYU 937	var. boscianum	Galveston, TX
Co407D	BYU 937	var. boscianum	Galveston, TX
654	BYU 937	var. boscianum	Galveston, TX
Real-1	BYU 1814	var. berlandieri	Falfurrias, TX (Interior South Texas)
Cherry Vanilla	BYU 1814	var. berlandieri	Falfurrias, TX
Real-1	BYU 1856	var. macrocalycium	Sandwich Beach, MA (Cape Cod)
Cherry Vanilla	BYU 18102	var. zschackei	Beckham Co., OK (Great Plains)
Real-1	BYU 1915	var. zschackei	Sanpete Co., UT (Great Basin)
Cherry Vanilla	BYU 14118	var. zschackei	Victorville, CA (Mojave Desert)

Phenotype segregating traits to map the underlying genes



Other target traits: seed size, height, abiotic stress tolerance, biotic stress tolerance









Cougar Quinoa: BYU, Washington State University release new quinoa varieties to address global food security, nutrition

June 01, 2023

Cougar, Shisha and Gikungu quinoa thrive in harsh African climates



Acknowledgments

Alejandro Bonifacio, PROINPA (Bolivia)

Bozena Kolano, Univ Silesia (Poland)

Daniel Bertero, Univ Buenos Aires (Argentina)

David Brenner, USDA-ARS, Iowa State Univ (USA)

Eulogio de la Cruz Torres, ININ (Mexico)

Eve Emshwiller Lab, Univ Wisconsin (USA)

Francisco Fuentes, Pontifical Univ Chile (Chile)

Helena Storchova Lab, Inst Exp Botany (Czech Rep)

Bohumil Mandak Lab, Czech Univ Life Sciences

- **Karol Krak, Gabrielle Philippi, Tereza Pospisilikova**

Jorge Rojas-Beltran, Univ Mayor San Simon (Bolivia)

Kevin Murphy Lab, Washington State Univ (USA)

Luz Gomez, Univ Nac Agraria - La Molina (Peru)

Mark Tester Lab, KAUST (Saudi Arabia)

- **Elodie Rey**

Nuri Benet-Pierce, San Diego State Univ (USA)

Patricia Mollinedo, Univ Mayor San Andrés (Bolivia)

Ramiro Curti, Univ Nac Salta (Argentina)

Robert van Loo and Theo Borm Labs, Wageningen Univ (Holland)

Sergei Mosyakin, M.G. Kholodny Inst Botany (Ukraine)

Tom Davis Lab, Univ New Hampshire (USA)

BYU Students/Postdocs: Lauren Young, Kate Jaggi, Heather Warner, Doug Brown, Veronica Cepeda-Cornejo, Ryan Brady, Kristin Durrant, Steven Jellen

Funding Sources: USDA-NIFA, Holmes Family Foundation, KAUST, Czech Government, McKnight Foundation CCRP, CONACYT, IAEA, USDA-NPGS

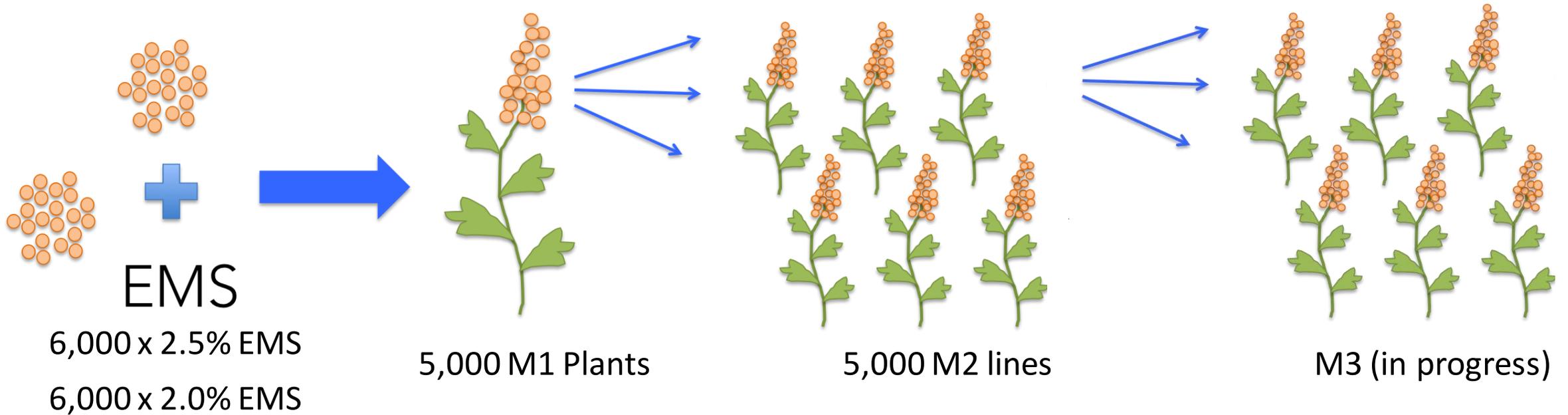
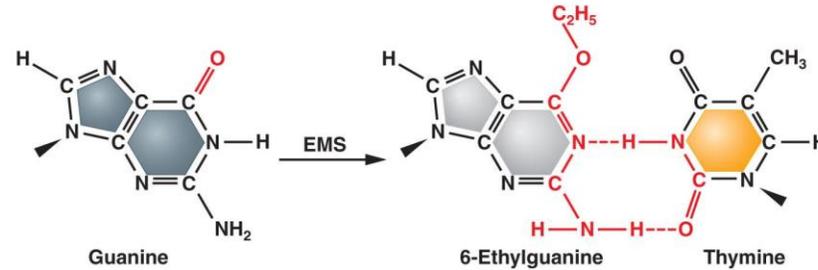


Thank you!

Inducing novel variation in quinoa



EMS is a chemical mutagen
G/C → A/T changes



Inducing novel variation in quinoa

Wild type quinoa
(QQ74)



Inducing novel variation in quinoa

Branching mutants



Inducing novel variation in quinoa

Meristem mutants



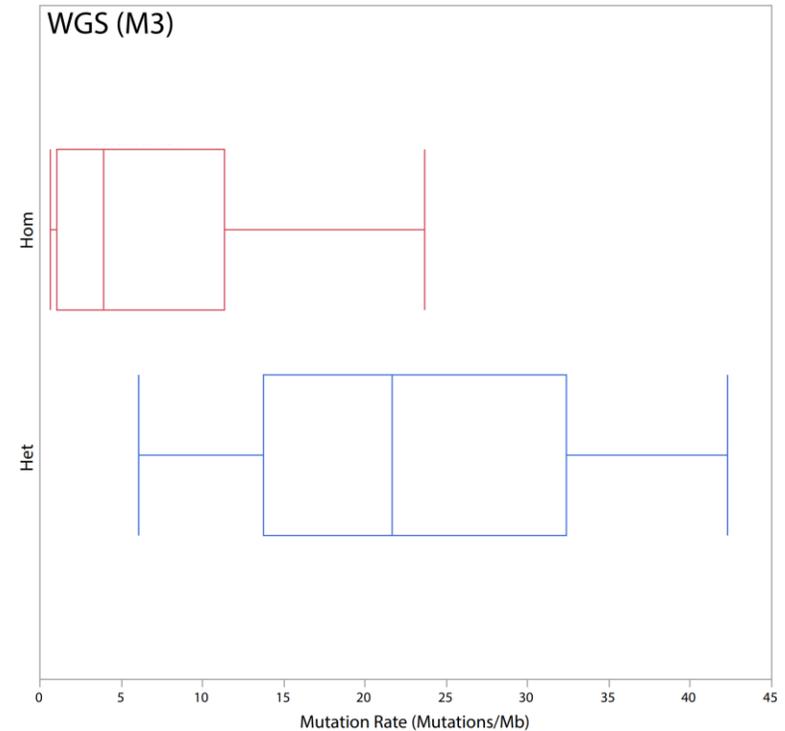
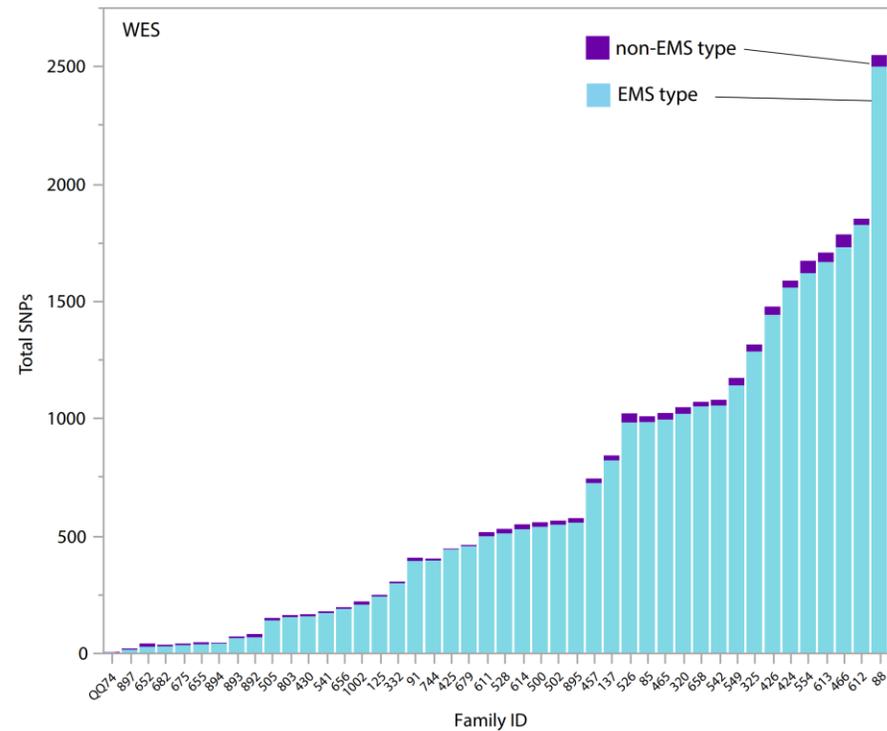
Inducing novel variation in quinoa

Other mutants



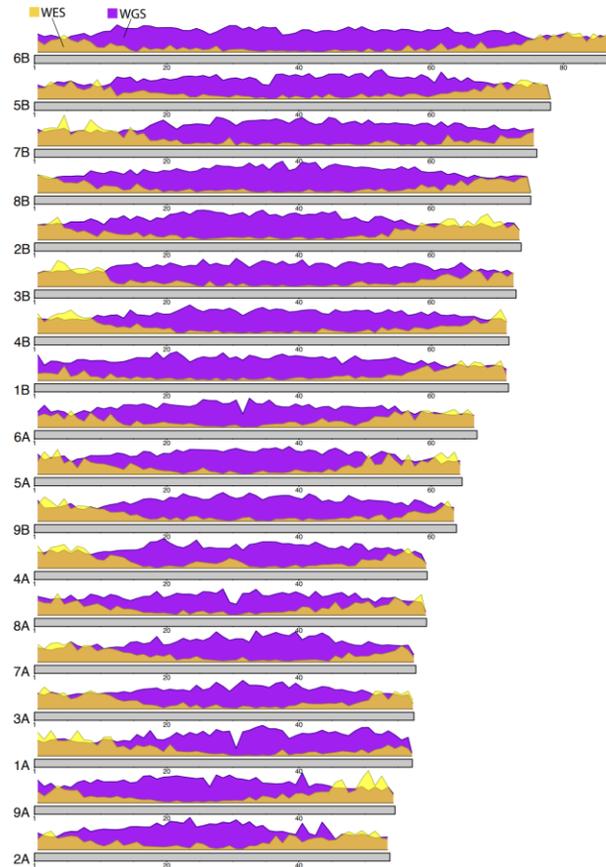
Linking mutations and mutant phenotypes

Genome sequencing of ~500 mutants



Linking mutations and mutant phenotypes

Genome sequencing of ~500 mutants



VEP mutation type	Number	Modifier	Low	Moderate	High
intergenic_variant	315559	*			
downstream_gene_variant	98535	*			
upstream_gene_variant	94010	*			
intron_variant	48121	*			
missense_variant	31105			*	
synonymous_variant	12781		*		
3_prime_UTR_variant	8657	*			
5_prime_UTR_variant	5175	*			
stop_gained	1946				*
splice_region_variant	1355		*		
missense_variant,splice_region_variant	502			*	
splice_acceptor_variant	319				*
splice_donor_variant	288				*
coding_sequence_variant	80	*			
start_lost	52				*
stop_gained,splice_region_variant	45				*
stop_retained_variant	42		*		
frameshift_variant	21				*
stop_lost	4				*
start_retained_variant	3		*		
start_lost,splice_region_variant	1				*

Linking mutations and mutant phenotypes



Genome sequencing of ~500 mutants

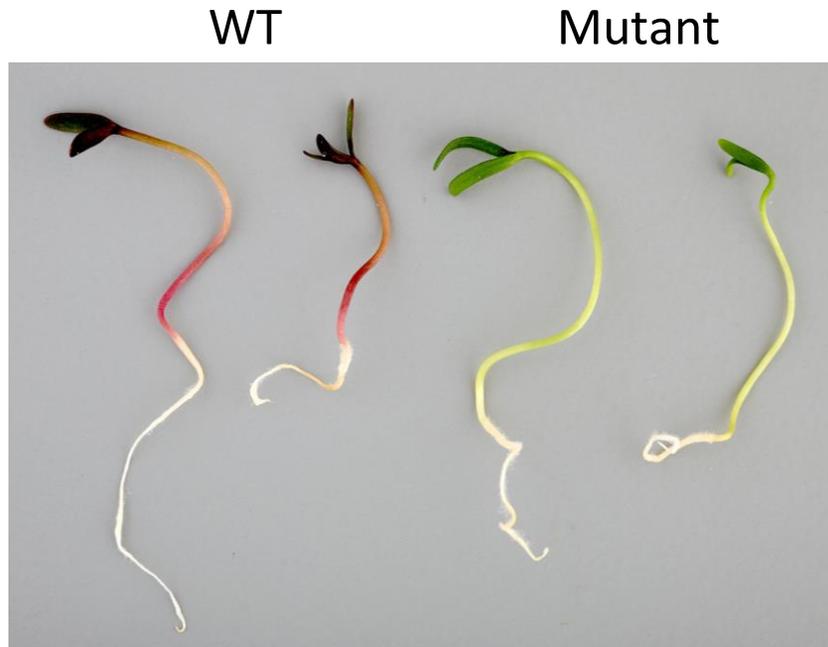
#GeneID	Uploaded_variation	Location	Allele	Feature_type	cDNA_position	CDS_position	Protein_position	Amino_acids	Existing_variation	Gene_description
CQ000002	EMS2427	Contig92_pilon:29015	T	missense_variant	394	132	V/I	Gta/Ata	Note=Similar to KCS11: 3-ketoacyl-CoA synthase 11 (Arabidopsis thaliana OX%3D3702);	
CQ000004	EMS3288	Contig92_pilon:43678	C	missense_variant	695	232	N/S	aAc/aGc	Note=Protein of unknown function;	
CQ000004	EMS3288	Contig92_pilon:43648	A	missense_variant	725	242	P/L	cCg/cTg	Note=Protein of unknown function;	
CQ000008	EMS2427	Contig92_pilon:123790	T	5_prime_UTR_variant	-	-	-	-	Note=Similar to BRK1: Protein BRICK 1 (Arabidopsis thaliana OX%3D3702);	
CQ000173	EMS3118	Contig92_pilon:2077208	T	missense_variant	391	131	G/R	Ggg/Agg	Note=Similar to At1g65750: Putative ribonuclease H protein At1g65750 (Arabidopsis thaliana OX%3D3702);	
CQ000175	EMS2427	Contig92_pilon:2148447	T	synonymous_variant	534	178	E	gaG/gaA	Note=Similar to RE2: Retrovirus-related Pol polyprotein from transposon RE2 (Arabidopsis thaliana OX%3D3702);	
CQ000178	EMS2427	Contig92_pilon:2208493	T	missense_variant	649	217	L/F	Ctt/Ttt	Note=Similar to SUC3: Sucrose transport protein SUC3 (Arabidopsis thaliana OX%3D3702);	
CQ000197	EMS1849	Contig92_pilon:2420986	T	missense_variant	226	76	D/N	Gat/Aat	Note=Similar to WRKY72: Probable WRKY transcription factor 72 (Arabidopsis thaliana OX%3D3702);	
CQ000197	EMS1445	Contig92_pilon:2420897	G	synonymous_variant	315	105	N	aaT/aaC	Note=Similar to WRKY72: Probable WRKY transcription factor 72 (Arabidopsis thaliana OX%3D3702);	
CQ000212	EMS3287	Contig92_pilon:2616807	T	3_prime_UTR_variant	-	-	-	-	Note=Similar to RAD52-2: DNA repair RAD52-like protein 2%2C chloroplastic (Arabidopsis thaliana OX%3D3702);	
CQ000219	EMS2427	Contig92_pilon:2652959	A	3_prime_UTR_variant	-	-	-	-	Note=Similar to At1g28120: Ubiquitin thioesterase otubain-like (Arabidopsis thaliana OX%3D3702);	
CQ000227	EMS3118	Contig92_pilon:2736384	T	missense_variant	99	33	M/I	atG/atA	Note=Similar to CRN: Inactive leucine-rich repeat receptor-like protein kinase CORYNE (Arabidopsis thaliana OX%3D3702);	
CQ000232	EMS3299	Contig92_pilon:2765081	T	missense_variant	257	86	S/F	tCt/tTt	Note=Similar to NXD1: Protein NEOXANTHIN-DEFICIENT 1 (Solanum lycopersicum OX%3D4081);	
CQ000233	EMS2427	Contig92_pilon:2766773	T	3_prime_UTR_variant	-	-	-	-	Note=Similar to SCPL45: Serine carboxypeptidase-like 45 (Arabidopsis thaliana OX%3D3702);	
CQ000234	EMS2077	Contig92_pilon:2781532	.-3TTT	5_prime_UTR_variant	-	-	-	-	Note=Similar to SCD2: Coiled-coil domain-containing protein SCD2 (Arabidopsis thaliana OX%3D3702);	
CQ000236	EMS3118	Contig92_pilon:2793407	T	missense_variant	88	30	G/R	Gga/Aga	Note=Protein of unknown function;	
CQ000240	EMS2077	Contig92_pilon:2830582	T	missense_variant	610	204	G/R	Gga/Aga	Note=Similar to LAX2: Protein LAX PANICLE 2 (Oryza sativa subsp. japonica OX%3D39947);	
CQ000240	EMS409	Contig92_pilon:2830721	T	stop_gained	471	157	W/*	tgG/tgA	Note=Similar to LAX2: Protein LAX PANICLE 2 (Oryza sativa subsp. japonica OX%3D39947);	

Linking mutations and mutant phenotypes



Genome sequencing of ~500 mutants

1. Find a mutant phenotype, work back to causative gene



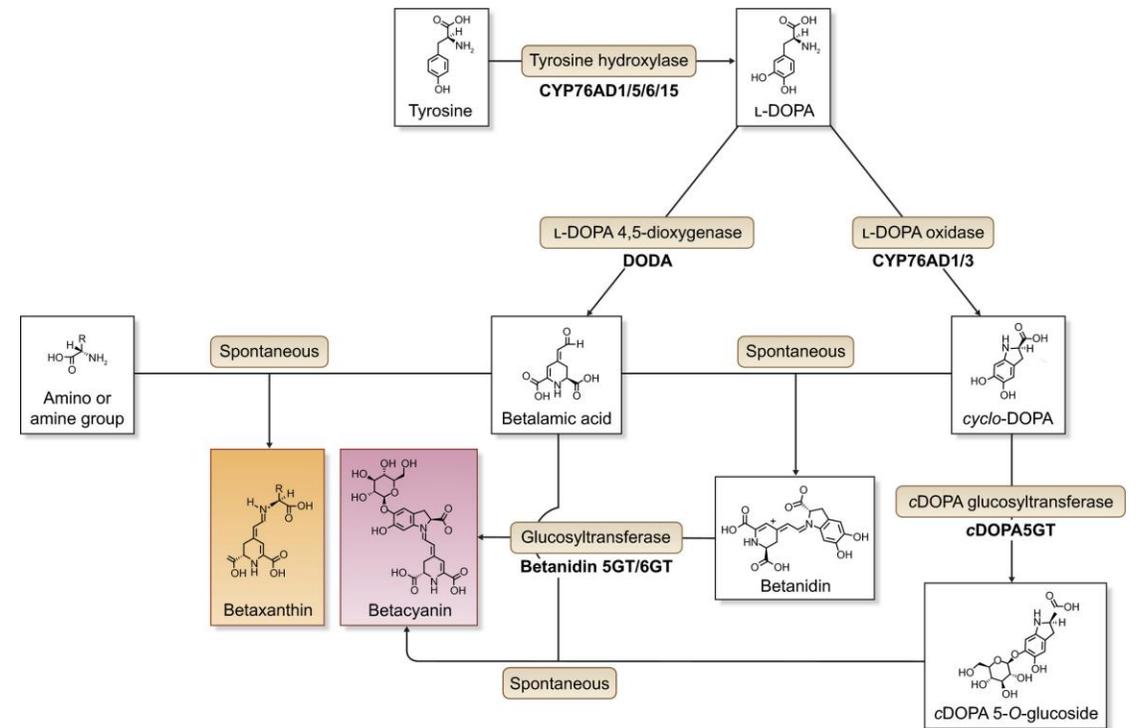
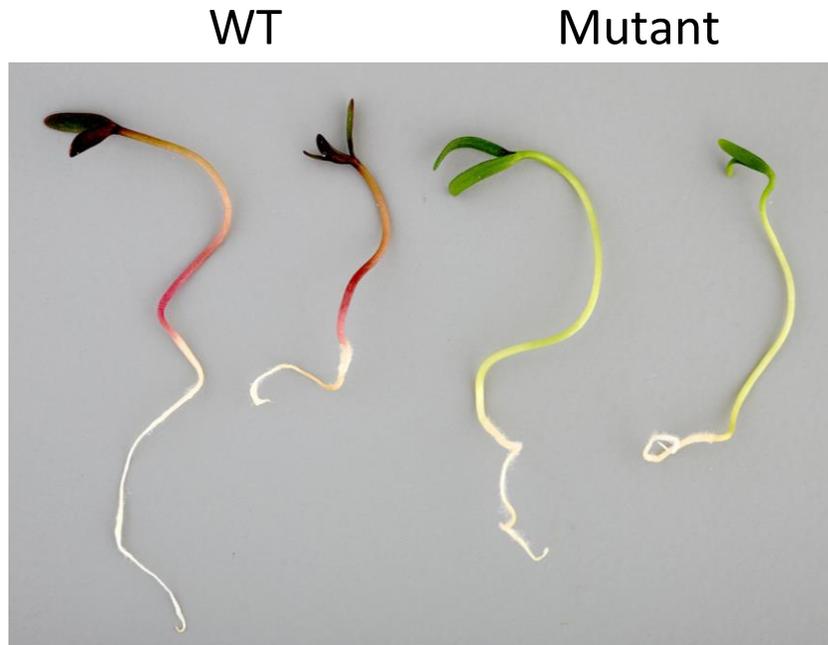
31,564 mutations in this mutant family
9,331 within genes

CQ000002	EMS2427	Contig92_pilon:29015	T	missense_variant	394	132	V/I	Gta/Ata	Note=Similar to KCS11: 3-ketoacyl-CoA synthase 11 (Arabidopsis thaliana OX%3D3702);
CQ000008	EMS2427	Contig92_pilon:123790	T	5_prime_UTR_variant	-	-	-	-	Note=Similar to BRK1: Protein BRICK 1 (Arabidopsis thaliana OX%3D3702);
CQ000014	EMS2427	Contig92_pilon:183134	T	missense_variant	175	59	L/F	Ctt/Ttt	Note=Similar to GRDP1: Glycine-rich domain-containing protein 1 (Arabidopsis thaliana OX%3D3702);
CQ000071	EMS2427	Contig92_pilon:828561	T	missense_variant	197	66	G/E	gGg/gAg	Note=Protein of unknown function;
CQ000076	EMS2427	Contig92_pilon:864128	T	missense_variant	838	280	A/T	Gcg/Acg	Note=Similar to PUMP3: Mitochondrial uncoupling protein 3 (Arabidopsis thaliana OX%3D3702);
CQ000082	EMS2427	Contig92_pilon:941695	T	5_prime_UTR_variant	-	-	-	-	Note=Similar to NAP2: NAC domain-containing protein 2 (Solanum lycopersicum OX%3D4081);
CQ000123	EMS2427	Contig92_pilon:1337673	T	splice_donor_variant	-	-	-	-	Note=Similar to APY6: Probable apyrase 6 (Arabidopsis thaliana OX%3D3702);
CQ000175	EMS2427	Contig92_pilon:2148447	T	synonymous_variant	534	178	E	gaG/gaA	Note=Similar to RE2: Retrovirus-related Pol polyprotein from transposon RE2 (Arabidopsis thaliana OX%3D3702);
CQ000178	EMS2427	Contig92_pilon:2208493	T	missense_variant	649	217	L/F	Ctt/Ttt	Note=Similar to SUC3: Sucrose transport protein SUC3 (Arabidopsis thaliana OX%3D3702);
CQ000219	EMS2427	Contig92_pilon:2652959	A	3_prime_UTR_variant	-	-	-	-	Note=Similar to At1g28120: Ubiquitin thioesterase otubain-like (Arabidopsis thaliana OX%3D3702);
CQ000233	EMS2427	Contig92_pilon:2766773	T	3_prime_UTR_variant	-	-	-	-	Note=Similar to SCPL45: Serine carboxypeptidase-like 45 (Arabidopsis thaliana OX%3D3702);

Linking mutations and mutant phenotypes

Genome sequencing of ~500 mutants

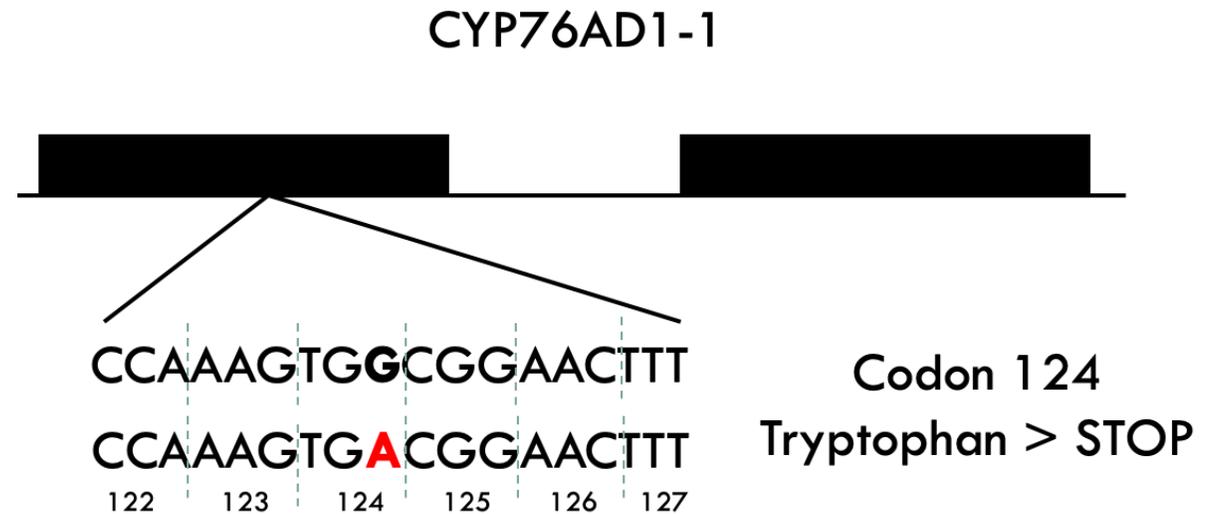
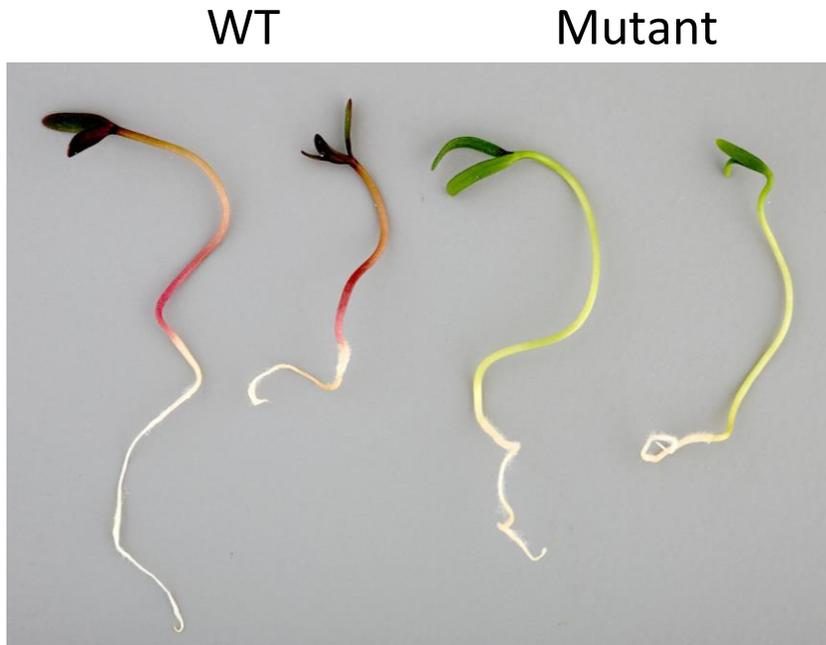
1. Find a mutant phenotype, work back to causative gene



Linking mutations and mutant phenotypes

Genome sequencing of ~500 mutants

1. Find a mutant phenotype, work back to causative gene



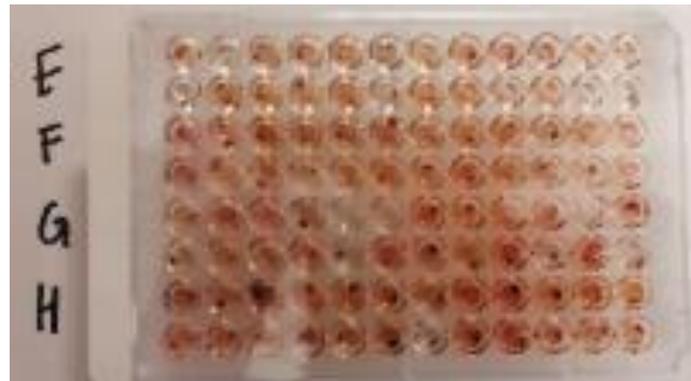
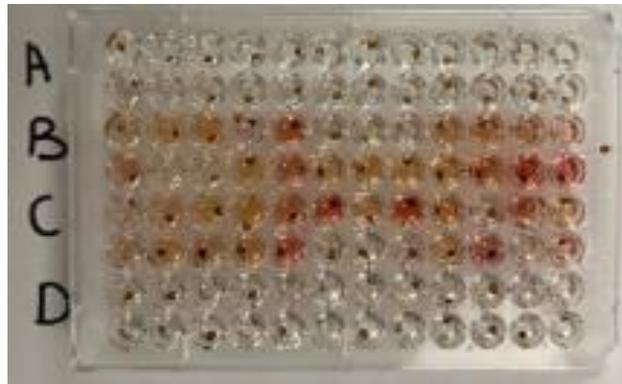
Linking mutations and mutant phenotypes



Genome sequencing of ~500 mutants

1. Find a mutant phenotype, work back to causative gene

Saponins: develop single-seed detection assay



Screen 24 seeds of each pooled M3 family to identify saponin-free mutants

Linking mutations and mutant phenotypes

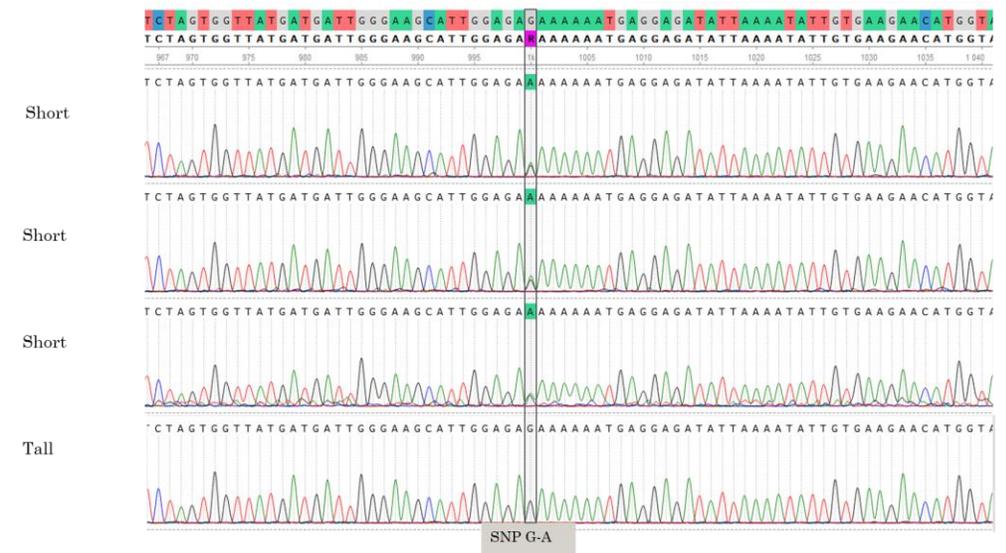


Genome sequencing of ~500 mutants

1. Find a mutant phenotype, work back to causative gene
2. Find a mutant gene, work forward to mutant phenotype

Plant height: find mutations in GA signaling and biosynthesis

Gene	EMS Family	Variant
GAI1	3067	Missense
	549	Missense
	88	Missense & Upstream
	541	Stop Gained
GID1-C	1679	Missense & Downstream
LE (GA3OX)	500	Missense & Downstream
	2427	Missense & Downstream
GA20OX-2	170	Missense & Upstream



Linking mutations and mutant phenotypes

Genome sequencing of ~500 mutants

1. Find a mutant phenotype, work back to causative gene
2. Find a mutant gene, work forward to mutant phenotype

Projects for new students in my lab (PWS 494R)

#GeneID	Uploaded_variation	Location	Allele	Feature_type	cDNA_position	CDS_position	Protein_position	Amino_acids	Existing_variation	Gene_description
CQ000002	EMS2427	Contig92_pilon:29015	T	missense_variant	394	132	V/I	Gta/Ata	Note=Similar to KCS11: 3-ketoacyl-CoA synthase 11 (Arabidopsis thaliana OX%3D3702);	
CQ000004	EMS3288	Contig92_pilon:43678	C	missense_variant	695	232	N/S	aAc/aGc	Note=Protein of unknown function;	
CQ000004	EMS3288	Contig92_pilon:43648	A	missense_variant	725	242	P/L	cCg/cTg	Note=Protein of unknown function;	
CQ000008	EMS2427	Contig92_pilon:123790	T	5_prime_UTR_variant	-	-	-	-	Note=Similar to BRK1: Protein BRICK 1 (Arabidopsis thaliana OX%3D3702);	
CQ000173	EMS3118	Contig92_pilon:2077208	T	missense_variant	391	131	G/R	Ggg/Agg	Note=Similar to Atig65750: Putative ribonuclease H protein Atig65750 (Arabidopsis thaliana OX%3D3702);	
CQ000175	EMS2427	Contig92_pilon:2148447	T	synonymous_variant	534	178	E	gaG/gaA	Note=Similar to RE2: Retrovirus-related Pol polyprotein from transposon RE2 (Arabidopsis thaliana OX%3D3702);	
CQ000178	EMS2427	Contig92_pilon:2208493	T	missense_variant	649	217	L/F	Ctt/Ttt	Note=Similar to SUC3: Sucrose transport protein SUC3 (Arabidopsis thaliana OX%3D3702);	
CQ000197	EMS1849	Contig92_pilon:2420986	T	missense_variant	226	76	D/N	Gat/Aat	Note=Similar to WRKY72: Probable WRKY transcription factor 72 (Arabidopsis thaliana OX%3D3702);	
CQ000197	EMS1445	Contig92_pilon:2420897	G	synonymous_variant	315	105	N	aaT/aaC	Note=Similar to WRKY72: Probable WRKY transcription factor 72 (Arabidopsis thaliana OX%3D3702);	
CQ000212	EMS3287	Contig92_pilon:2616807	T	3_prime_UTR_variant	-	-	-	-	Note=Similar to RAD52-2: DNA repair RAD52-like protein 2%2C chloroplastic (Arabidopsis thaliana OX%3D3702);	
CQ000219	EMS2427	Contig92_pilon:2652959	A	3_prime_UTR_variant	-	-	-	-	Note=Similar to Atig28120: Ubiquitin thioesterase otubain-like (Arabidopsis thaliana OX%3D3702);	
CQ000227	EMS3118	Contig92_pilon:2736384	T	missense_variant	99	33	M/I	atG/atA	Note=Similar to CRN: Inactive leucine-rich repeat receptor-like protein kinase CORYNE (Arabidopsis thaliana OX%3D3702);	
CQ000232	EMS3299	Contig92_pilon:2765081	T	missense_variant	257	86	S/F	tCt/tTt	Note=Similar to NXD1: Protein NEOXANTHIN-DEFICIENT 1 (Solanum lycopersicum OX%3D4081);	
CQ000233	EMS2427	Contig92_pilon:2766773	T	3_prime_UTR_variant	-	-	-	-	Note=Similar to SCPL45: Serine carboxypeptidase-like 45 (Arabidopsis thaliana OX%3D3702);	
CQ000234	EMS2077	Contig92_pilon:2781532	.-3TTT	5_prime_UTR_variant	-	-	-	-	Note=Similar to SCD2: Coiled-coil domain-containing protein SCD2 (Arabidopsis thaliana OX%3D3702);	
CQ000236	EMS3118	Contig92_pilon:2793407	T	missense_variant	88	30	G/R	Gga/Aga	Note=Protein of unknown function;	
CQ000240	EMS2077	Contig92_pilon:2830582	T	missense_variant	610	204	G/R	Gga/Aga	Note=Similar to LAX2: Protein LAX PANICLE 2 (Oryza sativa subsp. japonica OX%3D39947);	
CQ000240	EMS409	Contig92_pilon:2830721	T	stop_gained	471	157	W/*	tgG/tgA	Note=Similar to LAX2: Protein LAX PANICLE 2 (Oryza sativa subsp. japonica OX%3D39947);	

Select mutation of interest → Research the gene → Design experiment

Fundamental lab skills: Basic command line, greenhouse, wet lab

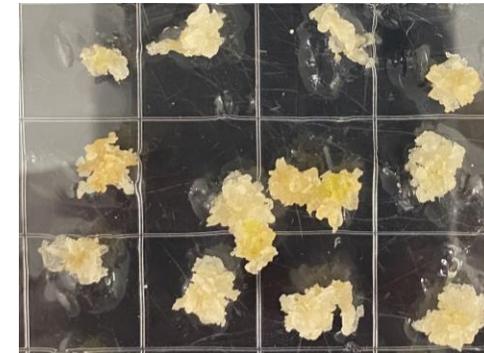
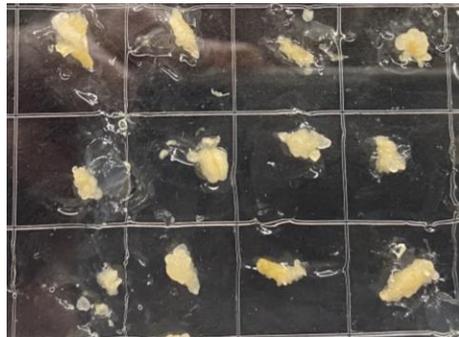
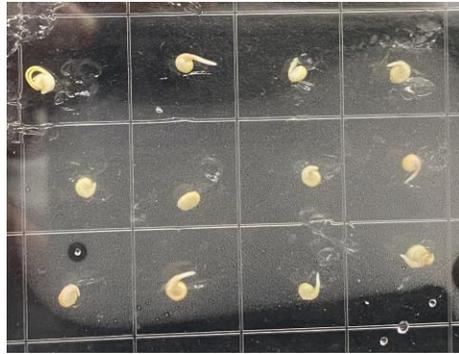
Fundamental research skills: Literature review, hypothesis, experiment, data analysis, troubleshooting

Inducing targeted variation in quinoa



Transformation of quinoa

Generate undifferentiated callus tissue → transform with exogenous DNA → regeneration/embryogenesis



Inducing targeted variation in quinoa

Transformation of quinoa

Generate undifferentiated callus tissue → transform with exogenous DNA → regeneration/embryogenesis

