QUINOA

A CLIMATE RESILIENT GRAIN OPTION FOR CLIMATE CHANGE PRONE FOOD INSECURE PAKISTAN

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A WORLD OF HUNGER

870 MILLION

PEOPLE STILL

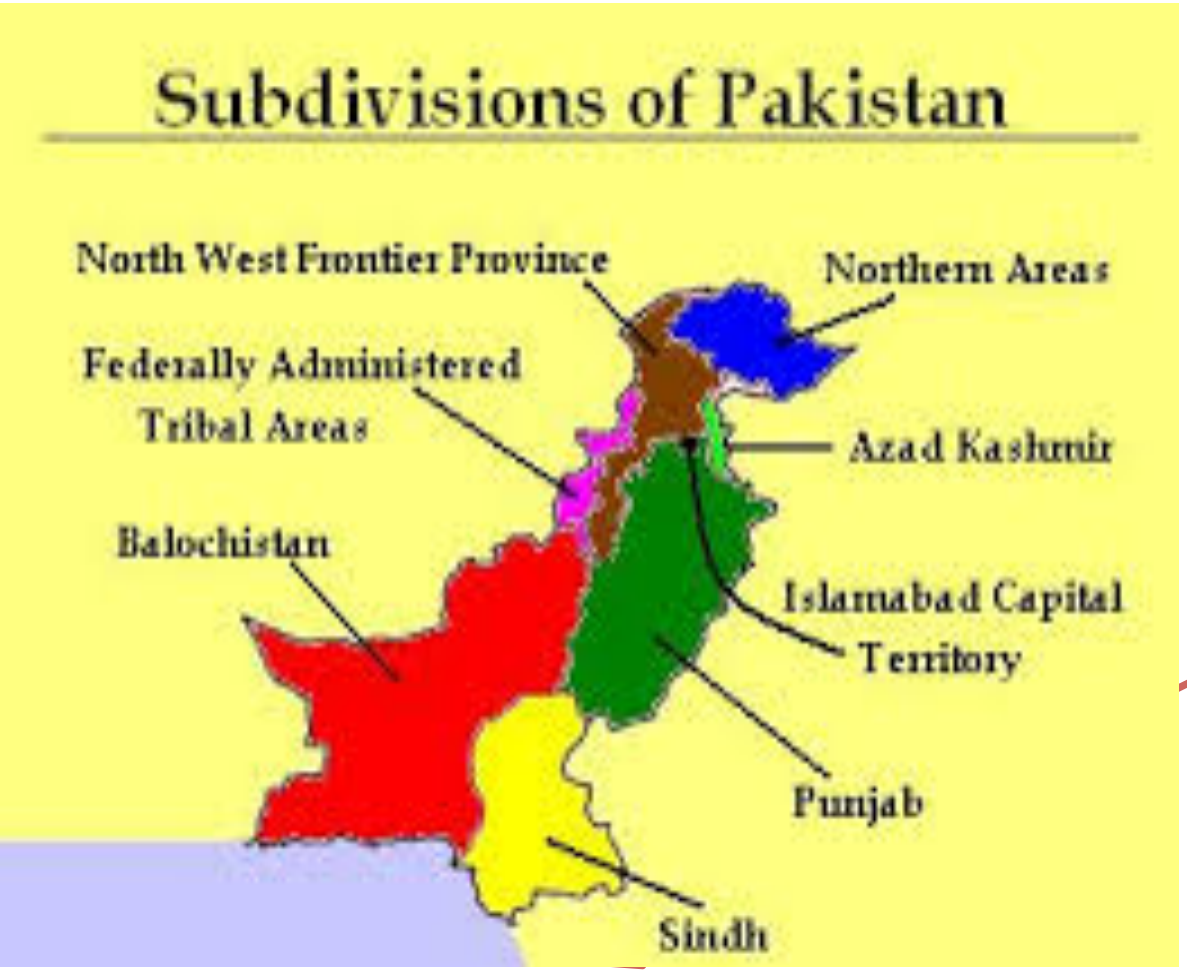
HUNGRY

50% **cereal production in Asia**

(UN)

PAKISTAN

- 184 million people living in 796000 km^2
- **Situated**: 24.53°N` and 67.00°E` and 35.44°N` and 74.37°E`
- **Indus valley**: one of the oldest centers of cultivation
- **15 agro-ecological zones**: from subtropical coastal to subtropical planes, salt ranges, gullies, highest mountains in the world up to Pamir (roof of the world)



Pakistan is 57th

GHI~19.5

(FAO)

PAKISTAN FIGHTING JINNI OF HUNGER

- World population — 7 billion
- World population in 2050 — 10.9 billion
- Malnourished 2009 — 963 million
- Pakistan (WFP, 2008) — 6th biggest nation today
  5th biggest in 2025
- Food insecure — 77 million
- Malnourished — 45 million Adults
  57% of the children

Six crops for food security in the world include

wheat, rice, corn, sweet potato, cassava (FAOSTAT)

Pakistan is having even less choices

Wheat, rice, maize (Econ. Survey of Pakistan, 2012)

PAKISTAN
SEASONS

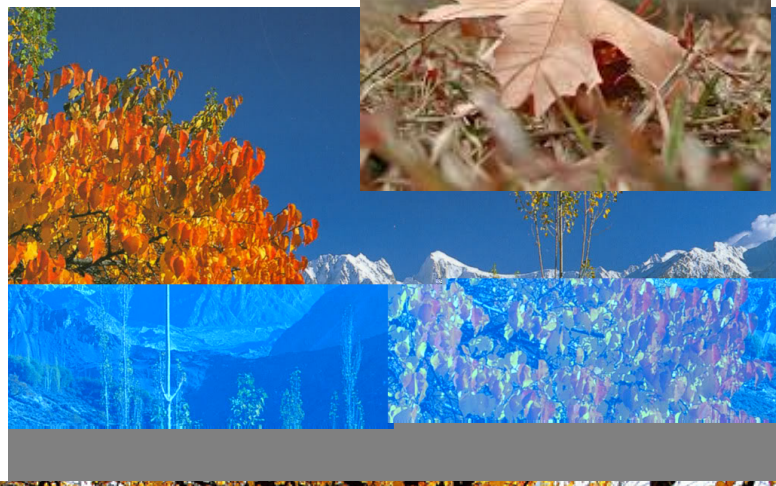
PAKISTAN

SUMMERS

Moonsoon

torrential rains

AUTUMN



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PAKISTAN WINTERS

PAKISTAN
SPRING

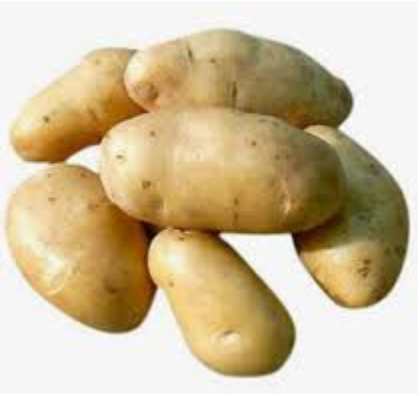
Pakistan
Geographic situation

- 800 miles long coast line
- 700 miles long and 350 miles wide planes in the Punjab and Sindh provinces
- Barren and arid regions in the Baluchistan
- World's 8th biggest desert (Tharparker)
- 400 miles long land exposed to severe frost
- Approx. 8 mha of land salt affected

Food Assurance???

- Developing new varieties (Money and time?)
  - hybridization, Mutation, cell culture
- Expanding cultivable land (impossible)
- Crop diversification through Crop introduction

(potato, maize, berseem, sunflower, upland cotton)



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Quinoa: An introduction in Pakistan

- Introduced in Pakistan in 2008 (Munir, 2011)
- Staple grain of Latin American highlands
- Tolerates up to 35°C (Valenica-Chomorro, 2003)
- High economic significance
- Exceptionally high Nutrition (Vega-Galvez et al., 2010)
- Extreme Resilience to climatic adversities
- United Nations chartered Icon for future food security in Zero Hunger initiative 2025

YIELD CONSTRAINTS

- **Salinity**: 1/3rd of the country's cultivable land is salt affected (secondary salinization, brackish ground waters)
- **Drought**: 30.6% irrigation water scarcity
- **Frost**: A large area with on and off exposures
- **Arid region**: Approx. 3.5 mha (marginal yields)
- **Cultivatable Waste Lands**: 4 mha
- Small land holdings

Annual Global Income losses
(water scarcity and salinity contribution)

Estimated at US$ 15 billion

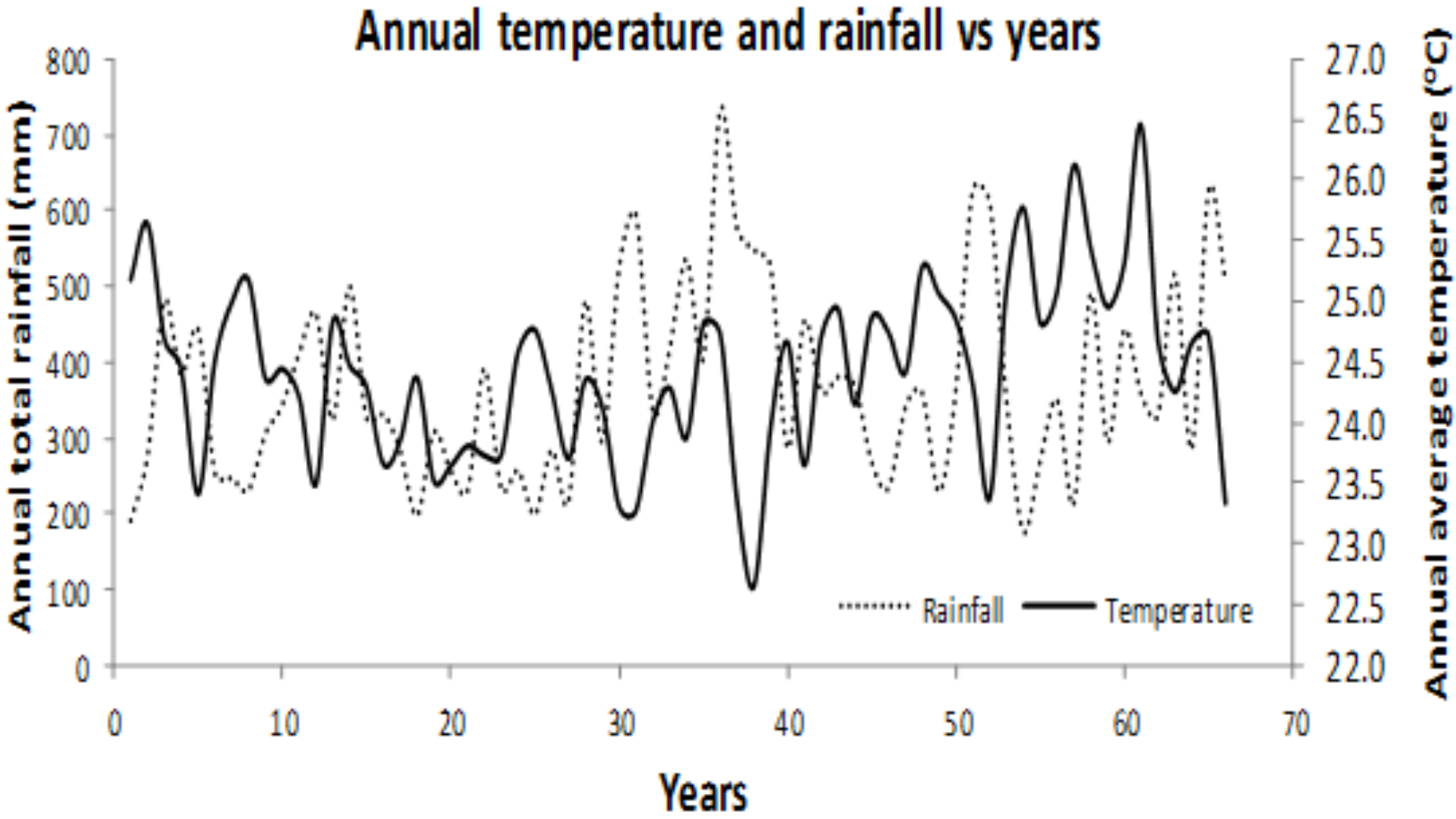
Indus Basin: US$ 230 million

(3rd biggest looser after Ural and Euphrates)

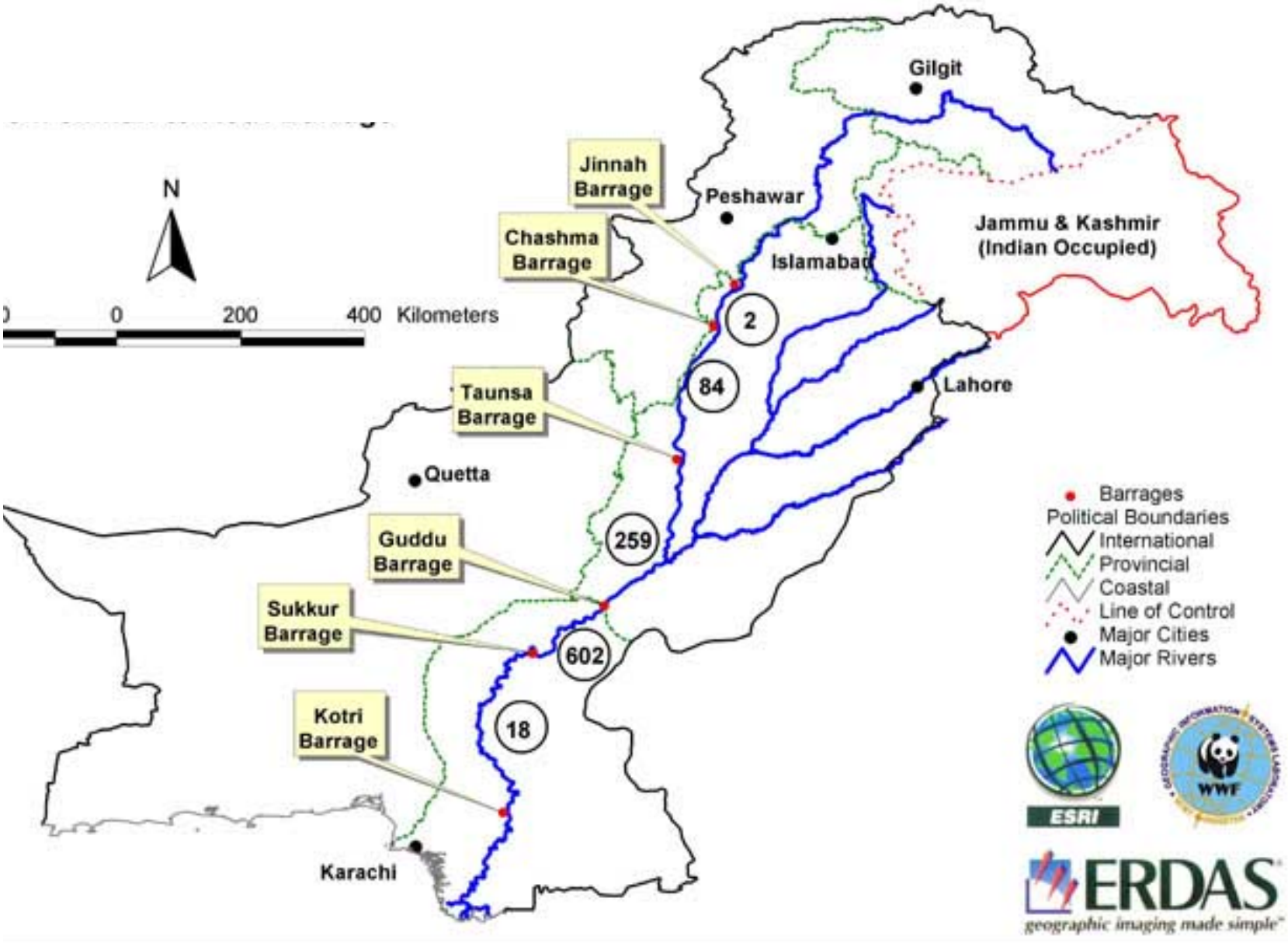
(ICARDA, 2009)

AGROMET HISTORY OF PAKISTAN

(Cheema, 2012)



INDUS BASIN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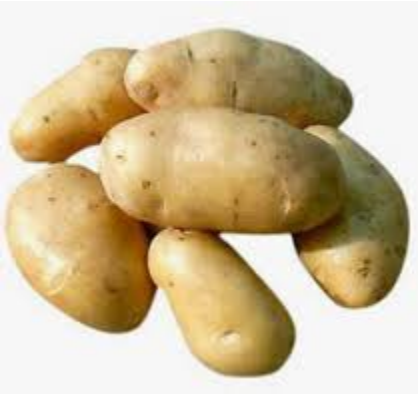
0
200
400 Kilometers
Gilgit
Jinnah Barrage
Peshawar
Chashma Barrage
Islamabad
Jammu & Kashmir (Indian Occupied)
2
84
Taunsa Barrage
Lahore
Quetta
Guddu Barrage
259
Sukkur Barrage
602
Kotri Barrage
18
Karachi
Barrages
Political Boundaries
International
Provincial
Coastal
Line of Control
Major Cities
Major Rivers
ESRI
WWF
ERDAS
geographic imaging made simple

Food Assurance???

- Developing new varieties (Money and time?)
  - hybridization, Mutation, cell culture
- Expanding cultivable land (impossible)
- Crop diversification through Crop introduction

(potato, maize, berseem, sunflower, upland cotton)



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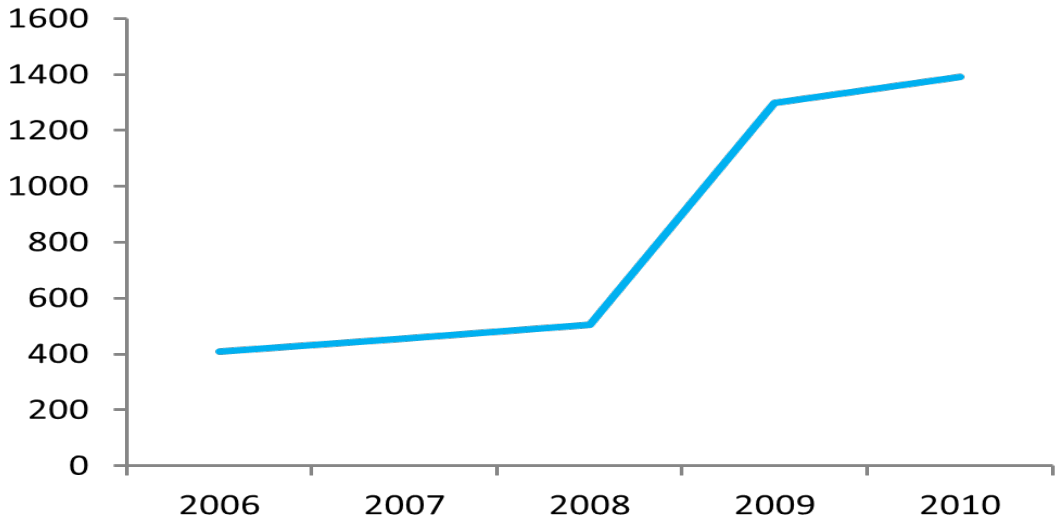
Response of Quinoa to land and climatic adversities

- Accepts a variety of soil pH from 4.5 to 9.5
- Extreme drought tolerance (up to 25% F.C.) (Geerts *et al*., 2008; Munir, 2011)
- Tolerates freezing ~-5^{o}C (Bonifacio, 2006)
- Tolerates salinity up to sea level (Jacobsen, 2003)

- Source crop for establishment of climate proof cropping system in Mediterranean (SWUP-MED, 2013; EU-FP7)

Travel across the continents



(Thousand metric Tonnes) (PROINPA, 2011)

INTRODUCTION IN PAKISTAN

- 2008-12 Faisalaad
- 2009-12 Chakwal, Bahawalpur and Sargodha
- Haripur, Hazara

EXPERIMENTAL BRIEF

Quinoa under Pakistan conditions

- *Collection of germplasm*
- *Preliminary growth and yield potential assessments*
- *Evaluation of stand establishment methods*
- *Multi-location trials*
- *Preliminary optimization trial for sowing date*
- *Assessments of physiological bases for salt & drought tolerance*
- *Nutritional assessment of locally produced quinoa*

GERMPLASM Collection:

- **Source**:
- United States Department of Agriculure (IOWA)
- University of Copenhagen, Denmark
- **Genotypes**: 25+2
  - Valley
  - Sea level
  - salars

winters 2008-09

EXPERIMENTAL SITES:

- **Controlled condition trials:**
  - *Laboratory and Net House:*

    Department of Crop Physiology, University of Agriculture, Faisalabad, Pakistan.
- **field trials:**

  Experimental Areas:
  - department of Agronomy, University of Agriculture, Faisalabad;
  - Barani Agricultural Research Station, Chakwal
  - Desert Research Institute, The Islamia University of Bahawalpur, Pakistan
  - Provincial extension departments

Selection of quinoa germplasm for seedling vigor

- **Genotypes:** **25**
- **Selection basis:** seed viability and seedling vigor and survillance
- **Design :** Completely Randomized Design (CRD)
- **Name of Genotypes:**

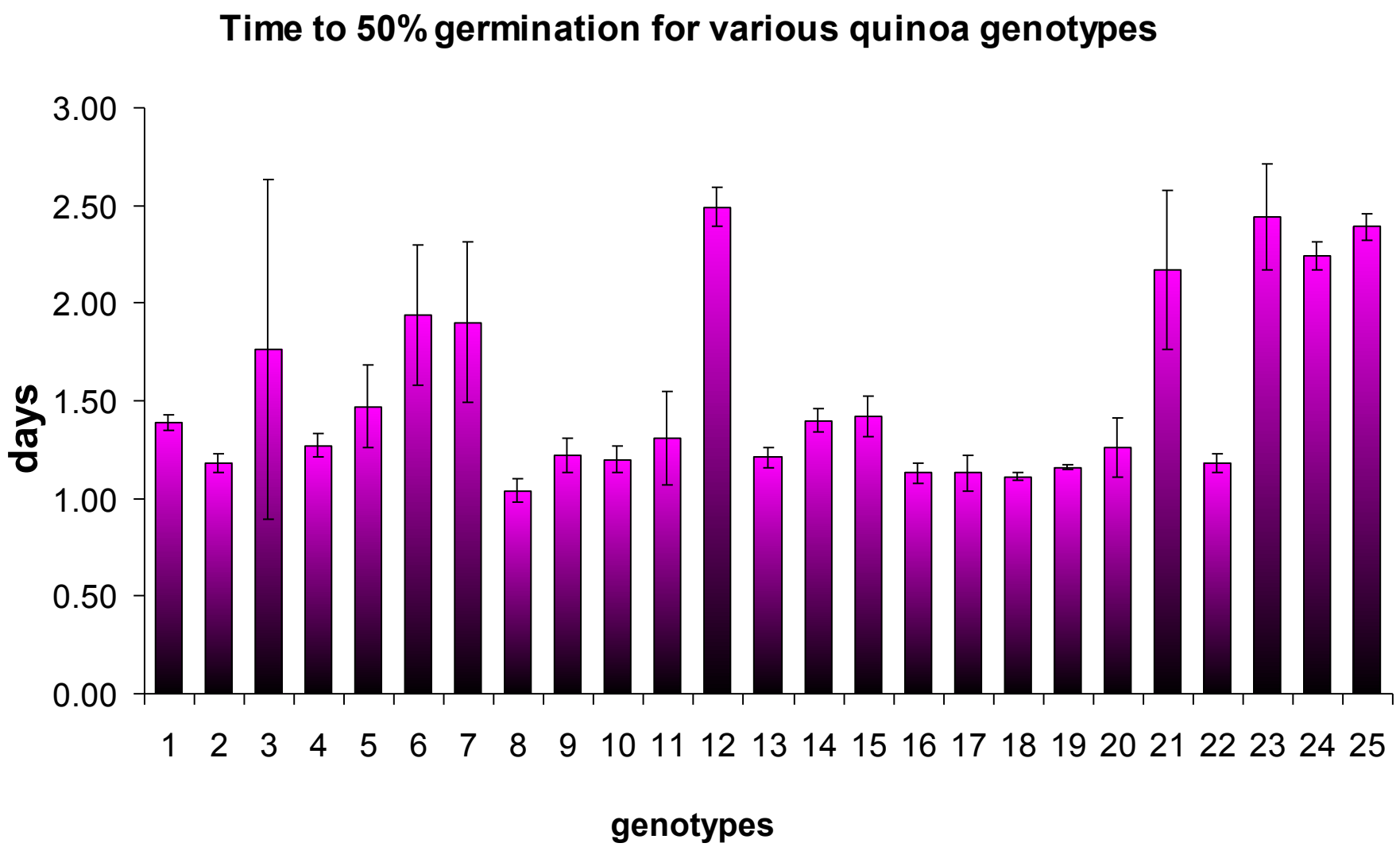
  (Ames-13730, Ames 13737, Ames-13739, Ames 13760, Ames-13762)

  (PI 510532, PI 510533, PI 510537, PI 510540, PI 510542)

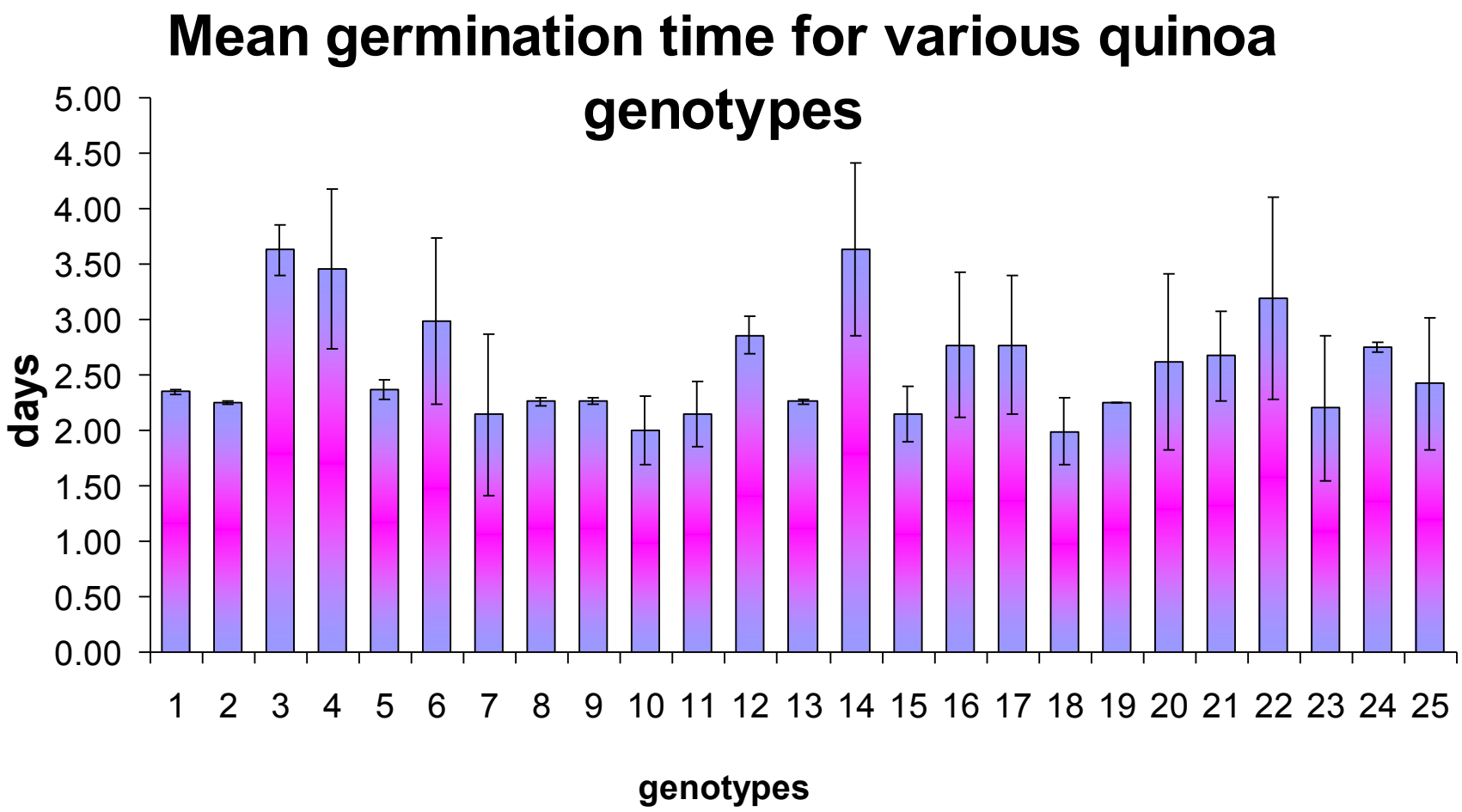
  (PI 643079, PI 634918, PI 634919, PI 634921, PI 634922)

  (PI 596293, PI 596498, PI 614922, PI 478410, PI 452512)

  (PI 614905, PI 614906, PI 614907 , PI 614908 , PI 614909)
- **Germination and seedling growth parameters:**
  - » Time to 50% germination (days)
  - » Mean germination time (days)
  - » Final germination (%)
  - » Root and shoot lengths (cm)
  - » Seedling survival percentage



1.Ames13730 **2.**Ames13737 **3.**Ames-13739 **4.**Ames13760 **5.**Ames-13762 **6.** PI510532 **7.**PI510533 **8.**PI510537 **9.**PI510540 **10.**PI510542 **11.**PI643079 **12.**PI634918 **13.**PI634919 **14.**PI634921 **15.**PI634922 **16.**PI596293 **17.**PI596498 **18.**PI614922 **19.**PI478410 **20.**PI452512 **21.**PI614905 **22.**PI614906 **23.**PI614907 **24.**PI614908 **25.**PI614909



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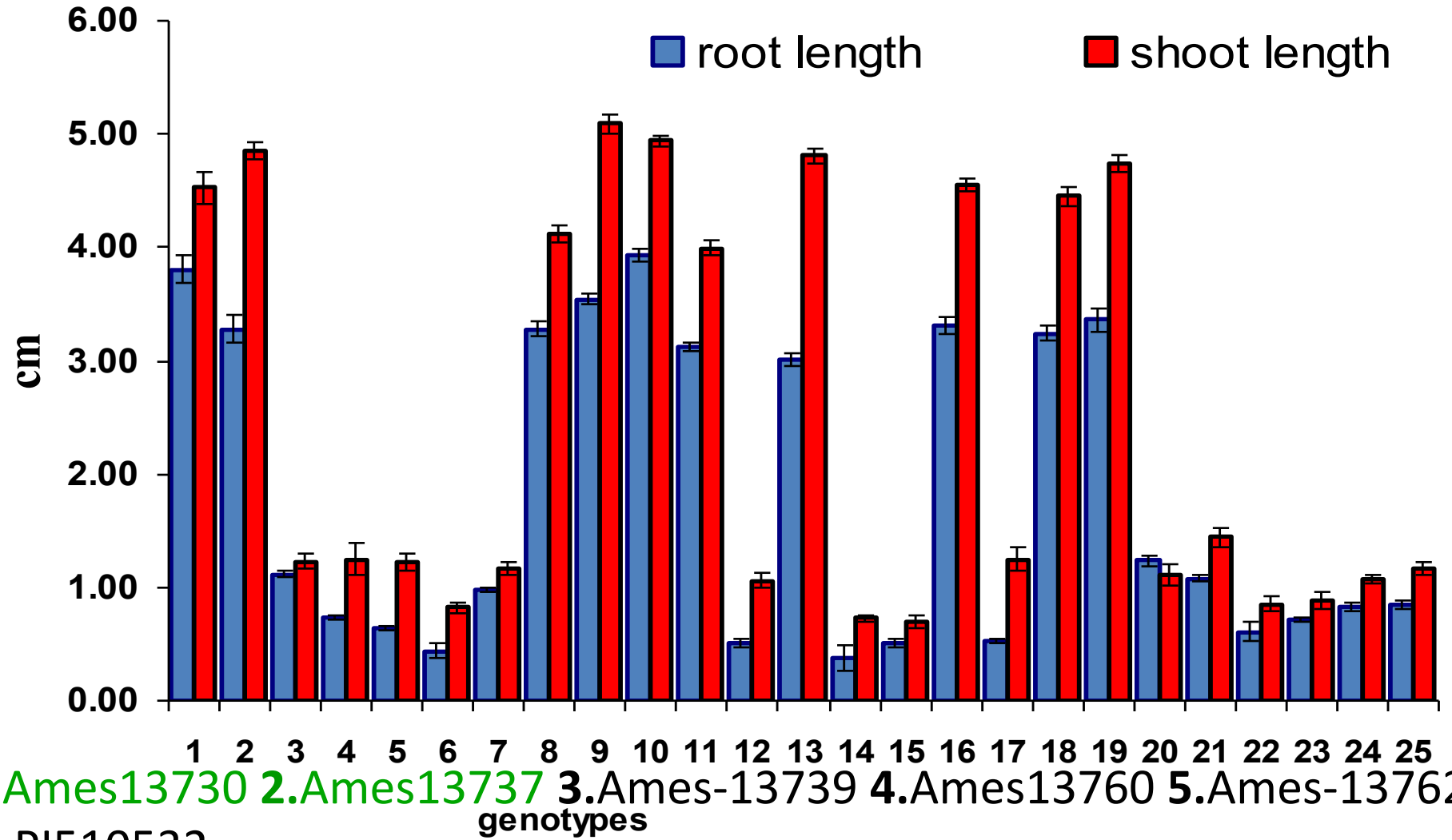

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12.PI634918 **13.**PI634919 **14.**PI634921 **15.**PI634922 **16.**PI596293
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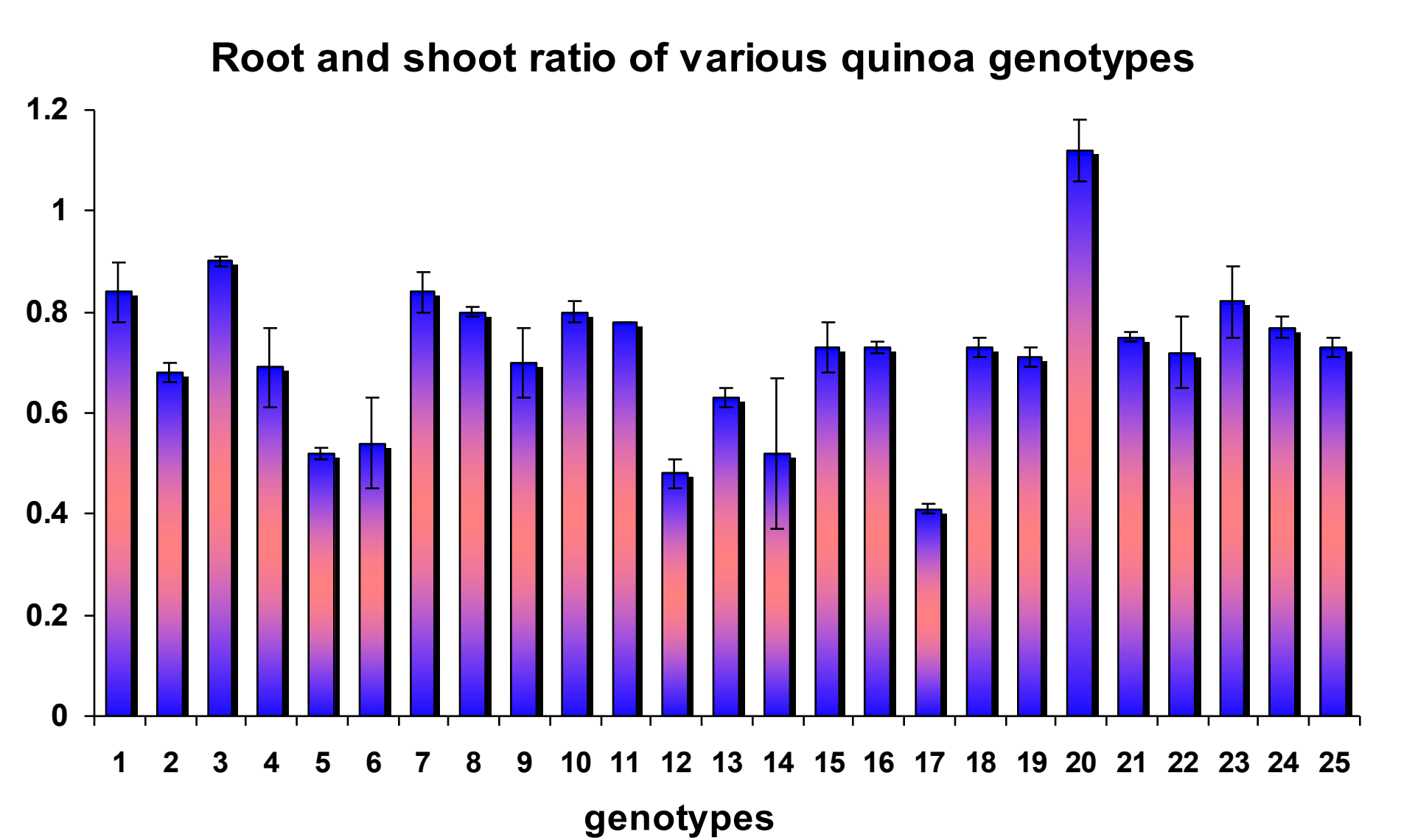

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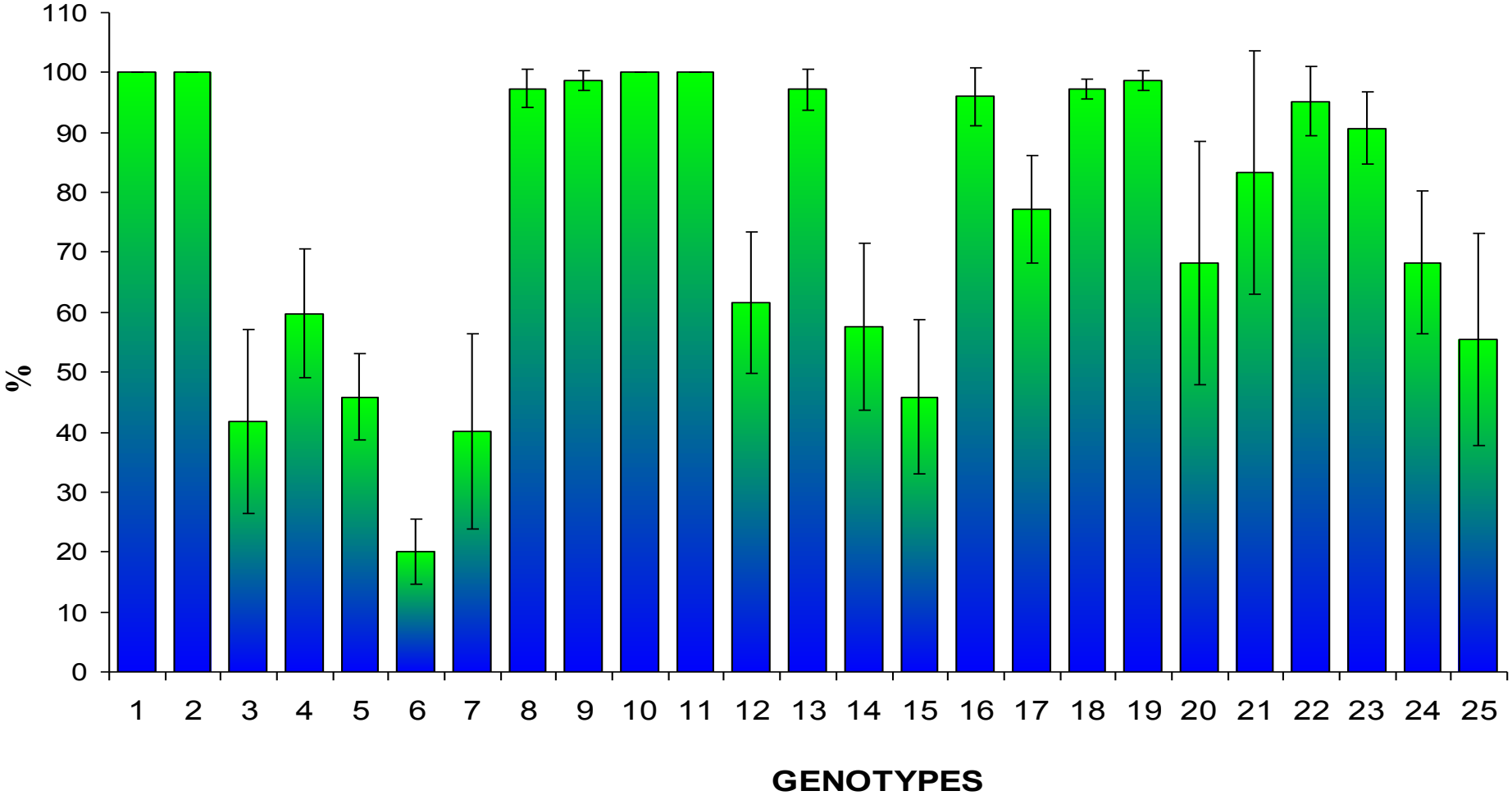
SEEDLING SURVIVAL RATE (%) OF EXOTIC QUINOA GENOTYPES



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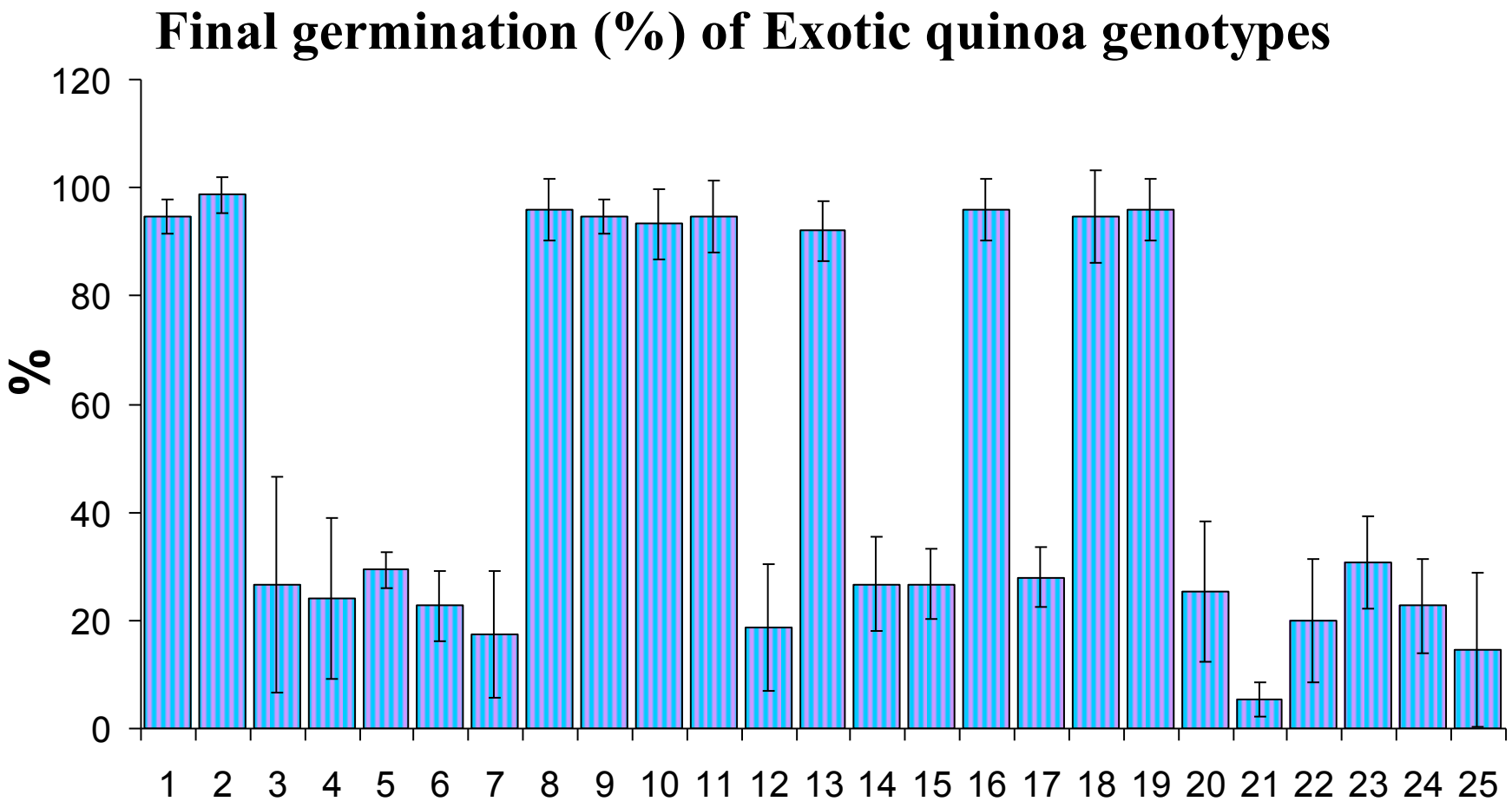

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17.PI596498 **18.**PI614922 **19.**PI478410 **20.**PI452512 **21.**PI614905

Selection of genotypes

- Because of less time to 50 % Germination, Mean Germination Time, higher root and shoot lengths, Final emergence and seedling survival rate Significantly higher Performance

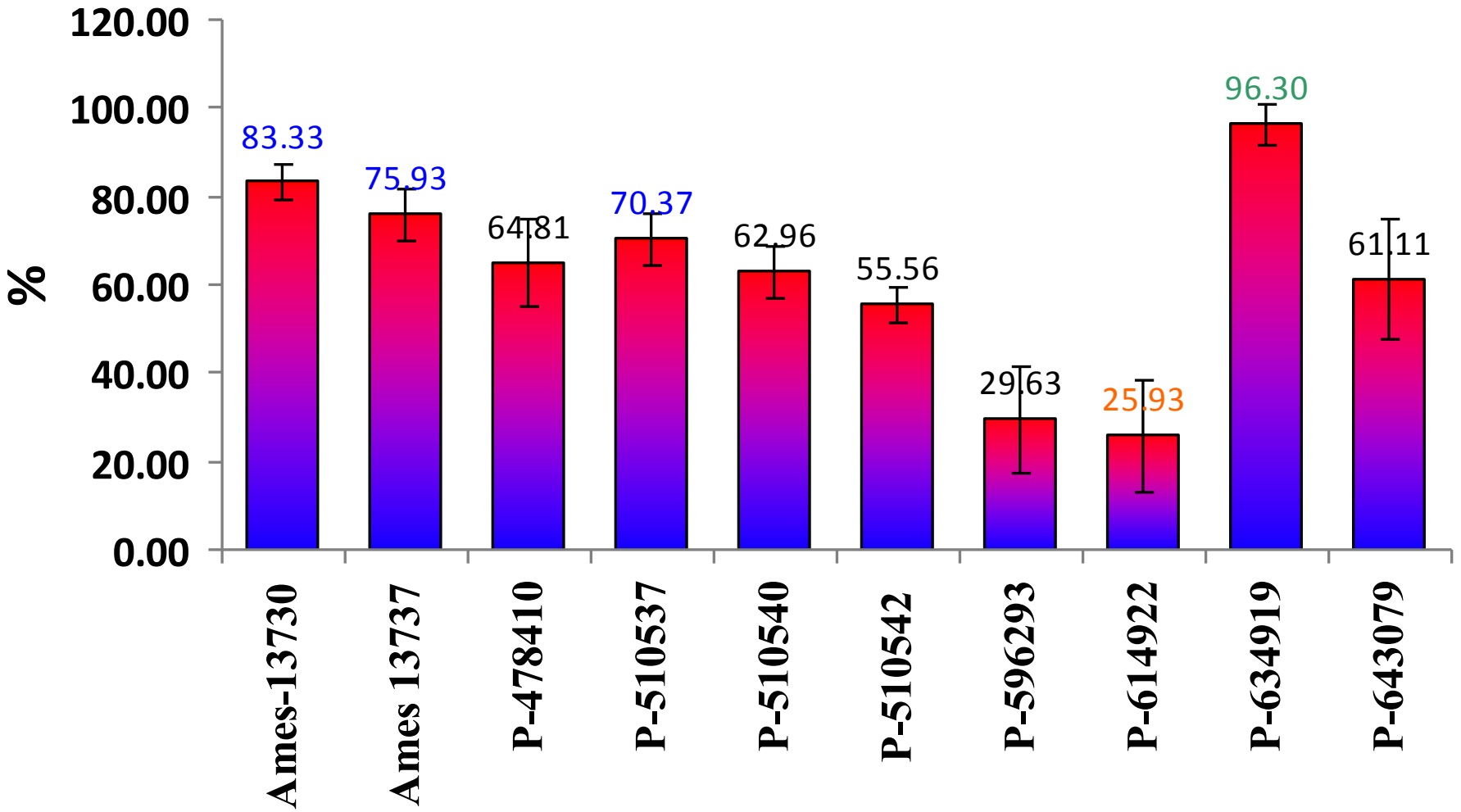
1.Ames13730
2.Ames13737
8. PI510537
9.PI510540
10.PI510542
11.PI643079
13.PI634919
16.PI596293
18.PI614922
19.PI478410

Evaluating growth and yield potential of quinoa under field conditions

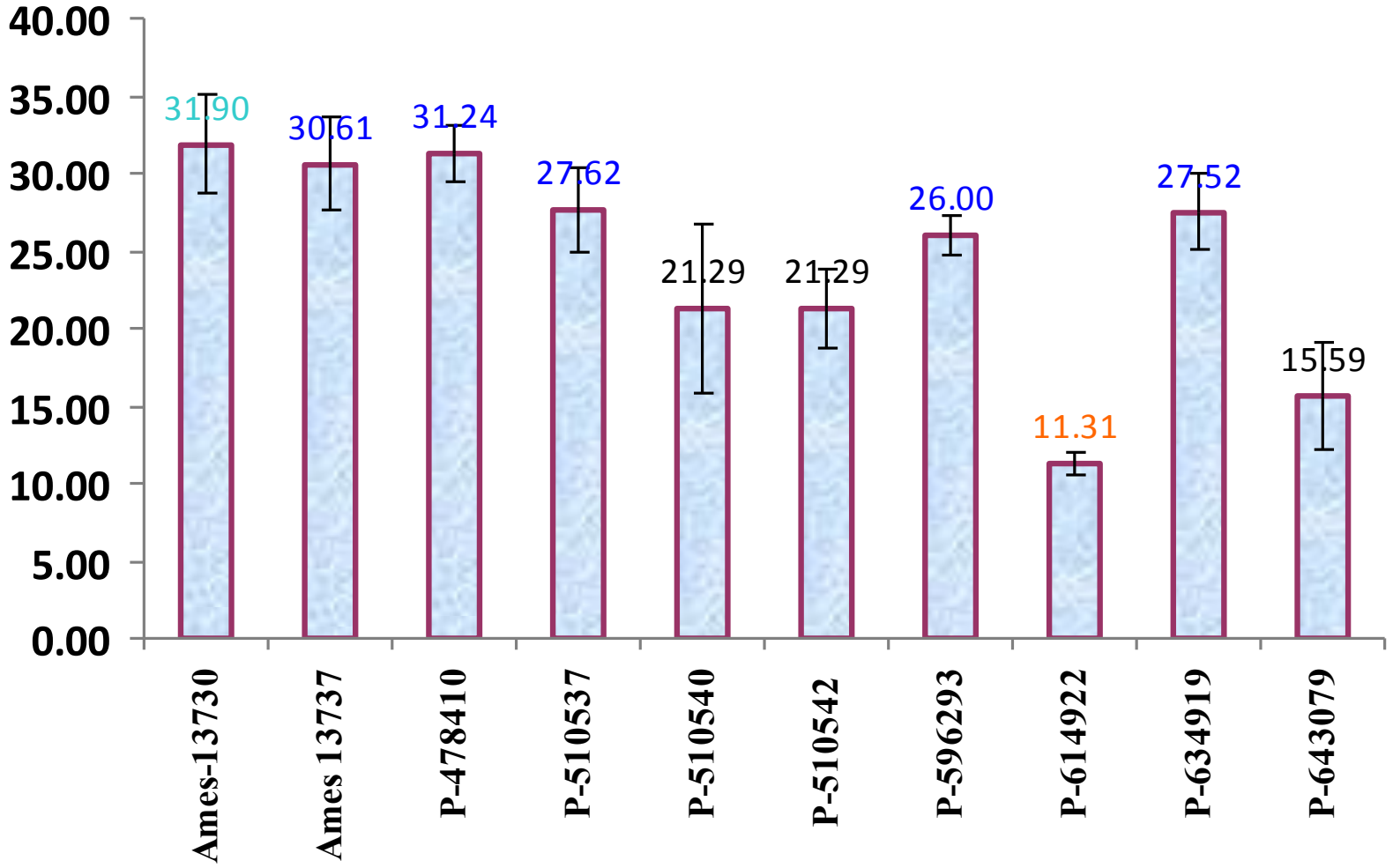
- **Genotypes:** 10 (selected)
- **Site**: Agronomy Research Farm, University of Agriculture, **Faisalabad**
- **Replications:** 3
- **Design:** Randomized Complete Block Design (RCBD)
- **Sowing architecture** **ridge sowing (RxR=75cm, PxP 15cm)**

- **Emergence and yield parameters**:
  - Final emergence (%)
  - Plant height (cm)
  - Leaf area (cm2)
  - No. of branches
  - No. of leaves
  - No. of panicles per plant
  - 1000 grain weight (g)
  - Biological yield (kg ha-1)
  - Economic yield (kg ha-1)
  - Harvest index
  - Seedling survival percentage
- **Analysis were done for evaluating individual effect of emergnece and growth parameters on Economic yield of field grown quinoa employing correlation matrix, path matrix and multi-regression equation**

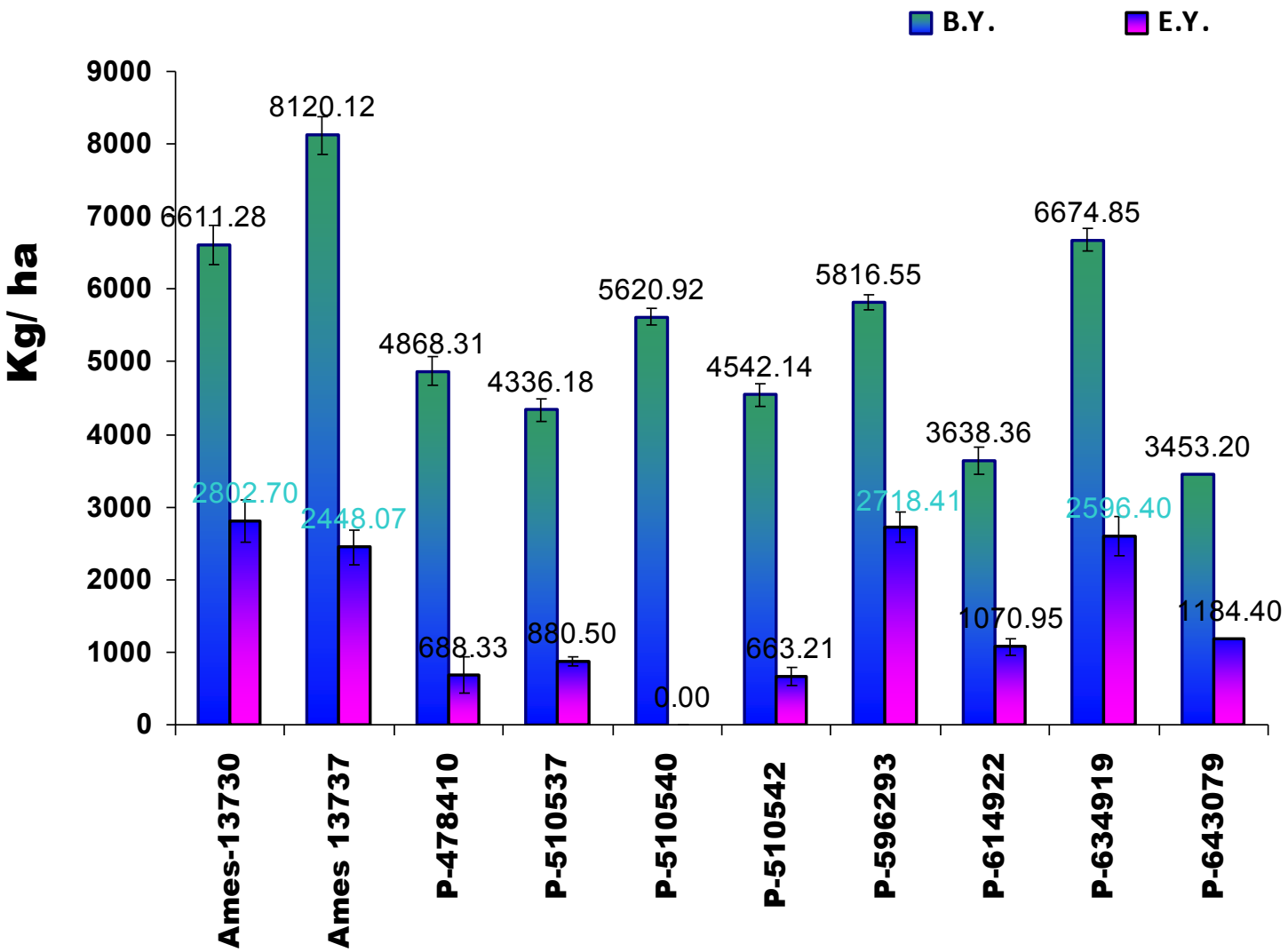
Emergence (%) of field grown quinoa genotypes



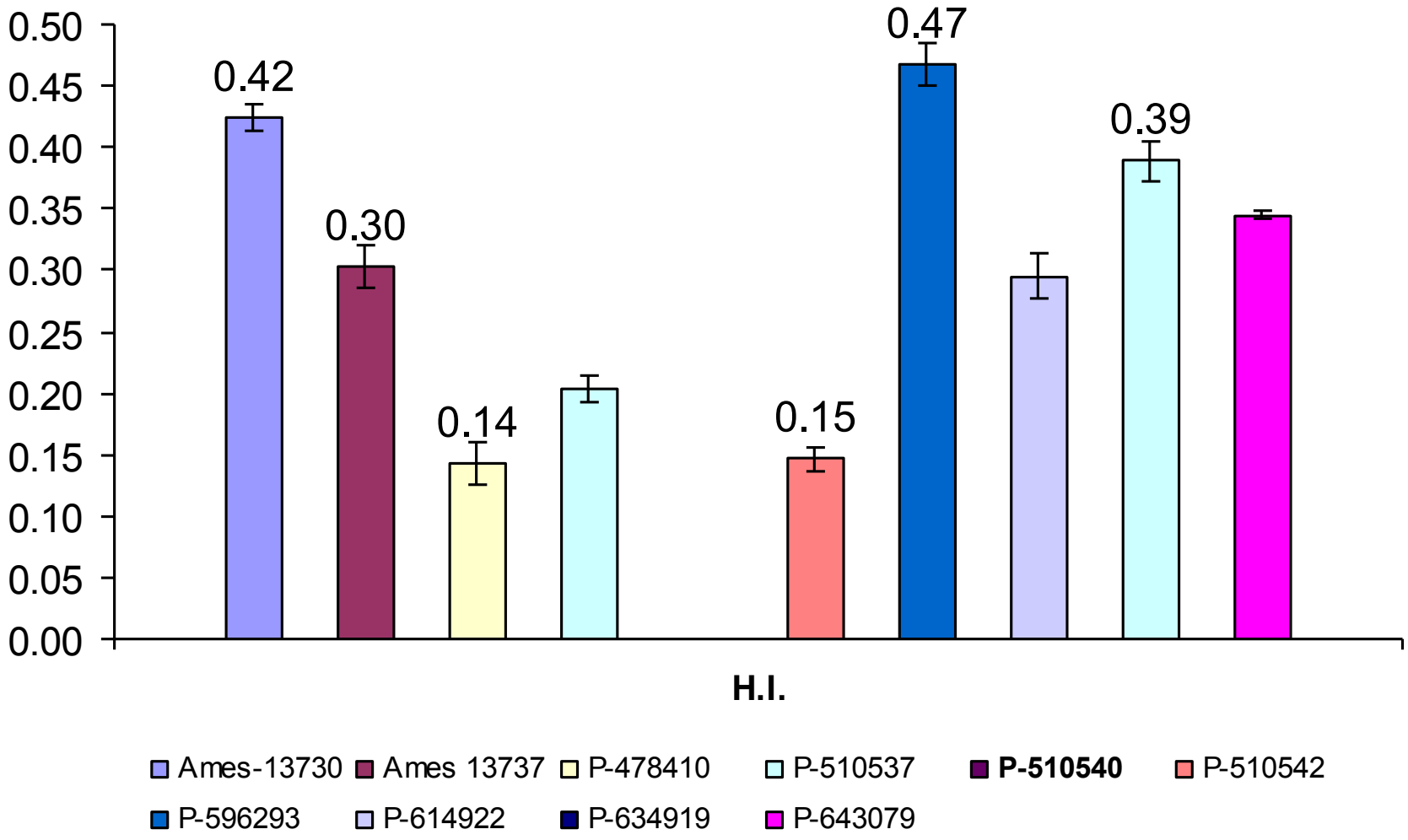
Number of Panicles per plant of field grown quinoa genotypes



Economic and biological yield of field grown quinoa



Comparison of field grown quinoa genotypes for Harvest Index



FSD-2008

Evaluating quinoa stand establishment methods

Sowing methods: 2

1. **Direct seeding**: choka method (hand placed)
2. **Transplantation:** ½ month age raised nursery (sand+soil+compost (1:1:1))

Replications 3

Genotypes: 10 (Agronomy Farm, University of Agriculture, Faisalabad)

Growth and yield parameters:

- Final emergence (%)
- Seedling survival rate (30 days after transplanting) (%)
- Plant height (cm)
- Leaf area (cm2)
- Number of branches
- Length of the main panicle (cm)
- Number of panicles per plant, and Number of leaves per

Table# 1

COMPARISON BETWEEN DIRECT SEEDED AND TRANSPLANTED QUINOA FOR FINAL EMERGENCE (%)

Genotypes	Direct sown	Transplant
Ames-13730	82.33 cd	94.68 a
Ames 13737	82.41 cd	96.27 a
P-478410	63.39 fg	85.64 bc
P-510537	70.37 ef	75.70 de
P-510540	61.77 gh	75.18 de
P-510542	54.78 h	75.48 de
P-596293	38.93 i	85.38 bc
P-614922	36.02 i	86.96 bc
P-634919	92.38 ab	91.82 ab
P-643079	56.97 gh	77.50 de

LSD for genotypes: 5.18
LSD for sowing method: 2.82
LSD for GxS interaction: 7.32

DIRECT SEED AND TRANSPLANTED QUINOA FOR NUMBER OF PANICLES PER PLANT

Genotypes	Direct sown	Transplant	mean
Ames-13730	29.84 ab	18.26 cde	24.05 A
Ames 13737	31.55 a	16.21 def	23.88 A
P-478410	32.26 a	9.14 hi	20.70 B
P-510537	29.22 ab	6.78 i	17.99 B
P-510540	18.73 cd	11.62 gh	15.18 C
P-510542	21.99 c	7.69 hi	14.85 C
P-596293	26.86 b	0.00 j	13.43 C
P-614922	11.69 fgh	0.00 j	5.84 D
P-634919	28.47 ab	18.64 cde	23.56 A
P-643079	14.75 efg	0.00 j	7.38 D
Means	24.54 A	8.84 B	

LSD for genotypes: 2.79
LSD for sowing method:
LSD for GxS interaction: 3.95

DIRECT SEED AND TRANSPLANTED QUINOA FOR SEEDLING SURVIVAL (%)

Genotypes	Direct sown	Transplant	mean
Ames-13730	98.82 a	85.83 b	92.33 B
Ames 13737	97.60 a	98.24 a	97.92 A
P-478410	74.16 c	36.34 g	55.25 D
P-510537	69.76 cd	64.25 d	67.00 C
P-510540	56.88 e	48.38 f	52.63 D
P-510542	56.70 e	24.58 h	40.64 E
P-596293	74.89 c	0.00 i	37.45 E
P-614922	40.05 g	0.00 i	20.02 F
P-634919	88.53 b	88.53 b	88.53 B
P-643079	27.65 h	0.00 i	13.83 G
Means	68.51 A	44.62 B	

LSD for genotypes: 4.23
LSD for sowing method: 3.61
LSD for GxS interaction: 5.98

DIRECT SEED AND TRANSPLANTED QUINOA FOR 1000 grain weight (g)

Genotypes	Direct sown	Transplant	mean
Ames-13730	2.80ab	2.26 cd	2.53 A
Ames 13737	2.59 ab	2.26 cd	2.43 A
P-478410	2.19 cd	0.76 gh	1.48 D
P-510537	2.28 cd	0.44 h	1.36 DE
P-510540	0.00 I	0.00 g	0.00 G
P-510542	1.61 fg	1.01ef	1.31 E
P-596293	3.42 a	0.00 g	1.71 C
P-614922	1.83 ef	0.00 g	0.91 F
P-634919	2.23 cd	1.88 ef	2.10 B
P-643079	2.51 b	0.00 g	1.25 E
Means	2.16 A	0.86 B	

LSD for genotypes: 0.14
LSD for sowing method: 0.23
LSD for GxS interaction: 0.29

DIRECT SEED AND TRANSPLANTED QUINOA FOR ECONOMIC YIELD (kg/ha)

Genotypes	Direct sown	Transplant	mean
Ames-13730	2689.3 a	1166.5 ef	1927.90 A
Ames 13737	2352.5 c	1234.1 e	1797.80 B
P-478410	663.35 h	129.89 i	396.62 FG
P-510537	845.18 g	82.62 ij	463.90 EF
P-510540	0.00 ij	0.00 j	0.00 H
P-510542	635.74 h	136.84i	386.29 G
P-596293	2611.0 a	0.00 j	1305.50 C
P-614922	1029.01f	0.00 j	514.50 DE
P-634919	2489.9 b	1381.1 d	1935.50 A
P-643079	1138.1ef	0.00 j	569.07 D
Means	1445.43 A	414.01 B	

LSD for genotypes: 72.70
LSD for sowing method: 150.44
LSD for GxS interaction: 102.82

DIRECT SEED AND TRANSPLANTED QUINOA FOR MAIN PANICLE LENGTH (cm)

Genotypes	Direct sown	Transplant	mean
Ames-13730	16.05 d	10.64 fg	13.43 CD
Ames 13737	23.78 c	10.84 fg	17.31 A
P-478410	12.78 ef	6.49 hi	9.64 EF
P-510537	14.77 de	4.20 i	9.48 F
P-510540	14.72 de	8.19 gh	11.45 DE
P-510542	13.67 de	7.71 h	10.69 EF
P-596293	29.38 b	0.00 j	14.69 BC
P-614922	27.76 b	0.00 j	13.88 C
P-634919	22.40 c	10.75 fg	16.56 AB
P-643079	33.43 a	0.00 j	16.72 A
mean	20.88 A	5.88 B	

LSD for genotypes: 1.96

LSD for sowing method: 0.85

LSD for GxS interaction: 2.77

DIRECT SEED AND TRANSPLANTED QUINOA FOR PLANT HEIGHT (cm)

Genotypes	Direct sown	Transplant	mean
Ames-13730	136.97 b	85.98 gh	111.47 E
Ames 13737	155.03 a	115.17 d	135.10 B
P-478410	119.84 cd	97.72 fg	108. 78 E
P-510537	132.60 b	102.17 ef	117.38 D
P-510540	150.81 a	107.84 de	129.33 C
P-510542	83.53 h	59.95 i	71.74 F
P-596293	97.91 efg	0.00 j	48.96 G
P-614922	65.75 i	0.00 j	32.88 I
P-634919	157.67 a	126.01 bc	141.84 A
P-643079	84.18 h	0.00 j	42.09 H
mean	118.43 A	69.48 B	

LSD for genotypes: 5.46
LSD for sowing method: 11.50
LSD for GxS interaction: 7.72

Table# 14

COMPARISON BETWEEN DIRECT SEED AND TRANSPLANTED QUINOA FOR DAYS TO PHYSIOLOGICAL MATURITY

Genotypes	Direct sown	Transplant	
Ames-13730	107.51 ef	115.94 de	111.73 CD
Ames 13737	129.32 b	114.62 de	121.97 B
P-478410	125.31 bc	127.03 bc	126.17 AB
P-510537	116.36 d	140.13 a	128.21 A
P-510540	0.00 g	0.00 g	0.00 G
P-510542	101.95 f	120.03 cd	110.99 D
P-596293	114.29 de	0.00 g	57.15 E
P-614922	102.93 f	0.00 g	51.47 F
P-634919	117.42 d	115.41 de	116.42 C
P-643079	103.32 f	0.00 g	51.67 F
Means	101.83 A	73.32 B	

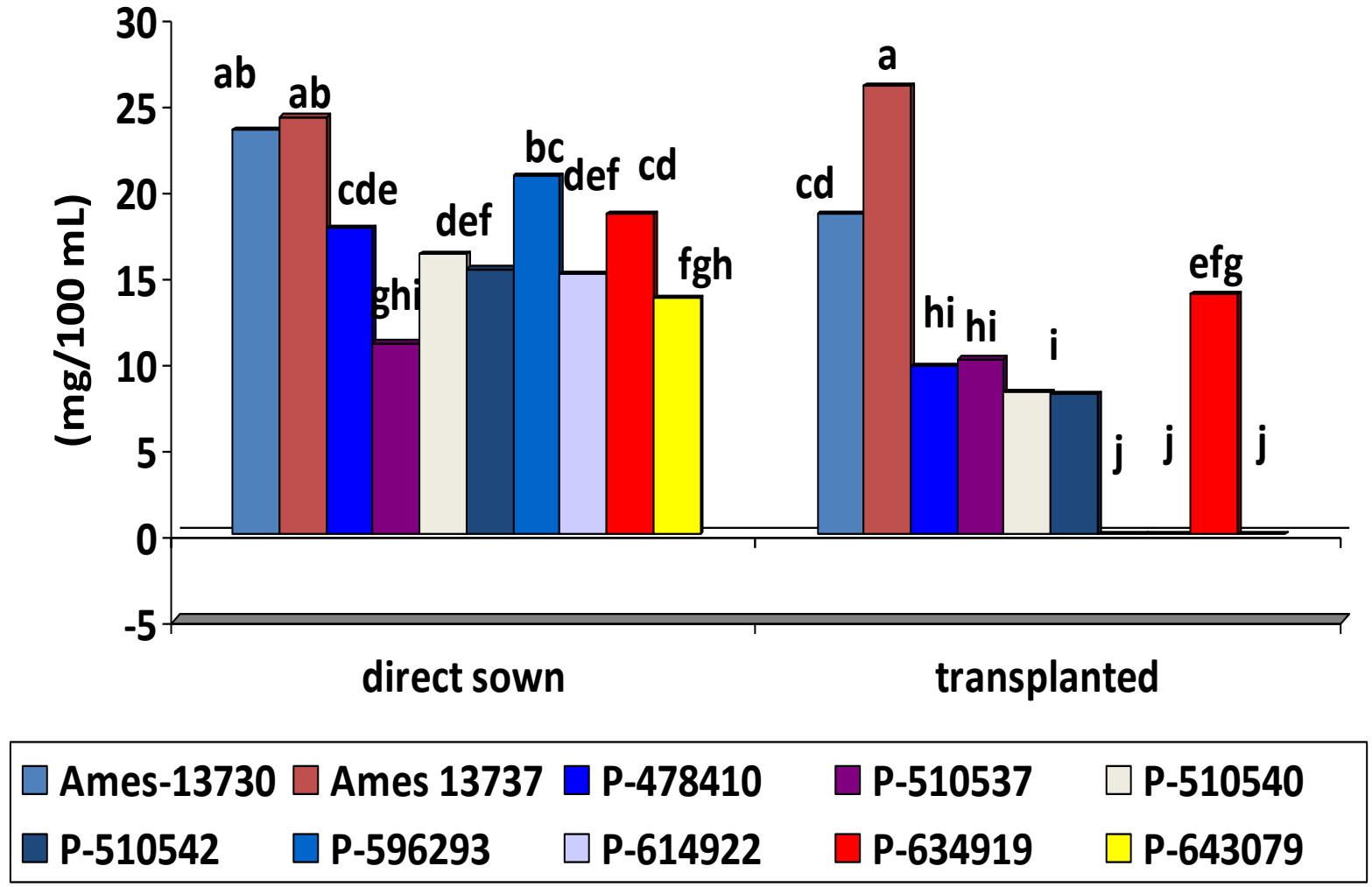
LSD for genotypes: 5.35

LSD for sowing method: 5.53

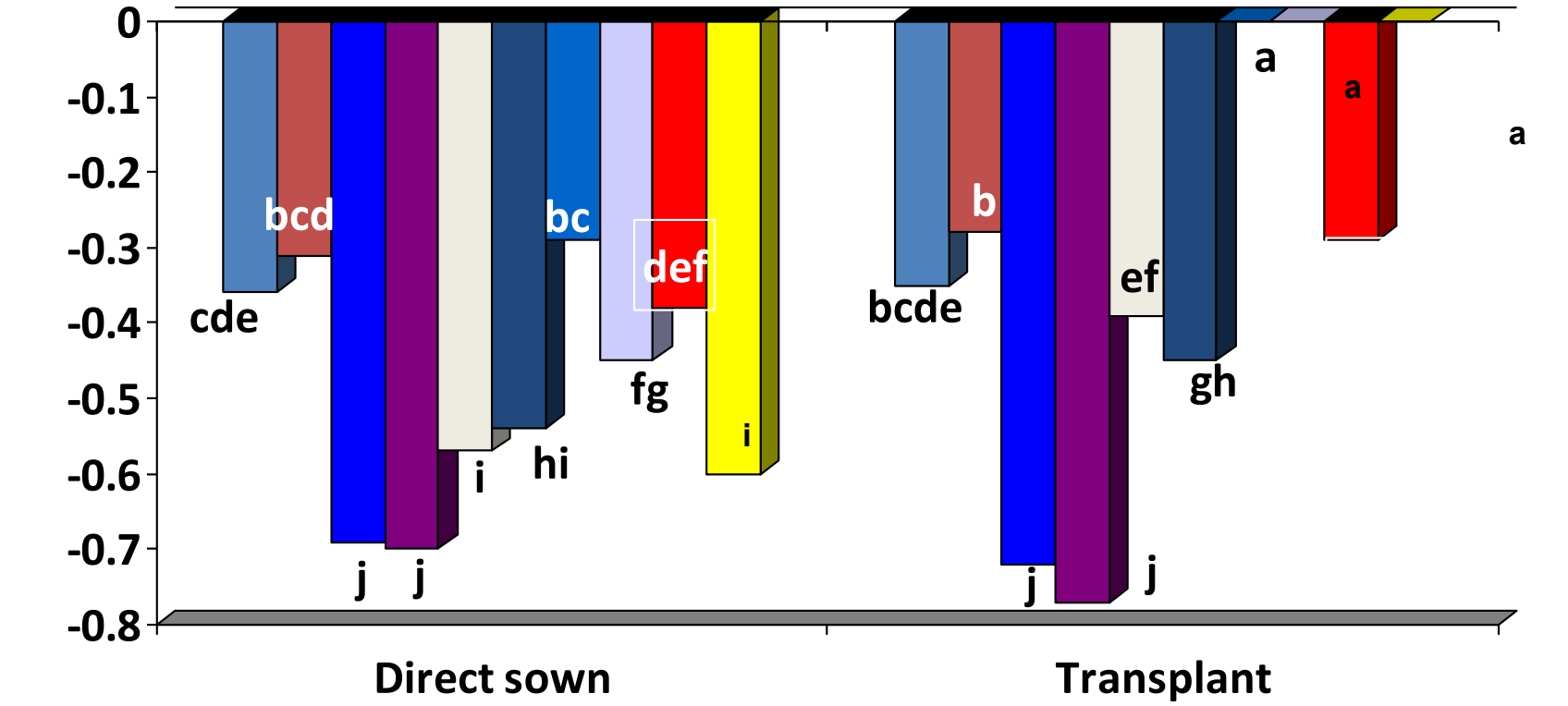
LSD for GxS interaction: 7.57

15

COMPARISON BETWEEN DIRECT SEED AND TRANSPLANTED QUINOA FOR Total Chlorophyll Content (mg/100 mL)

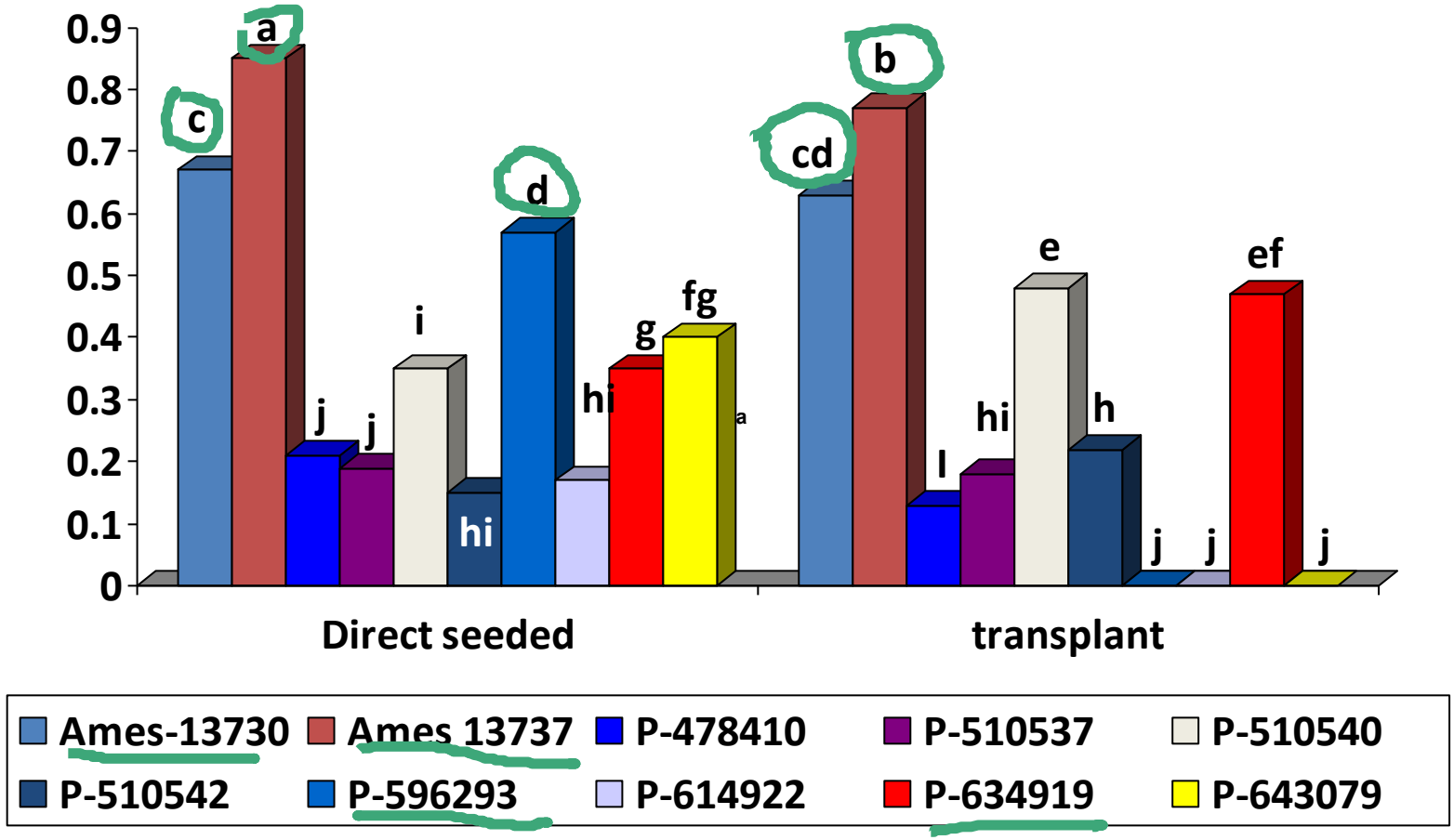


COMPARISON BETWEEN DIRECT SEED AND TRANSPLANTED QUINOA FOR LEAF WATER POTENTIAL (MPa)



LSD for GxS interaction:

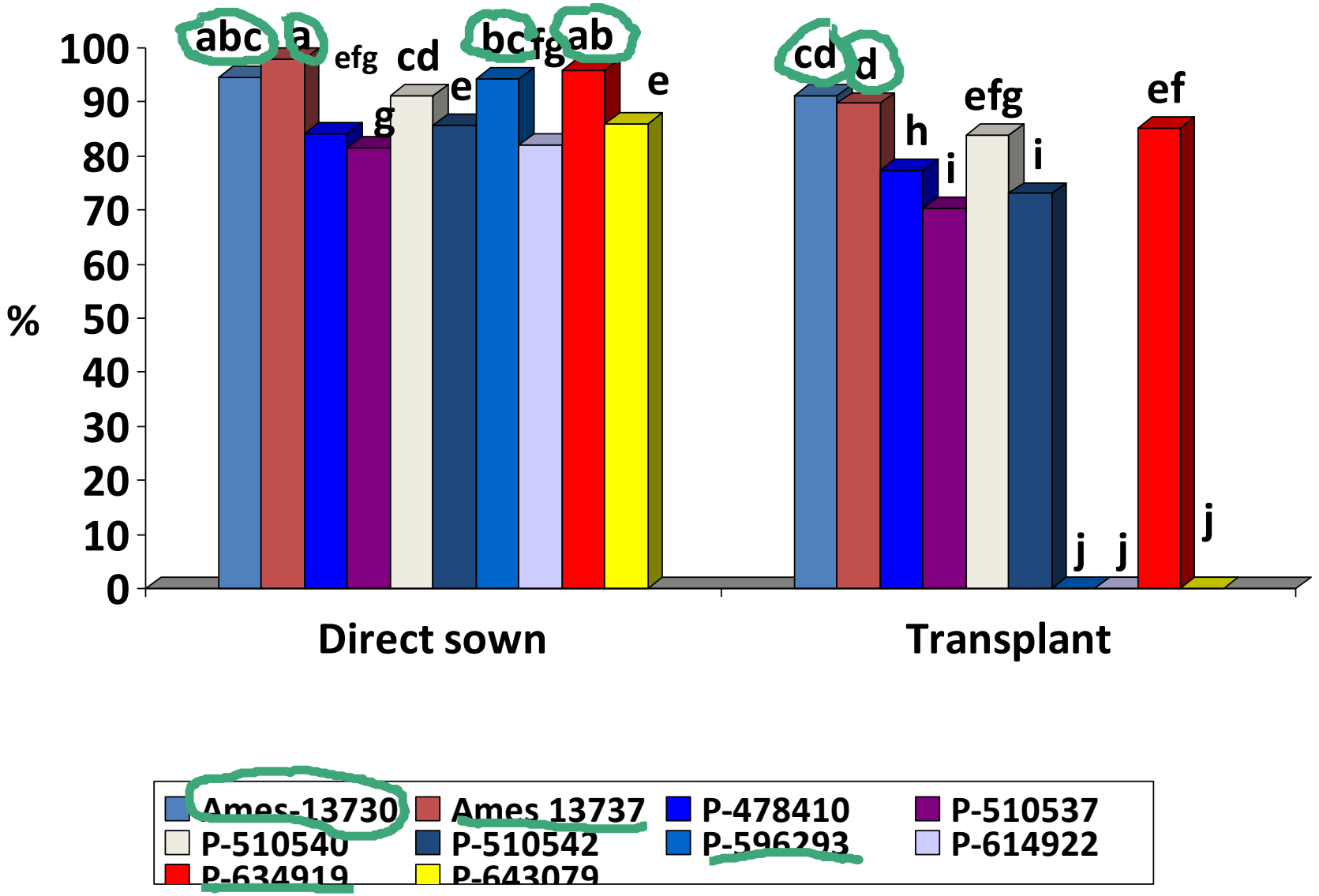
COMPARISON BETWEEN DIRECT SEED AND TRANSPLANTED QUINOA FOR PROLINE CONTENT (mmol./g fresh weight)



Table# 18

COMPARISON BETWEEN DIRECT SEED AND TRANSPLANTED QUINOA FOR RELATIVE WATER CONTENT (%)

LSD for GxS interaction:3



Winter 2009-10

GROWTH AND YIELD POTENTIAL OF QUINOA IN VARIOUS AGROECOLOGICAL ZONES OF PUNJAB

Sowing locations: **3 (Field Conditions)**

1. Faisalabad (R) **(UAF)** **2. Bahawalpur (R) S (DRI)** **3.** Chakwal (zr) **N (BARI)**

C=central S=South N= North (R) Rabi (zr) Zaid Rabi

- ***UAF: University** of Agriculture, Faisalabad*
- ***DRI: Desert Research Institute, The Islamia University of Bahawalpur***
- ***BARI: Barani Agricultural Research Institute, Chakwal***

Genotypes: **10**

Replications **3**

Emergence and yield parameters:

- Final emergence (%)
- Plant height (cm)
- Leaf area (cm^2)
- Number of branches
- Number of leaves
- Number of panicles per plant
- 1000 grain weight (g)
- Biological yield ($kg\ ha^{-1}$)
- Economic yield ($kg\ ha^{-1}$)
- Harvest index
- Seedling survival percentage

EFFECT OF DIFFERENT CLIMATIC CONDITIONS ON FINAL EMERGENCE (%) OF QUINOA

	FAISALABAD	CHAKWAL	BAHAWALPUR	Mean
Ames 13730	87.94 ab	71.82 de	75.26 d	78.341 A
Ames 13737	83.21 bc	58.67 hi	69.47 ef	70.45 B
P-478410	55.05 i-k	43.53 n	19.56 p	39.38 G
P-510537	64.71 fg	84.57 bc	50.93 k-m	66.74 C
P-510540	56.63 ij	68.07 ef	45.92 mn	56.87 E
P-510542	55.40 i-k	53.14 jk	25.57 o	44.70 F
P-596293	56.46 ij	67.86 ef	71.41 de	65.24 CD
P-614922	24.72 op	81.61 c	83.41 bc	63.25 D
P-634919	90.43 a	51.62 j-l	74.84 d	72.30 B
P-643079	55.08 i-k	47.45 l-n	62.38 gh	54.97 E
Mean	62.96 A	62.83 A	57.88 B	

LSD value for genotypes: 1.33
LSD value for Location: 0.73
LSD value for interaction: 2.31

EFFECT OF DIFFERENT CLIMATIC CONDITIONS ON 1000 GRAIN WEIGHT (g) OF QUINOA

	Faisalabad	Chakwal	Bahawalpur	Mean
Ames 13730	3.68 bc	2.43 gh	2.72 e	2.94 B
Ames 13737	3.11 d	2.66 ef	2.28 hi	2.68 C
P-478410	1.91 kl	2.14 ij	1.15 o	1.73 E
P-510537	1.21 o	1.65 m	1.75 lm	1.54 F
P-510540	0.00 p	0.00 p	0.00 p	0.00 I
P-510542	1.22 o	1.55 mn	0.00 p	0.92 H
P-596293	3.82 ab	3.11 d	3.97 a	3.63 A
P-614922	1.94 j-l	2.06 jk	0.00 p	1.33 G
P-634919	2.56 e-g	1.35 no	3.58 c	2.50 D
P-643079	2.48 f-h	2.14 ij	0.00 p	1.54 F
Mean	2.19 A	1.91 B	1.55 C	

LSD value for genotypes: 0.13

LSD value for Location: 0.07

EFFECT OF DIFFERENT CLIMATIC CONDITIONS ON LEAF AREA (cm) OF QUINOA

	FAISALABAD	CHAKWAL	BAHAWALPUR	Mean
Ames 13730	30.55 a	24.74 c-e	18.17 hi	24.49 A
Ames 13737	28.28 ab	25.31 b-d	13.77 jk	22.45 BC
P-478410	23.69 c-f	25.68 bc	13.16 k-l	20.84 CD
P-510537	22.36 d-g	21.06 f-h	10.39 lm	17.94 A
P-510540	20.12 gh	15.05 jk	10.33 lm	15.16 F
P-510542	14.46 jk	13.22 kl	9.30 m	12.33 G
P-596293	30.71 a	18.12 hi	20.03 gh	22.95 AB
P-614922	24.25 c-e	18.17 hi	0.00 n	14.14 F
P-634919	21.73 e-g	14.91 jk	22.35 d-g	19.66 DE
P-643079	16.70 ij	13.93 jk	0.00 n	10.21 H
Mean	23.28 A	19.02 B	11.75 C	

LSD value for genotypes: 1.77
LSD value for Location: 0.97
LSD value for interaction: 3.06

EFFECT OF DIFFERENT CLIMATIC CONDITIONS ON NUMBER OF PANICLES PER PLANT OF QUINOA

	Faisalabad	Chakwal	Bahawalpur	Mean
Ames 13730	34.54 a	25.03 e-f	28.53 cd	29.37 A
Ames 13737	26.18 d-f	20.12 hi	17.82 i	31.38 C
P-478410	31.88 ab	21.52 gh	8.73 lm	20.71 C
P-510537	27.97 cd	29.58 bc	5.90 m	21.15 C
P-510540	18.18 hi	10.44 kl	0.00 n	9.54 DE
P-510542	19.86 hi	13.08 j	0.00 n	10.98 D
P-596293	25.81 d-f	27.85 c-e	24.03 fg	25.90 B
P-614922	10.66 jk	13.85 j	0.00 n	8.17 E
P-634919	24.91 f	14.30 j	20.14 hi	19.78 C
P-643079	14.81 i	9.45 kl	0.00 n	8.09 E
Mean	23.48 A	18.52 B	10.52 C	

LSD value for genotypes: 1.69

LSD value for Location: 0.92

LSD value for interaction: 2.92

EFFECT OF DIFFERENT CLIMATIC CONDITIONS ON PLANT HEIGHT (cm) OF QUINOA

	Faisalabad	Chakwal	Bahawalpur	Mean
Ames 13730	134.98 cd	110.49 ij	102.68 k	116.05 C
Ames 13737	141.46 bc	118.82 e-g	117.33 e-i	125.87 B
P-478410	121.10 ef	100.60 kl	83.17 no	101.62 E
P-510537	113.14 g-i	113.40 g-i	83.13 o	103.22 E
P-510540	146.94 b	133.13 d	123.41 e	134.49 A
P-510542	94.42 lm	110.84 h-j	118.08 e-h	107.78 D
P-596293	120.28 f-g	104.11 jk	101.79 kl	108.73 D
P-614922	77.69 o	87.88 mn	0.00 p	55.19 G
P-634919	166.41 a	122.10 ef	114.71 f-i	134.41 A
P-643079	88.58 mn	110.90 h-j	0.00 p	66.49 F
Mean	120.5 A	11.23 B	84.43 C	

LSD value for genotypes: 4.28

LSD value for Location:

2.34

EFFECT OF DIFFERENT CLIMATIC CONDITIONS ON BIOLOGICAL YIELD (Kg/ha) OF QUINOA

	FAISALABAD	CHAKWAL	BAHAWALPUR	Mean
Ames 13730	5878.80 b	2891.81 j	1901.43 m	3557.30 C
Ames 13737	6684.50 a	3909.35 g	1630.63 n	4074.8 A
P-478410	3647.27 h	2172.13 l	1235.14 o	2351.5 F
P-510537	4184.81 f	4940.07 d	850.13 p	3325.0 D
P-510540	4781.92 de	3449.12 h	413.30 q	2881.4 E
P-510542	4167.16 f	2474.10 k	741.97 p	2461.18 F
P-596293	4586.01 e	3214.94 i	2417.62 k	3406.2 D
P-614922	3221.52 i	2898.28 j	0.00 r	2039.9 G
P-634919	5438.60 c	2707.30 j	3217.90 i	3787.9 B
P-643079	2754.12 j	1993.21 lm	0.00 r	1582.4 H
Mean	4534.5 A	3065.0 B	1240.8 C	

LSD value for genotypes: 128.31

LSD value for Location:

70.28

LSD value for interaction: 222.24

EFFECT OF DIFFERENT CLIMATIC CONDITIONS ON ECONOMIC YIELD (Kg/ha) OF QUINOA

	FAISALABAD	CHAKWAL	BAHAWALPUR	Mean
Ames 13730	2744.16 a	1300.41 e	468.19 kl	1504.30 BC
Ames 13737	2686.94 ab	1300.00 e	539.86 j	1508.90 B
P-478410	685.05 i	986.57 f	298.68 m	656.70 E
P-510537	712.02 hi	1626.95 c	199.72 n	846.23 D
P-510540	0.00 o	0 .00 o	0.00 o	0.00 H
P-510542	591.93 j	764.45 h	0.00 o	452.13 G
P-596293	2638.65 b	1474.16 d	850.46 g	1654.41 A
P-614922	880.46 g	436.85 l	0.00 o	439.10 G
P-634919	2746.35 a	888.53 g	771.72 h	1468.93 C
P-643079	1053.72 f	534.86 jk	0.00 o	529.53 F
Mean	1473.90 A	931.34 B	312.89 C	

LSD value for genotypes: 39.83

LSD value for Location: 21.82

LSD value for interaction: 69.0

Table 10

EFFECT OF DIFFERENT CLIMATIC CONDITIONS ON HARVEST INDEX OF QUINOA

	Faisalabad	Chakwal	Bahawalpur	Mean
Ames 13730	0.47 c	0.45 c	0.25 h-j	0.39 B
Ames 13737	0.40 d	0.33 fg	0.33 fg	0.36 C
P-478410	0.19 k	0.45 c	0.24 h-j	0.29 D
P-510537	0.17 kl	0.33 fg	0.24 j	0.25 E
P-510540	0.00 m	0.00 m	0.00 m	0.00 H
P-510542	0.14 l	0.31 g	0.00 m	0.15 G
P-596293	0.58 a	0.46 c	0.35 ef	0.46 A
P-614922	0.27 h	0.15 l	0.00 m	0.14 G
P-634919	0.51 b	0.33 fg	0.24 ij	0.36 C
P-643079	0.38 de	0.27 hi	0.00 m	0.22 F
Mean	0.31 A	0.31A	0.17 B	

LSD value for genotypes: 0.02

LSD value for Location:

LSD value for interaction: 0.03

Table 11

EFFECT OF DIFFERENT CLIMATIC CONDITIONS ON MAIN PANICLE LENGTH (cm) OF QUINOA

	FAISALABAD	CHAKWAL	BAHAWALPUR	Mean
Ames 13730	16.22 f	16.09 f	11.40 h-j	14.57 BC
Ames 13737	21.86 c-e	16.38 f	7.38 mn	15.21 B
P-478410	11.61 h-j	7.89 lm	5.99 n	8.50 E
P-510537	12.50 gh	23.13 bc	6.86 mn	14.17 C
P-510540	12.01 hi	10.21 jk	0.00 o	7.41 F
P-510542	16.73 f	8.97 kl	0.00 o	8.57 E
P-596293	24.23 ab	20.99 e	15.88 f	20.36 A
P-614922	15.26 f	10.75 ij	0.00 o	8.67 E
P-634919	24.98 a	22.68 cd	13.68 g	20.44 A
P-643079	21.42 de	11.05 h-j	0.00 o	10.82 D
Mean	17.68 A	14.81 B	6.12 C	

LSD value for genotypes: 0.85

LSD value for Location: 0.47

LSD value for interaction: 1.47

Table 12

EFFECT OF DIFFERENT CLIMATIC CONDITIONS ON STEM DIAMETER (cm) OF QUINOA

	FAISALABAD	CHAKWAL	BAHAWALPUR	Mean
Ames 13730	2.23 h-j	4.35 ab	4.17 b	3.59 A
Ames 13737	2.01 jk	4.65 a	3.23 de	3.30 B
P-478410	1.15 no	2.54 gh	1.48 l-n	1.72 F
P-510537	1.05 o	4.38 ab	2.14 i-k	2.53 D
P-510540	1.35 m-o	2.95 ef	2.27 h-j	2.19 E
P-510542	1.57 lm	2.49 g-i	2.66 fg	2.24 E
P-596293	2.33 g-j	4.18 b	4.24 b	3.58 A
P-614922	1.16 no	1.60 lm	0.00 p	0.92 G
P-634919	1.79 kl	3.39 cd	3.66 c	2.95 C
P-643079	1.12 o	2.00 jk	0.00 p	0.02 G
Mean	1.56 C	3.25 A	2.38 B	

LSD value for genotypes: 0.20

LSD value for Location: 0.11

LSD value for interaction: 0.35

Table 13

EFFECT OF DIFFERENT CLIMATIC CONDITIONS ON SEEDLING SURVIVAL (%) OF QUINOA

	FAISALABAD	CHAKWAL	BAHAWALPUR	Mean
Ames 13730	96.37 a	69.95 ef	52.39 g	72.9 A
Ames 13737	95.59 a	68.92 ef	54.71 g	73.08 A
P-478410	73.93 de	76.25 cd	30.89 i	60.36 B
P-510537	69.56 ef	85.33 b	29.04 i	61.31 B
P-510540	67.62 f	53.88 g	39.35 h	53.62 C
P-510542	57.66 g	43.99 h	31.51 i	44.39 D
P-596293	81.06 bc	70.90 d-f	71.10 d-f	74.35 A
P-614922	30.97 i	40.25 h	0.00 j	23.74 F
P-634919	86.09 b	66.93 f	73.81 de	75.61 A
P-643079	52.42 g	44.08 h	0.00 j	32.17 E
Mean	71.13 A	62.05 B	38.28 C	

LSD value for genotypes: 3.48

LSD value for Location: 1.90

LSD value for interaction: 6.01

Table 14

EFFECT OF DIFFERENT CLIMATIC CONDITIONS ON VIABILITY OF GRAIN PRODUCE (%) OF QUINOA

	FAISALABAD	CHAKWAL	BAHAWALPUR	Mean
Ames 13730	28.51 fg	48.70 c	9.95 i-k	29.05 C
Ames 13737	40.23 d	33.06 ef	16.62 h	29.97 C
P-478410	18.83 h	49.25 c	5.42 j-l	24.5 D
P-510537	13.86 hi	71.90 a	10.19 ij	31.98 C
P-510540	0.53 lm	0.00 m	0.00 m	0.19 G
P-510542	17.46 h	0.00 m	0.00 m	5.82 F
P-596293	57.14 b	35.19 de	27.22 g	39.85 B
P-614922	0.00 m	0.00 m	0.00 m	0.00 G
P-634919	61.99 b	60.43 b	33.99 e	52.13 A
P-643079	4.95 k-m	28.52 fg	0.00 m	11.16 E
Mean	24.35 B	32.71 A	10.34 C	

LSD value for genotypes: 3.01

LSD value for Location: 1.65

LSD value for interaction: 5.21

Summary

- Response of genotypes under:
  - **Faisalabad**: 634919, Ames 13730; 13737, 596293

  For economic or biological yield, final emergence, viability of the produce, per plant leaves; branches; panicles
  - **Chakwal**: 510537, Ames 13730; 13737 and to a certain extent 596293

  For viability of the produce, biological, economic yields, panicles, leaves
  - **Bahawalpur:** 634919 is key genotype
  - **PI-643079** was found most stable genotype for being low yielder as well as stable in all three regimes.

Faisalabad


2012 FSD

Chakwal

Optimization of sowing date in quinoa germplasm

Sowing dates: 1. 15Th October 2. 15th November
3. 15th December 4. 15th January

Genotypes: 10 (Screened during year I)

Emergence and yield parameters:

- Final emergence (%)
- Plant height (cm)
- Leaf area (cm2)
- Number of branches
- Number of leaves
- Number of panicles per plant
- 1000 grain weight (g)
- Biological yield (kg ha-1)
- Economic yield (kg ha-1)
- Harvest index
- Seedling survival percentage

Table IX:

EFFECT OF SOWING DATE ON ECONOMIC YIELD (kg/ha) OF DIFFERENT QUINOA GENOTYPES UNDER FAISALABAD CONDITIONS

	15 OCT	15 NOV	15 DEC	15 JAN	Mean
Ames 13730	1611.52 f	2470.54 c	2505.11 bc	542.70 j-m	1782.5 B
Ames 13737	1672.33 f	2643.94 b	2909.25 a	425.82 l-n	1912.8 A
P-478410	551.98 j-m	678.11 j	484.80 l-n	133.19 pq	462.0 E
P-510537	385.91 no	651.91 j	408.20 m-o	219.87 p	416.5 E
P-510540	0.00 pq	0.00 op	0.00 q	0.00 q	66.7 F
P-510542	0.00 q	990.03 h	567.75 j-l	0.00 q	389.4 E
P-596293	2051.52 e	1757.71 f	2488.54 c	406.37 m-o	1676.0 C
P-614922	389.44 m-o	831.03 i	501.86 k-n	0.00 q	430.6 E
P-634919	1262.74 g	2061.30 de	2207.95 d	641.15	1543.3 D
P-643079	0.00 q	1089.51 h	469.89 l-n	0.00 q	389.9 E
Mean	792.5 C	1344.1 A	1254.3 B	236.9 D	

LSD value for genotypes: 76.06

LSD value for Location: 46.85

LSD value for interaction: 148.14

Table X:
EFFECT OF SOWING DATE ON HARVEST INDEX OF DIFFERENT QUINOA GENOTYPES UNDER FAISALABAD CONDITIONS

	15 OCT	15 NOV	15 DEC	15 JAN	Mean
Ames 13730	0.42 f-h	0.51 de	0.47 ef	0.20 l-n	0.4 B
Ames 13737	0.51 de	0.61 ab	0.55 cd	0.19 l-o	0.46 A
P-478410	0.26 jk	0.18 m-p	0.15 o-q	0.10 r	0.17 F
P-510537	0.14 pq	0.20 l-n	0.11 qr	0.19 l-o	0.16 FG
P-510540	0.00 s	0.00 r	0.00 s	0.00 s	0.02 H
P-510542	0.00 s	0.00 fg	0.00 pq	0.00 s	0.14 G
P-596293	0.54 cd	0.58 bc	0.54 cd	0.23 j-l	0.47 A
P-614922	0.36 i	0.63 ab	0.17 n-p	0.00 s	0.29 D
P-634919	0.28 j	0.38 hi	0.38 hi	0.40 g-i	0.35 C
P-643079	0.00 s	0.65 a	0.23 km	0.00 s	0.22 E
Mean	0.25 C	0.42 A	0.27 B	0.13 D	

LSD value for genotypes: 0.02
LSD value for Location: 0.02
LSD value for interaction: 0.05

Table XIII:

EFFECT OF SOWING DATE ON seedling survival (%) OF DIFFERENT QUINOA GENOTYPES UNDER FAISALABAD CONDITIONS

% seedling survival	15 OCT	15 NOV	15 DEC	15 JAN	Mean
Ames 13730	70.58 bc	64.37 d	72.12 b	27.34 o-q	58.6A
Ames 13737	52.36 fg	57.70 e	79.41 a	23.32 p-r	53.2 B
P-478410	21.05 r-t	46.43 h-j	35.86 lm	26.99 o-q	32.58 E
P-510537	24.19 p-r	33.58 mn	43.12 jk	17.29 tu	29.55 F
P-510540	38.84 kl	50.78 gh	51.91 g	25.18 p-r	41.68 D
P-510542	18.30 s-u	27.98 op	33.40 mn	14.61 u-w	23.58 G
P-596293	66.84 cd	69.75 bc	64.35 d	27.83 o-q	57.19 A
P-614922	16.35 t-v	36.66 lm	45.15 ij	10.68 w	27.21 F
P-634919	48.82 g-i	57.10 ef	64.43 d	22.91 q-s	48.32 C
P-643079	17.17 tu	23.91 p-r	30.38 no	11.90 vw	20.84 H
Mean	37.45 C	46.83 B	52.01 A	20.80 D	

LSD value for genotypes: 2.48

LSD value for Location: 1.57

LSD value for interaction: 4.96

Table XIV:

EFFECT OF SOWING DATE ON DAYS TO PHYSIOLOGICAL MATURITY OF DIFFERENT QUINOA GENOTYPES UNDER FAISALABAD CONDITIONS

	15 OCT	15 NOV	15 DEC	15 JAN	Mean
Ames 13730	107.86 ij	96.30 l-n	114.29 gh	134.44	113.22 C
Ames 13737	125.06 ef	110.00 hi	134.35 d	127.08 e	124.12 B
P-478410	109.67 hi	99.41 lm	92.17 no	163.48 a	116.18 C
P-510537	109.00 hi	118.91 fg	85.78 p	150.48 b	116.04 C
P-510540	127.33 e	152.79 b	0.00 q	0.00 q	70.03 F
P-510542	110.00 hi	125.53 e	106.31 i-k	0.00 q	85.46 D
P-596293	129.66 de	116.68 g	101.15 kl	143.22 c	122.68 B
P-614922	109.33 hi	102.16 j-l	94.64mn	0.00 q	76.53 E
P-634919	123.67 ef	108.02 h-j	142.52 c	164.52 a	134.68 A
P-643079	109.90 hi	94.50 m-o	88.24 op	0.00 q	73.16 F
Mean	116.15 A	112.43 B	95.95 C	88.32 D	

LSD value for genotypes: 3.19

LSD value for Location: 2.02

LSD value for interaction: 6.39

Table XVIII:

EFFECT OF SOWING DATE ON VIABILITY OF THE PRODUCE (%) OF DIFFERENT QUINOA GENOTYPES UNDER FAISALABAD CONDITIONS

	15 OCT	15 NOV	15 DEC	15 JAN	Mean
Ames 13730	14.05 j	92.95 b-d	95.77 a-d	0.00 m	50.69 B
Ames 13737	19.44 i	95.69 a-d	96.69 ab	5.90 k	54.43 A
P-478410	7.65 k	83.16 e	93.20 b-d	0.00 m	46.01 C
P-510537	5.38 k	83.76 e	94.88 a-d	1.57 lm	46.39 C
P-510540	0.00 m	60.81 g	0.00 m	0.00 m	15.20 E
P-510542	0.00 m	64.53 fg	94.67 a-d	0.00 m	39.80 D
P-596293	17.35 ij	84.33 e	97.16 a	0.00 m	49.69 B
P-614922	5.07 kl	65.02 f	95.60 a-d	0.00 m	41.43 D
P-634919	26.56 h	92.18 d	96.43 a-c	7.65 k	55.7 A
P-643079	0.00 m	92.67 cd	93.63 a-d	0.00 m	46.58 C
Mean	9.55 C	81.51 B	85.81 A	1.51 D	

LSD value for genotypes: 1.89

LSD value for Location: 1.20

LSD value for interaction: 3.78

ASSESSMENT OF PHYSIOLOGICAL BASIS OF SALT TOLERANCE IN QUINOA

Salinity levels: 3

1. Control 2. 10 dS m^{-1} 3. 20 dS m^{-1}

Replication: 3

Varieties: 6 well acclimatized genotypes

Medium: Sand: Soil (1:1) (Pot study under net house conditions)

Stage of stress induction: 8 weeks old plants (gradual imposition)

Seedling growth parameters (after 30 days of stress imposition)**:**

- Plant height (cm)
- Root and shoot fresh and dry weights (g)
- Shoot and root lengths and ratio
- Number of Leaves
- Leaf area (cm^{-2})

ASSESSMENT OF PHYSIOLOGICAL BASIS OF SALT TOLERANCE IN QUINOA

- **Analytical parameters in leaves: (30 days after stress imposition)**
- Na^+, K^+ in leaf sap (mM)
- Leaf chlorophyll (mg 100 mL^{-1})
- Total soluble proteins (mg g^{-1} fresh wt)
- Antioxidants (Catalase, peroxidase, SOD, Total Phenolics)
- **Photosynthetic parameters and water relations** (15 days after stress imposition)
- Water potential (MPa)
- Osmotic pressure (MPa)
- Photosynthesis rate (µmol. m^{-2} S^{-1})
- Transpiration rate (mmol. m^{-2} S^{-1})

EFFECT OF SALINITY ON THE PLANT HEIGHT (cm) OF QUINOA GENOTYPES

	Control	10 dS m^{-1}	20 dS m^{-1}	Mean
Ames13730	86.283 b	86.730 b	75.560 c	82.858 B
Ames13737	76.220 c	67.620 ef	68.897 de	70.912 C
596293	72.313 cd	63.407 f	55.897 gh	63.872 D
634919	95.533 a	92.533 a	84.120 b	90.729 A
614922	67.957 de	57.720 g	49.787 i	58.488 E
643079	64.897 ef	52.220 hi	45.197 j	54.104 F
Mean	77.201 A	70.038 B	63.243 C	

LSD for genotype : 2.5388
LSD for saline levels : 1.7952
LSD for interaction : 4.3973

EFFECT OF SALINITY ON THE LEAF AREA (cm^2) OF QUINOA GENOTYPES

	Control	10 dS m^{-1}	20 dS m^{-1}	Mean
Ames13730	86.02 c	96.10 d	70.77 fg	84.30 C
Ames13737	104.01d	113.68 c	75.20 f	97.63 B
596293	64.92 g	56.21 h	44.34 i	55.15 D
634919	122.88 b	139.48 a	66.10 g	109.49 A
614922	44.63 i	20.25 j	21.77 j	28.88 E
643079	55.58 h	17.53 j	21.86 j	31.66 E
Mean	79.67 A	73.86 B	50.01 C	

LSD for genotype : 4.8599
LSD for saline levels : 3.4365
LSD for interaction : 8.4177

EFFECT OF SALINITY ON THE NUMBER OF DROPPED LEAVES OF SOME QUINOA GENOTYPES

	Control	10 dS m^{-1}	20 dS m^{-1}	Mean
Ames13730	10.087 gh	18.367 e	24.793 d	17.749 CD
Ames13737	8.477 gh	16.570 e	26.113 cd	17.053 D
596293	7.943 h	16.013 ef	24.593 d	16.183 D
634919	14.950 ef	24.630 d	29.987 c	23.189 B
614922	6.980 h	38.223 b	42.903 a	29.369 A
643079	12.180 fg	23.757 d	23.613 d	19.850 C
Mean	10.103 C	22.927 B	28.667 A	

LSD for genotype : 2.4177
LSD for saline levels : 1.7095
LSD for interaction : 4.1875

EFFECT OF SALINITY ON THE ROOT FRESH WEIGHT (g) OF SOME QUINOA GENOTYPES

	Control	10 dS m^{-1}	20 dS m^{-1}	Mean
Ames13730	9.867 cde	15.173 a	9.037 def	11.359 A
Ames13737	9.527 cdef	12.717 b	9.323 cdef	10.522 A
596293	12.963 b	12.543 b	8.223 f	11.243 A
634919	10.453 cd	13.690 ab	8.890 def	11.011 A
614922	9.390 cdef	10.627 c	8.363 ef	9.460 B
643079	10.727 c	13.807 ab	9.263 cdef	11.266 A
Mean	10.488 B	13.093 A	8.850 C	

LSD for genotype : 0.9130
LSD for saline levels : 0.6456
LSD for interaction : 1.5813

EFFECT OF SALINITY ON THE SHOOT FRESH WEIGHT (g) OF SOME QUINOA GENOTYPES

	Control	10 dS m^{-1}	20 dS m^{-1}	Mean
Ames13730	81.55 c	94.55 b	77.89 c	84.662 B
Ames13737	65.49 de	72.13 cd	63.54 de	67.057 C
596293	48.71 fg	56.25 ef	47.82 fgh	50.926 D
634919	97.63 ab	106.92 a	91.62 b	98.722 A
614922	48.84 fg	51.74 fg	32.36 i	44.316 E
643079	38.24 hi	42.31 gh	21.38 j	33.978 F
Mean	63.409 B	70.650 A	55.771 C	EF

LSD for genotype : 5.6572
LSD for saline levels : 4.00
LSD for interaction : 9.7985

EFFECT OF SALINITY ON THE ROOT DRY WEIGHT (g) OF SOME QUINOA GENOTYPES

	Control	10 dS m^{-1}	20 dS m^{-1}	Mean
Ames13730	2.93 fg	4.20 a	2.22 h	3.12 CD
Ames13737	3.03 efg	3.41 cde	2.58 gh	3.01 D
596293	3.94 ab	3.81 abc	3.09 ef	3.61 A
634919	3.21 def	3.93 ab	2.81 fg	3.32 BC
614922	3.63 bcd	2.98 efg	2.19 h	2.93 D
643079	3.05 ef	3.92 ab	3.57 bcd	3.51 AB
Mean	3.30 B	3.71 A	2.74 C	

LSD for genotype : 0.26
LSD for saline levels : 0.18
LSD for interaction : 0.45

EFFECT OF SALINITY ON THE TOTAL CHLOROPHYLL CONTENT (mg 100mL^{-1}) OF SOME QUINOA GENOTYPES

	Control	10 dS m^{-1}	20 dS m^{-1}	Mean
Ames13730	25.65 a	21.65 ab	17.33 cd	21.54 A
Ames13737	22.97 a	18.73 c	15.35 d	19.02 BC
596293	25.16 a	17.14 cd	12.13 def	18.15 C
634919	26.47 a	19.37 bc	14.97 de	20.27 AB
614922	14.78 d	10.93 ef	8.12 f	11.27 D
643079	16.25 cd	13.30 de	8.17 f	12.57 D
Mean	21.88 A	16.85 B	12.68 C	

LSD for genotype : 1.43

LSD for saline levels : 1.01

LSD for interaction : 4.06

EFFECT OF SALINITY ON THE LEAF SAP K CONTENT (Mm) OF SOME QUINOA GENOTYPES

	Control	10 dS m^{-1}	20 dS m^{-1}	Mean
Ames13730	282.12 a	189.91 de	155.03 fgh	209.02 A
Ames13737	283.86 a	200.01 cd	127.99 ij	203.95 A
596293	106.85 jk	136.67 hi	176.20 ef	139.90 B
634919	149.43 ghi	221.89 bc	267.51 a	212.94 A
614922	104.78 k	139.07 hi	163.55 fg	135.80 B
643079	153.83 fgh	225.80 b	264.57 a	214.73 A
Mean	180.14 B	185.56 AB	192.48 A	

LSD for genotype : 13.12
LSD for saline levels : 9.275
LSD for interaction : 22.72

EFFECT OF SALINITY ON THE LEAF SAP "Na" CONTENT (Mm) OF SOME QUINOA GENOTYPES

	Control	10 dS m^{-1}	20 dS m^{-1}	Mean
Ames13730	62.44 gh	18.03 k	143.52 d	74.66 C
Ames13737	66.53 fg	16.55 k	157.00 c	80.03 C
596293	29.31 jk	81.00 e	194.23 b	101.52 B
634919	32.27 j	75.73 ef	183.94 b	97.31 B
614922	51.51 hi	133.66 d	217.48 a	134.21 A
643079	40.67 ij	85.36 e	184.15 b	103.39 B
Mean	31.39 C	84.12 B	180.05 A	

LSD for genotype : 7.50

LSD for saline levels : 5.30

LSD for interaction : 13.00

EFFECT OF SALINITY ON LEAF K:Na RATIO OF SOME QUINOA GENOTYPES

	Control	10 dS m^{-1}	20 dS m^{-1}	Mean
Ames13730	17.220 a	3.067 bcde	1.087 cde	7.1244 A
Ames13737	17.860 a	3.020 bcde	0.827 de	7.2356 A
596293	3.653 bcd	1.687 cde	0.907 de	2.0822 BC
634919	4.643 b	2.990 bcde	1.457 cde	3.0300 B
614922	2.030 bcde	1.043 de	0.753 e	1.2756 C
643079	3.903 bc	2.657 bcde	1.437 cde	2.6656 BC
Mean	8.2183 A	2.4106 B	1.0778 C	

LSD for genotype : 1.64
LSD for saline levels : 1.16
LSD for interaction : 2.841

EFFECT OF SALINITY ON THE PEROXIDASE ACTIVITY (U. mg protein/ g fresh weight) IN LEAVES OF SOME QUINOA GENOTYPES

	Control	10 dS m^{-1}	20 dS m^{-1}	Mean
Ames13730	158.00 ghi	204.33 ef	257.33 bc	206.56 B
Ames13737	166.67 gh	213.33 de	287.33 a	222.44 A
596293	184.67 fg	124.67 jk	235.33 cd	181.56 C
634919	157.67 hi	216.00 de	272.67 ab	215.44 AB
614922	111.67 k	144.67 hij	125.67 jk	127.33 D
643079	114.33 k	136.00 ijk	162.67 ghi	137.67 D
Mean	148.83 C	173.17 B	223.50 A	

LSD for genotype : 10.97
LSD for saline levels : 15.516
LSD for interaction : 26.875

EFFECT OF SALINITY ON THE CATALASE ACTIVITY (U. mg protein/ g fresh weight) IN LEAVES OF SOME QUINOA GENOTYPES

	Control	10 dS m^{-1}	20 dS m^{-1}	Mean
Ames13730	29.420 b	24.747 cd	37.777 a	30.648 A
Ames13737	23.060 de	17.487 gh	27.120 bc	22.556 B
596293	18.790 fg	21.460 ef	27.013 bc	22.421 B
634919	17.370 gh	22.733 de	21.860 de	20.654 C
614922	14.853 hi	11.087 j	9.447 j	11.796 E
643079	18.850 fg	14.837 hi	12.083 ij	15.257 D
Mean	18.725 C	20.391 B	22.550 A	

LSD for genotype : 1.96

LSD for saline levels : 1.69

EFFECT OF SALINITY ON THE SUPER OXIDE DISMUTASE ACTIVITY (U. mg protein/ g fresh weight) IN LEAVES OF SOME QUINOA GENOTYPES

	Control	10 dS m^{-1}	20 dS m^{-1}	Mean
Ames13730	153.84 ef	175.06 bc	214.05 a	180.98 A
Ames13737	124.52 h	159.31 de	179.51 b	154.45 C
596293	115.83 h	118.02 h	145.48 fg	126.45 E
634919	142.72 fg	166.03 cd	208.24 a	172.33 B
614922	116.70 h	95.01 i	72.98 j	94.90 F
643079	115.86 h	140.78 g	162.44 de	139.69 D
Mean	128.24 C	142.37 B	163.78 A	

LSD for genotype : 6.69

LSD for saline levels : 4.73

LSD for interaction : 11.59

EFFECT OF SALINITY ON THE SUPER OXIDE DISMUTASE ACTIVITY (U. mg protein/ g fresh weight) IN LEAVES OF SOME QUINOA GENOTYPES

	Control	10 dS m^{-1}	20 dS m^{-1}	Mean
Ames13730	0.4333 fg	0.8133 c	1.0600 b	0.7689 A
Ames13737	0.4233 fg	0.8067 c	1.2700 a	0.8333 A
596293	0.2900 gh	0.5000 ef	0.7133 cd	0.5011 B
634919	0.4000 fg	0.7467 cd	1.2033 ab	0.7833 A
614922	0.2000 h	0.6167 de	0.5467 ef	0.4544 B
643079	0.1967 h	0.2100 h	0.2200 h	0.2089 C
Mean	0.3239 C	0.6156 B	0.8356 A	

LSD for genotype : 0.09
LSD for saline levels : 0.06
LSD for interaction : 0.15

EFFECT OF SALINITY ON THE TOTAL PHENOLIC CONTENT (µg g^{-1}fresh weight) IN LEAVES OF SOME QUINOA GENOTYPES

	Control	10 dS m^{-1}	20 dS m^{-1}	Mean
Ames13730	16.130 ijk	27.103 def	33.350 a	25.528 B
Ames13737	16.607 ij	25.937 ef	27.680 cde	23.408 C
596293	19.647 gh	24.960 f	28.797 bcd	24.468 BC
634919	14.843 jk	21.520 g	26.147 ef	20.837 D
614922	15.113 jk	30.793 b	30.133 bc	27.018 A
643079	20.127 gh	18.423 hi	14.117 k	15.884 E
Mean	17.078 C	24.789 B	26.704 A	

LSD for genotype : 1.43
LSD for saline levels : 1.01
LSD for interaction : 2.48

Table XXIII:

EFFECT OF SALINITY ON THE LEAF PHOTOSYNTHETIC RATE (u mol. m^{-2} s^{-1}) OF SOME QUINOA GENOTYPES

	Control	10 dS m^{-1}	20 dS m^{-1}	Mean
Ames13730	19.970 b	19.507 b	16.137 c	18.538 A
Ames13737	23.293 a	20.280 b	14.227 cd	19.267 A
596293	19.700 b	16.540 c	12.443 de	16.228 B
634919	23.680 a	16.013 c	10.037 ef	16.577 B
614922	16.023 c	8.807 f	7.693 f	10.841 C
643079	13.333 d	8.910 f	8.893 f	10.379 C
Mean	19.333 A	15.009 B	11.572 C	

LSD for genotype : 1.42

LSD for saline levels : 1.00

LSD for interaction : 2.45

EFFECT OF SALINITY ON THE LEAF TRANSPIRATION RATE (mmol. m^{-2} s^{-1}) OF SOME QUINOA GENOTYPES

	Control	10 dS m^{-1}	20 dS m^{-1}	Mean
Ames13730	8.4000 b	5.0733 d	3.1000 fgh	5.5244 A
Ames13737	8.5800 ab	5.2100 d	3.4667 f	5.7522 A
596293	7.8333 bc	5.1667 d	3.1900 fg	5.3967 A
634919	9.4067 a	4.5667 de	2.5133 ghi	5.4956 A
614922	6.9900 c	3.4267 f	2.2400 hi	4.2189 B
643079	7.1267 c	3.7200 ef	2.1533 i	4.3333 B
Mean	8.0561 A	4.5272 B	2.7772 C	

LSD for genotype : 0.50
LSD for saline levels : 0.35
LSD for interaction : 0.86

ASSESSMENT OF PHYSIOLOGICAL BASIS OF DROUGHT TOLERANCE IN QUINOA

- **Drought levels**: 2 i. Control ii. 50% F.C.
- **Replication**: 3
- **Varieties**: 6 well acclimatized genotypes
- **Medium**: sand:soil (1:1) (Pot)
- **Stage of stress induction**: 6 weeks old plants

Seedling growth parameters (after 30 days of stress imposition)**:**

- Plant height (cm)
- Root and shoot fresh and dry weights (g)
- Shoot and root lengths and ratio
- Number of Leaves
- Leaf area (cm^{-2})

Year II;Experiment IV:

ASSESSMENT OF PHYSIOLOGICAL BASIS OF DROUGHT TOLERANCE IN QUINOA

Analytical parameters in leaves: (30 days after stress imposition)

- Na+, K+ in leaf sap (mM)
- Leaf chlorophyll (mg 100 mL^{-1})
- Total soluble proteins (mg g^{-1} fresh wt)
- Antioxidant:
  (Catalase, peroxidase, SOD, Total Phenolics)

Photosynthetic parameters and water relations (15 days after stress imposition)

- Water potential (MPa)
- Osmotic pressure (MPa)
- Photosynthesis rate (µmol. m^{-2} S^{-1})
- Transpiration rate (mmol. m^{-2} S^{-1})

Table I
Effect of drought on Plant height (cm) of some quinoa genotypes

Treatment	Control	50% F.C.	Mean
Ames13730	85.007 b	52.077 de	68.542 A
Ames 13737	94.710 a	51.867 de	73.288 A
596293	76.930 c	49.333 e	61.075 B
634919	56.940 d	45.220 e	53.137 C
Mean	78.397 A	49.624 B	

LSD for drought: 3.48
LSD for genotype: 4.92
LSD for interaction: 6.9

Table XI

Effect of drought on total chlorophyll content (mg $100mL^{-2}$) of some quinoa genotypes

	CONTROL	50% F.C.	Mean
AMES13730	25.30 ab	10.96 d	18.13 BC
AMES 13737	26.97 a	11.67 d	19.32 AB
596293	18.76 c	10.79 d	14.77 C
634919	25.99 ab	20.15 bc	23.08 A
Mean	24.26 A	13.39 B	

LSD for drought: 3.13
LSD for genotype: 4.43
LSD for interaction: 6.26

Table XII

Effect of drought on Catalase activity (U. mg of protein g^{-1} fresh weight) **of some quinoa genotypes**

	CONTROL	50% F.C.	Mean
AMES13730	35.547 b	63.573 a	49.560 AB
AMES 13737	38.344 b	62.258 a	50.301 A
596293	23.920 c	62.997 a	43.458 BC
634919	39.402 b	39.094 b	39.248 C
Mean	34.303 B	56.980 A	

LSD for drought: 4.60
LSD for genotype: 6.51
LSD for interaction: 9.21

Table XIII

Effect of drought on leaf Melondialdehyde Content (MDA) of some quinoa genotypes

	CONTROL	50% F.C.	Mean
Ames13730	9.689 ab	10.053 a	9.8707 A
Ames 13737	9.952 a	9.584 ab	9.7684 A
596293	9.692 ab	9.423 ab	9.5573 A
634919	7.894 c	8.403 bc	8.1485 B
Mean	9.3069 A	9.3655 A	

LSD for drought:
0.70
LSD for genotype:
0.99
LSD for interaction:
1.40

Table XIV

Effect of drought on Peroxidase activity (U. mg of protein g^{-1} fresh weight) **of some quinoa genotypes**

	CONTROL	50% F.C.	Mean
AMES13730	142.72 d	215.79 a	179.26 A
AMES 13737	134.53 d	192.89 b	163.71 B
596293	158.72 c	217.56 a	188.14 A
634919	107.94 e	163.23 c	135.59 C
Mean	135.98 B	197.37 A	

LSD for drought: 6.95
LSD for genotype: 9.82
LSD for interaction: 13.89

Table XV

Effect of drought on Superoxide Dismutase activity (U. mg of protein g^{-1} fresh weight) **of some quinoa genotypes**

	CONTROL	50% F.C.	Mean
AMES13730	130.96 e	181.65 c	156.31 C
AMES 13737	156.43 d	221.54 b	188.98 B
596293	132.15 e	182.39 c	157.27 C
634919	173.55 c	257.66 a	215.60 A
Mean	148.27 B	210.81 A	

LSD for drought: 7.28
LSD for genotype: 10.30
LSD for interaction: 14.56

Table XVI

Effect of drought on Leaf Proline content (mmol. g^{-1} fresh weight) **of some quinoa genotypes**

	CONTROL	50% F.C.	Mean
AMES13730	0.2303 a	0.2792 a	0.2548 A
AMES 13737	0.2367 a	0.2965 a	0.2666 A
596293	0.2300 a	0.2728 a	0.2514 A
634919	0.1213 b	0.2352 a	0.1783 B
Mean	0.2046 B	0.2709 A	

LSD for drought: 0.05
LSD for genotype: 0.07
LSD for interaction: 0.10

Table XVII

Effect of drought on Leaf Total Phenolic content (GAE g^{-1} f. wt.) in leaf Sap of some quinoa genotypes

	CONTROL	50% F.C.	Mean
Ames13730	41.57 b	42.20 b	41.88 B
Ames 13737	41.73 b	44.62 b	43.17 B
596293	64.43 a	69.43 a	66.93 A
634919	45.47 b	42.47 b	43.97 B
Mean	48.30 A	49.68 A	

LSD for drought: 5.04
LSD for genotype: 7.13
LSD for interaction: 10.08

Table XVIII

Effect of drought on Leaf Total Soluble Proteins (mg g^{-1} f. wt.) in leaf Sap of some quinoa genotypes

Treatment	Control	50% F.C.	Mean
Ames13730	0.2967 e	0.7833 c	0.5400 C
Ames 13737	0.3567 de	0.9333 b	0.6450 AB
596293	0.4267 d	0.8233 c	0.6250 B
634919	0.2700 e	1.1467 a	0.7083 A
Mean	0.3375 B	0.9217 A	

LSD for drought: 0.05
LSD for genotype: 0.07
LSD for interaction: 0.10

Table XIX

Effect of drought on K content (mM) in leaf Sap of some quinoa genotypes

	CONTROL	50% F.C.	
AMES13730	157.74 a	72.79 e	115.26 A
AMES 13737	127.32 b	69.63 e	98.47 B
596293	139.79 b	62.77 e	101.28 B
634919	92.24 d	108.29 c	100.27 B
Mean	129.27 A	78.37 B	

LSD for drought: 7.71
LSD for genotype: 10.90
LSD for interaction: 15.42

Table XX

Effect of drought on Na content (mM) in leaf Sap of some quinoa genotypes

	CONTROL	50% F.C.	Mean
AMES13730	17.671 e	63.633 a	40.652 BC
AMES 13737	22.524 de	66.540 a	44.532 B
596293	35.224 c	66.208 a	50.716 A
634919	24.718 d	54.399 b	39.558 C
	25.034 B	62.695 A	

LSD for drought: 3.50
LSD for genotype: 4.95
LSD for interaction: 6.10

Table XXI

Effect of drought on Ratio of K: Na concentrations in leaf Sap of some quinoa genotypes

	CONTROL	50% F.C.	Mean
Ames13730	9.1145 a	1.1367 d	5.1256 A
Ames 13737	5.6640 b	1.0540 d	3.3590 B
596293	3.9812 c	0.9576 d	2.4694 C
634919	3.7478 c	2.0033 d	2.8755 BC
Mean	5.6269 A	1.2879 B	

LSD for drought: 0.56
LSD for genotype: 0.79
LSD for interaction: 1.12

Table XXII

Effect of drought on Photosynthetic rate (µmol. m^{-2} s^{-1}) of some quinoa genotypes

	CONTROL	50% F.C.	Mean
AMES13730	30.60 ab	23.46 cd	27.03 A
AMES 13737	15.32 e	13.82 e	14.57 B
596293	34.96 a	25.19 bc	30.08 A
634919	18.92 cde	17.05 de	17.99 B
Mean	24.95 A	19.88 B	

LSD for drought: 3.26
LSD for genotype: 4.61
LSD for interaction: 6.52

Table XXIII

Effect of drought on Photosynthetic rate (µmol. m^{-2} s^{-1}) of some quinoa genotypes

	CONTROL	50% F.C.	Mean
AMES13730	6.39 b	2.93 d	4.66 B
AMES 13737	7.73 a	3.47 d	5.60 A
596293	6.30 b	3.37 d	4.84 AB
634919	4.72 c	2.96 d	3.84 C
Mean	6.28 A	3.18 B	

LSD for drought: 0.55
LSD for genotype: 0.78
LSD for interaction: 1.10

EFFECT OF PRIMING ON THE GERMINATION AND SEEDLING VIGOR OF QUINOA UNDER SALINE CONDITIONS

Salinity levels: 1. 10 dS m^{-1} 2. 20 dS m^{-1} 3. 30 dS m^{-1}

Priming Treatments:

1. hydropriming 2. **$CaCl_2$** (ψ_s -1.25 MPa) **3. Moringa leaf Extract** 1:30 (30 times water dilution)

4. Ascorbic acid (50 mg L^{-1}) **5. Salicylic acid** (50 mg L^{-1}) **6. H_2O_2** (40 µM) **7.BAP** (50 mg L^{-1})

Medium: control conditions **(**100 mm Petri-plates using whatman's filte paper# 40)

Replications: 3

Stage of stress induction: Pre-germination

Germination parameters:

- Time to 50% germination (days)
- Final germination percentage

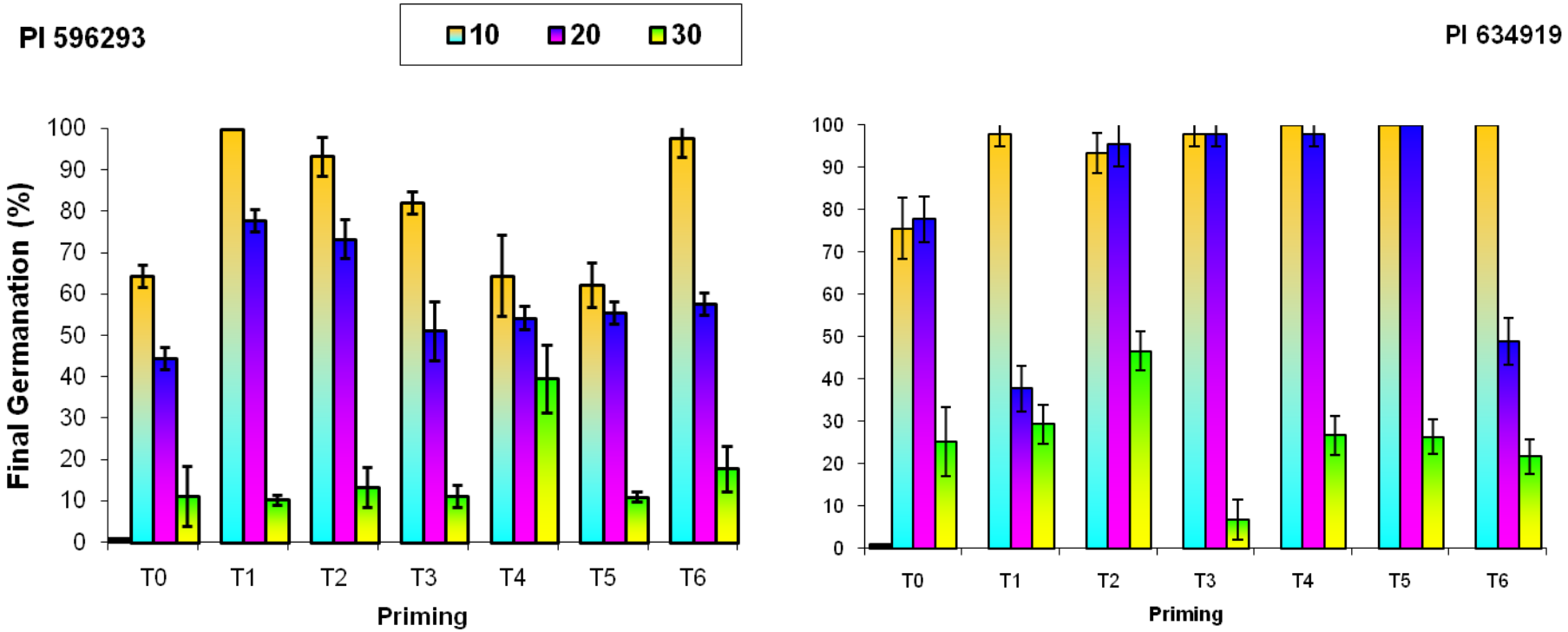
Seed Priming

TOOL FOR IMPROVED GERMINATION AND VIGOR

it is the alternate soaking and wetting technique in which seeds are being soaked in water with forced aeration, solutions of known osmotic potential, hormonal concentrations or solid matrix carrier substances and redried back to their original weight prior to radical protrusion to improve vigor and viability

(Munir and Basra, 2010)

Fig 1:
Effect of seed priming on final germination (%) of two accessions of *C. quinoa* under saline Conditions

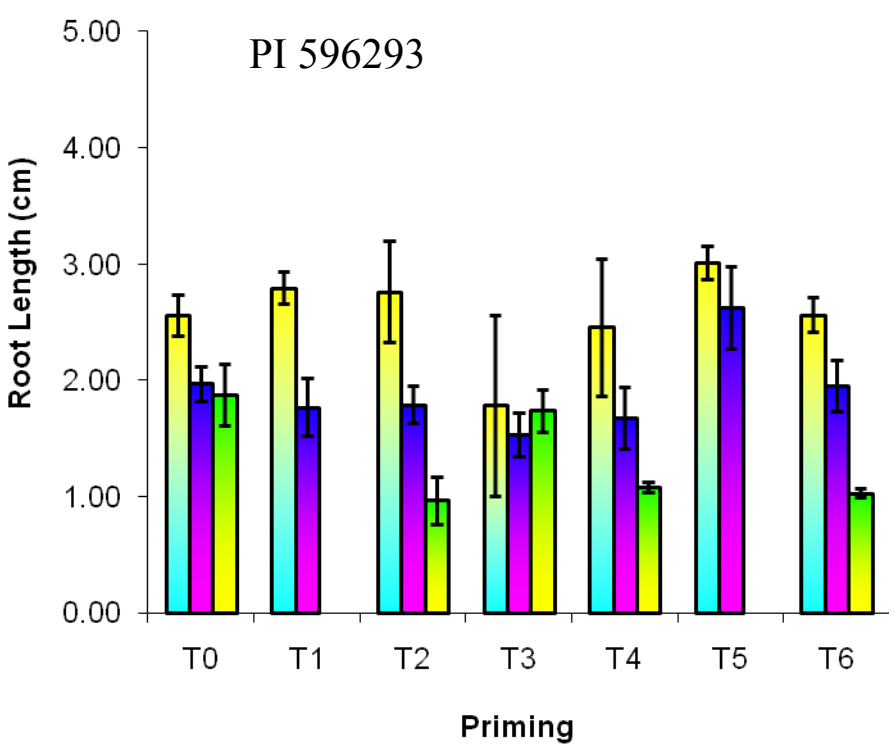


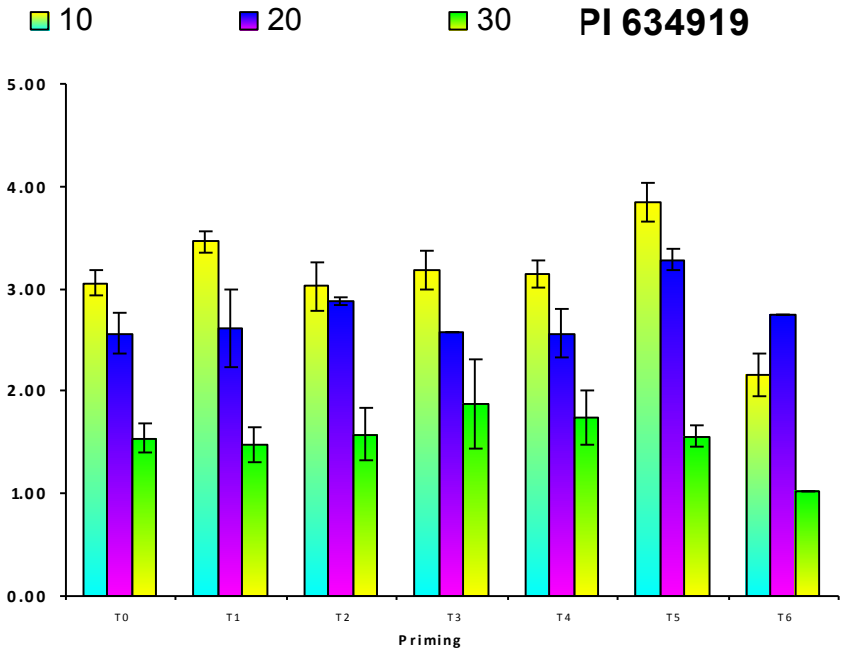
Priming Techniques

T_o: Control T_1: MLE 1:30 T_2: Hydropriming T_3: $CaCl_2.2H_2O$ (-1.25MPa)

T_4: Ascorbate (50 mg L^{-1}) T_5: BAP (50 mg L^{-1}) T_6: H_2O_2 (40 µM)

Fig 2:
Effect of seed priming on Root length of two accessions of *C. quinoa* under saline Conditions





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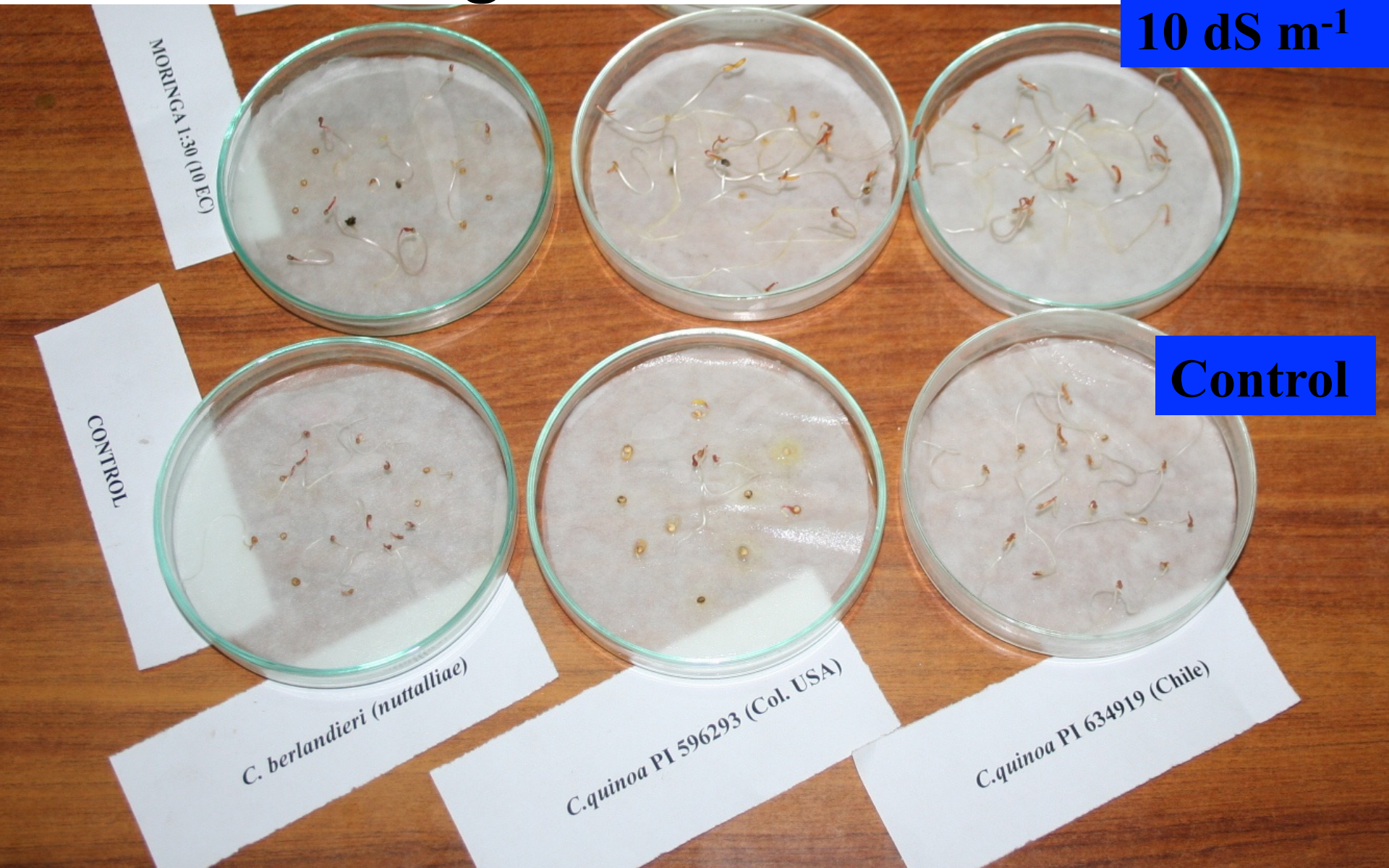
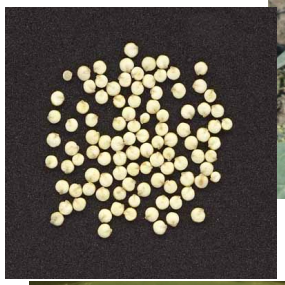
Moringa Leaf Extract 1:30

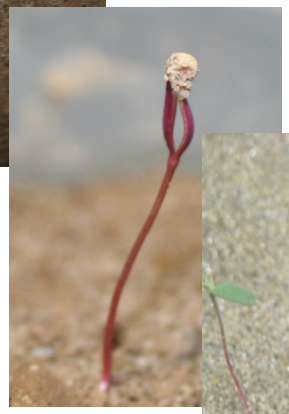











From Seed to Seed

Quinoa

NUTRITIVE VALUE QUINOA

Promixate Analysis (g/100g d.wt.)
Comparative scientific work

	References			
Component	Koziol[27]	Wright *et al.*[28]	De Bruin[29]	Dini *et al.*[30]
Protein	16.5	16.7	15.6	12.5
Fat	6.3	5.5	7.4	8.5
Ash	3.8	3.2	3.0	3.7
Carbohydrate	69.0	74.7	69.7	60.0
Crude fiber	3.8	10.5	2.9	1.92

2012	Protein	Fat	Ash	Carbohydrate	Crude Fiber
Pakistani Quinoa	14.79±3.27	6.79±1.66	5.79±2.18	66.85±8.69	5.78±2.28

Mineral composition (mg/kg d. wt.)

Comparative scientific work

lower sodium (Na) content than in wheat, barley or corn

higher in Ca, P, Mg, K, Fe, Cu,Mn and Zn

References	Minerals						
	Ca	P	Mg	Fe	Zn	K	Cu
Koziol[27]	1487	3837	2496	132	44	9267	51
Repo-Carrasco *et al.*[33]	940	1400	2700	168	48	ND	37
Ruales and Nair[17]	874	5300	260	81	36	12000	10
Bhargava *et al.*[10]	1274	3869	ND	20	48	6967	ND
Konishi *et al.*[50]	863	4110	5020	150	40	7320	ND
Dini *et al.*[30]	275	4244	ND	26	275	75	ND
Sanders[51]	565	4689	1760	14	28	11930	2
González *et al.*[34]	1020	1400	ND	105	ND	8225	ND

ND, not determined.

	Ca	P	Mg	Fe	Zn	K
Pakistani Quinoa	**1137±87**	**1176± 68**	**1694± 121**	**112± 12.26**	**27± 2.67**	**6121±131.7**

Unsaturated fatty acid

(mg/100 g of oil extract)

comparative scientific work

Oil content in quinoa ranges between 1.8% to 9.5% (5.2±1.78)% In PQ

	Fatty acid		
Reference	Oleic	Linoleic	Linolenic
Koziol[27]	23.3	53.1	6.2
Repo-Carrasco *et al.*[33]	26.0	50.2	4.8
Ruales and Nair[17]	24.8	52.3	3.9

	Oleic	Linoleic (O-6)	Linolenic (O-3)
Pakistani Quinoa	**21.12±2.17**	**49.05±4.78**	**4.24±0.66**

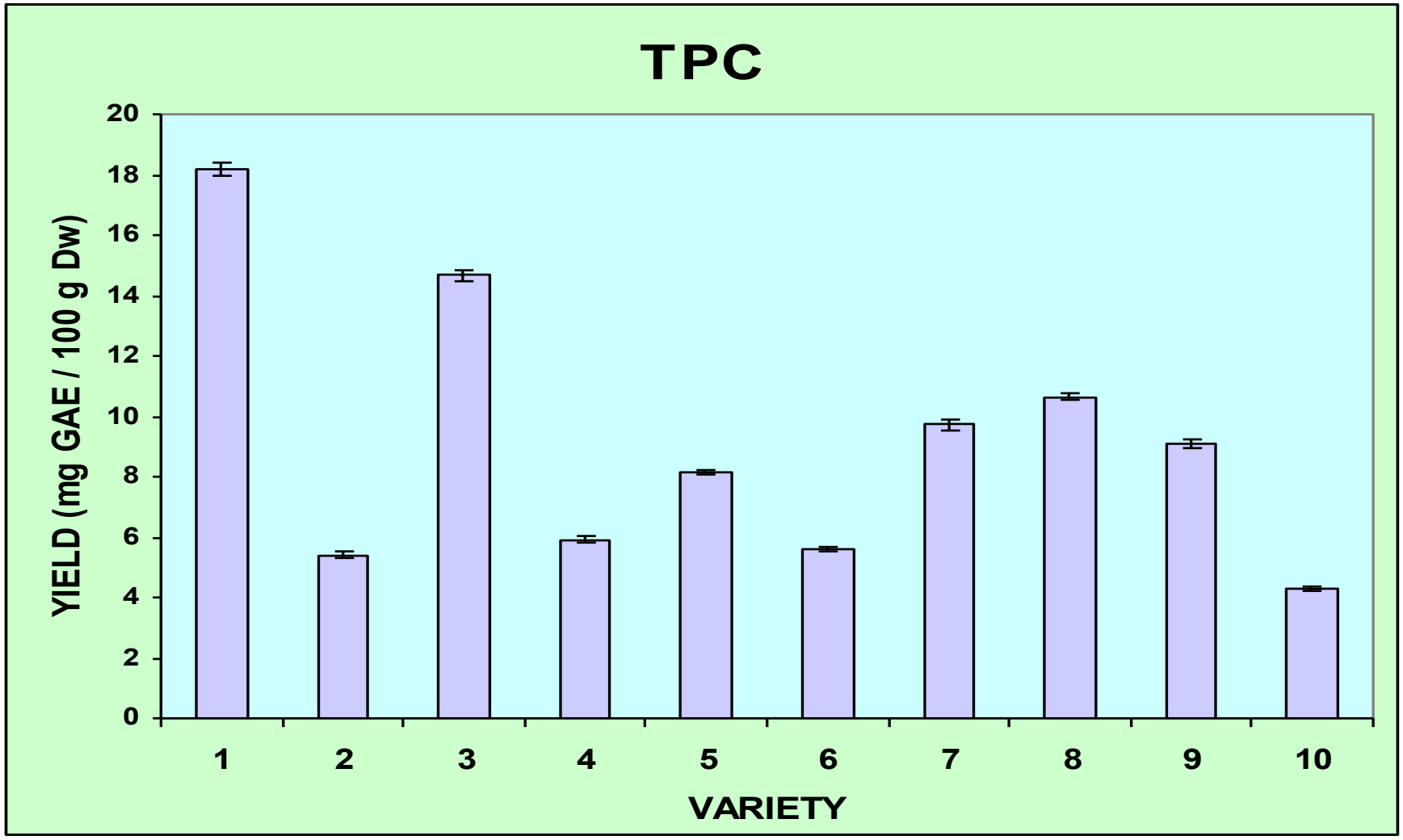
VITAMINS CONCENTRATION (mg/100 g d.wt.) comparative scientific work

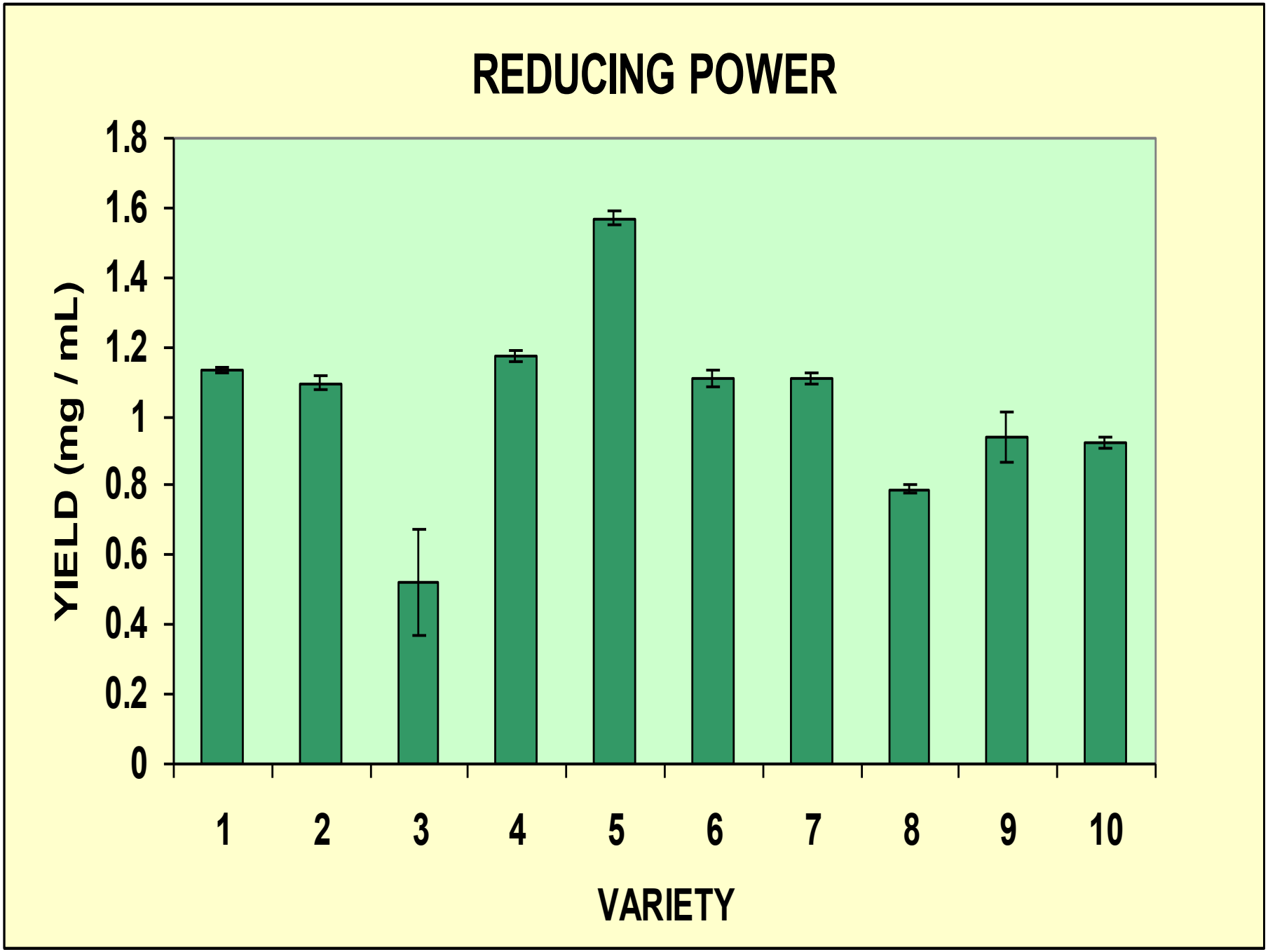
	References	
Vitamin	Koziol[27]	Ruales and Nair[17]
Ascorbic acid (C)	4.0	16.4
α-Tocoferol (E)	5.37	2.6
Thiamin (B_1)	0.38	0.4
Riboflavin (B_2)	0.39	ND
Niacin (B_3)	1.06	ND

ND, not determined.

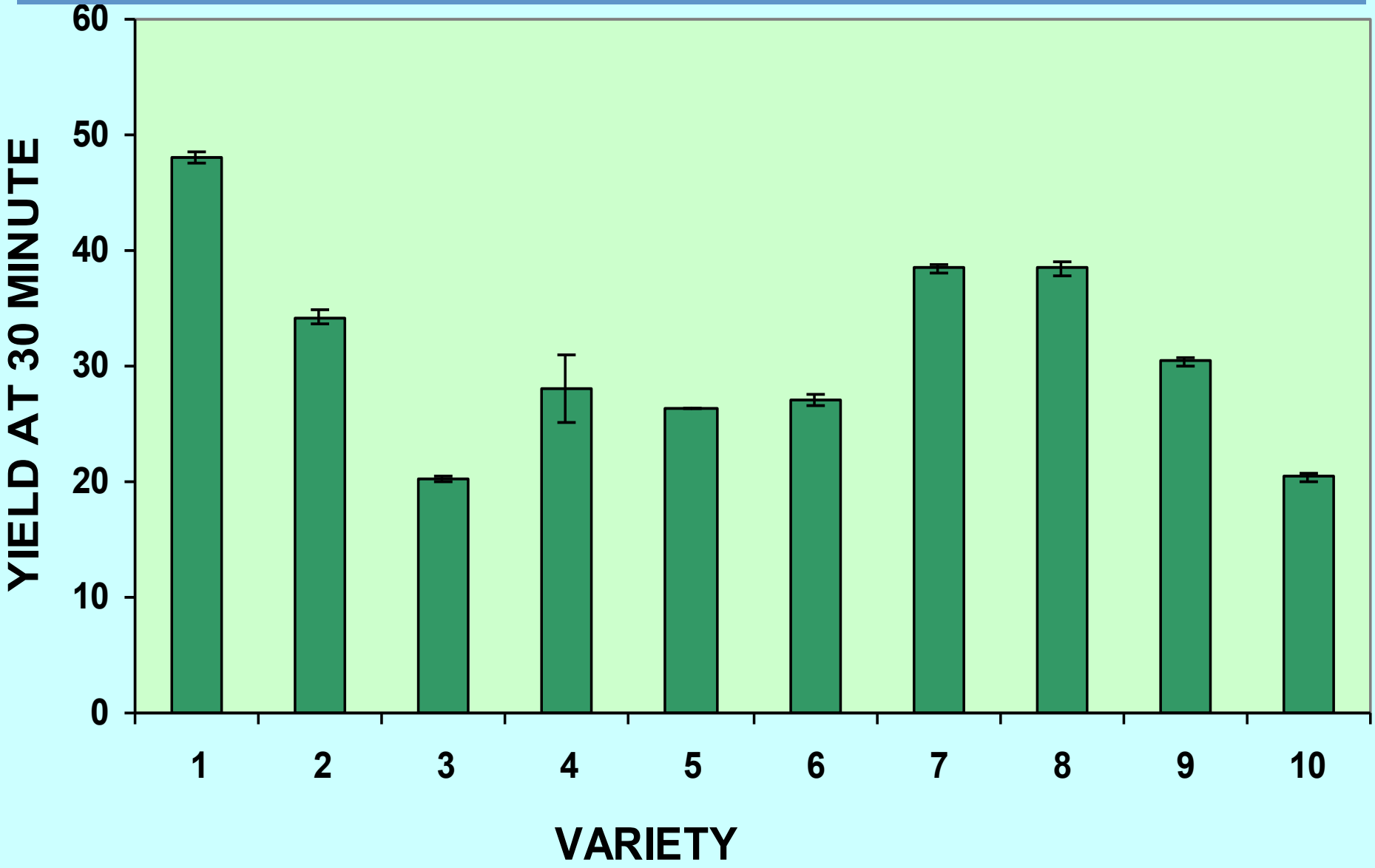
	Ascorbic acid
Pakistani Quinoa	**13.22±3.49**

Total Phenolic content in locally cultivated quinoa genotypes




REDUCING POWER
YIELD (mg / mL)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
2
3
4
5
6
7
8
9
10
VARIETY

2,2-diphenyl-2-picryl-hydrazyl(DPPH)



QUINOA IN PAKISTAN

Yield and net return per hectare of quinoa

Variety	Yield (Kg/ha)	Net Return (Rs./ha)
PI 603079	1184.4	-27107.19
Ames 13730	2802.7	114332.23
Ames 13737	2448.07	83337.568
PI 478410	688.33	-70463.708
PI 510537	886.55	-53139.28
PI 510542	663.21	-72659.196
PI 596293	2718.41	106965.284
P 614922	1070.95	-37022.72
PI 634919	2596.4	96301.61

Net Return = Gross Return – Total Cost

By assuming Gross return price in domestic market= US$1/kg

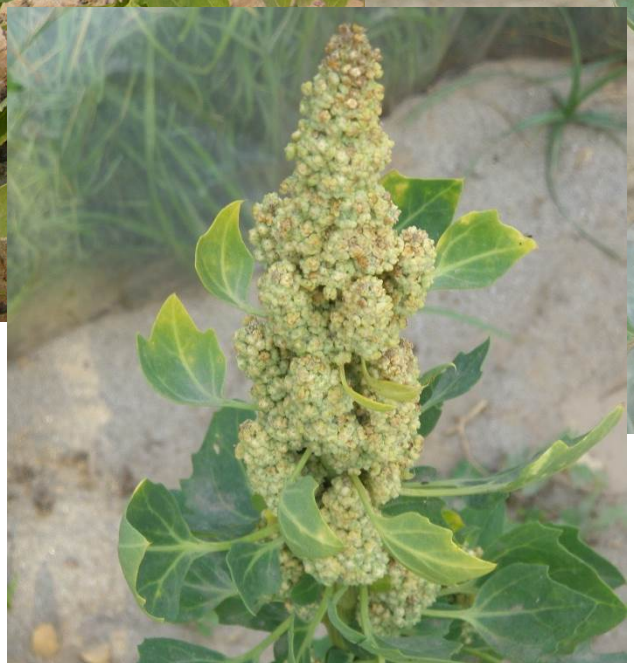
Comparison of quinoa yields

(Jacobsen, 2003; Munir *et al*., 2009)

Country	Yields (kg/ha)
Pakistan	2716
Vietnam	1685
Kenya	4000
Greece	3960
Bolivia, Peru and Ecuador	1000-2200
USA	1000
Italy	2280

- Pladicule

MUTANTS at 225 gray



AWARNESS

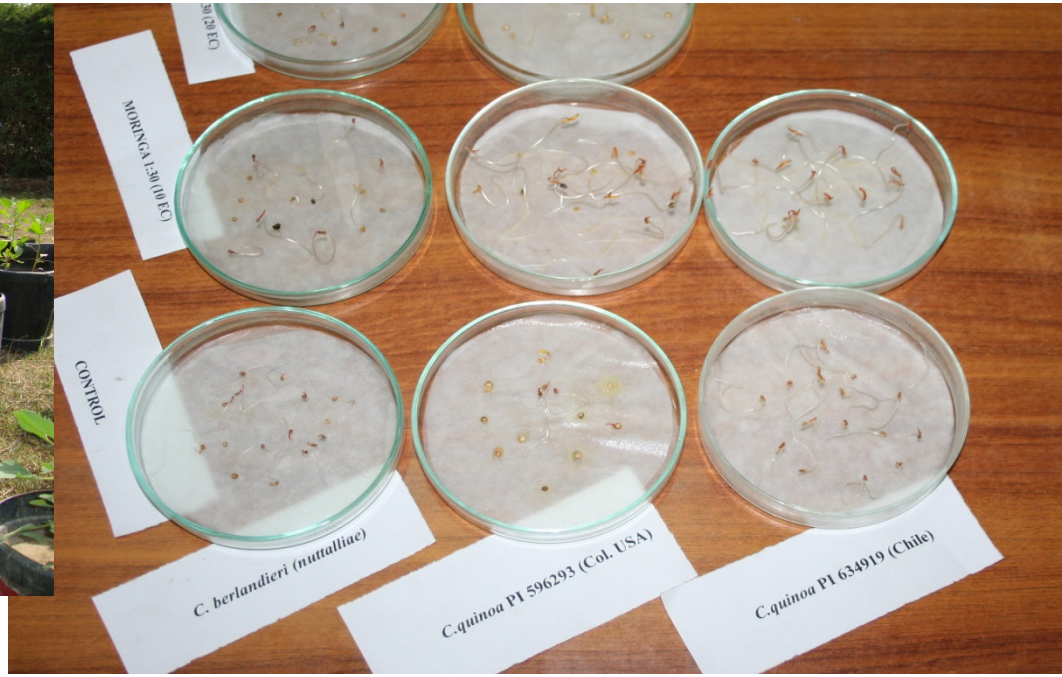

PARTNERS
for
United Nations'
Quinoa
2013 International Year
A New Climate Resilient Crop for Pakistan
GOLDEN JUBILEE CELEBRATIONS
Department of Crop Physiology
Striving for Nature Conservation In the World

IYQ-2013 & Pakistan

TITICACA

Drought

- Salinity


MORINGA 1:30 (10 EC)
CONTROL
C. berlandieri (nuttalliae)
C.quinoa PI 596293 (Col. USA)
C.quinoa PI 634919 (Chile)

Crop Diversity for mitigation of climate change

Climate Resilient / Smart Crops: Quinoa

No phytosanitary certificate can be issued until an application is completed (7 CFR 353)

FORM APPROVED
OMB NO. 0579-0052

UNITED STATES DEPARTMENT OF AGRICULTURE
ANIMAL AND PLANT HEALTH INSPECTION SERVICE
PLANT PROTECTION AND QUARANTINE

PHYTOSANITARY CERTIFICATE

FOR OFFICIAL USE ONLY

PLACE OF ISSUE
Beltsville, Maryland

NO.
F-S-24033-02927413-7-N

DATE INSPECTED
January 29, 2013

TO: THE PLANT PROTECTION ORGANIZATION(S) OF
Pakistan

CERTIFICATION

This is to certify that the plants, plant product or other regulated articles described herein have been inspected and/or tested according to appropriate official procedures and are considered to be free from the quarantine pests, specified by the importing contracting party and to conform with the current phytosanitary requirements of the importing contracting party including those for regulated non-quarantine pests.

DISINFESTATION AND/OR DISINFECTION TREATMENT

1. DATE	2. TREATMENT
**********	**********
3. CHEMICAL (active ingredient)	**4. DURATION AND TEMPERATURE**
**********	**********
5. CONCENTRATION	**6. ADDITIONAL INFORMATION**
**********	**********

DESCRIPTION OF THE CONSIGNMENT

7. NAME AND ADDRESS OF THE EXPORTER
USDA, ARS, North Central Regional Plant
Introduction Station
Exporter address information is printed on
the attachment page.

8. DECLARED NAME AND ADDRESS OF THE CONSIGNEE
Dr. Hassan Munir
University of Agriculture
Department of Crop Physiology
Faisalabad, Punjab 38040 Pakistan

9. NAME OF PRODUCE AND QUANTITY DECLARED
(1) 890 Grams Amaranth (Seeds)
(2) 540 Grams Quinoa (Seeds)
****

10. BOTANICAL NAME OF PLANTS
(1) Amaranthus sp.
(2) Chenopodium quinoa
****

11. NUMBER AND DESCRIPTION OF PACKAGES
(1-2) 1 Box
****

12. DISTINGUISHING MARKS
(1-2) None
****

13. PLACE OF ORIGIN
(1-2) Iowa, USA
****

14. DECLARED MEANS OF CONVEYANCE
Air Mail

15. DECLARED POINT OF ENTRY
Pakistan

WARNING: Any alteration, forgery, or unauthorized use of this phytosanitary certificate is subject to civil penalties of up to $250,000 (7 U.S.C. Section 7734(b)) or punishable by a fine of not more than $10,000, or imprisonment of not more than 5 years, or both (18 U.S.C. Section 1001).

ADDITIONAL DECLARATION

No Import Permit was presented.

16. DATE ISSUED	17. NAME OF AUTHORIZED OFFICER *(Type or Print)*	18. SIGNATURE OF AUTHORIZED OFFICER
January 29, 2013	Donna L. Crouch	Donna L Crouch

No liability shall attach to the United States Department of Agriculture or to any officer or representative of the Department with respect to this certificate.

PPQ Form 577 FEB 2001 Previous editions are obsolete after 6/30/01

SHIPPER'S ORIGINAL

Thanks to USDA


Quinoa
And
Keenoa
My son

THANKS

Food insecurity anywhere,
threatens peace everywhere