ACRYRED

FOUR YEARS OF ACRYRED WG2 “AGRONOMY AND PLANT BREEDING”: PROGRESS ON KNOWLEDGE ABOUT FREE ASPARAGINE ACCUMULATION IN CEREALS

Elena Baldoni

ACRYRED Conference

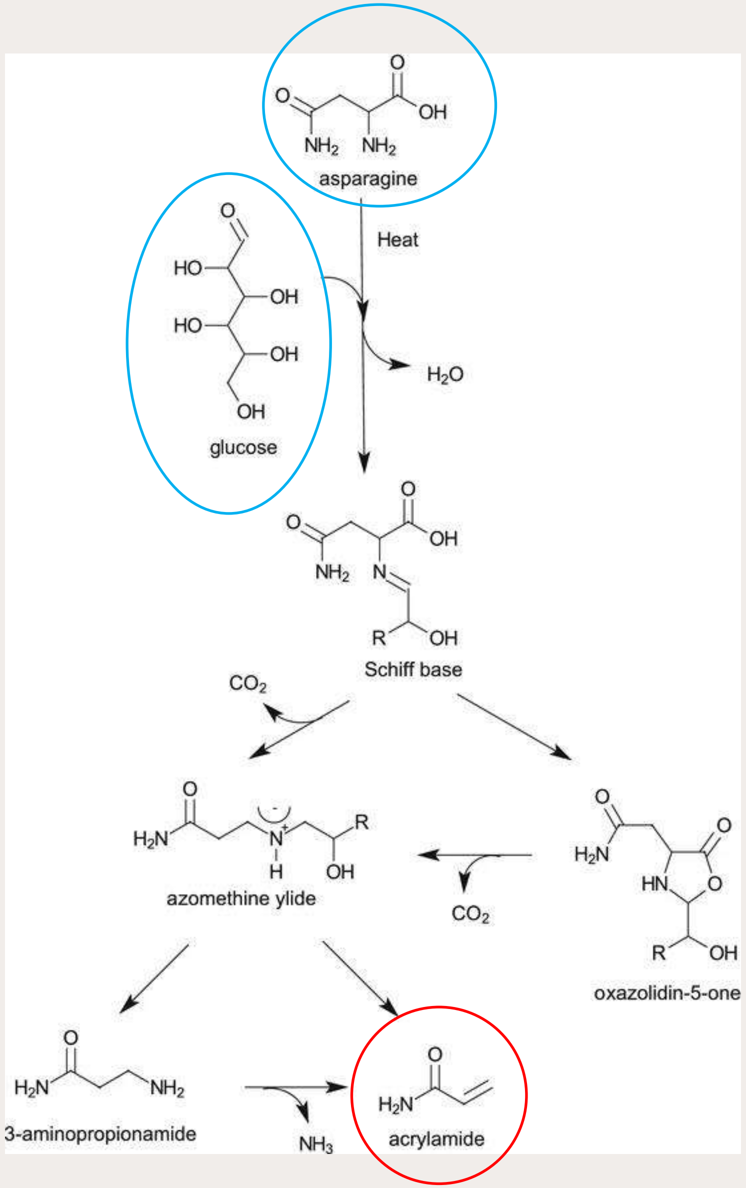
Palermo, 4th June 2026

ACRYRED • COST Action CA21149 • Reducing Acrylamide exposure of consumers by a Cereals supply-chain approach targeting Asparagine

This article/publication is based upon work from COST Action ACRYRED, CA21149, supported by COST. COST (European Cooperation in Science and Technology) is a funding agency for research and innovation networks. Our Actions help connect research initiatives across Europe and enable scientists to grow their ideas by sharing them with their peers. This boosts their research, career and innovation.

Acrylamide formation

Maillard reaction cascade



Temperature > 120°C

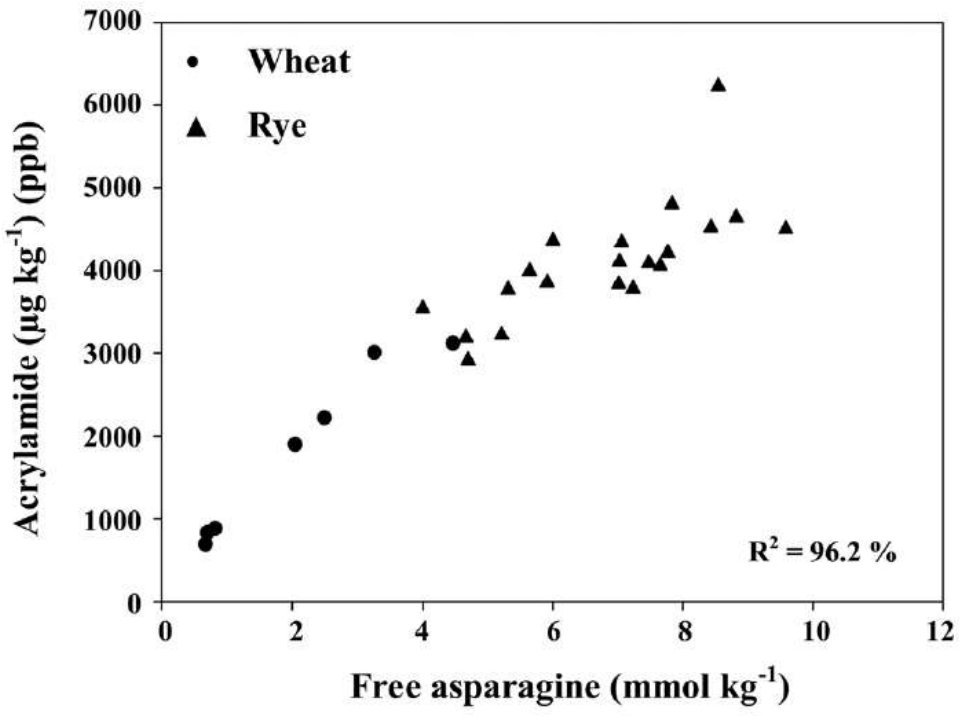


FIGURE 8 Relationship between free asparagine concentration and acrylamide formation in wheat and rye flour heated for 20 min at 180°C. Reproduced with modification from Curtis, Postles, and Halford (2014)

From: Raffan and Halford 2019

In cereal-based food, the quantity of **free asparagine** has been identified as a key factor in acrylamide formation.

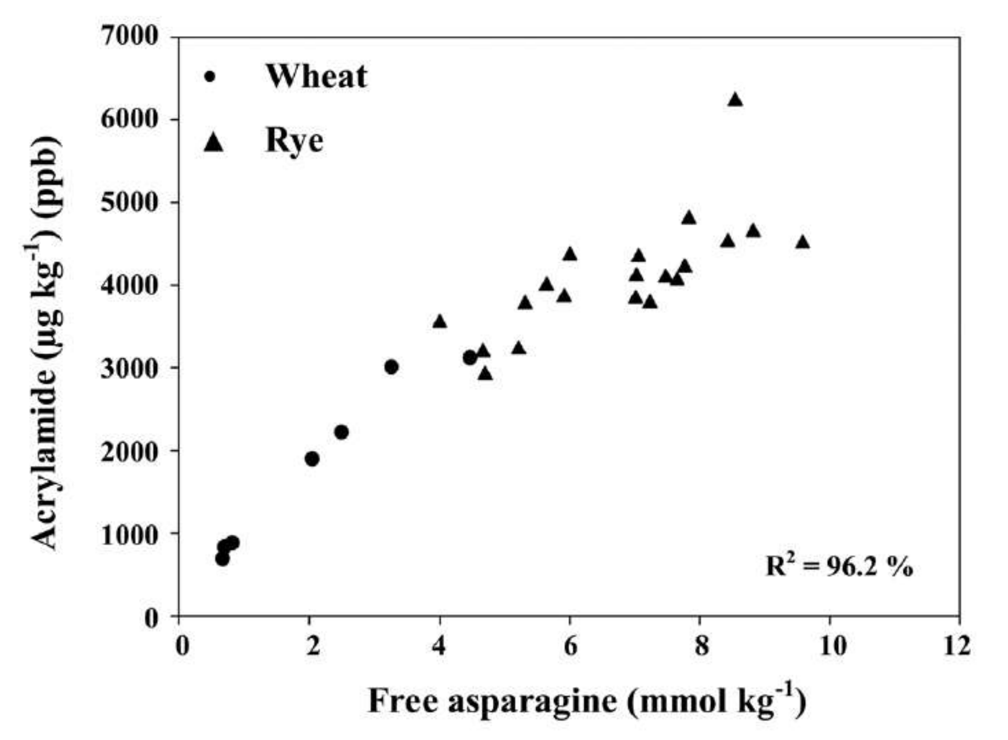
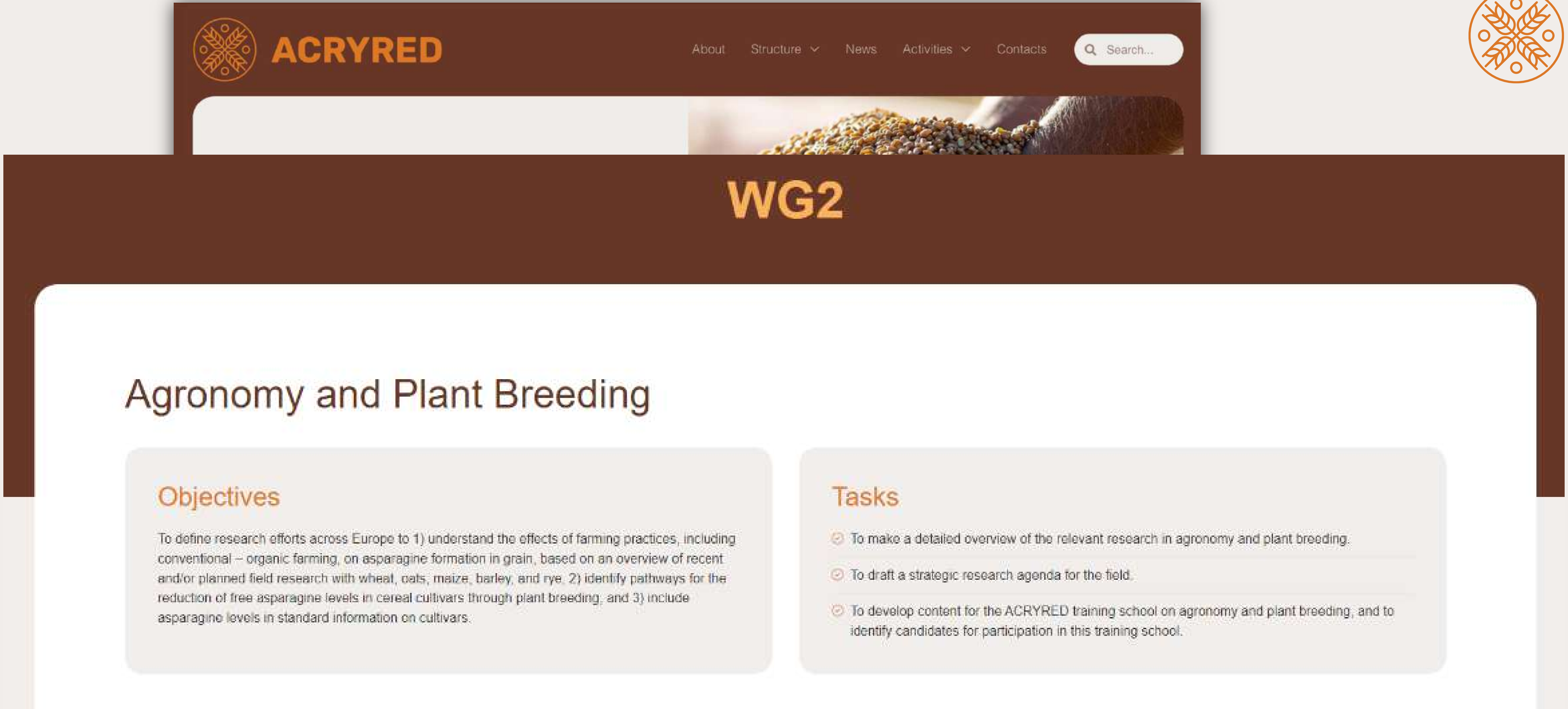


FIGURE 8 Relationship between free asparagine concentration and acrylamide formation in wheat and rye flour heated for 20 min at 180°C. Reproduced with modification from Curtis, Postles, and Halford (2014)

From: Raffan and Halford 2019

In cereal-based food, the quantity of **free asparagine** has been identified as a key factor in acrylamide formation.

Food industry recommends the use of grain with low free asparagine content to reduce acrylamide levels in cereal-based products.



Working Group 2 - Lowering asparagine levels through better breeding activities and farming practices, for reducing downstream acrylamide formation in cereals-based products.

How to lower free asparagine in cereal grain?

CROP MANAGEMENT

Control of soil N/S ratio

Balanced micronutrient composition

Avoiding water and salt stress

Disease control

BIOTECHNOLOGY

Genetic modification

Genome editing

TILLING

IDENTIFICATION OF GENETIC RESOURCES

Germplasm evaluation

Multi-environment trials

Natural deletion of *TaASN-B2*

STUDY OF GENETIC ARCHITECTURE

GWAS

QTL identification

Omics integration

How to lower free asparagine in cereal grain?

CROP MANAGEMENT

Control of soil N/S ratio

Balanced micronutrient composition

Avoiding water and salt stress

Disease control

BIOTECHNOLOGY

Genetic modification

Genome editing

TILLING

IDENTIFICATION OF GENETIC RESOURCES

Germplasm evaluation

Multi-environment trials

Natural deletion of *TaASN-B2*

STUDY OF GENETIC ARCHITECTURE

GWAS

QTL identification

Omics integration

What has been the scientific contribution of WG2?

2022-2026

CROP MANAGEMENT

Control of soil N/S ratio

Balanced micronutrient composition

Avoiding water and salt stress

Disease control

BIOTECHNOLOGY

Genetic modification

Genome editing

TILLING

IDENTIFICATION OF GENETIC RESOURCES

Germplasm evaluation

Multi-environment trials

Natural deletion of *TaASN-B2*

STUDY OF GENETIC ARCHITECTURE

GWAS

QTL identification

Omics integration

agronomy — Effects of Nitrogen plus Sulfur Fertilization and Seeding Density on Yield, Rheological Parameters, and Asparagine Content in Old Varieties of Common Wheat (*Triticum aestivum* L.)

plants — Sugar and Free Amino Acid Contents in Winter Wheat Flour Under Fusarium Head Blight Treatment and Natural ...

Journal of Agriculture and Food Research — Effect of soil tillage and a fungicide application on the accumulation of free asparagine on wheat flours and the risk of acrylamide formation in baked goods

agriculture — Factors Influencing the Accumulation of Free Asparagine in Wheat Grain and the Acrylamide Formation in Bread

Field Crops Research — Enhancing nutritional value of common wheat: Impact of foliar selenium application on grain yield and quality under rainfed conditions

Field Crops Research — Sulphur and selenium foliar fertilization enhances the protein profile and reduces anti-nutritional compounds in common wheat

Plant Biotechnology Journal — Brief Communication — Field assessment of genome-edited, low asparagine wheat: Europe's first CRISPR wheat field trial

Plant Biotechnology Journal — RESEARCH ARTICLE — Field Trials and Baking Studies of Ultra-Low Asparagine, Genome Edited (CRISPR/Cas9) and Mutant (TILLING) Wheat

SELEKCIJA I SEMENARSTVO, Vol. XXVIII (2022) broj 2 — doi: 10.5937/SelSem2202013N — CEREAL GRAIN WITH LOW ACRYLAMIDE FORMATION POTENTIAL AS A RAW MATERIAL FOR SAFER CEREAL-BASED FOOD PRODUCTS IN SERBIA

plants — Exploring Variability of Free Asparagine Content in the Grain of Bread Wheat (*Triticum aestivum* L.) Varieties Cultivated in Italy to Reduce Acrylamide-Forming Potential

LWT — Does the use of the Tritordeum, an alternative cereal for breadmaking, can be one of the mitigation strategies of acrylamide in bread?

Journal of Food Composition and Analysis — The variability of winter rye cultivars in relation to grain quality parameters with special regard to the free asparagine content

ORIGINAL ARTICLE — Genetic control of grain amino acid composition in a UK soft wheat mapping population

Food Chemistry — Integrated GWAS and metabolomic analyses identified metabolic pathways and candidate genes involved in free asparagine accumulation in durum wheat grain agronomy

Article

Effects of Nitrogen plus Sulfur Fertilization and Seeding Density on Yield, Rheological Parameters, and Asparagine Content in Old Varieties of Common Wheat (*Triticum aestivum* L.)

plants

Article

Sugar and Free Amino Acid Contents in Winter Wheat Flour Under Fusarium Head Blight Treatment and Natural

Journal of Agriculture and Food Research

Effect of soil tillage and a fungicide application on the accumulation of free asparagine on wheat flours and the risk of acrylamide formation in baked goods

agriculture

Article

Factors Influencing the Accumulation of Free Asparagine in Wheat Grain and the Acrylamide Formation in Bread

Field Crops Research

Enhancing nutritional value of common wheat: Impact of foliar selenium application on grain yield and quality under rainfed conditions

CROP MANAGEMENT

Control of soil N/S ratio

Balanced micronutrient composition

Avoiding water and salt stress

Disease control

IDENTIFICATION OF GENETIC RESOURCES

Germplasm evaluation

Multi-environment trials

Natural deletion of *TaASN-B2*

STUDY OF GENETIC ARCHITECTURE

GWAS

QTL identification

Omics integration

BIOTECHNOLOGY

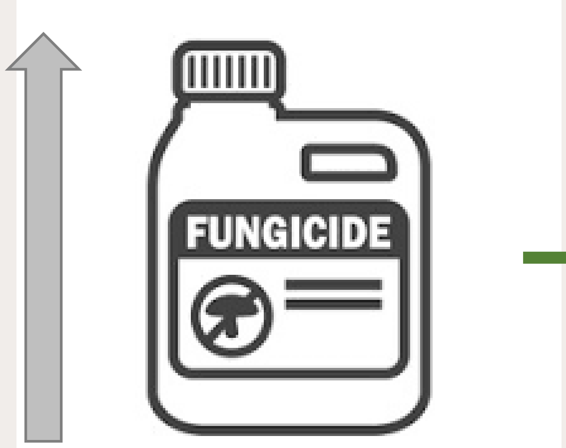
Genetic modification

Genome editing

TILLING

free asparagine

High levels of nitrogen supply

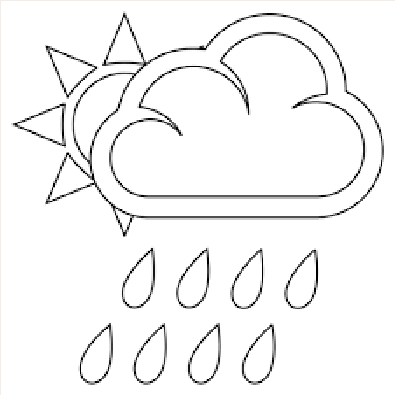


free asparagine

Fungicide application

free asparagine

Sulphur deficiency



changes of free asparagine levels

Level of precipitations and temperatures during grain development

2022 UNIVERSITÀ DEGLI STUDI FIRENZE

agronomy MDPI

Article

Effects of Nitrogen plus Sulfur Fertilization and Seeding Density on Yield, Rheological Parameters, and Asparagine Content in Old Varieties of Common Wheat (*Triticum aestivum* L.)

Quadratullah Soofizada [1], Antonio Pescatore [1], Lorenzo Guerrini [2], Carolina Fabbri [1], Marco Mancini [1], Simone Orlandini [1] and Marco Napoli [1,*]

Soofizada et al. 2022. https://doi.org/10.3390/agronomy12020351

14 old Italian bread **wheat** varieties

Evaluated Parameters:

- two seeding density levels
- three nitrogen levels (NL)
- two sulphur levels (SL)

effect on

- grain yield
- rheological characteristics
- **free asparagine content**

CROP MANAGEMENT

1

2022

UNIVERSITÀ DEGLI STUDI FIRENZE

agronomy

MDPI

Article

Effects of Nitrogen plus Sulfur Fertilization and Seeding Density on Yield, Rheological Parameters, and Asparagine Content in Old Varieties of Common Wheat (*Triticum aestivum* L.)

Quadratullah Soofizada [1], Antonio Pescatore [1], Lorenzo Guerrini [2], Carolina Fabbri [1], Marco Mancini [1], Simone Orlandini [1] and Marco Napoli [1,*]

14 old Italian bread **wheat** varieties

Evaluated Parameters:

- two seeding density levels
- three nitrogen levels (NL)
- two sulphur levels (SL)

effect on

- grain yield
- rheological characteristics
- **free asparagine content**

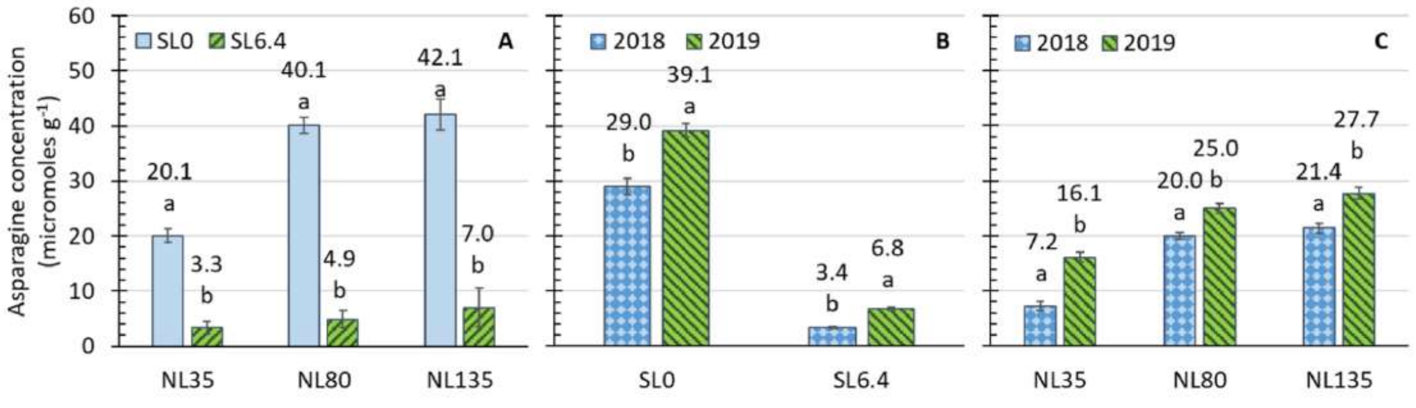


Figure 5. Interactions between years and agronomic treatments on asparagine content in grain; (**A**) Effect of nitrogen fertilization level (NL) and sulfur fertilization level (SL); (**B**) effect of year (Y) and sulfur fertilization level (SL); (**C**) effect of the year (Y) and nitrogen fertilization (NL). Lowercase letters represent the Tukey HSD post hoc test results.

- increased by 111% as NL increased;
- decreased by 85.1% with the SL treatment.

2022

UNIVERSITÀ DEGLI STUDI FIRENZE

agronomy

MDPI

Article

Effects of Nitrogen plus Sulfur Fertilization and Seeding Density on Yield, Rheological Parameters, and Asparagine Content in Old Varieties of Common Wheat (*Triticum aestivum* L.)

Quadratullah Soofizada [1], Antonio Pescatore [1], Lorenzo Guerrini [2], Carolina Fabbri [1], Marco Mancini [1], Simone Orlandini [1] and Marco Napoli [1,*]

14 old Italian bread **wheat** varieties

Evaluated Parameters:

- two seeding density levels
- three nitrogen levels (NL)
- two sulphur levels (SL)

effect on

- grain yield
- rheological characteristics
- **free asparagine content**

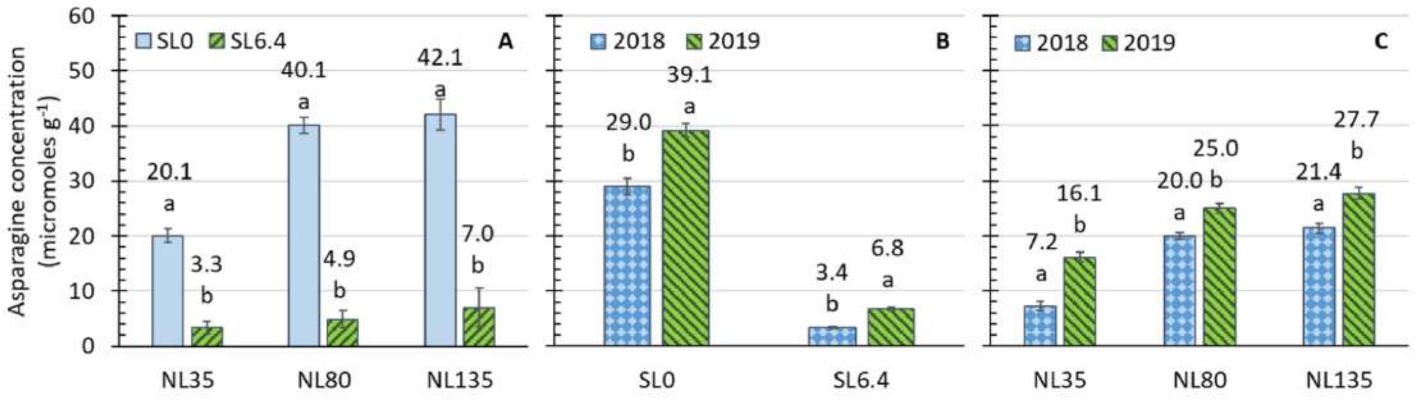


Figure 5. Interactions between years and agronomic treatments on asparagine content in grain; (**A**) Effect of nitrogen fertilization level (NL) and sulfur fertilization level (SL); (**B**) effect of year (Y) and sulfur fertilization level (SL); (**C**) effect of the year (Y) and nitrogen fertilization (NL). Lowercase letters represent the Tukey HSD post hoc test results.

- increased by 111% as NL increased;
- decreased by 85.1% with the SL treatment.

“135 kg N ha^{-1} combined with 6.4 kg S ha^{-1} can improve the technical performance of ‘old’ wheat wholegrain flours while maintaining free asparagine as low as possible.”

CROP MANAGEMENT 2

2024

INSTITUTE OF AGRICULTURAL AND FOOD BIOTECHNOLOGY STATE RESEARCH INSTITUTE

agriculture MDPI

Article

Factors Influencing the Accumulation of Free Asparagine in Wheat Grain and the Acrylamide Formation in Bread

Anna Szafrańska [1,*], Grażyna Podolska [2], Olga Świder [1], Danuta Kotyrba [1], Edyta Aleksandrowicz [2], Agnieszka Podolska-Charlery [3] and Marek Roszko [1]

Szafranska et al. 2024. https://doi.org/10.3390/agriculture14020207

5 bread **wheat** varieties

GxExM

Evaluated Parameters:

- genotype
- location
- two levels of sulphur fertilization

effect on

- technological properties
- **free asparagine content**
- **acrylamide level in bread**

2024 INSTITUTE OF AGRICULTURAL AND FOOD BIOTECHNOLOGY STATE RESEARCH INSTITUTE

agriculture MDPI

Article

Factors Influencing the Accumulation of Free Asparagine in Wheat Grain and the Acrylamide Formation in Bread

Anna Szafrańska [1,*], Grażyna Podolska [2], Olga Świder [1], Danuta Kotyrba [1], Edyta Aleksandrowicz [2], Agnieszka Podolska-Charlery [3] and Marek Roszko [1]

5 bread **wheat** varieties

Evaluated Parameters:

- genotype
- location
- two levels of sulphur fertilization

GxExM

effect on

- technological properties
- **free asparagine content**
- **acrylamide level in bread**

	Sources of Variation						
Parameter	Localization (A)	S Fertilization (B)	Cultivar (C)	A × B	A × C	B × C	A × B × C
Test weight	205.30 **	0.22	28.85 **	2.33	12.03 **	0.85	2.82
Protein content	2695.88 **	1.02	78.34 **	2.61	162.79**	3.09 *	6.92 **
Gluten content	2160.08 **	12.51 **	92.71 **	2.52	84.61 **	0.60	1.56
Zeleny index	84.70 **	0.42	9.97 **	0.58	14.52 **	0.91	0.74
Ash content	15.80 **	0.00	1.54	0.10	1.71	0.20	0.42
Asparagine	3418.61 **	1.50	43.33 **	27.35 **	17.04 **	2.82	4.88 **

Significant at: * $p < 0.05$, ** $p < 0.01$.

The **localization** had the biggest influence on the total variance in the measured technological parameters of wheat grain, followed by **cultivar**, and then by the **interaction between the localization x cultivar** (**localization x sulphur** for free asparagine).

CROP MANAGEMENT

2

2024

INSTITUTE OF AGRICULTURAL AND FOOD BIOTECHNOLOGY STATE RESEARCH INSTITUTE

agriculture

MDPI

Article

Factors Influencing the Accumulation of Free Asparagine in Wheat Grain and the Acrylamide Formation in Bread

Anna Szafrańska [1,*], Grażyna Podolska [2], Olga Świder [1], Danuta Kotyrba [1], Edyta Aleksandrowicz [2], Agnieszka Podolska-Charlery [3] and Marek Roszko [1]

5 bread **wheat** varieties

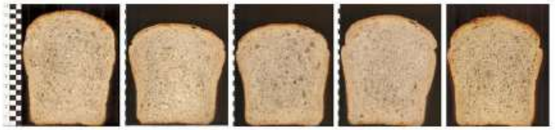
GxExM

Evaluated Parameters:
- genotype
- location
- two levels of sulphur fertilization

effect on
- technological properties
- **free asparagine content**
- **acrylamide level in bread**

	Sources of Variation						
Parameter	Localization (A)	S Fertilization (B)	Cultivar (C)	A × B	A × C	B × C	A × B × C
Loaf volume	12.22 **	18.03 **	68.75 **	1.47	20.02 **	1.74	1.51
Bread crumb hardness	119.35 **	25.87 **	4.33 **	3.08	6.25 **	29.19 **	37.75 **
Acrylamide content	1518.09 **	359.17 **	92.03 **	9.21 **	8.15 *	65.03 *	37.92 *
Lcrumb	404.92 **	0.61	85.12 **	1.59	11.63 **	0.84	0.81
*a**crumb	3059.32 **	12.69 **	62.99 **	0.61	25.49 **	4.68 **	12.79 **
*b**crumb	248.16 **	4.36 *	187.01 **	0.00	51.10 **	4.91 **	12.92 **
Lcrust	36.33 **	24.89 **	2.08	0.41	13.96 **	2.03	1.17
*a**crust	0.60	2.85	4.03 *	6.67 *	9.71 **	1.43	0.40
*b**crust	39.13 **	33.20 **	3.48 *	0.03	7.25 **	1.96	2.14

Significant at: * $p < 0.05$, ** $p < 0.01$.



The **localization** had the greatest share in the total variance of the measured acrylamide content in bread, followed by **S Fertilization** and then by **cultivar**.

CROP MANAGEMENT

2

2024

INSTITUTE OF AGRICULTURAL AND FOOD BIOTECHNOLOGY STATE RESEARCH INSTITUTE

agriculture

MDPI

Article

Factors Influencing the Accumulation of Free Asparagine in Wheat Grain and the Acrylamide Formation in Bread

Anna Szafrańska [1,*], Grażyna Podolska [2], Olga Świder [1], Danuta Kotyrba [1], Edyta Aleksandrowicz [2], Agnieszka Podolska-Charlery [3] and Marek Roszko [1]

5 bread **wheat** varieties

Evaluated Parameters:

- genotype
- location
- two levels of sulphur fertilization

GxExM

effect on

- technological properties
- **free asparagine content**
- **acrylamide level in bread**

	Sources of Variation						
Parameter	Localization (A)	S Fertilization (B)	Cultivar (C)	A × B	A × C	B × C	A × B × C
Loaf volume	12.22 **	18.03 **	68.75 **	1.47	20.02 **	1.74	1.51
Bread crumb hardness	119.35 **	25.87 **	4.33 **	3.08	6.25 **	29.19 **	37.75 **
Acrylamide content	1518.09 **	359.17 **	92.03 **	9.21 **	8.15 *	65.03 *	37.92 *
Lcrumb	404.92 **	0.61	85.12 **	1.59	11.63 **	0.84	0.81
*a**crumb	3059.32 **	12.69 **	62.99 **	0.61	25.49 **	4.68 **	12.79 **
*b**crumb	248.16 **	4.36 *	187.01 **	0.00	51.10 **	4.91 **	12.92 **
Lcrust	36.33 **	24.89 **	2.08	0.41	13.96 **	2.03	1.17
*a**crust	0.60	2.85	4.03 *	6.67 *	9.71 **	1.43	0.40
*b**crust	39.13 **	33.20 **	3.48 *	0.03	7.25 **	1.96	2.14

Significant at: * $p < 0.05$, ** $p < 0.01$.

"Asparagine content in wheat and acrylamide in bread varies mostly depending on cultivar and environment."

The **localization** had the greatest share in the total variance of the measured acrylamide content in bread, followed by **S Fertilization** and then by **cultivar**.

MAIZE RESEARCH INSTITUTE „ZEMUN POLJE" BELGRADE - ZEMUN

Agricultural Institute Osijek established 1878.

plants

MDPI

Article

Sugar and Free Amino Acid Contents in Winter Wheat Flour Under Fusarium Head Blight Treatment and Natural Infection

Valentina Španić [1,*], Beka Sarić [2], Katarina Šunić Budimir [1], Jurica Duvnjak [1] and Slađana Žilić [2]

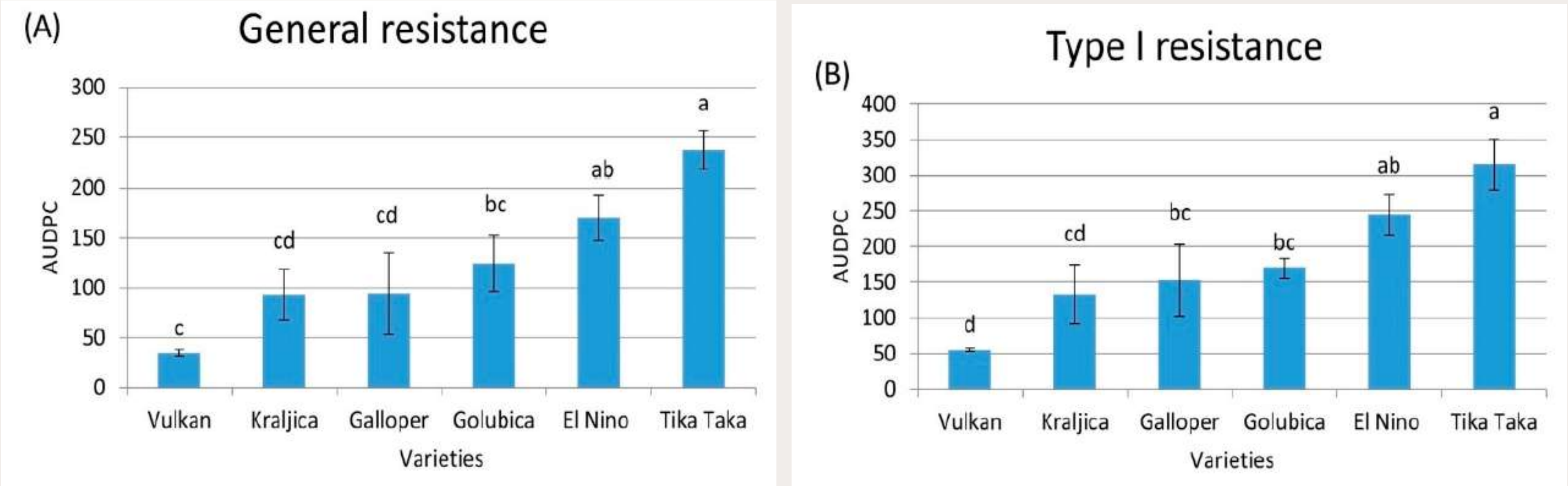
Spanic et al. 2025. https://doi.org/10.3390/plants14101504

6 bread **wheat** varieties, differing in Fusarium head blight (FHB) resistance.

Evaluated material:
- flour from *Fusarium* infected grains
- flour from *Fusarium* non-infected grains

effect on

- sugar content
- **free amino acid content**



AUDPC: area under disease progress curve

MAIZE RESEARCH INSTITUTE „ZEMUN POLJE" BELGRADE - ZEMUN
Agricultural Institute Osijek established 1878.


plants
MDPI

Article

Sugar and Free Amino Acid Contents in Winter Wheat Flour Under Fusarium Head Blight Treatment and Natural Infection

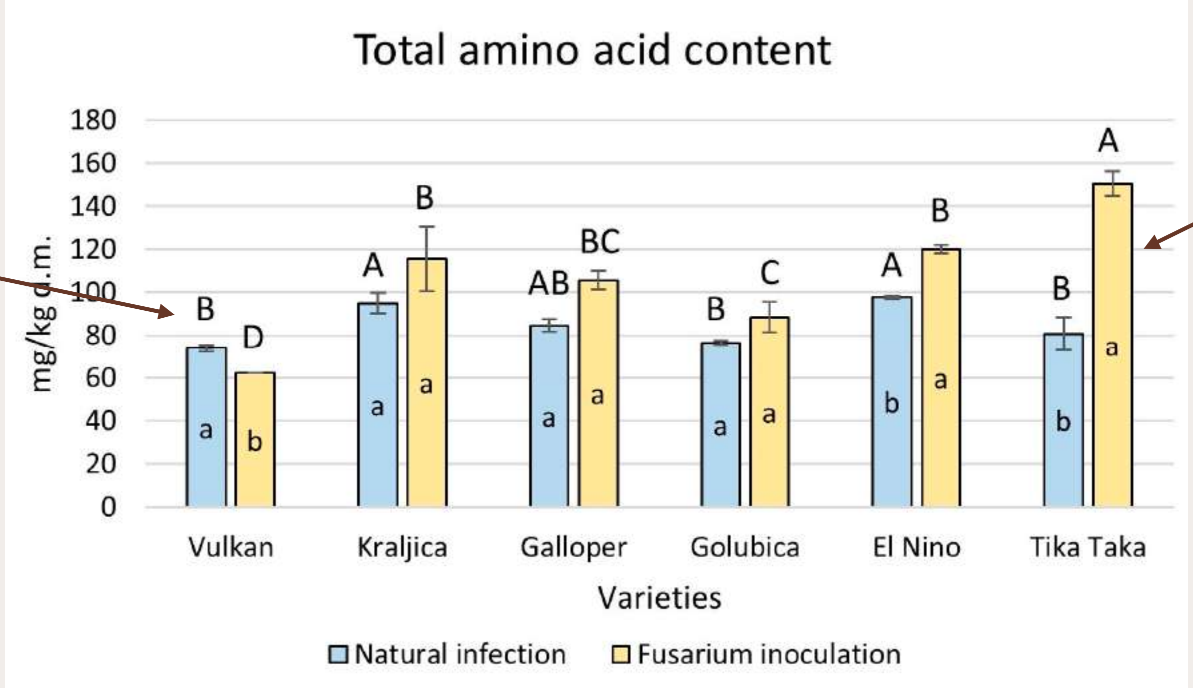
Valentina Španić [1,*], Beka Sarić [2], Katarina Šunić Budimir [1], Jurica Duvnjak [1] and Slađana Žilić [2]

6 bread **wheat** varieties, differing in Fusarium head blight (FHB) resistance.

Evaluated material:
- flour from *Fusarium* infected grains
- flour from *Fusarium* non-infected grains

effect on

- sugar content
- **free amino acid content**



-16%

+46%

The total content of free amino acids in flour from FHB-infected varieties increased **in proportion to their susceptibility**.

MAIZE RESEARCH INSTITUTE „ZEMUN POLJE" BELGRADE - ZEMUN

Agricultural Institute Osijek established 1878.

plants

MDPI

Article

Sugar and Free Amino Acid Contents in Winter Wheat Flour Under Fusarium Head Blight Treatment and Natural Infection

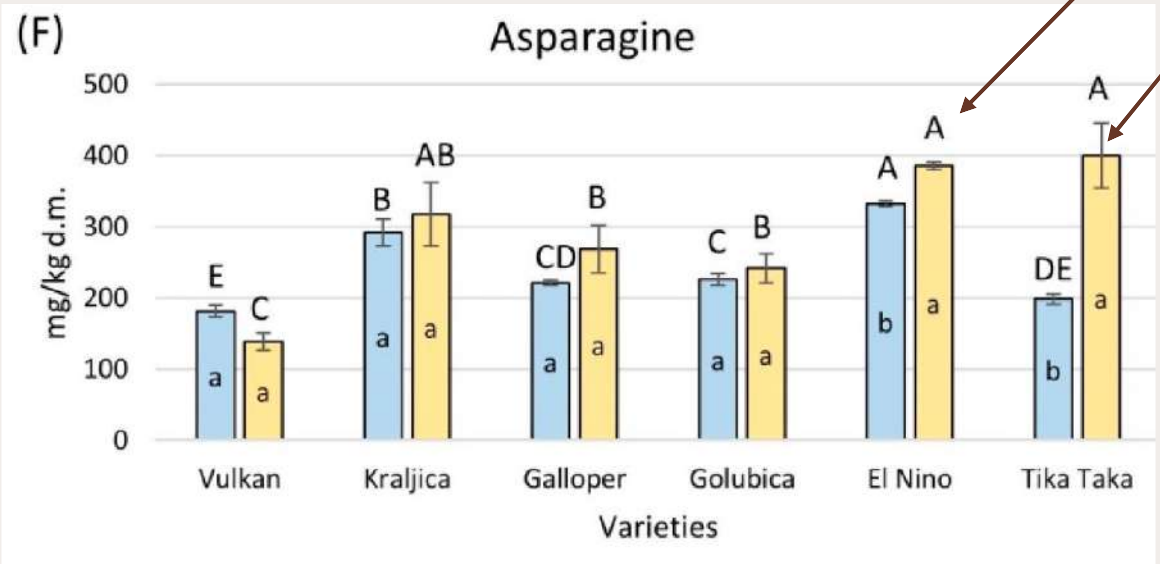
Valentina Španić [1,*], Beka Sarić [2], Katarina Šunić Budimir [1], Jurica Duvnjak [1] and Slađana Žilić [2]

6 bread **wheat** varieties, differing in Fusarium head blight (FHB) resistance.

Evaluated material:
- flour from *Fusarium* infected grains
- flour from *Fusarium* non-infected grains

effect on

- sugar content
- **free amino acid content**



+51%

The most FHB susceptible varieties accumulated the highest level of free asparagine.

MAIZE RESEARCH INSTITUTE „ZEMUN POLJE" BELGRADE - ZEMUN

Agricultural Institute Osijek established 1878.

plants MDPI

Article

Sugar and Free Amino Acid Contents in Winter Wheat Flour Under Fusarium Head Blight Treatment and Natural Infection

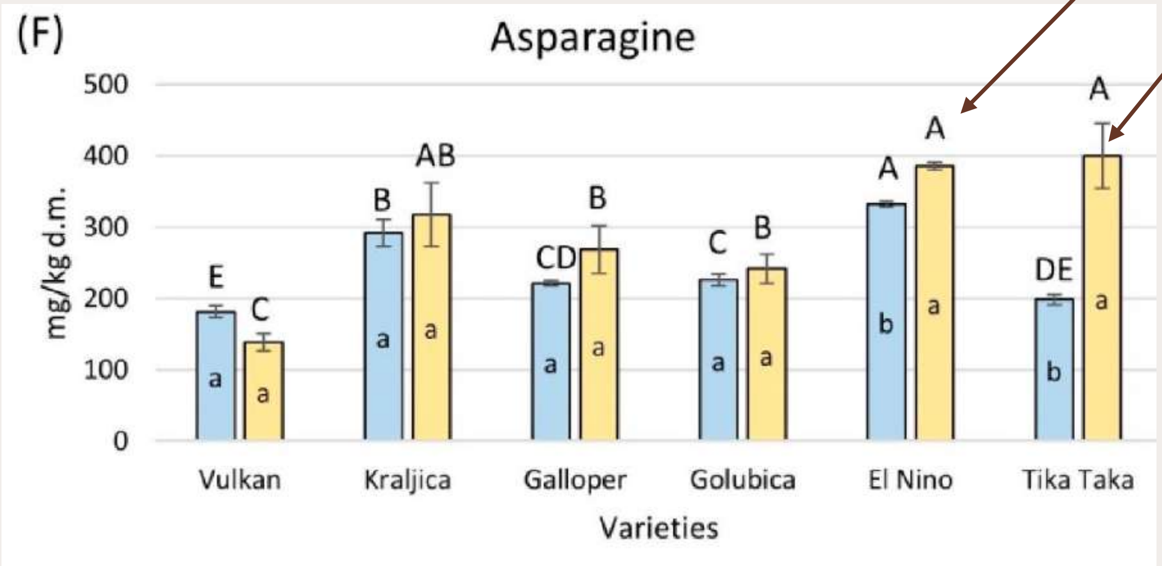
Valentina Španić [1,*], Beka Sarić [2], Katarina Šunić Budimir [1], Jurica Duvnjak [1] and Slađana Žilić [2]

6 bread **wheat** varieties, differing in Fusarium head blight (FHB) resistance.

Evaluated material:
- flour from *Fusarium* infected grains
- flour from *Fusarium* non-infected grains

effect on

- sugar content
- **free amino acid content**



+51%

The most FHB susceptible varieties accumulated the highest level of free asparagine.

"Winter wheat breeders may have an opportunity to reduce free asparagine concentration in the grain by identifying and selecting genotypes carrying FHB resistance."

UNIVERSITÀ DEGLI STUDI FIRENZE

2 bread **wheat** varieties (Bologna, modern variety, and Sieve, old variety)


Field Crops Research 330 (2025) 109969

Contents lists available at ScienceDirect

Field Crops Research

journal homepage: www.elsevier.com/locate/fcr

ELSEVIER

Enhancing nutritional value of common wheat: Impact of foliar selenium application on grain yield and quality under rainfed conditions

Yidenekachew Berhanu Beshah[a], Antonio Pescatore[a], Lorenzo Guerrini[b], Roberto Vivoli[a], Marco Napoli[a,*]

Beshah et al. 2025. https://doi.org/10.1016/j.fcr.2025.109969

Foliar **Se** application

effect on

- grain yield
- quality:
  - protein content
  - starch concentration
  - **free asparagine levels**
  - phytic acid content


Field Crops Research 336 (2026) 110229

Contents lists available at ScienceDirect

Field Crops Research

journal homepage: www.elsevier.com/locate/fcr

ELSEVIER

Sulphur and selenium foliar fertilization enhances the protein profile and reduces anti-nutritional compounds in common wheat

Yidenekachew Berhanu Beshah[a], Antonio Pescatore[a], Lorenzo Guerrini[b], Roberto Vivoli[a], Marco Napoli[a,*]

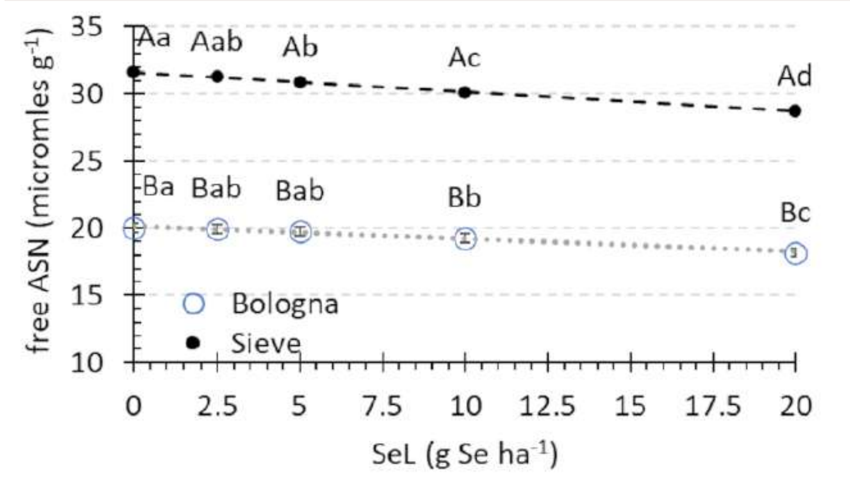
Beshah et al. 2026. https://doi.org/10.1016/j.fcr.2025.110229

Foliar **S** and **Se** application

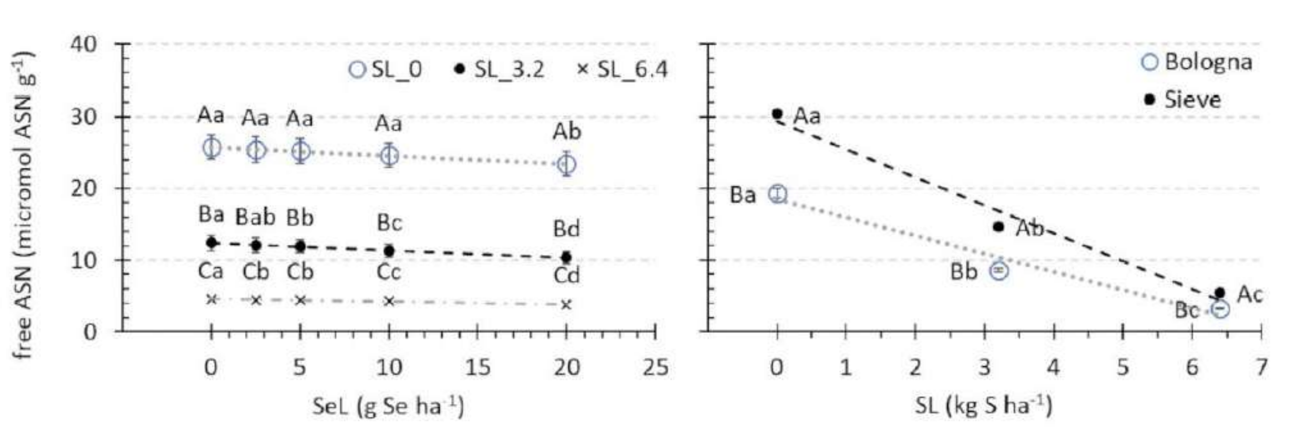
effect on

- grain yield
- protein composition
- mineral bioavailability
- dough properties


Field Crops Research
journal homepage: www.elsevier.com/locate/fcr
Enhancing nutritional value of common wheat: Impact of foliar selenium application on grain yield and quality under rainfed conditions
Yidenekachew Berhanu Beshah, Antonio Pescatore, Lorenzo Guerrini, Roberto Vivoli, Marco Napoli




Field Crops Research
journal homepage: www.elsevier.com/locate/fcr
Sulphur and selenium foliar fertilization enhances the protein profile and reduces anti-nutritional com
Yidenekachew Berhanu Beshah, A
Marco Napoli



Grain yield was not significantly affected by either Se or S treatments

S treatment mostly affected free asparagine (82.5 % variation).

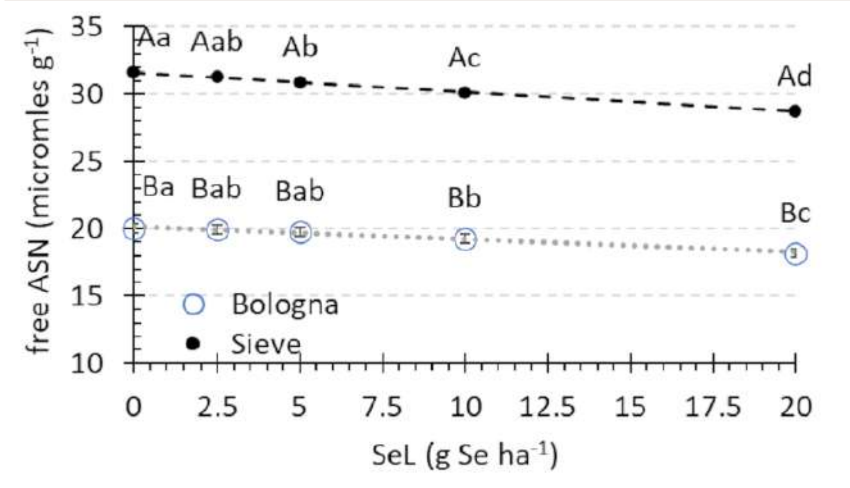
Se further reduced free asparagine, particularly under adequate S conditions.

UNIVERSITÀ DEGLI STUDI FIRENZE

Field Crops Research

Enhancing nutritional value of common wheat: Impact of foliar selenium application on grain yield and quality under rainfed conditions

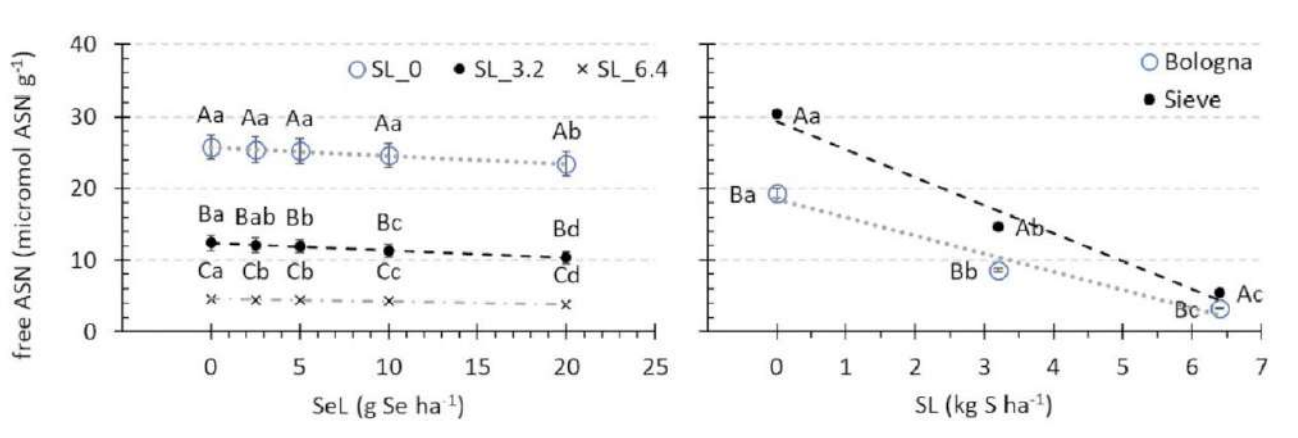
Yidenekachew Berhanu Beshah, Antonio Pescatore, Lorenzo Guerrini, Roberto Vivoli, Marco Napoli



Field Crops Research

Sulphur and selenium foliar fertilization enhances the protein profile and reduces anti-nutritional com

Yidenekachew Berhanu Beshah, Ar
Marco Napoli



Grain yield was not significantly affected by either Se or S treatments

S treatment mostly affected free asparagine (82.5 % variation).

Se further reduced free asparagine, particularly under adequate S conditions.

"These findings support the adoption of targeted foliar fertilization strategies combining Se and S to improve wheat quality."

2026

UNIVERSITÀ DI TORINO

Journal of Agriculture and Food Research 28 (2026) 102916

Contents lists available at ScienceDirect

Journal of Agriculture and Food Research

journal homepage: www.sciencedirect.com/journal/journal-of-agriculture-and-food-research

ELSEVIER

Effect of soil tillage and a fungicide application on the accumulation of free asparagine on wheat flours and the risk of acrylamide formation in baked goods

Valentina Guarino[a], Valentina Scarpino[a], Raffaele Meloni[a], Christos Fryganas[b], Laura Righetti[c,d], Vincenzo Fogliano[b], Massimo Blandino[a,*]

Guarino et al. 2026. https://doi.org/10.1016/j.jafr.2026.102916

3 bread **wheat** varieties (Aubusson, Giorgione, Solehio), with medium susceptibility to foliar disease and Fusarium head blight (FHB) resistance

Two years field trial.
Aubusson analysed for five agronomic years.

Evaluated agronomic conditions: combined effect of soil tillage + fungicide application

- MT, minimum tillage,
- CT, conventional tillage,
- NF, untreated control,
- F, fungicide application at flowering

effect on

- **Free asparagine** in wholegrain and refined flour
- **Acrylamide levels** in biscuits
- deoxynivalenol (DON) contamination in wholemeal flours and biscuits

CROP MANAGEMENT

6

2026

UNIVERSITÀ DI TORINO


Journal of Agriculture and Food Research 28 (2026) 102916

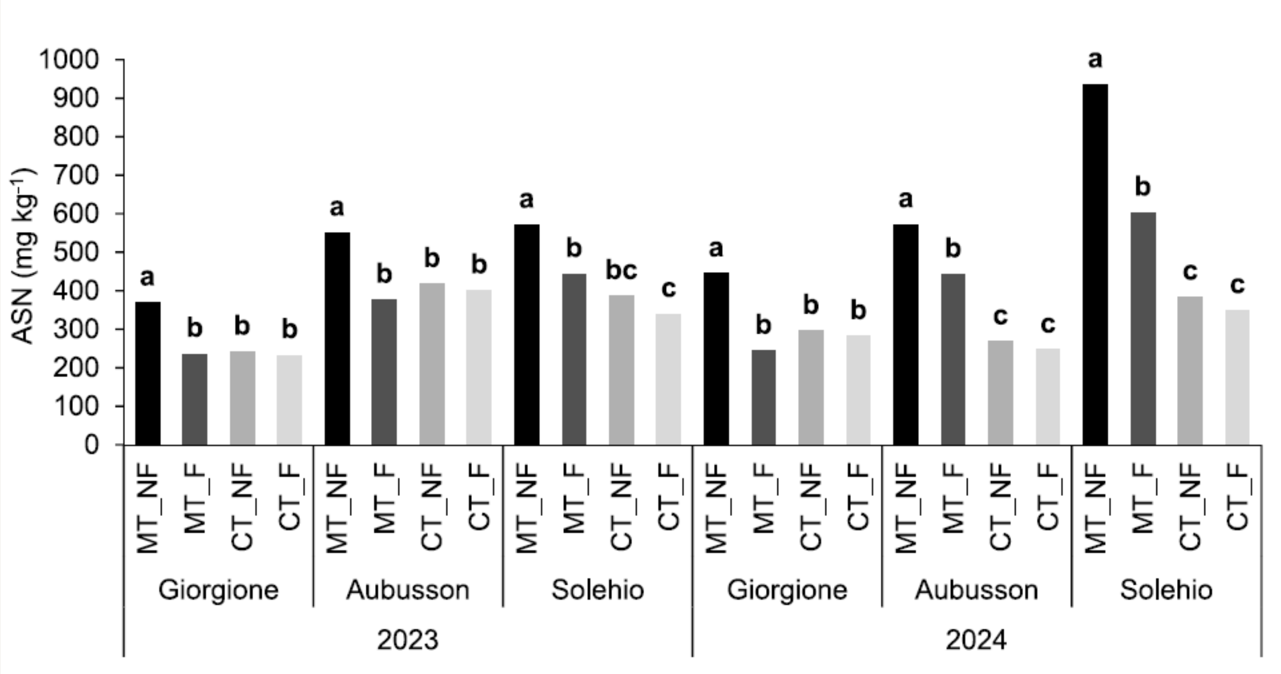
Contents lists available at ScienceDirect

Journal of Agriculture and Food Research

journal homepage: www.sciencedirect.com/journal/journal-of-agriculture-and-food-research

Effect of soil tillage and a fungicide application on the accumulation of free asparagine on wheat flours and the risk of acrylamide formation in baked goods

Valentina Guarino[a], Valentina Scarpino[a], Raffaele Meloni[a], Christos Fryganas[b], Laura Righetti[c,d], Vincenzo Fogliano[b], Massimo Blandino[a,*]



ASN in wholemeal flour: → AA in biscuits:

MT_NF → MT_NF

CT_NF -22% → CT_NF -14%

MT_F -37% → MT_F -18%

CT_F -48% → CT_F -22%

CT_F (conventional tillage + fungicide application) showed the lowest levels of free asparagine (ASN) in wholegrain flour and acrylamide (AA) in biscuits

CROP MANAGEMENT

6

2026

UNIVERSITÀ DI TORINO


Journal of Agriculture and Food Research 28 (2026) 102916

Contents lists available at ScienceDirect

Journal of Agriculture and Food Research

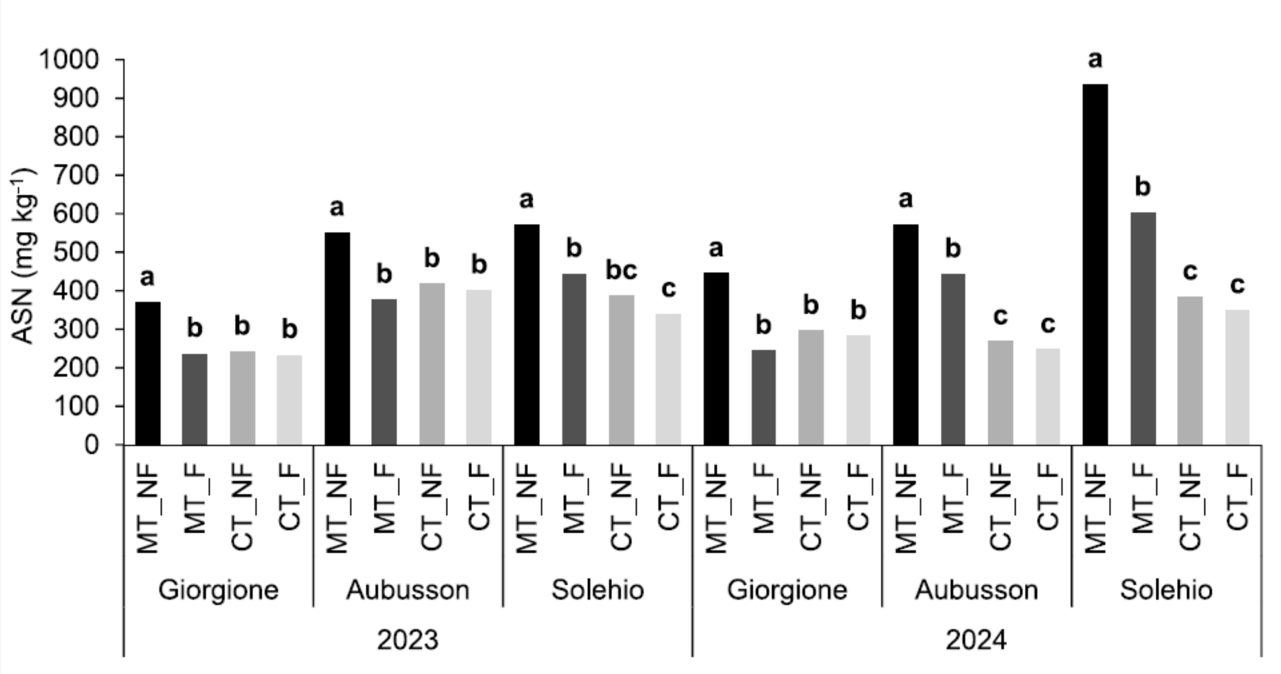
journal homepage: www.sciencedirect.com/journal/journal-of-agriculture-and-food-research

ELSEVIER

Effect of soil tillage and a fungicide application on the accumulation of free asparagine on wheat flours and the risk of acrylamide formation in baked goods

Valentina Guarino[a], Valentina Scarpino[a], Raffaele Meloni[a], Christos Fryganas[b], Laura Righetti[c,d], Vincenzo Fogliano[b], Massimo Blandino[a,*]

“Agronomic practices that ensure an appropriate grain filling can dilute free asparagine in whole kernels and reduce the acrylamide content of wheat-based products.”



ASN in wholemeal flour: → AA in biscuits:

ASN in wholemeal flour:		AA in biscuits:
MT_NF	→	MT_NF
CT_NF -22%	→	CT_NF -14%
MT_F -37%	→	MT_F -18%
CT_F -48%	→	CT_F -22%

CT_F (conventional tillage + fungicide application) showed the lowest levels of free asparagine (ASN) in wholegrain flour and acrylamide (AA) in biscuits

CROP MANAGEMENT

Control of soil N/S ratio

Balanced micronutrient composition

Avoiding water and salt stress

Disease control

BIOTECHNOLOGY

Genetic modification

Genome editing

TILLING

IDENTIFICATION OF GENETIC RESOURCES

Germplasm evaluation

Multi-environment trials

Natural deletion of *TaASN-B2*

STUDY OF GENETIC ARCHITECTURE

GWAS

QTL identification

Omics integration


SELEKCIJA I SEMENARSTVO, Vol. XXVIII (2022) broj 2

doi: 10.5937/SelSem2202013N

CEREAL GRAIN WITH LOW ACRYLAMIDE FORMATION POTENTIAL AS A RAW MATERIAL FOR SAFER CEREAL-BASED FOOD PRODUCTS IN SERBIA

Valentina Nikolić[1], Slađana Žilić[1], Marijana Simić[1], Natalija Kravić[1], Vesna Kandić[1], Milan Brankov[1], Marko Vasić[1]

plants MDPI

Article

Exploring Variability of Free Asparagine Content in the Grain of Bread Wheat (*Triticum aestivum* L.) Varieties Cultivated in Italy to Reduce Acrylamide-Forming Potential

LWT

ELSEVIER

Does the use of the Tritordeum, an alternative cereal for breadmaking, can be one of the mitigation strategies of acrylamide in bread?

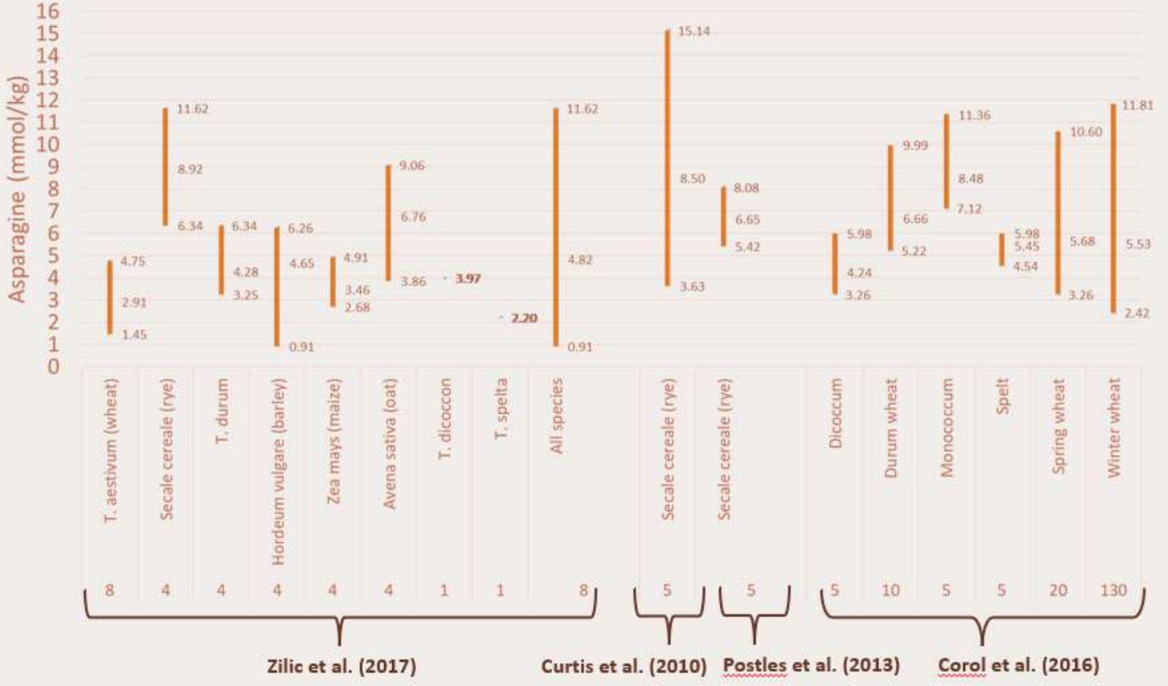
Journal of Food Composition and Analysis

ELSEVIER

The variability of winter rye cultivars in relation to grain quality parameters with special regard to the free asparagine content

Several studies have reported data on the differing propensities of cereals genotypes to accumulate free asparagine in the grain.

cereal genotypes



wheat genotypes

Certain genotypes maintain low and stable levels of free asparagine in the grain.

GERMPLASM EVALUATION / MULTI-ENVIRONMENT TRIALS

IDENTIFICATION OF GENETIC RESOURCES

1

2022

MAIZE RESEARCH INSTITUTE „ZEMUN POLJE" BELGRADE - ZEMUN

SELEKCIJA I SEMENARSTVO, Vol. XXVIII (2022) broj 2

doi: 10.5937/SelSem2202013N

CEREAL GRAIN WITH LOW ACRYLAMIDE FORMATION POTENTIAL AS A RAW MATERIAL FOR SAFER CEREAL-BASED FOOD PRODUCTS IN SERBIA

Valentina Nikolić[1], Slađana Žilić[1], Marijana Simić[1], Natalija Kravić[1], Vesna Kandić[1], Milan Brankov[1], Marko Vasić[1]

Nikolic et al. 2022. doi: 10.5937/SelSem2202013N

Review in "Selekcija i Semenarstvo" ("Plant Breed and Seed Production")

"In Serbia, there are no guidelines for the cultivation of cereals with a reduced potential for acrylamide formation."

Figure 1. The mitigation measures for safer low acrylamide cereal-based food production
Grafikon 1. Preventivne mere za bezbedniju proizvodnju hrane na bazi žitarica sa niskim sadržajem akrilamida

IDENTIFICATION OF GENETIC RESOURCES

2

2023

plants

Article

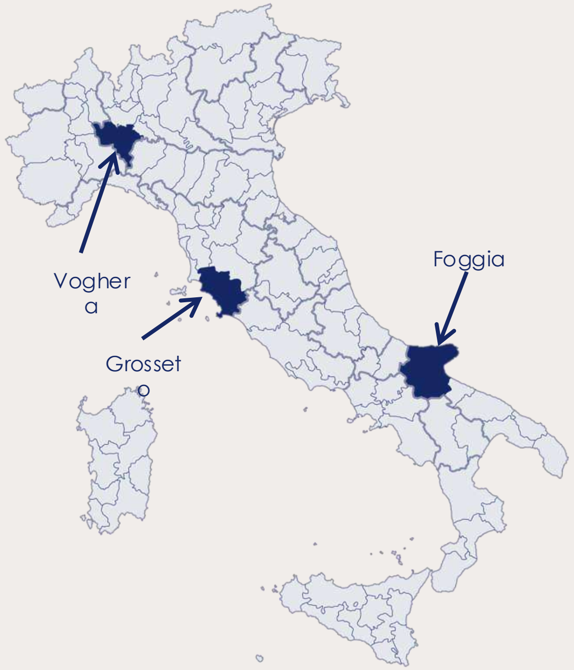
Exploring Variability of Free Asparagine Content in the Grain of Bread Wheat (*Triticum aestivum* L.) Varieties Cultivated in Italy to Reduce Acrylamide-Forming Potential

Andrea Tafuri [1,2,3], Melania Zuccaro [1], Stefano Ravaglia [2], Raul Pirona [1], Stefania Masci [3], Francesco Sestili [3], Domenico Lafiandra [3], Aldo Ceriotti [1] and Elena Baldoni [1,*]

Tafuri et al. 2023. https://doi.org/10.3390/plants12061349

Analysis of 54 **bread wheat** cultivars - used in the Italian market

- 3 growth locations
- 2 years



36 varieties in 2018–2019
3 field trials: 3 locations

36 varieties in 2019–2020
3 field trials: 3 locations

18 varieties in both years
6 field trials: 3 locations for 2 years

2023

Consiglio Nazionale delle Ricerche
Istituto di Biologia e Biotecnologia Agraria


plants MDPI

Article

Exploring Variability of Free Asparagine Content in the Grain of Bread Wheat (*Triticum aestivum* L.) Varieties Cultivated in Italy to Reduce Acrylamide-Forming Potential

Andrea Tafuri [1,2,3], Melania Zuccaro [1], Stefano Ravaglia [2], Raul Pirona [1], Stefania Masci [3], Francesco Sestili [3], Domenico Lafiandra [3], Aldo Ceriotti [1] and Elena Baldoni [1,*]

First year of field trials (2018–2019)

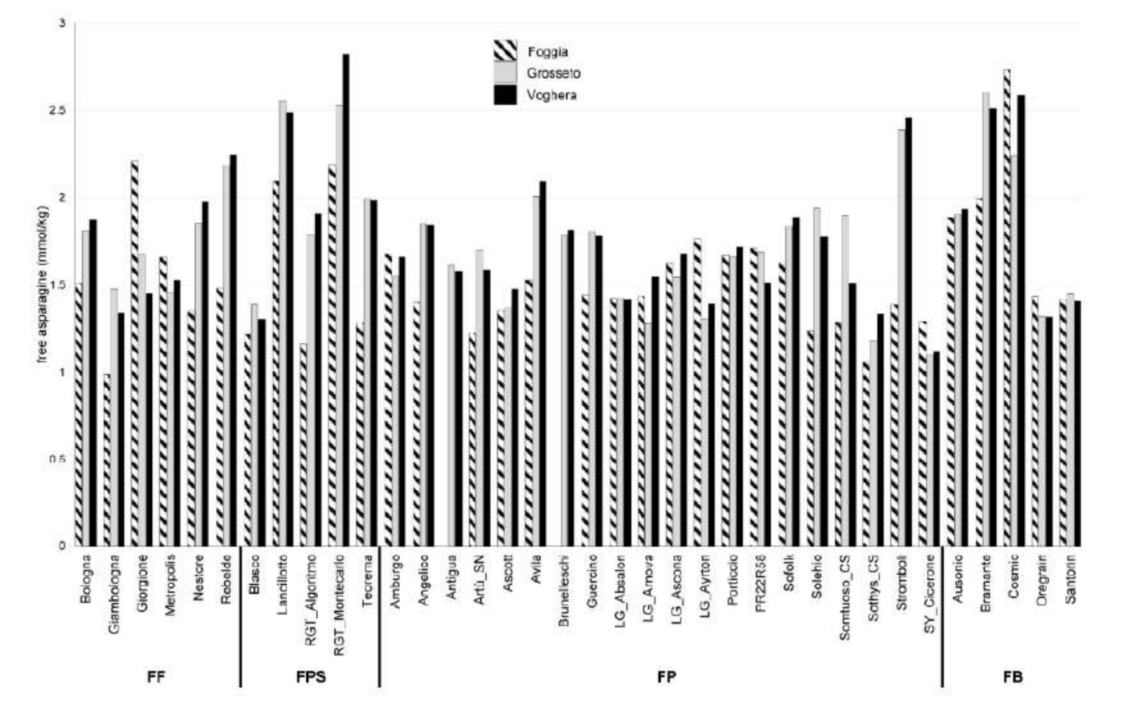


Figure 1. Concentration of fAsn in the grain of 36 bread wheat varieties grown in 2018–2019 in the three locations Foggia, Grosseto, and Voghera. FF: improver wheat; FPS: superior bread making wheat; FP: ordinary bread making wheat; FB: wheat for biscuits.

Second year of field trials (2019–2020)

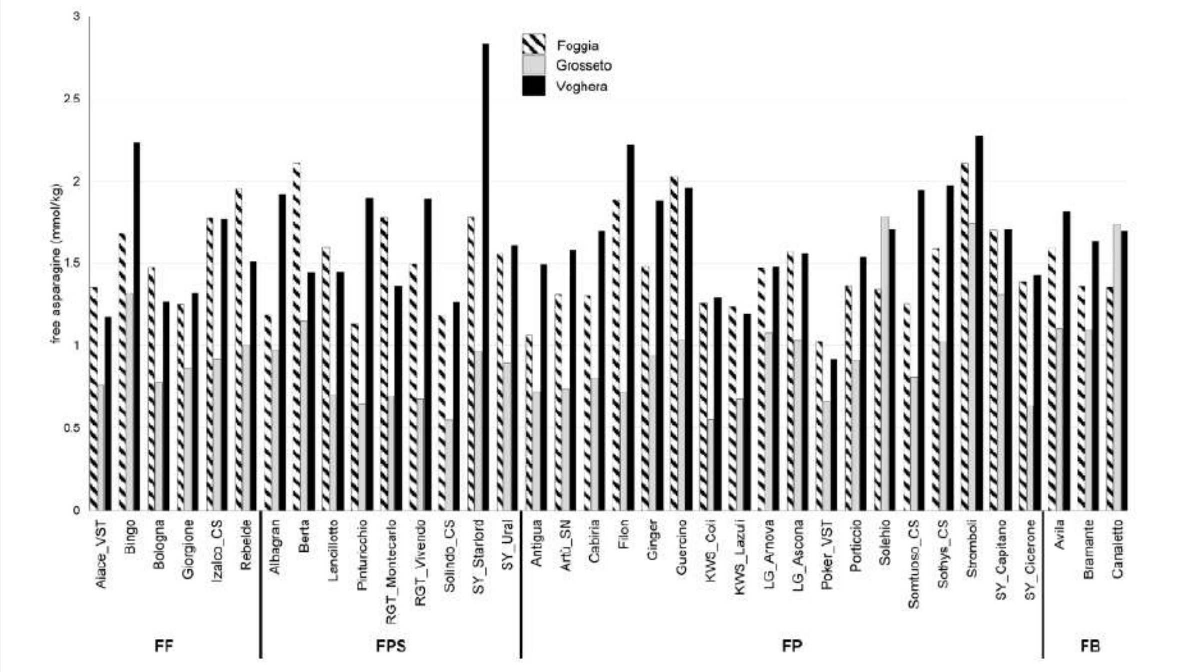


Figure 2. Concentration of fAsn in the grain of 36 bread wheat varieties grown in 2019–2020 in the three locations Foggia, Grosseto, and Voghera. FF: improver wheat; FPS: superior bread making wheat; FP: ordinary bread making wheat; FB: wheat for biscuits.

2023 Consiglio Nazionale delle Ricerche IBBA Istituto di Biologia e Biotecnologia Agraria

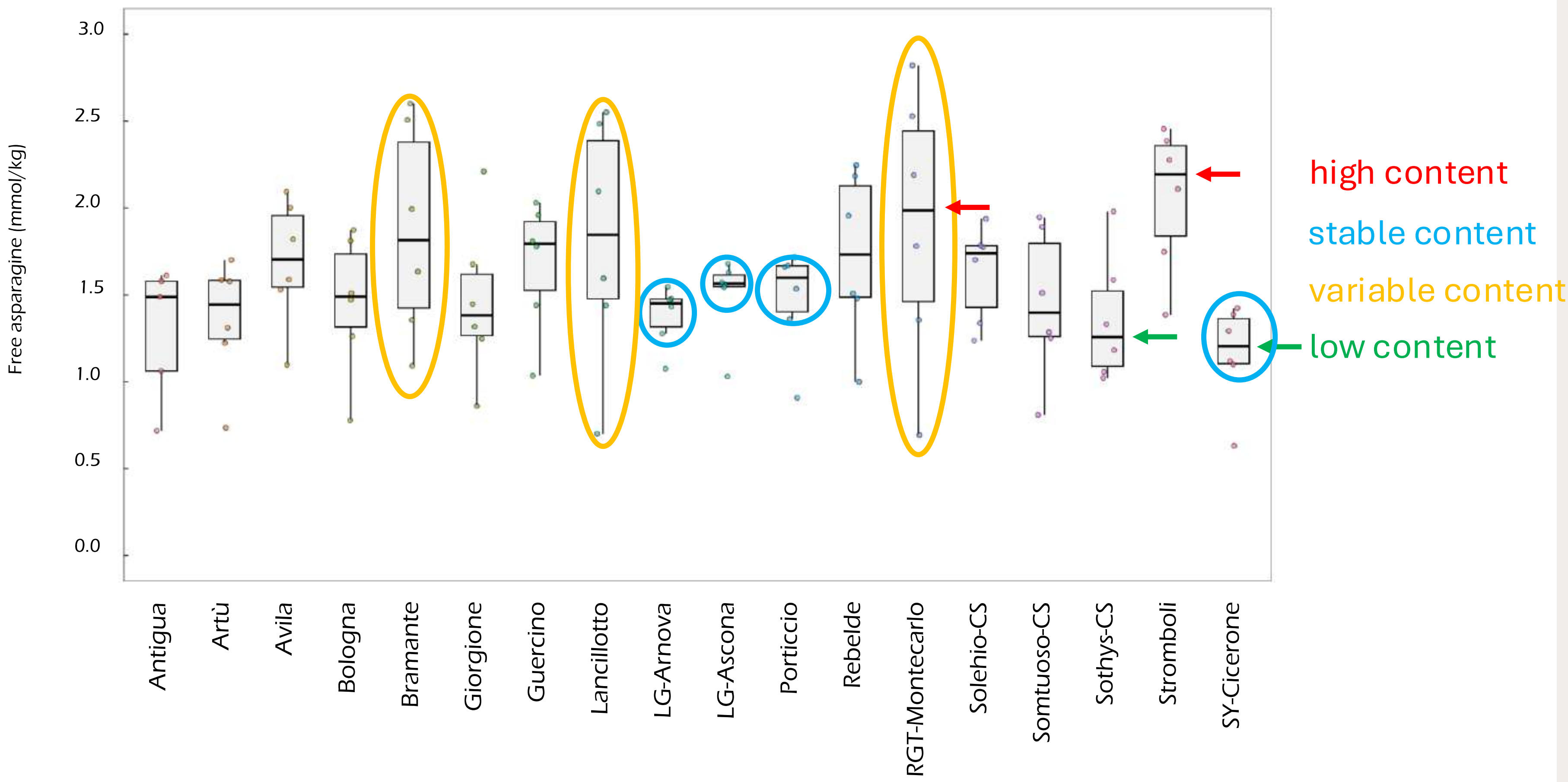
plants MDPI

Article

Exploring Variability of Free Asparagine Content in the Grain of Bread Wheat (*Triticum aestivum* L.) Varieties Cultivated in Italy to Reduce Acrylamide-Forming Potential

Andrea Tafuri [1,2,3], Melania Zuccaro [1], Stefano Ravaglia [2], Raul Pirona [1], Stefania Masci [3], Francesco Sestili [3], Domenico Lafiandra [3], Aldo Ceriotti [1] and Elena Baldoni [1,*]

Identification of cultivars with low and stable free asparagine content



2023 Consiglio Nazionale delle Ricerche IBBA Istituto di Biologia e Biotecnologia Agraria


plants MDPI

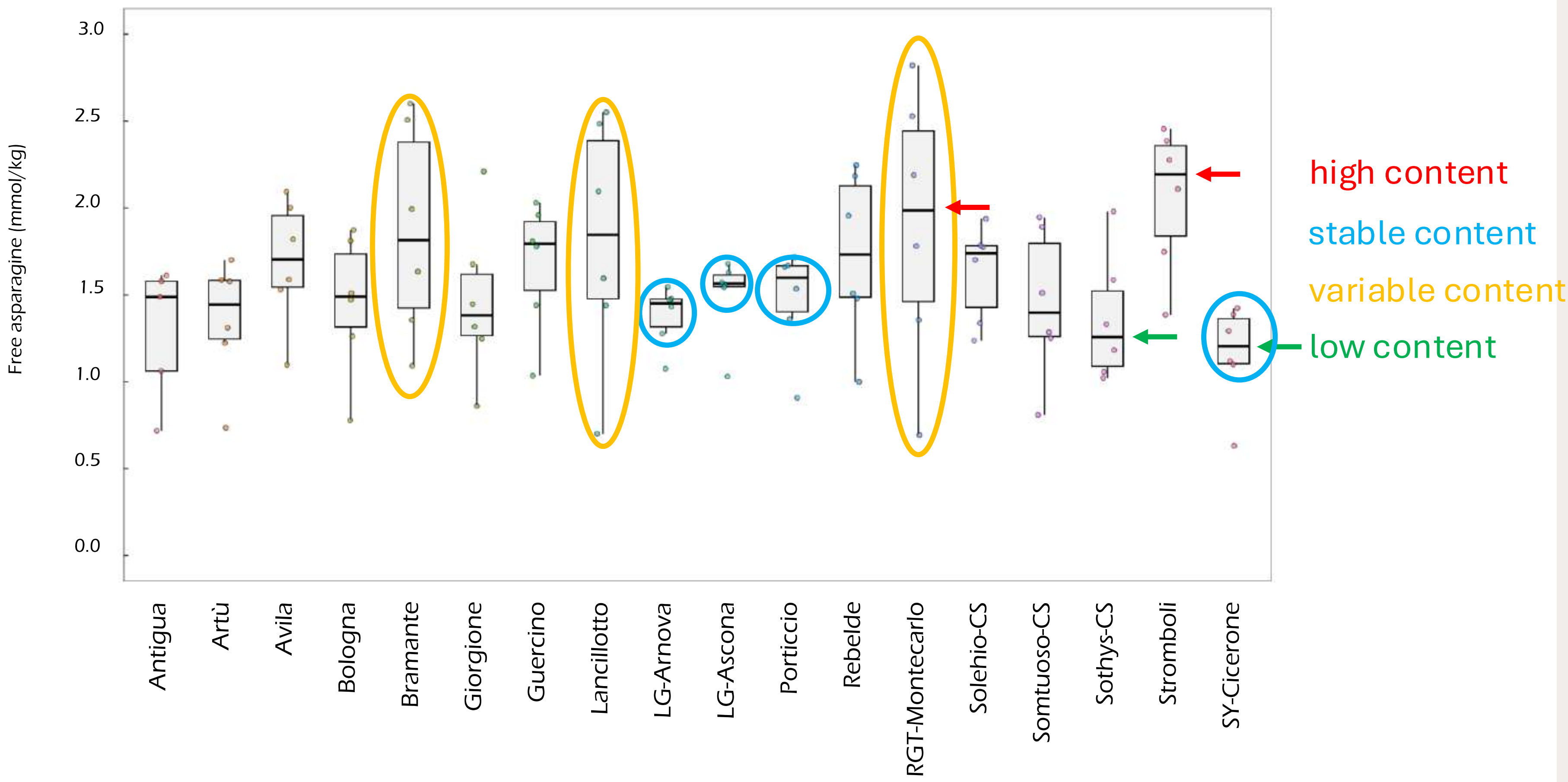
Article

Exploring Variability of Free Asparagine Content in the Grain of Bread Wheat (*Triticum aestivum* L.) Varieties Cultivated in Italy to Reduce Acrylamide-Forming Potential

Andrea Tafuri [1,2,3], Melania Zuccaro [1], Stefano Ravaglia [2], Raul Pirona [1], Stefania Masci [3], Francesco Sestili [3], Domenico Lafiandra [3], Aldo Ceriotti [1] and Elena Baldoni [1,*]

"These materials can be useful to dissect the mechanisms involved in free asparagine accumulation in wheat grain, and in breeding programs to reduce the acrylamide-forming potential of wheat varieties."

Identification of cultivars with low and stable free asparagine content



2025

INSTITUTE OF AGRICULTURAL AND FOOD BIOTECHNOLOGY STATE RESEARCH INSTITUTE

Journal of Food Composition and Analysis 148 (2025) 108605

Contents lists available at ScienceDirect

Journal of Food Composition and Analysis

journal homepage: www.elsevier.com/locate/jfca

ELSEVIER

The variability of winter rye cultivars in relation to grain quality parameters with special regard to the free asparagine content

Anna Szafrańska [a,1,*], Grażyna Podolska [b,2], Olga Świder [a,3], Marian Wiwart [c,4]

Szafranska et al. 2025. https://doi.org/10.1016/j.jfca.2025.108605

26 (13 open-pollinated – OPC, and 13 hybrids cultivars - HC) **winter rye** cultivars

Table 1
Open-pollinated and hybrid winter rye cultivars examined in the crop years 2018/2019 and 2019/2020 on field trials.

Population (open-pollinated) cultivars		Hybrid cultivars	
Cultivar	Origin	Cultivar	Origin
Antonińskie	Poznańska Hodowla Roślin sp. z o.o.	KWS Binntto	KWS Lochow Polska sp. z o.o.
Dańkowskie Amber	DANKO Hodowla Roślin sp. z o.o.	KWS Bono	KWS Lochow Polska sp. z o.o.
Dańkowskie Diament	DANKO Hodowla Roślin sp. z o.o.	KWS Dolaro	KWS Lochow Polska sp. z o.o.
Dańkowskie Granat	DANKO Hodowla Roślin sp. z o.o.	KWS Florano	KWS Lochow Polska sp. z o.o.
Dańkowskie Hadron	DANKO Hodowla Roślin sp. z o.o.	KWS Serafino	KWS Lochow Polska sp. z o.o.
Dańkowskie Rubin	DANKO Hodowla Roślin sp. z o.o.	KWS Trebiano	KWS Lochow Polska sp. z o.o.
Dańkowskie Skand	DANKO Hodowla Roślin sp. z o.o.	KWS Vinetto	KWS Lochow Polska sp. z o.o.
Dańkowskie Turkus	DANKO Hodowla Roślin sp. z o.o.	Piano	Saaten-Union Polska sp. z o.o.
Horyzo	Hodowla Roślin Smolice sp. z o.o.	SU Arvid	Saaten-Union Polska sp. z o.o.
Inspector	Saaten-Union Polska sp. z o.o.	SU Nasri	Saaten-Union Polska sp. z o.o.
Piastowskie	Poznańska Hodowla Roślin sp. z o.o.	SU Performer	Saaten-Union Polska sp. z o.o.
Poznańskie	Poznańska Hodowla Roślin sp. z o.o.	SU Promotor	Saaten-Union Polska sp. z o.o.
Reflektor	Saaten-Union Polska sp. z o.o.	Tur	Hodowla Roślin Smolice sp. z o.o.

- 2 cultivation managements (integrated and intensive), differing in the amount of nitrogen fertilization and fungicide protection.
- 2 years (2018/2019 and 2019/2020)

2025

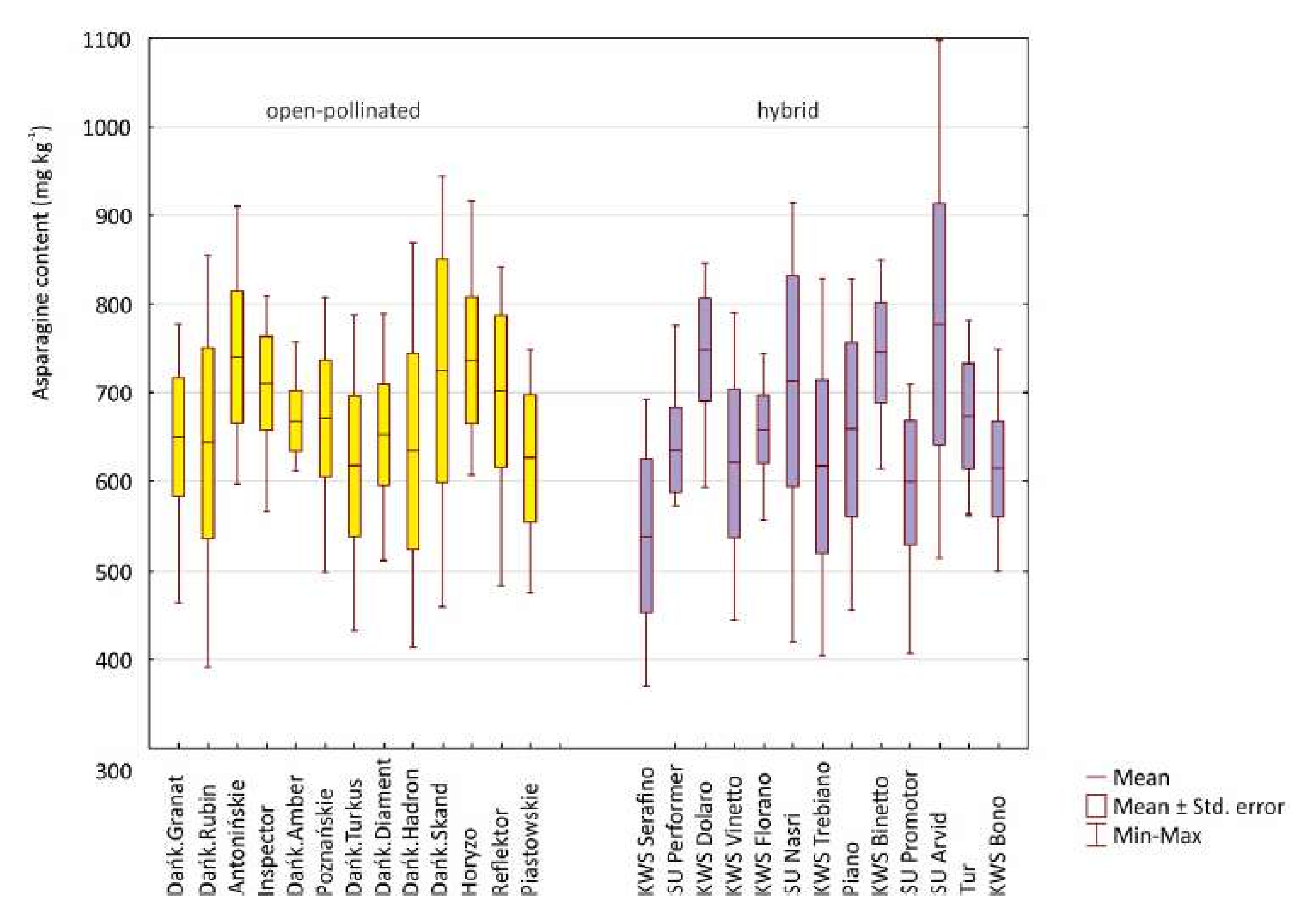
INSTITUTE OF AGRICULTURAL AND FOOD BIOTECHNOLOGY STATE RESEARCH INSTITUTE


Journal of Food Composition and Analysis 140 (2025) 108865
Contents lists available at ScienceDirect
Journal of Food Composition and Analysis
journal homepage: www.elsevier.com/locate/jfca

The variability of winter rye cultivars in relation to grain quality parameters with special regard to the free asparagine content

Anna Szafrańska, Grażyna Podolska, Olga Świder, Marian Wiwart

- Free asparagine content varied widely among cultivars (370–1098 mg kg-1);
- Weather conditions strongly affected its levels;
- Nine cultivars were highly affected by crop year and cultivation technology;
- The highest free asparagine content was found in HC SU Arvid;
- The highest free asparagine content was found in HC KWS Serafino had the lowest;
- OPC Dànkowskie Amber showed the lowest variability.



2025 INSTITUTE OF AGRICULTURAL AND FOOD BIOTECHNOLOGY STATE RESEARCH INSTITUTE


Journal of Food Composition and Analysis 140 (2025) 108605

Contents lists available at ScienceDirect

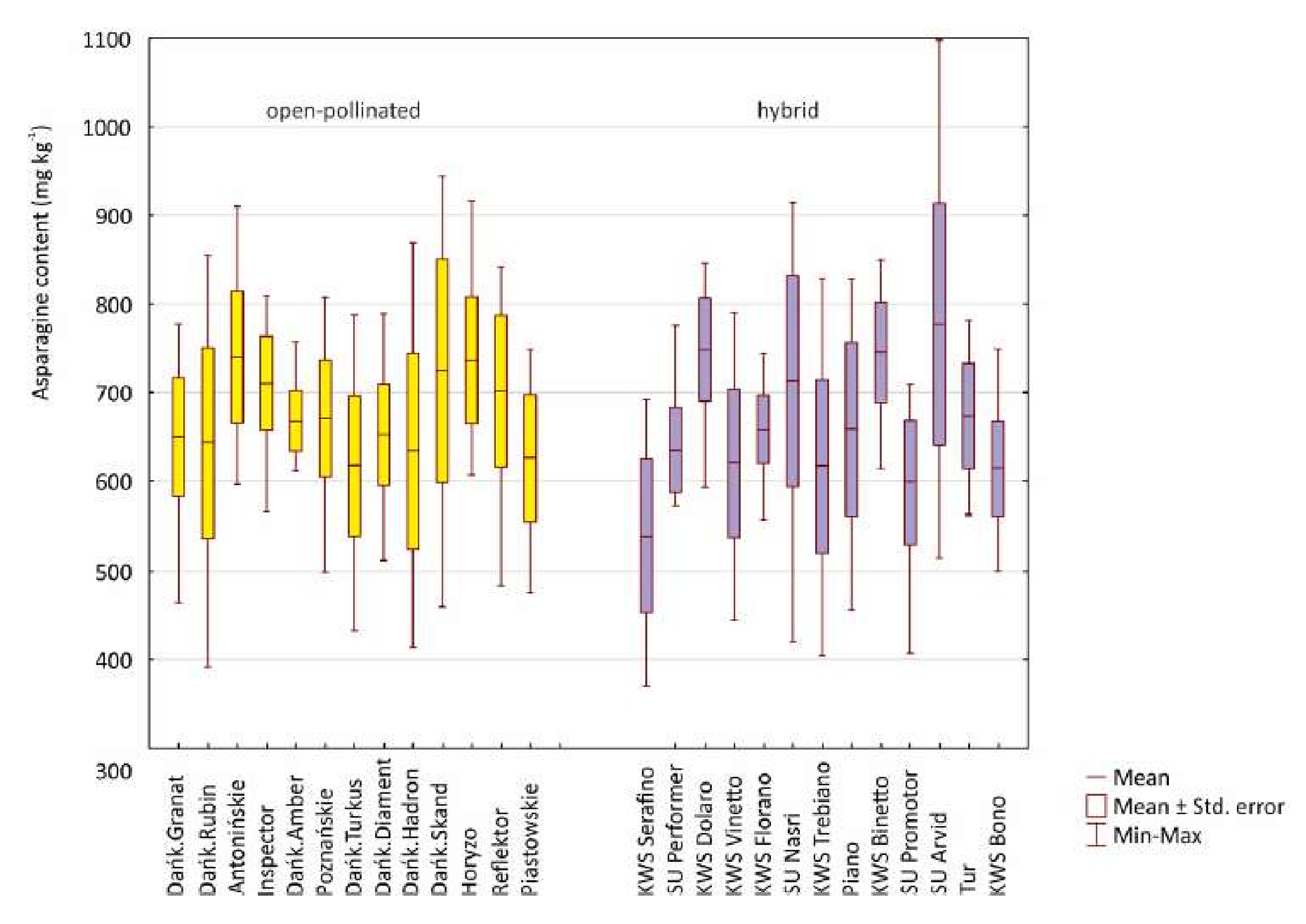
Journal of Food Composition and Analysis

journal homepage: www.elsevier.com/locate/jfca

The variability of winter rye cultivars in relation to grain quality parameters with special regard to the free asparagine content

Anna Szafrańska, Grażyna Podolska, Olga Świder, Marian Wiwart

- Free asparagine content varied widely among cultivars (370–1098 mg kg-1);
- Weather conditions strongly affected its levels;
- Nine cultivars were highly affected by crop year and cultivation technology;
- The highest free asparagine content was found in HC SU Arvid;
- The highest free asparagine content was found in HC KWS Serafino had the lowest;
- OPC Dànkowskie Amber showed the lowest variability.



“Overall, harvest year had the greatest effect on Asn content (67 %), followed by cultivar (14 %) and the interaction between harvest year and cultivar (9 %).”

2025

INSTITUTE OF AGRICULTURAL AND FOOD BIOTECHNOLOGY STATE RESEARCH INSTITUTE

UNIVERSITY OF WARMIA AND MAZURY IN OLSZTYN

LWT - Food Science and Technology 223 (2025) 117715

Contents lists available at ScienceDirect

LWT

journal homepage: www.elsevier.com/locate/lwt

ELSEVIER

Does the use of the Tritordeum, an alternative cereal for breadmaking, can be one of the mitigation strategies of acrylamide in bread?

Marian Wiwart[a], Anna Szafrańska[b,*], Elżbieta Suchowilska[a]

Wiwart et al. 2025. https://doi.org/10.1016/j.jfca.2025.108605

Characterization of 11 **spring *Tritordeum*** breeding lines

Comparison with modern cultivars of durum wheat, bread wheat, and naked barley

Tritordeum (*Tritordeum martinii* A. Pujadas, nothosp. nov.) is a relatively new allohexaploid crop obtained by crossing diploid wild barley (*Hordeum chilense* Roem. et Schultz) (HchHch) with tetraploid durum wheat (*Triticum turgidum* ssp. *durum* (Desf.) Husn.) (AABB)

2025 INSTITUTE OF AGRICULTURAL AND FOOD BIOTECHNOLOGY STATE RESEARCH INSTITUTE · UNIVERSITY OF WARMIA AND MAZURY IN OLSZTYN


LWT - Food Science and Technology 223 (2025) 117713

Contents lists available at ScienceDirect

LWT

Journal homepage: www.elsevier.com/locate/lwt

ELSEVIER

Does the use of the Tritordeum, an alternative cereal for breadmaking, can be one of the mitigation strategies of acrylamide in bread?

Marian Wiwart[a], Anna Szafrańska[b], Elżbieta Suchowilska[a]

	Tritordeum	*vs*	bread wheat
protein content	14%		13.3%
ash	0.60%		0.54%
wet gluten	34.3%		31.9%
gluten index	51%		90%
Free asparagine content in grain	185 mg/kg		188 mg/kg
content of acrylamide in bread	15 µg/kg		21.9 µg/kg

2025

INSTITUTE OF AGRICULTURAL AND FOOD BIOTECHNOLOGY STATE RESEARCH INSTITUTE

UNIVERSITY OF WARMIA AND MAZURY IN OLSZTYN

LWT - Food Science and Technology 223 (2026) 117713

Contents lists available at ScienceDirect

LWT

journal homepage: www.elsevier.com/locate/lwt

Does the use of the Tritordeum, an alternative cereal for breadmaking, can be one of the mitigation strategies of acrylamide in bread?

Marian Wiwart, Anna Szafrańska, Elżbieta Suchowilska

	Tritordeum	*vs*	bread wheat
protein content	14%		13.3%
ash	0.60%		0.54%
wet gluten	34.3%		31.9%
gluten index	51%		90%
Free asparagine content in grain	185 mg/kg		188 mg/kg
content of acrylamide in bread	15 µg/kg		21.9 µg/kg

“The lower acrylamide content in Tritordeum bread is likely due to its reduced asparagine content, lower starch damage content and denser bread structure. However, other factors, such as sugar composition and Maillard reaction kinetics, may also play a role in this outcome.”

CROP MANAGEMENT

Control of soil N/S ratio

Balanced micronutrient composition

Avoiding water and salt stress

Disease control

BIOTECHNOLOGY

Genetic modification

Genome editing

TILLING

IDENTIFICATION OF GENETIC RESOURCES

Germplasm evaluation

Multi-environment trials

Natural deletion of *TaASN-B2*

STUDY OF GENETIC ARCHITECTURE

GWAS

QTL identification

Omics integration

ORIGINAL ARTICLE

Genetic control of grain amino acid composition in a UK soft wheat mapping population

Joseph Oddy | Monika Chhetry | Rajani Awal | John Addy | Mark Wilkinson | Dan Smith | Robert King | Chris Hall | Rebecca Testa | Eve Murray | Sarah Raffan | Tanya Y. Curtis | Lucie Wingen | Simon Griffiths | Simon Berry | J. Stephen Elmore | Nicholas Cryer | Isabel Moreira de Almeida | Nigel G. Halford

Food Chemistry

Integrated GWAS and metabolomic analyses identified metabolic pathways and candidate genes involved in free asparagine accumulation in durum wheat grain

GWAS and QTL identification

Complex genetic architecture of the trait	**No major-effect QTL** have been identified - multiple loci with moderate additive effects.	–
High influence of the environment	**Instability in MTAs** - many loci exhibiting environment-specific effects.	–
Strong G×E interactions	Potential **pleiotropic effects on agronomic traits**, such as yield and grain quality.	–
Heritability of free asparagine content is **medium to high**.	Possibility to breed for this trait.	+

MULTI-ENVIRONMENT TRIALS

INTEGRATIVE APPROACHES

STUDY OF GENETIC ARCHITECTURE

1

2023 ROTHAMSTED RESEARCH

Received: 11 July 2022 | Accepted: 13 March 2023

DOI: 10.1002/tpg2.20335

The Plant Genome

ORIGINAL ARTICLE

Special Section: Grain Quality and Nutritional Genomics for Breeding Next Generation Crops

Genetic control of grain amino acid composition in a UK soft wheat mapping population

Joseph Oddy[1] | Monika Chhetry[2] | Rajani Awal[2] | John Addy[1] | Mark Wilkinson[1] | Dan Smith[1] | Robert King[1] | Chris Hall[1] | Rebecca Testa[1] | Eve Murray[1] | Sarah Raffan[1] | Tanya Y. Curtis[3] | Luzie Wingen[2] | Simon Griffiths[2] | Simon Berry[4] | J. Stephen Elmore[5] | Nicholas Cryer[6] | Isabel Moreira de Almeida[7] | Nigel G. Halford[1]

Tafuri et al. 2023. https://doi.org/10.3390/plants12061349

"High free asparagine and low lysine concentrations limit the nutritional value of wheat grain"

- Robigus × Claire doubled haploid population
- 2 years field trial (2017–2018, 2018–2019)

Evaluation of:

amino acids composition

grain related trait:

- grain diameter
- kernel hardness index (KHI),
- Grain weight measurements
- Grain length, width, and area
- Hagberg falling number

✓ Linkage analysis

✓ Identification of quantitative trait loci (QTL) controlling free amino acids and other traits

STUDY OF GENETIC ARCHITECTURE

1

2023 ROTHAMSTED RESEARCH

Received: 11 July 2022 | Accepted: 13 March 2023

DOI: 10.1002/tpg2.20335

The Plant Genome

ORIGINAL ARTICLE

Special Section: Grain Quality and Nutritional Genomics for Breeding Next Generation Crops

Genetic control of grain amino acid composition in a UK soft wheat mapping population

Joseph Oddy[1] | Monika Chhetry[2] | Rajani Awal[2] | John Addy[1] | Mark Wilkinson[1] | Dan Smith[1] | Robert King[1] | Chris Hall[1] | Rebecca Testa[1] | Eve Murray[1] | Sarah Raffan[1] | Tanya Y. Curtis[3] | Luzie Wingen[2] | Simon Griffiths[2] | Simon Berry[4] | J. Stephen Elmore[5] | Nicholas Cryer[6] | Isabel Moreira de Almeida[7] | Nigel G. Halford[1]

"High free asparagine and low lysine concentrations limit the nutritional value of wheat grain"

- Robigus × Claire doubled haploid population
- 2 years field trial (2017–2018, 2018–2019)

TABLE 1 Multi-environment quantitative trait locus (QTL) for measured amino acids.

	Multi-environment single trait linkage analysis (H18 and H19)							
Trait	Marker	Chr.	cM	Mbp	$-\log_{10}(p)$	H18 (%)	H19 (%)	High val.
Ala	WC.0223839	7B	211.2	719	5.03	7.1	5.7	Robigus
Asn	WC.0221262	4B	114.47	601	5.96	2.6	14.8	Robigus
Asp	WC.0218489	1B	54.4	530	5.4	8	5.9	Claire
	WC.0214359	3A2	2.3	738	7.95	7.3	15.3	Robigus
	WC.0221037	4A	148.8	703	8.08	12.6	9.3	Claire
	WC.0227146	4D	48.8	16	3.7	5.5	4.1	Claire
Gln	WC.0221302	4B	103.7	547	3.5	5.4	4.5	Robigus
	WC.0228471	6B	19.7	25	5.09	8.2	6.7	Claire
Glu	WC.0221329	4B	100.8	518	4.27	3.7	10.1	Robigus
Gly	WC.0226796	4B	155.2	327	4.26	3.2	5.3	Robigus
Iso	WC.0223785	7B	211.2	717	3.6	6.8	3.7	Robigus
Lys	WC.0218011	1A2	27.3	593	4.95	12.1	2.6	Claire
Phe	WC.0220622	3B1	78.1	116	3.83	6.2	5.6	Robigus

Abbreviations: Chr., chromosome; cM, centimorgan; H18/H19 (%), percentage of variation explained by QTL in respective year; High val., parental line carrying the allele responsible for the higher value; Mbp, megabase pair location in Chinese Spring v1.0.

STUDY OF GENETIC ARCHITECTURE

1

2023 ROTHAMSTED RESEARCH

Received: 11 July 2022 | Accepted: 13 March 2023
DOI: 10.1002/tpg2.20335
The Plant Genome
ORIGINAL ARTICLE
Special Section: Grain Quality and Nutritional Genomics for Breeding Next Generation Crops

Genetic control of grain amino acid composition in a UK soft wheat mapping population

Joseph Oddy[1] | Monika Chhetry[2] | Rajani Awal[2] | John Addy[1] | Mark Wilkinson[1] | Dan Smith[1] | Robert King[1] | Chris Hall[1] | Rebecca Testa[1] | Eve Murray[1] | Sarah Raffan[1] | Tanya Y. Curtis[3] | Luzie Wingen[2] | Simon Griffiths[2] | Simon Berry[4] | J. Stephen Elmore[5] | Nicholas Cryer[6] | Isabel Moreira de Almeida[7] | Nigel G. Halford[1]

"High free asparagine and low lysine concentrations limit the nutritional value of wheat grain"

- Robigus × Claire doubled haploid population
- 2 years field trial (2017–2018, 2018–2019)

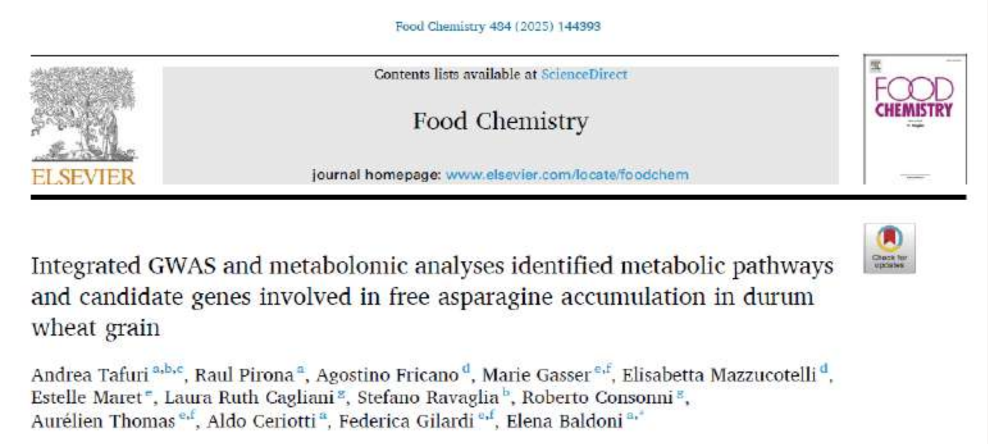
"Breeding for lower free asparagine and higher lysine using Claire and Robigus diversity is possible but limited."

TABLE 1 Multi-environment quantitative trait locus (QTL) for measured amino acids.

	Multi-environment single trait linkage analysis (H18 and H19)							
Trait	Marker	Chr.	cM	Mbp	$-\log_{10}(p)$	H18 (%)	H19 (%)	High val.
Ala	WC.0223839	7B	211.2	719	5.03	7.1	5.7	Robigus
Asn	WC.0221262	4B	114.47	601	5.96	2.6	14.8	Robigus
Asp	WC.0218489	1B	54.4	530	5.4	8	5.9	Claire
	WC.0214359	3A2	2.3	738	7.95	7.3	15.3	Robigus
	WC.0221037	4A	148.8	703	8.08	12.6	9.3	Claire
	WC.0227146	4D	48.8	16	3.7	5.5	4.1	Claire
Gln	WC.0221302	4B	103.7	547	3.5	5.4	4.5	Robigus
	WC.0228471	6B	19.7	25	5.09	8.2	6.7	Claire
Glu	WC.0221329	4B	100.8	518	4.27	3.7	10.1	Robigus
Gly	WC.0226796	4B	155.2	327	4.26	3.2	5.3	Robigus
Iso	WC.0223785	7B	211.2	717	3.6	6.8	3.7	Robigus
Lys	WC.0218011	1A2	27.3	593	4.95	12.1	2.6	Claire
Phe	WC.0220622	3B1	78.1	116	3.83	6.2	5.6	Robigus

Abbreviations: Chr., chromosome; cM, centimorgan; H18/H19 (%), percentage of variation explained by QTL in respective year; High val., parental line carrying the allele responsible for the higher value; Mbp, megabase pair location in Chinese Spring v1.0.

2025 Consiglio Nazionale delle Ricerche IBBA Istituto di Biologia e Biotecnologia Agraria


Food Chemistry 484 (2025) 144393

Contents lists available at ScienceDirect

Food Chemistry

journal homepage: www.elsevier.com/locate/foodchem

ELSEVIER

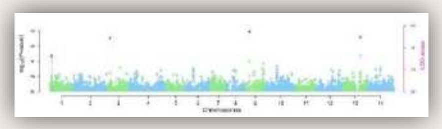
Integrated GWAS and metabolomic analyses identified metabolic pathways and candidate genes involved in free asparagine accumulation in durum wheat grain

Andrea Tafuri [a,b,c], Raul Pirona [a], Agostino Fricano [d], Marie Gasser [e,f], Elisabetta Mazzucotelli [d], Estelle Maret [e], Laura Ruth Cagliani [g], Stefano Ravaglia [b], Roberto Consonni [g], Aurélien Thomas [e,f], Aldo Ceriotti [a], Federica Gilardi [e,f], Elena Baldoni [a,*]

Tafuri et al. 2025. https://doi.org/10.3390/plants12061349

- 201 genotypes (180 landraces) of *Triticum turgidum* L. ssp. *durum* (Desf.) originated from 33 different countries from the Global Durum Panel (GDP)

- 3 years field trial

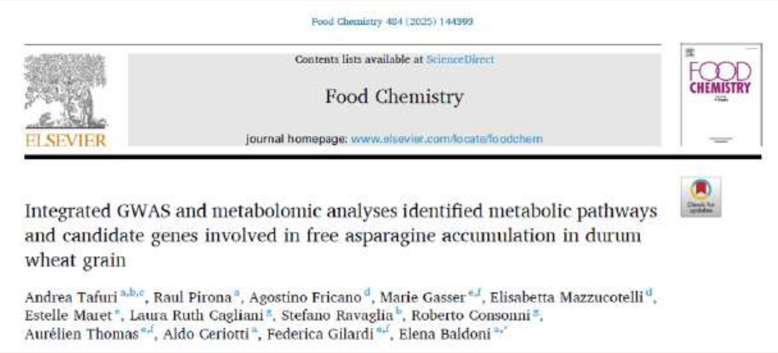


Genome Wide Association Study (GWAS)

Metabolomic analysis (+/- UPLC-HRMS) –

Identification of candidate genes

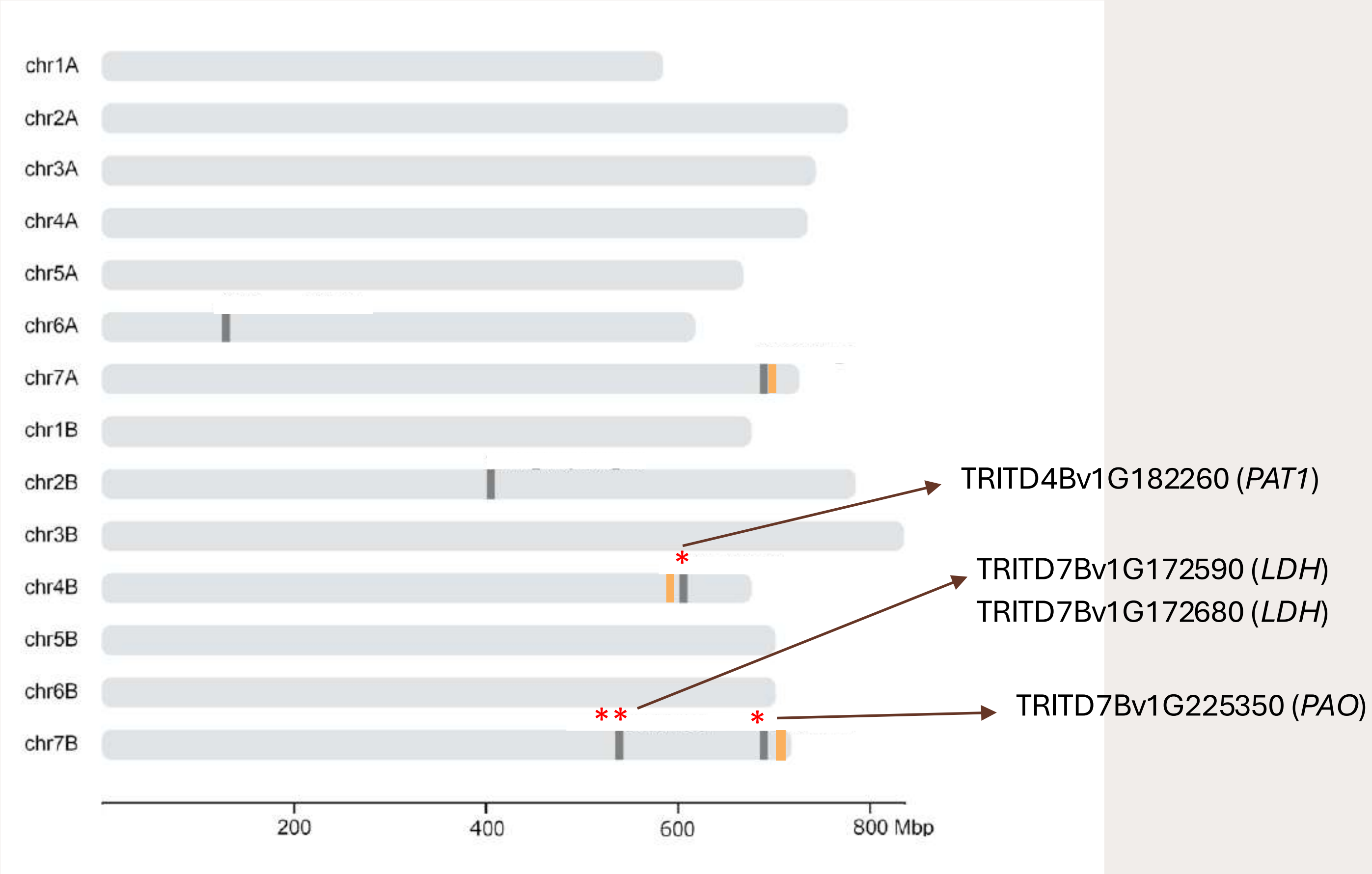
2025 IBBA Consiglio Nazionale delle Ricerche
Istituto di Biologia e Biotecnologia Agraria


Food Chemistry 484 (2025) 144393
Contents lists available at ScienceDirect
Food Chemistry
journal homepage: www.elsevier.com/locate/foodchem

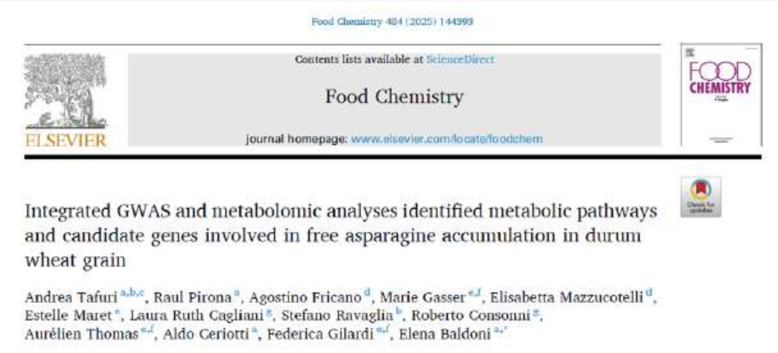
Integrated GWAS and metabolomic analyses identified metabolic pathways and candidate genes involved in free asparagine accumulation in durum wheat grain

Andrea Tafuri[a,b,c], Raul Pirona[a], Agostino Fricano[d], Marie Gasser[e,f], Elisabetta Mazzucotelli[d], Estelle Maret[e], Laura Ruth Cagliani[g], Stefano Ravaglia[b], Roberto Consonni[g], Aurélien Thomas[e,f], Aldo Ceriotti[a], Federica Gilardi[e,f], Elena Baldoni[a,*]

Identification of six QTNs associated to free asparagine content in the grain and four candidate genes involved in this trait.



2025 Consiglio Nazionale delle Ricerche IBBA Istituto di Biologia e Biotecnologia Agraria



Food Chemistry 484 (2025) 144399

Contents lists available at ScienceDirect

Food Chemistry

journal homepage: www.elsevier.com/locate/foodchem

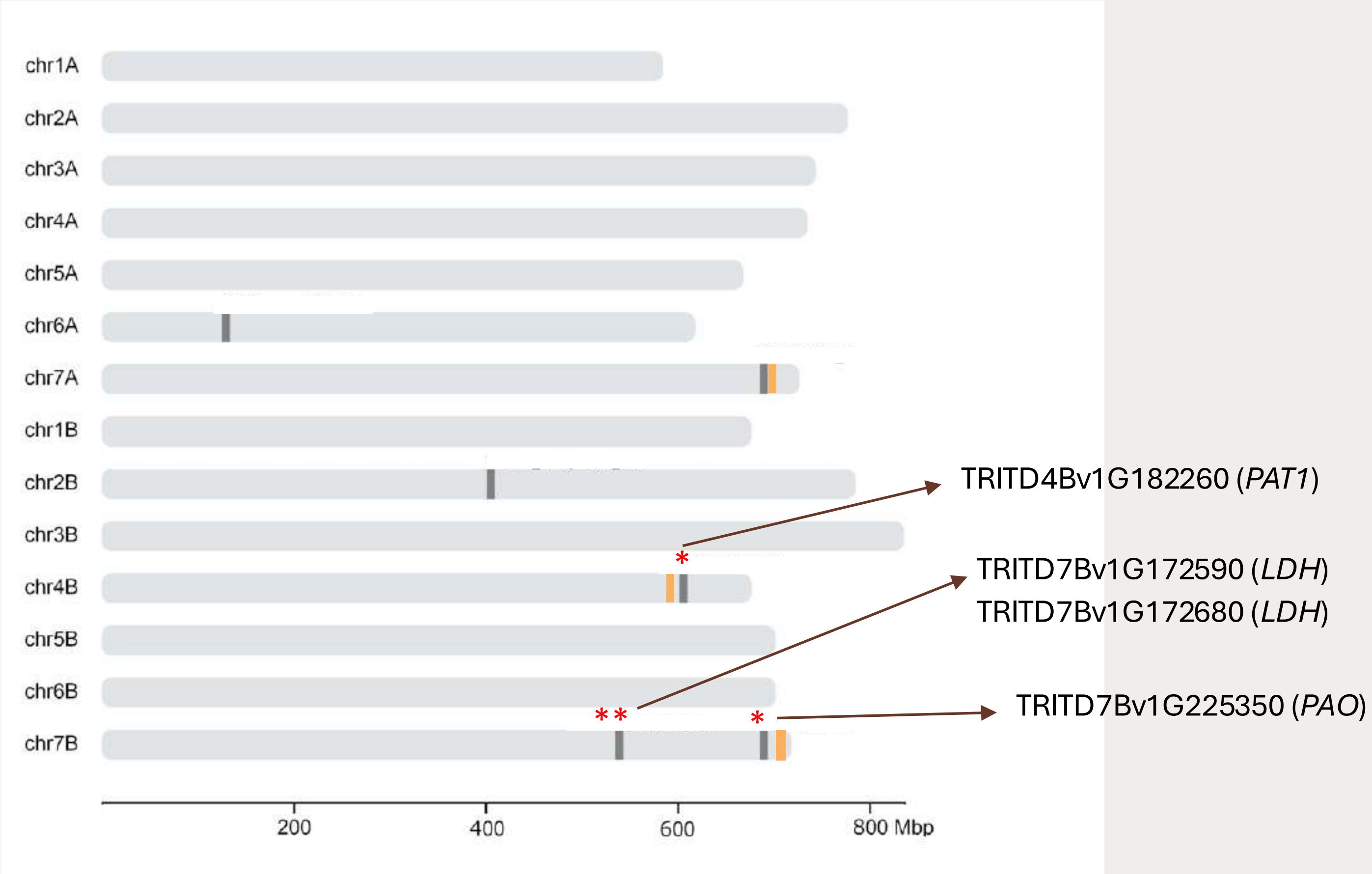
Integrated GWAS and metabolomic analyses identified metabolic pathways and candidate genes involved in free asparagine accumulation in durum wheat grain

Andrea Tafuri [a,b,c], Raul Pirona [a], Agostino Fricano [d], Marie Gasser [e,f], Elisabetta Mazzucotelli [d], Estelle Maret [e], Laura Ruth Cagliani [g], Stefano Ravaglia [b], Roberto Consonni [g], Aurélien Thomas [e,f], Aldo Ceriotti [a], Federica Gilardi [e,f], Elena Baldoni [a,*]

Identification of six QTNs associated to free asparagine content in the grain and four candidate genes involved in this trait.

“The six detected QTNs could be of interest for future breeding programs in elite varieties aimed to reduce acrylamide forming potential.

This study gave new insight in the complex metabolic network that control free asparagine levels in wheat grain.”



GWAS and QTL identification

Reference	n. of analysed genotypes	n. of QTLs	Chromosome
Emebiri, 2014	92 varieties	1 QTL (9 SNPs)	5A
Rapp et al. 2018	149 varieties	8 QTL/SNPs	1A, 4A, 7A, 1B, 6B, 7B, 2D, 6D
Lavoignat et al. 2024	481 varieties	16 QTL (146 SNPs)	1A, 3A (2), 6A, 7A, 1B, 2B, 3B (2), 5B, 6B (2), 7B (2), 2D
Rączka et al. 2025	174 elite winter wheat lines	15 QTL (43 SNPs)	1B, 1D, 2B, 2D, 3A, 3B, 3D, 4A, 5B, 5D, 6B, 6D, 7A, 7B, 7D
Oddy et al. 2023	**171 doubled haploid lines of Robigus × Claire**	**1 QTL/SNP**	**4B**
Tafuri et al. 2025	**201 landraces and varieties of durum wheat**	**6 QTNs**	**6A, 7A, 2B, 4B, 7B**

Candidate genes and associated markers

Species	Candidate gene	Gene name	Metabolic pathway	Chr	Associated QTL	Peak marker position (Mbp)	Reference
T. aestivum	***TraesCS3A02G077100; TraesCS3D02G077300***	**asparagine synthetase 2 (*TaASN2*)**	**asparagine synthesis in seed**	**3A, 3D**	**-**	**-**	**Raffan et al. 2021**
	-	**asparagine synthetase 2B (*TaASN-B2*)**	**asparagine synthesis in seed**	**3B**	**-**	**-**	**Oddy et al. 2021**
	TraesCS1B03G0736700	H-subunit of mitochondrial NAD(P)H dehydrogenase	mitochondrial electron transport chain	1B	QGfac.rut.1B.1	468.9	Rączka et al. 2025
T. turgidum ssp. durum	***TRITD4Bv1G182260***	**anthranilate phosphoribosyl transferase (*PAT1*)**	**tryptophan biosynthesis pathway**	**4B**	**GENE-4008_418**	**609.4**	**Tafuri et al. 2025**
	TRITD7Bv1G172590	**L-lactate dehydrogenase (*LDH*)**	**glucose metabolism / asparaginase II pathway**	**7B**	**BS00108573_51**	**545.2**	
	TRITD7Bv1G172680	**L-lactate dehydrogenase (*LDH*)**	**glucose metabolism / asparaginase II pathway**	**7B**	**BS00108573_51**	**545.2**	
	TRITD7Bv1G225350	**polyamine oxidase (*PAO*)**	**polyamine metabolism /asparagine-methionine bicycle**	**7B**	**BS00062611_51**	**697.6**	


Plant Biotechnology Journal

Brief Communication

Field assessment of genome-edited, low asparagine wheat: Europe's first CRISPR wheat field trial

Sarah Raffan[1], Joseph Oddy[1], Andrew Mead[1], Gary Barker[2], Tanya Curtis[3], Sarah Usher[1], Christopher Burt[4] and Nigel G. Halford[1,*]


Plant Biotechnology Journal

WILEY

RESEARCH ARTICLE

Field Trials and Baking Studies of Ultra-Low Asparagine, Genome Edited (CRISPR/Cas9) and Mutant (TILLING) Wheat

CROP MANAGEMENT

Control of soil N/S ratio

Balanced micronutrient composition

Avoiding water and salt stress

Disease control

BIOTECHNOLOGY

Genetic modification

Genome editing

TILLING

IDENTIFICATION OF GENETIC RESOURCES

Germplasm evaluation

Multi-environment trials

Natural deletion of *TaASN-B2*

STUDY OF GENETIC ARCHITECTURE

GWAS

QTL identification

Omics integration

2021
2026

ROTHAMSTED RESEARCH

Plant Biotechnology Journal

Plant Biotechnology Journal (2021) 19, pp. 1602–1613 doi: 10.1111/pbi.13573

Wheat with greatly reduced accumulation of free asparagine in the grain, produced by CRISPR/Cas9 editing of asparagine synthetase gene *TaASN2*

Sarah Raffan[1], Caroline Sparks[1], Alison Huttly[1], Lucy Hyde[1,a], Damiano Martignago[1,b], Andrew Mead[2], Steven J. Hanley[2], Paul A. Wilkinson[3], Gary Barker[3], Keith J. Edwards[3], Tanya Y. Curtis[4], Sarah Usher[4], Ondrej Kosik[4] and Nigel G. Halford[1,*]

Raffan et al. 2021. doi: 10.1111/pbi.13573

Plant Biotechnology Journal

Plant Biotechnology Journal (2023) 21, pp. 1097–1099 doi: 10.1111/pbi.14026

Brief Communication

Field assessment of genome-edited, low asparagine wheat: Europe's first CRISPR wheat field trial

Sarah Raffan[1], Joseph Oddy[1], Andrew Mead[1], Gary Barker[2], Tanya Curtis[3], Sarah Usher[3], Christopher Burt[4] and Nigel G. Halford[1,*]

Raffan et al. 2023. doi: 10.1111/pbi.14026

Plant Biotechnology Journal

WILEY

RESEARCH ARTICLE OPEN ACCESS

Field Trials and Baking Studies of Ultra-Low Asparagine, Genome Edited (CRISPR/Cas9) and Mutant (TILLING) Wheat

Navneet Kaur[1] | Sarah Raffan[1] | Suzanne J. Clark[1] | Shpresa Musa[2] | Katharina Scherf[3,4] | J. Stephen Elmore[5] | Tanya Y. Curtis[6] | Emma Honan[6] | Nigel G. Halford[1]

Kaur et al. 2026. https://doi.org/10.1111/pbi.70661

What we have learned...

- ✓ A **comprehensive and balanced approach** to soil management and fertilization, coupled with **innovations in soil biology and digital agriculture**, is essential.
- ✓ **Genetic diversity** for free asparagine content can be used in breeding programs.
- ✓ The trait is complex and multigenic, but it is possible to **find specific genetic determinants** that control free asparagine content.
- ✓ Using **integrated -omic approaches** to provide novel information about this complex trait.

⬇

COLLABORATIVE FIELD TRIALS

SHARING OF PHENOTYPIC AND GENETIC DATA

COLLABORATION AMONG PUBLIC INSTITUTIONS AND PRIVATE COMPANIES

SIS/CNR: a successful example of public-private collaboration

Public Research Institution

Consiglio Nazionale delle Ricerche
IBBA
Istituto di Biologia e Biotecnologia Agraria

Private Seed Company

SIS
società italiana sementi

plants

MDPI

Article

Exploring Variability of Free Asparagine Content in the Grain of Bread Wheat (*Triticum aestivum* L.) Varieties Cultivated in Italy to Reduce Acrylamide-Forming Potential

Andrea Tafuri [1,2,3], Melania Zuccaro [1], Stefano Ravaglia [2], Raul Pirona [1], Stefania Masci [3], Francesco Sestili [3], Domenico Lafiandra [3], Aldo Ceriotti [1] and Elena Baldoni [1,*]

Production of recombinant lines for fine mapping

bread wheat

high free asparagine

X

low free asparagine

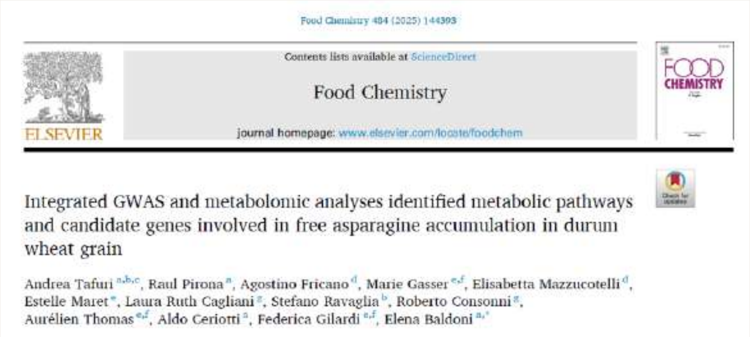
F_1

ⓧ

F_2

ⓧ

F_3


Food Chemistry 484 (2025) 144393

Contents lists available at ScienceDirect

Food Chemistry

journal homepage: www.elsevier.com/locate/foodchem

ELSEVIER

Integrated GWAS and metabolomic analyses identified metabolic pathways and candidate genes involved in free asparagine accumulation in durum wheat grain

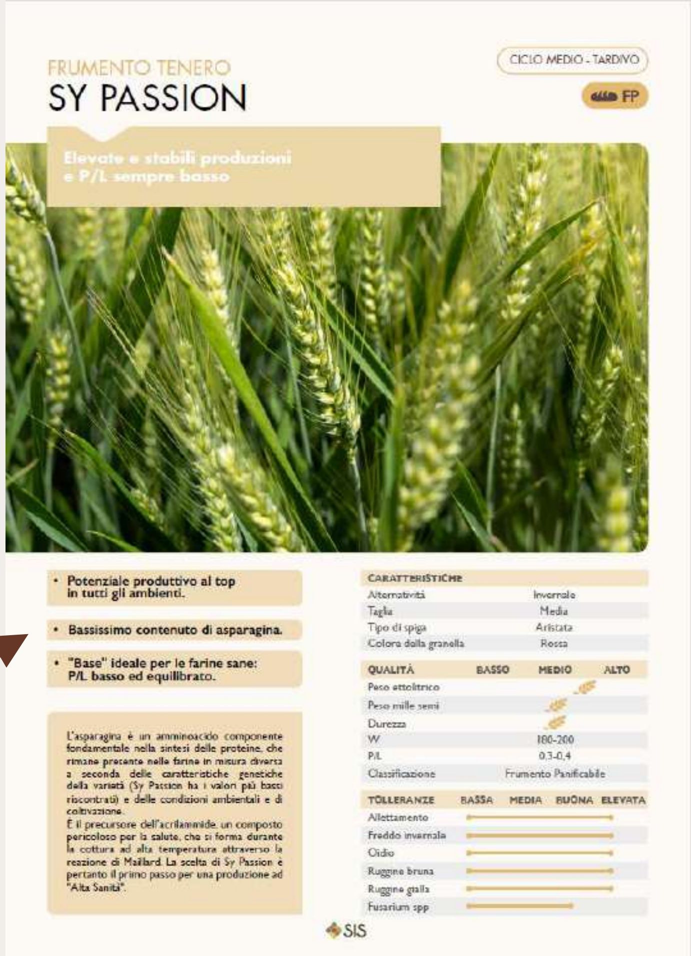
Andrea Tafuri[a,b,c], Raul Pirona[a], Agostino Fricano[d], Marie Gasser[e,f], Elisabetta Mazzucotelli[d], Estelle Maret[e], Laura Ruth Cagliani[g], Stefano Ravaglia[b], Roberto Consonni[g], Aurélien Thomas[e,f], Aldo Ceriotti[a], Federica Gilardi[e,f], Elena Baldoni[a,*]

✓ <u>Validation of QTLs on bread wheat</u>

Phenotyping (free asparagine) and genotyping (Illumina 25K Wheat Infinium Array) of 326 bread wheat (*Triticum aestivum* L.) varieties representing the SIS germplasm

single-locus and multi-locus GWAS

Eleven QTNs on eight chromosomes were found as associated to free asparagine content by both GWAS - two of them close to the QTNs reported in durum wheat very low free asparagine



FRUMENTO TENERO

SY PASSION

CICLO MEDIO - TARDIVO

FP

Elevate e stabili produzioni
e P/L sempre basso

- Potenziale produttivo al top in tutti gli ambienti.
- Bassissimo contenuto di asparagina.
- "Base" ideale per le farine sane: P/L basso ed equilibrato.

L'asparagina è un amminoacido componente fondamentale nella sintesi delle proteine, che rimane presente nelle farine in misura diversa a seconda delle caratteristiche genetiche della varietà (Sy Passion ha i valori più bassi riscontrati) e delle condizioni ambientali e di coltivazione.
È il precursore dell'acrilammide, un composto pericoloso per la salute, che si forma durante la cottura ad alta temperatura attraverso la reazione di Maillard. La scelta di Sy Passion è pertanto il primo passo per una produzione ad "Alta Sanità".

CARATTERISTICHE	
Alternatività	Invernale
Taglia	Media
Tipo di spiga	Aristata
Colore della granella	Rossa

QUALITÀ	BASSO	MEDIO	ALTO
Peso ettolitrico			
Peso mille semi			
Durezza			
W		180-200	
P/L		0,3-0,4	
Classificazione		Frumento Panificabile	

TOLLERANZE	BASSA	MEDIA	BUONA	ELEVATA
Allettamento				
Freddo invernale				
Oidio				
Ruggine bruna				
Ruggine gialla				
Fusarium spp				

SIS

FRUMENTO TENERO

SY PASSION

FRUMENTO AD ALTA SANITÀ

ACRILAMMIDE

- Rese elevate in tutti gli ambienti
- Base per le farine: valori di P/L sempre bassi
- Il frumento sul mercato con i più bassi valori di asparagina

IL PROGETTO «FRUMENTO ALTA SANITA' SY PASSION»

Per venire incontro alla richiesta di prodotti sani e controllati da parte del consumatore e alle esigenze dell'industria molitoria di garantire bassi contenuto di asparagine, S.I.S. propone un percorso agronomico e di filiera che si basa su queste azioni:

- Fornire al cerealicoltore un frumento con rese elevate e stabili: SY PASSION.
- Favorire con il coinvolgimento della propria rete di distributori/stoccatori l'approvvigionamento da parte dell'industria molitoria del frumento con il più basso contenuto di asparagine presente sul mercato e con eccellenti e stabili caratteristiche molitorie: SY PASSION.
- Esaltare le caratteristiche qualitative e di salubrità di SY PASSION attraverso un protocollo di produzione messo a punto dal servizio tecnico S.I.S. che prevede:
  - Piano di concimazione equilibrato con le corrette somministrazioni di N e S per l'ulteriore riduzione del contenuto di asparagina nelle farine e per valorizzare le caratteristiche molitorie di SY PASSION;
  - Programma di difesa da patogeni fungini per il contenimento delle micotossine e per evitare fattori di stress alla coltura che possono alterare la sintesi proteica o favorire la formazione di asparagina;
  - Monitoraggio satellitare dello «stato di salute» delle coltura.

CHE COSA È L'ACRILAMMIDE?

L'acrilammide è un composto organico, altamente solubile in acqua, pericoloso per la salute. La sua presenza negli alimenti può aumentare il rischio di sviluppare un cancro in consumatori di tutte le fasce di età e i bambini costituiscono la fascia di età più esposta. Si forma negli alimenti che subiscono un trattamento ad alte temperature, attraverso la reazione tra gli zuccheri e le proteine nota come reazione di Maillard, ed è dovuta principalmente all'aminoacido asparagina. Al fine di ridurre la presenza di acrilammide negli alimenti, il REGOLAMENTO (UE) 2017/2158 DELLA COMMISSIONE del 20 novembre 2017) istituisce misure di attenuazione e livelli di riferimento e prevede una serie di azioni e misure da parte degli «OSA» (operatori del settore alimentare) che a ricaduta interessano i mulini tenuti a tenere sotto controllo il contenuto del precursore dell'acrilammide presente nelle farine: l'asparagina.

SIS società italiana sementi

healthy wheat

What is still to be done...

- ✓ Better understanding of **agronomic practices beyond fertilization**, as well as the **impact of abiotic stresses** on free asparagine accumulation in cereals.

What is still to be done...

- ✓ Better understanding of **agronomic practices beyond fertilization**, as well as the **impact of abiotic stresses** on free asparagine accumulation in cereals.

- ✓ Identification of **genes and molecular pathways** involved in free asparagine accumulation.

What is still to be done...

- ✓ Better understanding of **agronomic practices beyond fertilization**, as well as the **impact of abiotic stresses** on free asparagine accumulation in cereals.

- ✓ Identification of **genes and molecular pathways** involved in free asparagine accumulation.

GENOMICS

Identification of chromosomic regions associated with the trait of interest

PROTEOMICS

To provide insights into the protein interactions involved in asparagine metabolism

METABOLOMICS

Definition of cereal grain composition, enabling the identification of molecules whose levels correlate with free asparagine

What is still to be done…

- ✓ Better understanding of **agronomic practices beyond fertilization**, as well as the **impact of abiotic stresses** on free asparagine accumulation in cereals.
- ✓ Identification of **genes and molecular pathways** involved in free asparagine accumulation.
- ✓ Exploitation of **genome editing** for the creation of cereal genotypes accumulatin low free asparagine.

What is still to be done…

- ✓ Better understanding of **agronomic practices beyond fertilization**, as well as the **impact of abiotic stresses** on free asparagine accumulation in cereals.

- ✓ Identification of **genes and molecular pathways** involved in free asparagine accumulation.

- ✓ Exploitation of **genome editing** for the creation of cereal genotypes accumulatin low free asparagine.

- ✓ Set up of **molecular markers** for free asparagine accumulation in the grain.

What is still to be done…

- ✓ Better understanding of **agronomic practices beyond fertilization**, as well as the **impact of abiotic stresses** on free asparagine accumulation in cereals.

- ✓ Identification of **genes and molecular pathways** involved in free asparagine accumulation.

- ✓ Exploitation of **genome editing** for the creation of cereal genotypes accumulatin low free asparagine.

- ✓ Set up of **molecular markers** for free asparagine accumulation in the grain.

- ✓ Creation of a shared **database about cereal genotypes** accumulating low and stable free asparagine levels, for breeding programs.

July 2024

ACRYRED

Deliverable 9 – Draft agenda for the next 5 years for agronomy and plant breeding research (M20)

Project Name	ACRYRED
Contractual Delivery Date	18.06.2024
Actual Delivery Date	15.07.2024
Working Group	WG2
Authors	Elena Baldoni, CNR-IBBA, and WG 2 of ACRYRED consortium
Grant Period	GP2

Funded by the European Union

Authors and Reviewers

Main Responsible		
Organization	**Name**	**Mail**
National Research Council (CNR) – Institute of Agricultural Biology and Biotechnology (IBBA), Milan, Italy	Dr. Elena Baldoni	elena.baldoni@cnr.it
Author(s) / Contributor (s)		
Organization	**Name**	**Mail**
Department of Agriculture, Food, Environment and Forestry (DAGRI) - University of Florence, Florence, Italy	Dr. Marco Napoli MSc. Antonio Pescatore	marco.napoli@unifi.it antonio.pescatore@unifi.it
Prof. Wacław Dabrowski Institute of Agricultural and Food Biotechnology – State Research Institute, Warsaw, Poland	Dr. Anna Szafrańska	anna.szafranska@ibprs.pl
Maize Research Institute, Zemun Polje, Belgrade, Serbia	Dr. Slađana Žilić MSc. Beka Sarić	szilic@mrizp.rs bsaric@mrizp.rs
CREA – Research Centre for Genomics and Bioinformatics, Fiorenzuola d'Arda, Italy	Dr. Delfina Barabaschi	delfina.barabaschi@crea.gov.it
Institute of Field and Vegetable Crops, Novi Sad, Serbia	Dr. Sonja Ilin	sonja.nsseme@gmail.com
University of Hohenheim, State Plant Breeding Institute, Research Group Wheat, Hohenheim, Germany	Dr. Khaoula El Hassouni	khaoula.elhassouni@uni-hohenheim.de
KWS SAAT SE & Co. KGaA, Einbeck, Germany	Dr. Viktor Korzun	viktor.korzun@kws.com
Department of Food Science and Technology, International Hellenic University, Thessaloniki, Greece	Prof. Maria Papageorgiou	mariapapaga@ihu.gr
Groupe de recherche Amélioration des grandes cultures et ressources génétiques, Département fédéral de l'économie, de la formation et de la recherche (DEFR), Agroscope, Switzerland	Dr. Dario Fossati	dario.fossati@agroscope.admin.ch
National Research Council (CNR) – Institute of Agricultural Biology and Biotechnology (IBBA), Milan, Italy	Dr. Andrea Tafuri	andrea.tafuri@ibba.cnr.it

July 2024

ACRYRED

Deliverable 9 – Draft agenda for the next 5 years for agronomy and plant breeding research (M20)

Project Name	ACRYRED
Contractual Delivery Date	18.06.2024
Actual Delivery Date	15.07.2024
Working Group	WG2
Authors	Elena Baldoni, CNR-IBBA, and WG 2 of ACRYRED consortium
Grant Period	GP2

cost

Funded by the European Union

Authors and Reviewers

Main Responsible		
Organization	**Name**	**Mail**
National Research Council (CNR) – Institute of Agricultural Biology and Biotechnology (IBBA), Milan, Italy	Dr. Elena Baldoni	elena.baldoni@cnr.it
Author(s) / Contributor (s)		
Organization	**Name**	**Mail**
Department of Agriculture, Food, Environment and Forestry (DAGRI) - University of Florence, Florence, Italy	Dr. Marco Napoli MSc. Antonio Pescatore	marco.napoli@unifi.it antonio.pescatore@unifi.it
Prof. Waclaw Dabrowski Institute of Agricultural and Food Biotechnology – State Research Institute, Warsaw, Poland	Dr. Anna Szafrańska	anna.szafranska@ibprs.pl
Maize Research Institute, Zemun Polje, Belgrade, Serbia	Dr. Slađana Žilić MSc. Beka Sarić	szilic@mrizp.rs bsaric@mrizp.rs
CREA – Research Centre for Genomics and Bioinformatics, Fiorenzuola d'Arda, Italy	Dr. Delfina Barabaschi	delfina.barabaschi@crea.gov.it
Institute of Field and Vegetable Crops, Novi Sad, Serbia	Dr. Sonja Ilin	sonja.nsseme@gmail.com
University of Hohenheim, State Plant Breeding Institute, Research Group Wheat, Hohenheim, Germany	Dr. Khaoula El Hassouni	khaoula.elhassouni@uni-hohenheim.de
KWS SAAT SE & Co. KGaA, Einbeck, Germany	Dr. Viktor Korzun	viktor.korzun@kws.com
Department of Food Science and Technology, International Hellenic University, Thessaloniki, Greece	Prof. Maria Papageorgiou	mariapapage@ihu.gr
Groupe de recherche Amélioration des grandes cultures et ressources génétiques, Département fédéral de l'économie, de la formation et de la recherche (DEFR), Agroscope, Switzerland	Dr. Dario Fossati	dario.fossati@agroscope.admin.ch
National Research Council (CNR) – Institute of Agricultural Biology and Biotechnology (IBBA), Milan, Italy	Dr. Andrea Tafuri	andrea.tafuri@ibba.cnr.it

D2.3 Agenda for the next 5 years for agronomy and plant breeding research – M42

ACRYRED

EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

Funded by the European Union

This article/publication is based upon work from COST Action ACRYRED, CA21149, supported by COST. COST (European Cooperation in Science and Technology) is a funding agency for research and innovation networks. Our Actions help connect research initiatives across Europe and enable scientists to grow their ideas by sharing them with their peers. This boosts their research, career and innovation.