Amino Acids (1994) 7: 327–331

Amino
Acids

Effect of natural amino alcohols on the yield of essential amino acids and the amino acid pattern in stressed barley

Short Communication

H. Bergmann, B. Machelett, and **V. Leinhos**

Institut für Ernährung und Umwelt, Friedrich-Schiller-Universität Jena, Jena, Federal Republic of Germany

Accepted March 23, 1994

Summary. By application with 2-aminoethanol (2-AE) and choline chloride (CC) in pot experiments the effect of drought stress on barley plants was diminished. In treated plants an increase of the grain yield by 14% (2-AE) and 40% (CC) and a decrease of the stress metabolites glycine betaine and trigonelline was observed. Additionally, treated barley plants showed higher yields of essential amino acids as well. The contents of proline (stress indicator) and arginine (precursor of the stress metabolite putrescine) of treated plants were by 12% and 22% respectively, lower than in untreated plants.

Keywords: Amino acids – Drought stress – Stress diminishing – Food quality

Introduction

Plants react to environmental stress (e.g. drought, extreme temperatures) with changes of their metabolism and morphology. These stress related effects may result in losses of yield and quality for crop plants (Roth and Bergmann, 1988; Bergmann and Eckert, 1990). One out of several possibilities of a quality drop is that the content of stress metabolites increases. In barley an increase of the content of the stress metabolite glycine betaine (Eckert et al., 1992; Bergmann et al., 1993) was shown earlier. An other nutritional physiological undesirable stress effect is the decrease of the content of value determinating plant substances e.g. essential amino acids.

The native amino alcohols 2-aminoethanol (2-AE) and choline as chloride (CC) have stress diminishing effects (Bergmann et al., 1991). Therefore, the objective of our work was, to investigate the effect of 2-AE and CC (applied exogenously) on the content of essential amino acids in barley plants. Simultaneously, we determined the stress intensity by using the changes of the glycine betaine content.

Methods

Cultivation

In a Mitscherlich pot experiment (substrate in Mitscherlich pots: 2 kg quartz sand, water capacity 15%; 4 kg mixed soil, water capacity 30%, pH 7.0, fine particles 16%, P_{DL} 11.2 mg/100 g soil, K_{DL} 20 mg/100 g soil, Mg 11.6 mg/100 g soil, $CaCO_3$ 0.6%, B 0.83 ppm, Cu 8.3 ppm, Mn 52 ppm, Mo 0.20 ppm, Zn 10 ppm) spring barley (12 plants per pot, var. "Alexis") was cultivated under a drought stress regime (4 periods of 5 days each at < 30% of the water use capacity of the soil, Bergmann et al., 1991). The following macroelements were added (amounts per pot): 1 g N as NH_4NO_3, 0.6 g P as KH_2PO_4, 2.5 g K as K_2SO_4, 0.8 g Mg as $MgSO_4 \cdot 7\ H_2O$ before planting.

2-AE (as secondary phosphate, 10 mg/pot) and choline (as chloride, 9 mg/pot) were applied before the first stress period. Nutritional effects of the amino alcohols used can be excluded. Well watered plants (soil water capacity: 60%) were used as controls in the experiment. Four Mitscherlich pots were used per treatment.

Analysis

After the drought regime the mature barley plants were harvested. The content of selected amino acids (Table 1) in barley caryopses was determined after acid hydrolysis (Gruhn and Schubert, 1975). Glycine betaine and trigonelline were analysed in the shoots harvested during the anthesis stage of the plants according to Eckert et al. (1992).

Statistics

The results presented are the means of three replicates. The significances were analysed using the Tuckey-test. Because of the higher variability of the stress variants significances were also tested at the $\alpha \leq 0.1$ level.

Results and discussion

Water deficit reduced the yield of the grain biomass (as a complex morphogenetic indicator of stress) by 70% (Table 1). Simultaneously, the tillering efficiency (number of fertile tillers/total number of tillers) was reduced. Compared with that, 2-AE and CC (applied exogenously) had a stress diminishing effect. However, as assumed, the water deficit could not be compensated completely. A stress diminishing by 20–60% compared to the well watered control was achieved. Due to the drought stress in barley plants the content of the stress metabolites glycine betaine and trigonelline increased by 47% and 22% respectively (Table 1). By treatment with CC the content of these stress metabolites was reduced. This stress weakening effect agrees with results of other experiments using CC and 2-AE (Eckert et al., 1992). Therefore, choline has a stress diminishing effect at a biochemical level.

Due to the water deficit the total protein yield and the amount of essential proteinogenic amino acids was reduced too (Table 1). Application of choline counteracted to this yield depending effect significantly and resulted for example in an increase of the lysine yield per plant by 33%.

Table 1. Effect of 2-aminoethanol (2-AE) and choline (CC) on shoot morphogenesis, yield and the content of stress metabolites in barley plants under different drought stress conditions

Treatment	Tillering efficiency[2]	Grain yield	Protein yield	Lysine yield	Yield of essential amino acids	Glycine betaine content	Trigonelline content
Drought stress[1]	(0.31) 100	(1.4 g/plant) 100	(0.18 g/plant) 100	(11.3 mg/plant) 100	(72 mg/plant) 100	(2.4 g/kg d.m.) 100	(39 mg/kg d.m.) 100
Well watered No stress	213*	173*	154*	151*	158*	68(*)	82
Drought stress +CC-treatment	212*	140*	125*	132(*)	126*	89(*)	90
Drought stress +2-AE-treatment	136	114	114(*)	114	n.d.	n.d.	n.d.

[1] see Methods, numbers in brackets = absolute amounts
[2] number of fertile tillers/number of total tillers, tillers = "second" shoots
* significant CC- and 2-AE-effect at $\alpha \leq 0.05$
(*) significant CC- and 2-AE-effect only at $\alpha \leq 0.10$
d.m. dry matter
n.d. not detected

Table 2. Content of essential amino acids in grain of drought stressed barley plants after treatment with choline (CC)

	No stress	Drought stress[1]		
Amino acid	No treatment[2] (g/100 g protein)	No treatment[2] (g/100 g protein)	CC-treatment[2] (g/100 g protein)	CC-treatment[3] (%)
Lysine	3.12	3.29	3.29	100
Histidine	1.97	1.79	1.73	97
Arginine	5.95	6.43	5.04	78(*)
Asparagine	7.47	6.43	6.09	95
Threonine	3.27	2.99	2.82	94
Serine	4.79	3.70	3.73	101
Glutamic acid	27.42	27.20	27.80	102
Proline	11.55	13.10	11.60	89(*)
Glycine	3.56	3.28	3.23	98
Alanine	3.13	3.53	3.39	96
Valine	5.17	5.42	5.36	99
Isoleucine	4.09	3.86	3.59	93
Leucine	10.61	7.66	7.36	96
Tyrosine	2.94	2.64	2.44	92
Phenylalanine	4.66	5.55	5.34	96
n.d.	0.30	3.13	7.19	–

[1] see Methods
[2] amino acid content in crude protein
[3] relative amino acid content (%), "Drought stress No treatment" = 100%
(*) significant CC-effect only at $\alpha \leq 0.10$
n.d. not detected

In case of proline and arginine the pattern of amino acids in the cereal grains was changed (Table 2). A decrease of the proline and arginine yields by 12% and 22% respectively, was observed in plants cultivated under drought stress and treated with CC compared to untreated plants. Proline, similar to glycine betaine, is a stress indicator in plants whereas arginine serves as a precursor of the stress metabolite putrescine.

In summary, metabolic pathways activated by stress may increase the yield of non-nutritive metabolites and decreased the content of value providing contents in plants. Therefore, amino alcohols could be useful tools for investigating stress tolerance mechanisms in plants.

Acknowledgements

The authors wish to thank Dr. R. Schubert (Friedrich-Schiller-Universität Jena) for the amino acid analyses. This work was supported by grants from the Deutsche Forschungsgemeinschaft (DFG).

References

Bergmann H, Eckert H (1990) Effect of monoethanol amine on growth and biomass formation of rye and barley. Plant Growth Reg 9: 1–8

Bergmann H, Eckert H, Weber C, Roth D (1991) Effect of monoethanol amine on yield of crops. J. Agron Crop Sci 168: 117–126
Bergmann H, Leinhos V, Machelett B (1993) Increase of stress resistance in crop plants by using phenolic compounds. Acta Hort (in press)
Eckert H, Bergmann H, Eckert G, Müller M (1992) Einfluß von Aminoalkoholen auf die Glycinbetainakkumulation in Sommergerstenpflanzen bei mäßigem Trockenstreß. Angew Bot 66: 124–129
Gruhn K, Schubert R (1975) Die Wirkung variierender Zeit-Druck-Kombinationen auf die Aminosäureausbeute nach säulenchromatographischer Trennung. Arch Tierernähr 25: 183–193
Roth D, Bergmann H (1988) Trockenstreß und seine Auswirkungen auf die Erträge landwirtschaftlicher Fruchtarten sowie Möglichkeiten zur ertragswirksamen Verbesserung der Trockenresistenz. Arch Acker Pflanzenb Bodenk 32: 459–471

Authors' address: Prof. Dr. H. Bergmann, Institut für Erährung und Umwelt, Friedrich-Schiller-Universität Jena, Naumburger Strasse 98, D-07743 Jena, Federal Republic of Germany.

Received August 23, 1993

Verleger: Springer-Verlag KG, Sachsenplatz 4–6, A-1201 Wien. – Herausgeber: Prof. Dr. Gert Lubec, Universitäts-Kinderklinik, Währinger Gürtel 18–20, A-1090 Wien. – Redaktion: Sachsenplatz 4–6, A-1201 Wien. – Satz und Umbruch: Asco Trade Typesetting Limited, Hong Kong; Offsetdruck: Novographic, Ing. W. Schmid, Maurer-Lange-Gasse 64, A-1238 Wien. – Verlagsort: Wien – Herstellungsort: Wien. Printed in Austria.