Note

Effects of 5-Aminolevulinic Acid on the Growth and Ripening of Wheat

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INTRODUCTION

5-Aminolevulinic acid (ALA) is a precursor of tetrapyrrole compounds such as chlorophyll, phycobilin, heme and vitamin B₁₂, all found in animals and plants. ALA formation is the rate limiting step in chlorophyll biosynthesis^{1,2)} and very low levels of ALA are maintained *in vivo*.^{3,4)} ALA treatment in plants has often been reported in relation to chlorophyll biosynthesis and plant greening. The relationship between ALA and cytokinin has also been studied.⁵⁾ However, the physiological properties of ALA have not been sufficiently understood.

ALA promotes the growth and yield of crops and vegetables at low concentrations by 10–60% over the control as observed in cases of crops of radish, kidney beans, barley, potatoes, garlic, rice, and corn.^{6–8)} The low concentrations of ALA increase chlorophyll synthesis and fixation of CO₂ in light and suppress the release of CO₂ in darkness.^{6,7)} ALA thus appears to act as a multi-functional stimulator in plants. The effects of ALA is related to the precise timing of its application and the concentration used.

In our research, the effects of ALA on the growth and ripening of wheat resulting from seed soaking and foliar spray treatment at the seedling and flowering stages were studied.

MATERIALS AND METHODS

1. Materials and Cultivation Conditions

Plant, wheat (*Triticum aestivum* L. cv. Huamai No. 8); 5-aminolevulinic acid hydrochloride (ALA·HCl), chemical reagent produced by Wako Co. Ltd.; test pot, Quadrate unglazed pot (25 cm×25 cm) with field soil (clay 80%, organic matter 20%); compound fertilizer (N:P:K = 15:15:10), 10 g per pot as a basal fertilizer.

Wheat seeds were sown in pots on November 4, 1995, and grown outdoors (Wuhan, China). The seedlings were thinned so that ten plants remained per pot on January 4, 1996, (61 days after sowing). Tests were conducted under natural

conditions with the exception of water control.

2. ALA Treatment

ALA treatment was implemented using seed soaking and foliar spray treatment. In the seedling stage test, treatment was implemented twice at the tilling start stage on December 27, 1995 (53 days after sowing), and at the stem elongation stage on February 7, 1996 (95 days after sowing). In the flowering stage test, treatment was implemented twice, that is, 4 days before flowering on April 16, 1996 (132 days after sowing), and 2 days after flowering on April 22, 1996 (138 days after sowing).

For seed soaking, the wheat seeds were soaked for 2.5 hr in aqueous solutions of ALA at concentrations of 0, 0.5, 5, 20 and 50 ppm after soaking in tap water overnight, and then they were sown in pots.

For foliar spray treatment, ALA aqueous solutions of 0, 10, 50 and 100 ppm containing Tween 20 (0.1%) were sprayed in amounts of 40 ml/pot at the seedling growth stage or 60 ml/pot at the following stage.

3. Investigation

After seed treatment, the ratio of the surviving plants and the dry weight of the young seedlings were calculated at the time of thinning (January 4, 1996, 61 days after sowing). The number of tillers per plant was counted at each growth stage [December 27, 1995 (53 days after sowing), January 24 (81 days after sowing), February 6 (94 days after sowing) and March 7, 1996 (123 days after sowing)]. The ears were harvested on May 20, 1996 (136 days after sowing), and the numbers of grains per ear, the weight of 1000 grains, the weight of caryopsis per plant and yield per pot were measured. The ears harvested after foliar spray treatment were also examined by the same method as those used after seed soaking. Examination was carried out using 4 replicates, and the mean of the 40 plants and the standard error were calculated.

4. Bioassay of Wheat Spikelets by Agar Plate Culture

Spikelets were selected from the middle position of young ears first 4 days before flowering and then 2 days after flowering, and were then sterilized with 70% ethanol. Five spikelets with 7 replicates were cultivated in a 100 ml grass plate with 30 ml Murashige-Skoog agar medium (pH 5.5) containing 50 g/l sucrose and ALA concentrations of 0, 0.1, 1.0 and 10 ppm. The culture conditions were as follows: a light period of 12 hr (25°C) at 10,000 lx and a dark period of 12 hr (15°C). After cultivation for 30 days, the weight and ripening of the caryopsis were measured. The mean of the 35 spikelets and the standard error were calculated.

RESULTS AND DISCUSSION

The effects of ALA at 0.5–50 ppm resulting from seed soaking are shown in Table 1. The growth and weight of the young seedlings measured on January 4 (61 days after sowing) did not change from ALA treatment. The number of tillers was increased with ALA treatment by 20% over the control as measured on January 24 (81 days after sowing), and an increase of 15% was noted on March 7 (123 days after sowing). At harvest, the weight of caryopsis per plant was found to be increased by approximately 10%, and the number of grains per ear increased by approximately 5%. However, there were no effects on the number of ears per plant and the weight of 1000 grains. As a result, the total yield per pot was found to be increased by approximately 5%.

The effects of ALA resulting from foliar application at the seedling stage are shown in Table 2. The number of tillers increased by approximately 15% as measured on March 7 (123 days after sowing) by ALA at all concentrations. At harvest stage, ALA at 10 and 50 ppm increased the grain yield by 15%, but the effect of ALA was diminished by 5% at 100 ppm.

The effect of ALA was found to be greatest on the weight of caryopsis per plant. The number of grains per plant and the weight of 1000 grains were also increased slightly by ALA at 10 and 50 ppm. This yield increase might have been caused by the enhanced ripening of the caryopsis.

To estimate how the ripening of caryopsis enhances grain yield, the effects of ALA at the flowering stage were tested, at which stage there was no effect on the number of ears and spikelets. The results are shown in Table 3. ALA increased the weight of 1000 grains and caryopsis. Therefore, the yield increased by approximately 5% with ALA.

The promotive effects of ALA by seed soaking quickly appeared on the number of tillers in the early growth stage, but only temporary. As a result, the effect of ALA on grain yield was small (approximately 5%). The increase of tillers caused by ALA may not contribute to the amount of yield increase due to other factors in the environment. The yield increase caused by ALA treatment at the flowering stage was smaller than by ALA treatment at the seedling stage. By contrast, the weight increase of 1000 grains caused by ALA applied at the flowering stage was found to be the highest of

Table 1 Effects of ALA on the growth and grain yield of wheat resulting from seed treatment.

	ALA (ppm)				
	0	0.5	5	20	50
Survival rate (%)	81.7 (6.4)	84.2 (7.5)	81.7 (8.8)	85.8 (6.8)	85.0 (6.9)
Number of tillers/plant					
12/27	2.0	2.1	2.0	2.2	2.3
1/24	4.0 (0.5)	4.8 (0.7)	4.6 (0.4)	5.0 (0.6)	4.8 (0.8)
2/6	7.2 (0.5)	8.1 (1.4)	8.0 (0.6)	8.1 (1.2)	8.0 (0.9)
3/7	9.7 (0.8)	11.2 (1.1)	10.2 (1.0)	11.1 (1.2)	11.1 (1.3)
Weight of aerial part ^{a)}	0.86 (0.08)	0.88 (0.09)	0.86 (0.05)	0.90 (0.05)	0.88 (0.04)
Number of ears/plant	3.3 (0.2)	3.4 (0.3)	3.4 (0.5)	3.5 (0.4)	3.4 (0.3)
Number of grains/ear	31.6 (2.3)	33.5 (0.3)	33.4 (0.7)	33.9 (2.7)	32.2 (1.8)
Weight of 1000 grains (g)	39.9 (2.6)	40.7 (1.8)	40.0 (2.9)	38.6 (2.1)	38.2 (1.5)
Weight of caryopsis/plant (g)	4.2 (0.2)	4.6 (0.4)	4.5 (0.3)	4.6 (0.5)	4.2 (0.3)
Yield /pot (g)	38.1 (2.6)	40.0 (2.7)	39.4 (2.3)	40.3 (2.1)	39.0 (2.4)

(): SE. ^{a)} DW (g)/young seedlings at January 4.

Table 2 Effects of ALA on the growth and grain yield of wheat resulting from foliar application at the seedling stage.

	ALA (ppm)			
	0	10	50	100
Number of tillers				
12/27	2.0 (0.3)	2.1 (0.4)	2.2 (0.3)	2.0 (0.2)
2/7	7.2 (0.5)	7.6 (1.2)	7.3 (0.8)	7.3 (1.0)
3/7	9.7 (0.8)	11.4 (1.1)	11.1 (1.2)	11.3 (1.4)
Number of ears/plant	3.3 (0.5)	3.5 (0.7)	3.5 (0.8)	3.4 (1.1)
Number of grains/ear	31.6 (2.3)	33.4 (1.6)	33.2 (2.2)	33.0 (2.4)
Weight of 1000 grains (g)	39.9 (2.6)	41.4 (1.2)	41.0 (1.5)	39.1 (2.5)
Weight of caryopsis/plant (g)	4.2 (0.3)	4.8 (0.3)	4.7 (0.3)	4.3 (0.4)
Yield/pot (g)	38.1 (2.7)	44.1 (2.3)	43.2 (3.2)	40.3 (2.9)

(): SE. Application on December 27, 1995, and February 7, 1996.

	ALA (ppm)			
	0	10	50	100
Number of ears/plant	3.3 (0.5)	3.2 (0.4)	3.4 (0.4)	3.4 (0.3)
Number of grains/ear	31.6 (2.3)	33.3 (3.3)	32.2 (1.7)	32.0 (1.4)
Weight of 1000 grains (g)	39.9 (2.6)	41.8 (1.5)	42.9 (2.2)	40.8 (2.5)
Weight of caryopsis/plant (g)	4.2 (0.3)	4.5 (0.4)	4.6 (0.5)	4.4 (0.5)
Yield /pot (g)	38.1 (2.6)	40.6 (3.7)	40.9 (4.2)	40.1 (3.7)

	ALA (ppm)			
	0	0.1	1	10
(4 days before flowering)				
Number of tested spikelets	35	35	35	35
Number of ripening caryopsis/spikelet	1.40	1.68	2.17	1.60
Rate of ripening (%)				
1st caryopsis	37.1	60.0	42.9	34.3
2nd caryopsis	42.9	45.7	68.6	57.1
3rd caryopsis	40.0	48.6	77.1	57.1
4th caryopsis	17.1	14.3	28.6	11.4
Weight of caryopsis/spikelet (mg)	14.4	16.9	18.8	16.0
(%)	(100)	(117)	(131)	(111)
(2 days after flowering)				
Number of tested spikelets	30	30	34	30
Number of ripening caryopsis/spikelet	1.87	2.97	2.85	2.40
Rate of ripening (%)				
1st caryopsis	66.7	100.0	85.3	70.0
2nd caryopsis	50.0	76.7	79.4	76.0
3rd caryopsis	50.0	86.7	88.2	60.0
4th caryopsis	20.0	33.3	32.4	33.3
Weight of caryopsis/spikelet (mg)	19.5	27.7	26.5	24.2
(%)	(100)	(142)	(136)	(124)

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要 約

コムギの成長と登熟におよぼす5-アミノレブリン酸の影響

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著者らは、低濃度の5-アミノレブリン酸(ALA)が、高濃度における除草活性とは逆に、成長促進を中心とする多様な植物成長調節作用を持つことを見出している。今回、コムギの生育と収量に及ぼすALAの影響について種子処理、生育期処理、開花期処理の三つの条件について検討した。さらに、小穂を用いた培養試験を行い、ALAの作用性についても若干の考察を加えた。種子処理では幼植物の初期の生育が促進されたが、その効果は持続せず、収量増に対してはわずかであった。生育期の茎葉処理では苗の生育や分けつに対する促進効果が観察され、10 ppmの処理で16%の収量増加が得られた。開花期の処理では穂当たりの着粒数と1000粒重の増加が観察され、体系的な処理等、実用的な側面からの検討に興味を持たれた。また、小穂培養試験により、ALAが糖の転流や蓄積、多糖類の生成にも関与している可能性が示唆され、作用機作の面からも興味を持たれる。