Precocious germination and its regulation in embryos of triticale caryopses

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Abstract

Triticale var. Lasko embryos, isolated from grain gathered at milk ripeness, the beginning of wax ripeness and at full ripeness, were allowed to germinate for 48 h on agar with glucose. The highest incorporation of tritiated adenosine into polyribosomal RNA during germination was found in the ribosome fractions from embryos of grain gathered at full ripeness, lower incorporation was in preparations from embryos of milk ripe grain and the lowest in preparations from embryos of wax ripe grain. Different tendencies were observed in respect to the synthesis of ribosomal proteins. The highest incorporation of ^{14}C -amino acids into ribosomal proteins was found in preparations of ribosome fractions from embryos of milk ripe grain, lower in preparations of embryos from fully ripe grain, the lowest in preparations of embryos from wax ripe grain. ABA (10^{-4} M) completely inhibited the external symptoms of germination of immature embryos, while its inhibition of the synthesis of polyribosomal RNA and ribosomal proteins was greater the more mature the embryos that were germinated. The greatest stimulation of precocious germination by exogenous BA and GA_3 was demonstrated in the least mature embryos isolated from milk ripe grain. Under the influence of both stimulators, an increase of the proportion of polyribosomes in the total ribosome fraction occurred in this sample, as did a rise in the intensity of ribosomal protein synthesis. The incorporation of ^3H -adenosine into polyribosomal RNA, however, was lower than in the control sample. The results obtained suggest that the regulation of precocious germination of triticale embryos by phytohormones is not directly related to transcription.

Key words: triticale embryos, precocious germination, dormancy, phytohormones

INTRODUCTION

Several sources of inhibition of preharvest sprouting may exist in developing cereal grain.

The dormancy of whole, intact cereal grains is dependent to a large extent on the existence of the embryoless part of the grain. However, it does not seem very probable that the role of the seed coat is reduced only to the function of collecting large concentrations of carbon dioxide inside the grain, since, e.g., the germination of lettuce seeds is stimulated properly by an elevated concentration of this gas (Wareing and Philips 1985). Also, the seed coat could have blocked oxygen uptake by the embryo (see Gordon 1980) although others have discarded this possibility (e.g. Chao et al. 1959).

An inhibitory effect is also ascribed to the tissues immediately surrounding the embryo (Wellington 1956, Radley 1976, 1979). Radley (1976) suggests that the inner layers of the pericarp containing chloroplasts, because of compartmentation, can be the only source of ABA to the embryo. She also found (Radley 1979) that the effect caused by the tissues is similar to that due to a low concentration of ABA and can be reversed by GA_3 .

King (1976) demonstrated on two wheat varieties that "dormancy" can occur in the embryo itself. Responsible for this relatively short period of inhibition of precocious germination (before full ripeness of the grain) are, most probably, changes in the level of endogenous hormones in the embryo, especially the balance between GA and ABA (King 1976, 1982, Radley 1979).

Differential response of excised embryos to endogenous inhibitor(s) has been found in various wheat genotypes by McCrate et al. (1982) and Paulsen and Heyne (1983). It was demonstrated that the sensitivity of excised embryos to an endogenous inhibitor extracted from wheat pericarp (with a phenolic structure) was high in sprouting-resistant cultivars and low in the susceptible genotypes. Embryo responsiveness was also high in fresh seeds and decreased during after-ripening. It should be underscored that sprouting in the ear have posed a serious problem for breeding of agriculturally acceptable lines of triticale (Bishoni and Saprà 1985, Bursas and Skinnes 1985, Salmon and Helm 1985).

The purpose of the studies undertaken here was to find if embryos of triticale grain (var. Lasko) exhibit endogenous inhibition of germination during their development, and to what degree can treating embryos with exogenous hormones influence the speeding up or delay of precocious germination. A different aspect of the study was the demonstration of eventual changes in polyribosome formation or polyribosomal RNA and

protein synthesis in precociously germinating embryos of different degrees of maturity. The effect of ABA, BA and GA_3 on the mentioned processes was also studied.

MATERIAL AND METHODS

The experiments were conducted in 1986 on triticale var. Lasko caryopses, cultivated on experimental plots of the Chair of Plant Physiology and Biochemistry of the Agricultural-Technical Academy in Olsztyn. The period of development and maturation of the caryopses lasted about 50 days. The material for the study was collected weekly starting from the 7th day after anthesis. The cut ears were taken to the laboratory where the caryopses were removed by hand from the middle part of the ear, discarding the three upper and three lower spiklets. The water content in whole caryopses and embryos was determined in each sample. Freshly collected caryopses were allowed to germinate in a Jacobsen germination apparatus at a temperature of 21–22°C for 20 days.

From the 14th day after anthesis embryos were isolated from the same samples of freshly collected caryopses, which were allowed to germinate after being sterilized in a solution of sodium hypochlorite. The embryos, isolated by hand, were placed (50 embryos) in sterile Petri dishes containing approx. 30 cm³ 0.9% agar with 1% glucose and chloramphenicol (10 µg cm⁻³). Germination was conducted in the dark at 21–22°C for 10 days. An embryo was considered to have germinated when a 2 mm long radicle had appeared.

In addition, embryos were also isolated at the three main stages of development for studying the synthesis and formation of polyribosomes. The embryos were isolated from grain at the milk ripeness stage — 17 days after anthesis (with a water content of the embryos and whole caryopses of about 72 and 64%, respectively), at the beginning of the wax ripeness stage — 30 days after anthesis (with a water content of about 63 and 47% in the embryos and whole caryopses, respectively) and at full ripeness — 52 days after anthesis (with a water content of about 13 and 14% in the embryos and whole caryopses, respectively). The embryos from the three stages of embryogenesis, immediately after isolation and sterilization, were allowed to germinate for 48 h in Petri dishes on agar with glucose. Germination was conducted in the presence of two radioactive precursors, ¹⁴C-hydrolysate of amino acids (0.4 MBq cm⁻³) and 8-³H-adenosine (0.4 MBq cm⁻³) and chloramphenicol (10 µg cm⁻³). Gibberellin A₃ or benzyladenine were added to a final concentration of 10⁻⁵ M to chosen samples, as was abscisic acid to a final concentration of 10⁻⁴ M.

The concentrations of the hormones were chosen on the basis of previous experiments (Weidner 1984a, b, 1986). After 48 h of germination, the percentage of germinated embryos was determined, the embryos were collected from the surface of the agar medium, unmetabolised precursors were washed off their surfaces, which were then dried and the embryos frozen in liquid nitrogen and stored for further study.

The total ribosome fraction (polyribosomes + monosomes + ribosomal subunits) was isolated from embryos of different degrees of ripeness according to the method described earlier (Weidner 1984b). For this purpose, about 2 g of plant material were homogenized in buffer "A" (0.2 M sucrose, 200 mM Tris-HCl (pH 8.5), 30 mM MgCl_2 , 60 mM KCl). The homogenate was centrifuged at $29\,000 \times g$ in a Janetzki (K-70) centrifuge. The supernatant was transferred onto a 4 cm³ layer of 1.5 M sucrose in buffer "B" (40 mM Tris-HCl (pH 8.5), 10 mM MgCl_2 , 20 mM KCl) in 65 Ti rotor tubes, and centrifuged in a Spinco L-3-40 ultracentrifuge at $95\,000 \times g$ for 90 min. The pellet (approx. 1 mg) was suspended in 1 cm³ of buffer "B" and layered onto the surface of a sucrose concentration gradient. Polyribosomes were fractionated by ultracentrifugation at $122\,000 \times g$ in a SW 41 rotor for 75 min. In order to assay the amount of ribosomes, it was accepted that the absorbance of a 1% solution of ribosomes measured in a cuvette with a 1 cm optical path at 260 nm equals $E_{260}^{1\%} = 135$ (Gualerzi and Cammarano 1969). Radioactivity measurements were made using a LS-1801 Beckman liquid scintillation counter by adding 10 cm³ of "Tritosol" as the scintillator to every 1 cm³ sample (Fricke 1973). The incorporation of ³-uridine into polyribosomal RNA and ¹⁴C amino acids into ribosomal proteins was measured using the program for dual label counting. All of the values presented in this paper are the means obtained from 3–6 independent experiments.

RESULTS

The water content of caryopses is decisive, to a large extent, for the metabolic activity of both the endosperm and embryo. From the data presented on Fig. 1 it can be seen that in the early stage of development (milk ripeness), the water content of whole triticales caryopses quickly rises until the 21st day after anthesis and then gradually falls, whereas the dry weight content increases until the 42nd day after anthesis and undergoes a small reduction during full ripeness. In respect to the dry weight and water contents of embryos, a practically constant increase in both during embryogenesis, and a decrease in both values during full ripeness are observed.

The results of the experiments on the germination of immature, freshly gathered, whole caryopses and isolated embryos are presented on Fig. 1 and 2. It can be seen from them that as development proceeds, an increase in the germination capacity of isolated embryos and whole caryopses occurs. Albeit, both during the studies on the germination of isolated embryos and of whole caryopses, a period of reduced germination capacity

Fig. 1. The dry weight and water contents of embryos (A) and whole caryopses (B) and the germination capacities of embryos and triticales caryopses during growth and development. The vertical bars denote the standard deviation ($\pm$ SE) calculated on the basis of three parallel samples of 100 caryopses each

was observed around the 35th day after anthesis, with a water content in the embryos and caryopses of about 62 and 44%, respectively. In this sample, a distinct drop in the rate of the increase in the number of germinated embryos on agar and glucose was also observed (Fig. 2).

The total ribosome fraction isolated from triticales embryos of different degrees of maturity after 48 h of germination of embryos on agar with glucose was represented by two major fractions, polyribosomes and mono-ribosomes, with ribosomal subunits making up only a small portion (Table 1). The polyribosome content in the total pool of ribosomes of an embryo subjected to germination depended on its degree of maturity. After two days of germination of embryos isolated from freshly gathered caryopses at milk ripeness, the proportion of polyribosomes in the total ribosome fraction was 57.8%, at the start of wax ripeness — 71.4% and at full morphological ripeness — 62%

Growth stimulators used during germination of isolated embryos increased the proportion of polyribosomes in embryos isolated from grain at milk

Fig. 2. The germination of freshly gathered isolated embryos of different maturity on agar with glucose. The numbers 14, 21, 28, 35, 42, 49 next to the curves indicate the number of days after anthesis on which the sample was collected. An embryo was considered to have germinated if its radicle attained 2 mm in length. Standard deviation ($\pm$ SE) is denoted by vertical bars and calculated on the basis of six parallel repetitions of 50 embryos each

and full ripeness (Table 1). Both of the growth stimulators, gibberellin- A_3 and benzyladenine (BA) showed the greatest stimulation of germination of embryos from grain at milk ripeness (Fig. 3). It should be added that during the germination of isolated embryos on agar, gibberellin- A_3 was more active than benzyladenine, both in respect to the stimulation of polyribosome formation in embryos (Table 1) and in general, in the process of germination, the intensity of which was evaluated by determining the increase in the number of germinated embryos (Figs. 3, 4, 5).

Abscisic acid (10^{-4} M) completely inhibited the external signs of germination of embryos from grain at milk and wax ripeness (Figs. 3, 4). A small percentage of germinated embryos (3.2%) was seen after 48 h of germination in the presence of ABA only in embryos from fully ripe grain (Fig. 5). However, ABA strongly inhibited polyribosome formation in germinating embryos from wax ripe and fully ripe grain (Table 1). No effect of ABA on polyribosome formation during 48 h incubation of isolated embryos from milk ripe grain was found (Fig. 3, Table 1).

The incorporation of ^3H -adenosine into polyribosomal RNA and ^{14}C -amino acids into ribosomal proteins is presented on Figs. 3, 4 and 5 and in Table 1. The most intensive incorporation of tritiated adenosine during the 48 h long germination of isolated embryos was found in

Fig. 3. Sedimentation profiles (in 12.5–50% sucrose gradients) of polyribosomes isolated from tritcale embryos after 48 h of germination on agar with glucose. The germinated embryos were prepared from freshly collected grain at milk ripeness (17 days after anthesis). Germination was conducted in the presence of: ^{14}C -hydrolysate of amino acids (0.4 MBq cm^{-3}), $8\text{-}^3\text{H}$ -adenosine (0.4 MBq cm^{-3}), chloramphenicol ($10 \mu\text{g cm}^{-3}$) and in the designated samples: gibberellin A_3 (10^{-5} M), benzyloadenine (10^{-5} M) and abscisic acid (10^{-4} M). The percent of germinated embryos after 48 h is given in parentheses along with the standard deviation. The data is calculated from six parallel repetitions of 50 embryos each. The monoribosome fraction (80 S) is marked with an arrow

Table 1

Polyribosome formation and the incorporation of ^3H -uridine and ^{14}C -hydrolysate of amino acids into the total ribosome fraction after 48 h of germination of isolated embryos on agar with glucose. The germinated embryos were prepared from freshly collected grain at milk ripeness (17 days after anthesis) at the beginning of wax ripeness (30 days after anthesis) and at full ripeness (52 days after anthesis). In the designated samples, germination was conducted in the presence of gibberellin A_3 , benzyloadenine (BA) or abscisic acid (ABA)

Stage of maturity	Treatment	cpm $1\ \mu\text{g}^{-1}$ of the total ribosome fraction		Percentage of ribosomal fractions		
		^3H	^{14}C	polyribosomes	monoribosomes	ribosomal subunits
Milk	control	1019	1868	57.8	36.7	5.5
	GA_3	960	1859	79.9	16.9	3.0
	BA	958	1796	67.6	27.4	5.0
	ABA	920	1507	57.7	34.2	8.1
Wax	control	701	1053	71.4	23.1	5.4
	GA_3	745	1121	71.8	22.4	5.7
	BA	787	1182	71.0	23.8	5.2
	ABA	556	752	56.5	37.4	6.1
Full	control	3313	1248	60.3	33.4	6.3
	GA_3	3317	1285	64.8	32.2	2.7
	BA	3307	1221	62.3	33.2	4.6
	ABA	2261	701	51.7	41.6	6.7

preparations of ribosome fractions of embryos from grain gathered at full ripeness, about 3 times less in preparations obtained from embryos of grain gathered at milk ripeness and the lowest in preparations of ribosome fractions of embryos of wax ripe grain. A different tendency was observed in the incorporation of ^{14}C -amino acids into ribosomal proteins in the same samples of germinating embryos of different degrees of maturity. The highest incorporation of the radioactive precursor into ribosomal proteins was observed in preparations of ribosome fractions from embryos isolated from grain at milk ripeness, lower incorporation in preparations isolated from embryos of fully ripe grain, and the lowest was in preparations of ribosome fractions of embryos of wax ripe grain.

The influence of growth stimulators on the synthesis of polyribosomal RNA and ribosomal proteins during 48 h long germination isolated embryos of different degrees of ripeness, was limited to samples of grain gathered at milk and wax ripeness. No significant changes in the incorporation of both radioactive precursors was noticed under the influence of GA_3 and benzyloadenine in the preparations of ribosome fractions isolated from embryos of fully ripe grain (Table 1). In the germinating embryos of milk ripe grain, where the stimulation of germination by GA_3 and BA was the

Fig. 4. Sedimentation profiles (in 12.5–50% sucrose gradients) of polyribosomes isolated from triticale embryos after 48 h of germination on agar with glucose. The germinated embryos were prepared from freshly collected grain at the early wax ripe stage (30 days after anthesis). Germination was conducted in the presence of ^{14}C -hydrolysate of amino acids 0.4 MBq cm^{-3} , $8\text{-}^3\text{H}$ -adenosine (0.4 MBq cm^{-3}), chloramphenicol ($10 \mu\text{g cm}^{-3}$) and, in the designated samples: gibberellin- A_3 (10^{-5} M), benzyloadenine (10^{-5} M) and abscisic acid (10^{-4} M). The percent of germinated embryos after 48 h is given in parentheses along with the standard deviation. The data was calculated on the basis of six parallel repetitions of 50 embryos each. The monoribosome fraction (80 S) is marked with an arrow

Fig. 5. Sedimentation profiles (in 12.5–50% sucrose gradients) of polyribosomes isolated from tritcale embryos after 48 h of germination on agar with glucose. The germinated embryos were prepared from freshly collected grain at full ripeness (52 days after anthesis). Germination was conducted in the presence of: ^{14}C -hydrolysate of amino acids (0.4 MBq cm^{-3}), $8\text{-}^3\text{H}$ -adenosine (0.4 MBq cm^{-3}), chloramphenicol ($10 \mu\text{g cm}^{-3}$) and in the designated samples: gibberellin A_3 (10^{-5} M) benzyladenine (10^{-5} M) and abscisic acid (10^{-4} M). The percent of germinated embryos after 48 h is given in parentheses along with the standard deviation. The data are calculated on the basis of six parallel repetitions of 50 embryos each. The monoribosome fraction (80 S) is marked with an arrow

greatest (Fig. 3), only the increased synthesis of ribosomal proteins was found in both samples treated with growth stimulators (Fig. 3, Table 1). The incorporation of tritiated adenosine into polyribosomal RNA was, however, even lower in this sample than in the control (Table 1). In respect to the stimulation of germination of isolated embryos from the early phase of wax ripeness by BA and GA₃ (Fig. 4), this process was accompanied by relatively low stimulation of the synthesis of polyribosomal RNA and ribosomal proteins (Fig. 4 and Table 1).

As was already mentioned, abscisic acid completely halted the external symptoms of germination of immature embryos. From the studies on the inhibitory effect of ABA on the synthesis of ribosomal proteins and synthesis of polyribosomal RNA, it results, however, that during germination of embryos of different degrees of ripeness, this effect was greater the more mature were the embryos subjected to germination (Table 1, Figs. 3, 4, 5). It should be added that in all of the samples, ABA inhibited the synthesis of ribosomal proteins more than of polyribosomal RNA. The degree of inhibition of polyribosomal RNA synthesis and of ribosomal proteins was, respectively, in germinating embryos isolated from milk ripe grain, about 10 and 14%, wax ripe — about 21 and 22% and fully ripe — about 32 and 44%.

DISCUSSION

Isolated cereal embryos can already germinate 2–3 weeks after anthesis. It has been shown, however, that in certain varieties of wheat, 5–6 weeks after anthesis a period of strong inhibition of germination of isolated embryos occurs (King 1976, 1982, Radley 1979). In varieties of wheat such as Sonora or Huntsman, the germination capacity of isolated embryos falls during this time to zero. This points to the possibility that in the embryo itself, endogenous factors or factor can exist which inhibit germination. The studies carried out on triticales caryopses of the Lasko variety support this view. In embryos isolated from caryopses gathered 35 days after anthesis, significant inhibition of germination was found. Because younger embryos often germinate by 100%, this phenomenon is not related to immaturity, or even the physical effect of the seed coat. From the studies by King (1976, 1982) it results that ABA is a factor that evokes this inhibition. Radley (1979) however, demonstrated a low bound GA level and an increasing level of bound ABA in the embryo. She also found that GA₃ almost completely reverses this endogenous inhibition.

In previous studies (Weidner 1983, 1984a) conducted on whole intact cereal caryopses, it was shown that in the mentioned period of development,

the germination of caryopses is also inhibited. It was also found that this inhibition can be slightly reversed by GA_3 . In further studies (Weidner 1984b) it was shown that the mechanism which prevents immature triticales caryopses from germinating and polyribosomes from forming, arises during the final stages of development of the grain, before full ripeness. Worth considering also is the fact that the seedlings grown from caryopses gathered during wax ripeness contained, even after complete release of dormancy of the grain being germinated, polyribosomes and ribonucleic acids of the lowest radioactivity when compared with the seedlings grown from grain gathered during milk or full ripeness (Weidner and Wielgat 1983a, b). This can indicate fixation of certain traits of the embryonic genome, deriving from the period of embryogenesis.

In this study, isolated embryos from the three main phases of development were subjected to germination. The second sample of embryos was collected at the start of the way ripeness stage (30 days after anthesis) before the period of inhibition (about 35 days after anthesis). In this sample, the highest percentage of polyribosomes induces by germination — which can be indicative of the highest overall biosynthesis of protein, and the lowest incorporation of tritiated adenosine into polyribosomal RNA and of ^{14}C -amino acids into ribosomal proteins were found. In earlier studies, the lowest availability of DNA as the template for endogenous polymerases and the lowest activity of RNA polymerases (I and II) were demonstrated in triticales embryos on days 30–40 after anthesis (Weidner and Wielgat 1984). During this same period, developing embryos have the highest ability for the uptake of amino acids and peptides (Sopanen et al. 1985). Also, during this period, specific embryo storage proteins are synthesized (Dure 1985). It should be added that in cereals, the accumulation of nitrogen in developing caryopses takes place to a great extent due to redistribution of nitrogen from other parts of the plant, especially from the leaves (Dalling et al. 1976, Reed et al. 1980, Simpson and Dalling 1981).

The greatest stimulation of precocious germination of isolated embryos by exogenous GA_3 and BA was seen in the least mature embryos isolated from milk ripe grain. On the basis of the results presented in this study and in previous papers (Weidner 1984a, 1986), it can be stated that the embryos from this sample are the most sensitive to treatment with both growth promoters and ABA. Gibberellic acid always acted more strongly than cytokinins, and when they were used jointly, a synergetic effect was observed (Weidner 1984a).

The ABA and GA contents of wheat embryos do not undergo any greater changes during the whole period of embryogenesis, until the final week when the concentration of both hormones significantly drops (Radley 1979). It seems then that the stimulation of embryo germination (isolated

from milk ripe grain) by exogenous GA_3 and BA is connected to a high degree with the reversal of the inhibition of endogenous ABA and, most probably, of other germination inhibitors, as for instance, phenolic compounds. It should be added that the highest total content of phenolic compounds was found in cereal grain at the milk ripeness stage (Kulka 1980). The results of biochemical studies obtained in this study are similar to the results on the release of triticales caryopses from ABA-induced "dormancy" by GA_3 and zeatin (Weidner et al. 1984).

The effect of ABA on the external symptoms of precocious germination of isolated embryos decreases with their development (Eisenberg and Mascarenhas 1985, Weidner 1986). Similar results were obtained in this study where ABA at 10^{-4} M completely inhibited the germination of isolated embryos from grain at milk and wax ripeness. The results of biological studies on the inhibition of precocious germination, based on the observation of the elongation of the radicle, do not correlate with the results of biochemical studies. The synthesis of polyribosomal RNA and ribosomal proteins was inhibited the most by ABA in germinating embryos from fully ripe grain, less in embryos from grain at wax ripeness, the least in embryos from milk ripe grain. It should be stressed that in the embryos from grain at milk ripeness, ABA did not even change the proportion of polyribosomes in the total ribosome fraction. When Dure (1985) summarized the results of his own studies and the current state of knowledge on the molecular mechanism through which ABA prevents precocious germination, he stated in conclusion that this mechanism remains totally unknown. From the results presented here it should be concluded that the regulation of the precocious germination of triticales embryos by phytohormones is not directly connected with transcription.

The results obtained in this study are puzzling in that the highest protein synthesis was seen in the germinating embryos isolated from grain at milk ripeness. Only a very small percentage of these embryos germinated (during 48 h), and the synthesis of polyribosomal RNA was about three times lower than in germinating embryos from grain at full ripeness. Maybe this increased synthesis is connected with the lack in the ribosomes of embryos from milk ripe grain of a group of ribosomal proteins which are indispensable in the process of germination. In earlier studies (Weidner and Zalewski 1982) it was found that during development, new, low molecular weight proteins are built into the embryo's ribosomes. In spite of this fact, more exact interpretation of the above results is difficult, since the functions of the individual proteins remain unknown.

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Przedwczesne kiełkowanie i jego regulacja w zarodkach ziarniaków triticales

Streszczenie

Zarodki ziarniaków triticales odmiany Lasko, wyizolowane z ziarna zebranego w dojrzałości młeczej, na początku dojrzałości woskowej i w dojrzałości pełnej, poddano 48-godzinnemu kiełkowaniu na agarze z glukozą. Największe wcielenie trytonowej adenozyiny do polirybosomalnego RNA podczas kiełkowania stwierdzono w preparatach frakcji rybosomalnej zarodków ziarna zebranego w dojrzałości pełnej, mniejsze w preparatach zarodków ziarna o dojrzałości młeczej, a najmniejsze w preparatach zarodków ziarna o dojrzałości woskowej. Inne tendencje obserwowano w syntezie białek rybosomalnych. Największe wcielenie ^{14}C -aminokwasów do białek rybosomalnych stwierdzono w preparatach frakcji rybosomalnej zarodków ziarna o dojrzałości młeczej, mniejsze w preparatach zarodków ziarna o dojrzałości pełnej a najmniejsze w preparatach zarodków ziarna o dojrzałości woskowej. ABA (10^{-4} M) wstrzymywał całkowicie zewnętrzne objawy kiełkowania zarodków niedojrzałych, natomiast syntezę polirybosomalnego RNA i białek rybosomalnych hamował tym silniej, im bardziej dojrzałe zarodki poddawano kiełkowaniu. Największą stymulację przedwczesnego kiełkowania przez podane z zewnątrz BA i GA_3 , wykazano w najmniej dojrzałych zarodkach wyizolowanych z ziarna o dojrzałości młeczej. Pod wpływem obu stymulatorów następował w tej próbie wzrost udziału polirybosomów w ogólnej puli rybosomów oraz wzmożona synteza białek rybosomalnych. Wcielenie natomiast 3H -adenozyiny do polirybosomalnego RNA było mniejsze niż w próbie kontrolnej. Uzyskane wyniki sugerują, że regulacja przedwczesnego kiełkowania zarodków triticales przez fitohormony nie jest bezpośrednio związana z procesem transkrypcji.