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Comparative effects of some plant growth regulators on the germination of barley and radish seeds under high temperature stress

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Abstract
The effects of gibberellic acid, kinetin, benzyladenine, ethylene, 24-epibrassinolide, triacontanol and polyamines (cadaverine, putrescine, spermidine, spermine), alone or in combinations, on germination and early seedling growth under high temperature conditions of barley and radish seeds were studied. High temperature both delayed and inhibited the germinations of both the species. Only three of the single applications gibberellic acid, kinetin and 24-epibrassinolide could alleviate the effects of high temperature on germination of barley seeds. All the combinations composed of these three growth regulators removed more successfully this adverse effect on germination. High temperature effect on the germination of radish seeds was overcome by all the pretreatments alone or in combinations to varying degrees. Although the mentioned regulators carried on their success on the early growth of barley seedlings, the regulators used for radish had no effect on the seedlings in general.

Keywords: High temperature stress, plant growth regulator, seed germination, seedling growth.

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INTRODUCTION

High temperature is one of the important factors affecting seed germination in nature. When the seeds are exposed to high temperature conditions, both germination (Berrie 1966, Reynolds and Thompson 1971, Carter and Stevens 1998) and seedling growth (Ungar 1974, Sattelmacher et al. 1990) are generally inhibited. Increases in the medium temperature cause enhances in transpiration and evaporation and so, deficiency of water in plants (Gates 1968).

Decrease in moisture level in the germinating medium deeply affects seed performance. Various studies indicated that profound changes in endogenous levels of the growth regulators caused by high temperature stress, increase in the inhibitors (Gonai et al. 2004) and decrease in the stimulators (Corbineau et al. 1993) greatly inhibit germination.

A number of studies were conducted with the aim of removing the inhibitory effect of high temperature stress on germination, using various growth regulators. It has been known for a long time that gibberellins (Biddington and Thomas 1978, Biddington et al. 1980), cytokinins (Kaufmann and Ross 1970, Keys et al. 1975) and ethylene (Corbineau et al. 1988, Gallardo et al. 1991) can reduce the adverse effects of high temperature stress during seed germination. However, only limited studies have been carried out on the roles of growth regulator chemicals which were discovered in the last 20-30 years such as brassinosteroids, triacontanols and polyamines in relation to seed germination under high temperature stress. Stanislaw and

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Elbieta (1982) reported that triacontanols were ineffective in germination of lettuce seeds under high temperature conditions. Wilen et al. (1995) and Dhaubhadel et al. (1999) observed that the brassinosteroids increased the tolerance of cabbage and tomato seedlings against high temperature stress. In addition, it was found that in many plant species exposed to high temperature, there was an increase in the endogenous polyamine contents (Roy and Gosh 1996, Bouchereau et al. 1999).

The purpose of this study is to observe the effects of the new chemicals mentioned above in the reducing of the inhibitive effects of high temperature on germination and early growth of seedlings, and to compare their effects with the ones of gibberellins, cytokinins and ethylene which are very well known and have been used for years.

MATERIAL AND METHODS

Seeds and plant growth regulators

In this work, seeds of barley (*Hordeum vulgare* L. cv. Bülbül 89) and radish (*Raphanus sativus* L.) which were of good quality and had a high germination rate of 100% under optimum conditions were used. The seeds were surface sterilized with 1.0% sodium hypochloride.

As test solutions, 900 μM gibberellic acid (GA_3), 100 μM kinetin (Kin), 100 μM benzyladenine (BA), 400 μM ethylene (E), 3 μM 24-epibrassinolide (EBR), 10 μM triacontanol (TRIA) and 10 μM polyamine (polyamines are: cadaverine-Cad, putrescine-Put, spermidine-Spd and spermine-Spm) were used for both species. The concentrations of the growth regulators were determined in a preliminary study.

Germination of seed

Germination experiments were carried out in an incubator at 35° (for barley) or 38°C (for radish) and to prevent germination, in continuous dark. The seeds, in an adequate amount, were presoaked in distilled water (control, C) or in aqueous solutions of GA_3, Kin, BA, E, EBR, TRIA, Spm, Spd, Put and Cad alone or in combinations prepared with two, three or four of these regulators for 24 h at room temparature. After pre-treatment, the solutions were decanted off and the seeds were dried in a vacuum (Braun and Khan 1976). Twenty-five seeds from every application were arranged in 10 cm Petri dishes covered with two sheets of filter paper moistened with 8 mL of distilled water. Following sowing, Petri dishes were placed in an incubator for germination for 7 days. Barley and radish seeds were considered germinated when the radicles reached 10 mm, and 5 mm in length, respectively. The germination percentages of the seeds were determined for each 24 h up to 7th day. At the end of experiment (7th day), shoot (coleoptile/hypocotyl) percentages, the lengths of the radicle and shoot in mm, and fresh weights of the seedlings (mg/seedling) from 25 seeds were recorded. Because only GA_3, Kin and EBR of the single applications could be effective in alleviation of high temperature on barley seed germination, a limited combination composed of them was used. Whereas, many combinations were used in the case of radish since all the single treatments were successful. All the experiments were repeated four times. Statistical evaluation concerning all parameters was realized by using an SPSS program according to Duncan's multiple range test.

RESULTS

Effects of plant growth regulators on germination percentage

High temperature, as expected, both delayed and inhibited the germination of the seeds (Table 1, 2). The seeds of barley and radish in the medium of high temperature were able to begin the germination on the 2nd day and they reached scarcely 28% and 22% final germination at the end of the experiment, respectively.

Of the growth regulator pretreatments alone, GA_3, Kin and EBR not only overcame the preventive effect of high temperature on germination of barley seeds but also shortened the time required for germination by

Table 1. Effects of various growth regulator pretreatments on the time course of germination of barley seeds at 35°C.

Growth regulator	Days						
	1	2	3	4	5	6	7
C	0.0±0.0	24±0.0	26±2.3	26±2.3	28±0.0	28±0.0	28±0.0
GA_3	0.0±0.0	54±2.3	56±0.0	56±0.0	56±0.0	56±0.0	56±0.0
Kin	0.0±0.0	56±4.6	60±0.0	60±0.0	60±0.0	60±0.0	60±0.0
BA	0.0±0.0	4±0.0	4±0.0	6±2.3	6±2.3	6±2.3	6±2.3
E	0.0±0.0	4±0.0	4±0.0	6±2.3	6±2.3	6±2.3	6±2.3
EBR	0.0±0.0	46±2.3	46±2.3	46±2.3	46±2.3	46±2.3	46±2.3
TRIA	0.0±0.0	6±2.3	10±2.3	10±2.3	10±2.3	10±2.3	10±2.3
Spm	0.0±0.0	0.0±0.0	6±2.3	6±2.3	6±2.3	6±2.3	6±2.3
Spd	0.0±0.0	0.0±0.0	0.0±0.0	1±2.0	1±2.0	1±2.0	4±0.0
Cad	0.0±0.0	0.0±0.0	16±0.0	16±0.0	16±0.0	16±0.0	16±0.0
Put	0.0±0.0	8±0.0	14±2.3	14±2.3	14±2.3	14±2.3	14±2.3
GA_3 + Kin	100±0.0	100±0.0	100±0.0	100±0.0	100±0.0	100±0.0	100±0.0
GA_3 + EBR	100±0.0	100±0.0	100±0.0	100±0.0	100±0.0	100±0.0	100±0.0
Kin + EBR	100±0.0	100±0.0	100±0.0	100±0.0	100±0.0	100±0.0	100±0.0
GA_3 + Kin + EBR	100±0.0	100±0.0	100±0.0	100±0.0	100±0.0	100±0.0	100±0.0
GA_3 + Kin + E	0.0±0.0	100±0.0	100±0.0	100±0.0	100±0.0	100±0.0	100±0.0

alleviating its germination-delaying effect. The others had no effect. For example, while control seeds at 35°C showed 28% germination on the 5th day, the seeds pretreated with GA_3, Kin and EBR reached 2 folds of this value on the 2nd day and gained a time of 96 h. On the other hand, double and triple combinations of these regulators much more successfully shortened the period of germination. All double and triple combinations, except GA_3 + Kin + E, increased the germination rate up to 100% on the 1st day and provided an important gain of time. GA_3 + Kin + E combination showed this success on the 2nd day (Table 1).

The growth regulator pretreatments overcame in varying degrees the inhibitory effect of high temperature on the final germination percentage of radish seeds. GA_3 + E pretreatment showed the most positive effect on this parameter. The final germination of the seeds with this combination was 100%. Double combinations were more effective than triple and quartet combinations. Moreover, many of the growth regulator pretreatments were able to alleviate the germination-delaying effect of high temperature. While the control seeds showed 22% germination on the 4th day at 38°C, in the seeds pretreated with growth regulators, both single and in combination, this value was exceeded on the 1st, 2nd or at the latest the 3rd day, and an important gain of time occured. For instance, the seeds pretreated with GA_3 + Cad, GA_3 + Spd, GA_3 + Kin, GA_3 + BA + E, GA_3 + EBR + E and GA_3 + BA + TRIA + E reached approximately two folds of the final germination rate of 22% of control on the 1st day (Table 2).

Effects of plant growth regulators on the some parameters of growth of the seedlings

The results of high temperature-stimulator interaction on the shoot (coleoptile/hypocotyl) percentages, radicle and shoot lengths and fresh weight of the seedlings of barley and radish are presented in Table 3 and 4.

Shoot percentage

Of the pretreatments, GA_3, Kin, EBR and their combinations gave similar results to germination percentages on coleoptile emergence of barley seedlings. That is, while these single applications could reduce the inhibitory effect of high temperature, the others had no effect. Double and triple combinations alleviated more successfully the inhibitory effect of high temperature on this parameter (Table 3).

Many regulator pretreatments alleviated quite successfully the reductive effect of high temperature on hypocotyl percentage of radish seedlings. GA_3 + Spd had the best effect on this parameter. The double combinations, as on the final germination percentage, were more successful than triple and quartet combinations on hypocotyl percentage (Table 4).

Table 2. Effects of various growth regulator pretreatments on the time course of germination of radish seeds at 38°C.

Growth regulator	Days						
	1	2	3	4	5	6	7
C	0.0±0.0	16±0.0	20±0.0	22±2.3	22±2.3	22±2.3	22±2.3
GA_3	0.0±0.0	30±2.3	52±0.0	74±2.3	82±2.3	88±0.0	88±0.0
Kin	0.0±0.0	40±0.0	50±2.3	54±2.3	56±0.0	58±2.3	64±0.0
BA	0.0±0.0	42±2.3	58±2.3	78±2.3	82±2.3	82±2.3	86±2.3
E	0.0±0.0	22±2.3	50±2.3	56±0.0	64±0.0	70±2.3	72±0.0
EBR	0.0±0.0	42±2.3	54±2.3	58±2.3	62±2.3	62±2.3	66±2.3
TRIA	0.0±0.0	8±0.0	24±0.0	50±2.3	56±0.0	62±2.3	64±0.0
Spm	0.0±0.0	8±0.0	8±0.0	40±0.0	50±2.3	60±0.0	70±2.3
Spd	0.0±0.0	38±2.3	52±0.0	62±2.3	68±0.0	68±0.0	70±2.3
Cad	0.0±0.0	34±2.3	40±0.0	66±2.3	68±0.0	68±0.0	74±2.3
Put	0.0±0.0	0.0±0.0	26±2.3	40±0.0	48±0.0	48±0.0	52±0.0
GA_3 +E	16±0.0	76±0.0	90±2.3	94±2.3	96±0.0	100±0.0	100±0.0
GA_3 +EBR	16±0.0	52±0.0	76±0.0	88±0.0	92±0.0	92±0.0	92±0.0
GA_3+TRIA	22±2.3	58±2.3	78±2.3	88±0.0	90±2.3	92±0.0	92±0.0
GA_3+Cad	42±2.3	62±2.3	84±0.0	90±2.3	90±2.3	90±2.3	90±2.3
GA_3+Spd	38±2.3	64±0.0	90±2.3	92±0.0	96±0.0	98±2.3	98±2.3
GA_3+Kin	36±0.0	62±2.3	86±2.3	92±0.0	92±0.0	92±0.0	92±0.0
GA_3+BA	26±2.3	62±2.3	82±2.3	94±2.3	94±2.3	94±2.3	94±0.0
BA+EBR	12±0.0	60±0.0	84±0.0	88±0.0	88±0.0	88±0.0	90±2.3
BA+TRIA	0.0±0.0	54±2.3	72±0.0	88±0.0	88±0.0	90±2.3	92±0.0
BA+Cad	18±2.3	76±0.0	94±2.3	96±0.0	96±0.0	96±0.0	96±0.0
BA+Spd	4±0.0	50±2.3	66±2.3	80±0.0	80±0.0	80±0.0	80±0.0
BA+E	0.0±0.0	48±0.0	78±2.3	84±0.0	90±2.3	90±2.3	90±2.3
EBR+TRIA	16±0.0	50±2.3	74±2.3	80±0.0	80±0.0	80±0.0	82±2.3
EBR+Cad	16±0.0	70±2.3	76±0.0	76±0.0	80±0.0	80±0.0	80±0.0
EBR+E	14±2.3	76±0.0	80±0.0	84±0.0	90±2.3	90±2.3	92±0.0
EBR+Spd	10±2.3	44±0.0	76±0.0	80±0.0	88±0.0	96±0.0	96±0.0
TRIA+E	0.0±0.0	12±0.0	70±2.3	82±2.3	86±2.3	88±0.0	88±0.0
TRIA+Cad	8±0.0	28±0.0	56±0.0	72±0.0	76±0.0	76±0.0	76±0.0
TRIA+Spd	4±0.0	46±2.3	72±0.0	78±2.3	80±0.0	80±0.0	88±0.0
GA_3+ BA+E	48±0.0	92±0.0	92±0.0	94±2.3	94±2.3	94±2.3	94±2.3
GA_3+ BA+TRIA	14±2.3	46±2.3	80±0.0	80±0.0	84±0.0	88±0.0	88±0.0
GA_3+ BA+Spd	4±0.0	48±0.0	58±2.3	70±2.3	70±2.3	74±2.3	74±2.3
GA_3+Kin+E	18±2.3	60±0.0	74±2.3	82±2.3	82±2.3	84±0.0	84±0.0
GA_3+EBR+E	40±0.0	82±2.3	84±0.0	84±0.0	92±0.0	92±0.0	92±0.0
GA_3+TRIA+E	28±0.0	70±2.3	82±2.3	88±0.0	88±0.0	88±0.0	88±0.0
GA_3+TRIA+Spd	12±0.0	46±2.3	68±0.0	82±2.3	82±2.3	84±0.0	84±0.0
GA_3+TRIA+Cad	10±2.3	40±0.0	66±2.3	80±0.0	80±0.0	80±0.0	80±0.0
BA+TRIA+E	0.0±0.0	8±0.0	28±0.0	54±2.3	68±0.0	68±0.0	68±0.0
BA+TRIA+EBR	8±0.0	44±0.0	58±2.3	74±2.3	74±2.3	76±0.0	76±0.0
BA+TRIA+Cad	12±0.0	34±2.3	42±2.3	58±2.3	68±0.0	68±0.0	68±0.0
BA+TRIA+Spd	8±0.0	24±0.0	40±0.0	48±0.0	56±0.0	56±0.0	56±0.0
GA_3+BA+TRIA+Spd	4±0.0	40±0.0	70±2.3	78±2.3	78±2.3	80±2.3	80±0.0
GA_3+BA+TRIA+EBR	0.0±0.0	56±0.0	78±2.3	80±0.0	80±0.0	80±0.0	80±0.0
GA_3+BA+TRIA+E	42±2.3	82±2.3	86±2.3	94±2.3	94±2.3	94±2.3	96±0.0
TRIA + Spd+EBR+BA	12±0.0	52±0.0	72±0.0	72±0.0	76±0.0	76±0.0	76±0.0
TRIA + Spd+EBR+GA_3	20±0.0	60±0.0	84±0.0	84±0.0	84±0.0	88±0.0	88±0.0
TRIA + Spd+EBR+E	8±0.0	64±0.0	74±2.3	80±0.0	80±0.0	80±0.0	80±0.0

Radicle elongation

Both single and double and triple combinations had no effect in the alleviation of high temperature-induced inhibitory effect on radicle elongation of barley seedlings (Table 3).

As for radicle elongation of radish seedlings, a lot of regulators were not able to overcome high temperature stress. While some of the single and double applications increased radicle elongation, none of the triple and quadrupled combinations had a positive effect on this parameter. TRIA+Spd statistically showed the most positive effect (Table 4).

Shoot elongation

Except E, TRIA, Spd and Put, all of single, double and triple pretreatments were able to alleviated the inhibitory effect of high temperature on coleoptile elongation of barley

Table 3. Effects of various growth regulator pretreatments on the some growth parameters of the seedlings from germinated barley seeds at 35°C.

Growth regulator	Growth parameters				
	Germination percentage	Coleoptile percentage	Radicle length (mm)	Coleoptile length (mm)	Fresh weight (mg/seedling)
C	*28±0.0 d	24±0.0 f	10.0±0.0 a	15.4±0.0 d	99.2±0.6 c
GA_3	56±0.0 f	56±0.0 h	10.0±0.0 a	21.8±0.5 i	122.1±1.1 g
Kin	60±0.0 g	60±0.0 i	10.0±0.0 a	22.6±0.6 j	144.3±0.8 i
BA	6±2.3 a	6±2.3 b	10.0±0.0 a	17.0±0.8 f	130.0±1.6 h
E	6±2.3 a	0.0±0.0 a	10.0±0.0 a	0.0±0.0 a	115.0±0.8 e
EBR	46±2.3 e	42±2.3 g	10.0±0.0 a	16.8±0.6 ef	119.9±0.8 f
TRIA	10±2.3 b	8±0.0 c	10.0±0.0 a	14.5±0.1 c	135.0±0.8 i
Spm	6±2.3 a	6±2.3 b	10.0±0.0 a	16.5±0.5 ef	135±1.6 i
Spd	4±0.0 a	0.0±0.0 a	10.0±0.0 a	0.0±0.0 a	115.0±0.8 e
Cad	16±0.0 c	12±0.0 d	10.0±0.0 a	16.1±0.7 de	118.7±1.5 f
Put	14±2.3 c	14±2.3 e	10.0±0.0 a	13.6±0.1 b	111.2±1.0 d
GA_3 + Kin	100±0.0 h	100±0.0 i	10.2±0.0 b	19.0±0.8 h	90.8±0.8 a
GA_3 + EBR	100±0.0 h	100±0.0 i	10.0±0.0 a	18.3±0.3 gh	97.6±0.3 b
Kin+ EBR	100±0.0 h	100±0.0 i	10.0±0.0 a	20.5±0.5 i	115.0±1.6 e
GA_3 + Kin+ EBR	100±0.0 h	100±0.0 i	10.0±0.0 a	16.8±0.6 ef	111.4±0.8 d
GA_3 + Kin+ E	100±0.0 h	100±0.0 i	10.0±0.0 a	17.7±0.5 g	96.8±1.3 b

*The difference between values with the same letter in each column is not significant at the level 0.05 (± Standard deviation)

seedlings. Kin showed the most positive effect on this parameter (Table 3).

Some applications of the growth regulators alleviated high temperature stress on hypocotyl elongation of radish seedlings. TRIA+Cad and GA_3+Spd were the most successful applications on this parameter. Many of the triple and quadrupled combinations were quite ineffective on hypocotyl elongation as the case of radicle elongation. Only GA_3+EBR+E, GA_3+TRIA+E, GA_3+TRIA+Spd and TRIA+Spd+EBR+GA_3 pretreatments had an inductive effect on this parameter (Table 4).

Fresh weight

All pretreatments, except GA_3+Kin, GA_3+EBR and GA_3+Kin+E, prevented the decreasing in the fresh weight of barley seedlings caused by high temperature in varying levels. On this parameter, the fact that the applications alone were more successful than double and triple combinations was an surprising result. The most effective regulator was again Kin (Table 3).

None of the applications were able to overcome the adverse effect of high temperature stress on the fresh weight of radish seedlings. Only GA_3+EBR had the same values with the control group. All other pretreatments decreased the fresh weight of the seedlings (Table 4).

DISCUSSION

As known, supraoptimal temperatures drastically decrease seed germination (Chris Small and Gutterman 1992, Carter and Stevens 1998) and seedling growth (Odegbaro and Smith 1969, Sattelmacher et al. 1990) in many species. The seedling growth and germination of barley and radish seeds, as expected, were inhibited under high temperature conditions (Table 1-4). High temperature stress can perform its preventive effect in many ways. It may interfere with seed germination by changing the water status of the seed so that water uptake is inhibited (Kabar and Baltepe 1990). All the single applications of growth regulators leaded to increases in various levels in imbibition of barley seeds at 35°C (Table 3). However, only GA_3, Kin and EBR alone succeed in alleviating the thermoinhibition of germination of barley seeds. It may be said that the mentioned regulators overcame thermoinhibition of germination by counteracting high temperature on the imbibition of barley seeds. The fact that although all the pretreatments singly or in combination in the case of radish and some applications with combination in barley were not able to overcome the water uptake-

Table 4. Effects of various growth regulator pretreatments on the some growth parameters of the seedlings from germinated radish seeds at 38°C.

Growth regulator	Growth parameters				
	Germination percentage	Hypocotyl percentage	Radicle length (mm)	Hypocotyl length (mm)	Fresh weight (mg/seedling)
C	*22±2.3 [a]	20±0.0 [f]	5.9±0.7 [efgh]	5.4±0.1 [bcd]	45.0±0.8 [ü]
GA_3	88±0.0 [mn]	36±0.0 [j]	5.5±0.1 [bcd]	5.6±0.0 [def]	24.4±0.6 [d]
Kin	64±0.0 [d]	20±0.0 [f]	5.2±0.0 [ab]	5.3±0.0 [bcd]	41.5±0.1 [ş]
BA	86±2.3 [l]	42±2.3 [l]	5.7±0.1 [def]	5.2±0.1 [bc]	38.0±0.0 [s]
E	72±0.0 [h]	30±2.3 [ı]	5.7±0.0 [def]	5.3±0.2 [bcd]	21.8±0.8 [ab]
EBR	66±2.3 [e]	46±2.3 [m]	6.1±0.5 [ghı]	5.7±0.4 [efg]	41.8±0.7 [ş]
TRIA	64±0.0 [d]	24±0.0 [g]	5.6±0.0 [cde]	5.5±0.1 [cde]	36.8±0.6 [r]
Spm	70±2.3 [g]	18±2.3 [e]	5.5±0.1 [bcd]	5.3±0.2 [bcd]	29.6±0.6 [ıij]
Spd	70±2.3 [g]	36±0.0 [j]	6.2±0.0 [hı]	5.9±0.4 [ghı]	36.5±0.1 [pr]
Cad	74±2.3 [ı]	40±0.0 [k]	5.7±0.0 [def]	5.5±0.0 [cde]	33.6±1.1 [n]
Put	52±0.0 [b]	16±0.0 [d]	5.8±0.1 [defg]	5.1±0.0 [b]	35.3±0.9 [oö]
GA_3 +E	100±0.0 [s]	68±0.0 [ş]	5.2±0.0 [ab]	7.1±0.9 [k]	27.4±0.8 [fg]
GA_3 +EBR	92±0.0 [oö]	78±2.3 [ü]	6.8±0.4 [j]	5.4±0.0 [bcd]	45.4±0.1 [ü]
GA_3+TRIA	92±0.0 [oö]	64±0.0 [r]	6.6±0.6 [ij]	6.9±0.1 [k]	43.8±0.4 [tu]
GA_3+Cad	90±2.3 [no]	70±2.3 [t]	6.3±0.3 [ıi]	5.7±0.4 [efg]	38.4±0.7 [s]
GA_3+Spd	98±2.3 [r]	92±0.0 [y]	6.6±0.2 [ij]	7.6±0.1 [l]	42.0±0.6 [ş]
GA_3+Kin	92±0.0 [oö]	72±0.0 [u]	5.3±0.1 [abc]	6.4±0.1 [j]	31.0±0.8 [klm]
GA_3+BA	94±0.0 [ö]	32±0.0 [i]	5.0±0.0 [a]	5.3±0.2 [bcd]	31.5±0.5 [m]
BA+EBR	90±2.3 [no]	48±0.0 [n]	5.0±0.0 [a]	6.2±0.4 [ij]	31.2±0.7 [lm]
BA+TRIA	92±0.0 [oö]	40±0.0 [k]	5.0±0.0 [a]	5.6±0.1 [def]	29.3±1.2 [ıi]
BA+Cad	96±0.0 [p]	82±2.3 [v]	5.1±0.0 [a]	6.0±0.0 [hıij]	33.5±0.1 [n]
BA+Spd	80±0.0 [j]	52±0.0 [o]	5.0±0.0 [a]	6.0±0.0 [hıij]	35.5±0.8 [ö]
BA+E	90±2.3 [no]	64±0.0 [r]	5.0±0.0 [a]	5.9±0.2 [ghı]	38.8±0.6 [s]
EBR+TRIA	82±2.3 [j]	60±0.0 [p]	6.0±0.5 [fghı]	5.9±0.3 [ghı]	30.4±0.3 [jkl]
EBR+Cad	80±0.0 [j]	64±0.0 [r]	6.9±0.2 [j]	5.5±0.1 [cde]	43.0±0.5 [t]
EBR+E	92±0.0 [oö]	72±0.0 [u]	5.6±0.0 [cde]	5.7±0.1 [efg]	35.8±0.6 [öp]
EBR+Spd	96±0.0 [p]	66±2.3 [s]	6.6±0.1 [ij]	5.7±0.0 [efg]	44.1±0.4 [u]
TRIA+E	88±0.0 [mn]	64±0.0 [r]	6.1±0.4 [ghı]	6.0±0.4 [hıij]	43.5±0.5 [tu]
TRIA+Cad	76±0.0 [i]	32±0.0 [i]	5.7±0.0 [def]	7.8±0.8 [l]	32.8±0.7 [n]
TRIA+Spd	88±0.0 [mn]	72±0.0 [u]	7.2±0.1 [k]	6.1±0.4 [ıij]	37.0±0.5 [r]
GA_3+ BA+E	94±2.3 [ö]	16±0.0 [d]	5.0±0.0 [a]	5.0±0.0 [b]	27.1±0.1 [ef]
GA_3+BA+TRIA	88±0.0 [mn]	8±0.0 [c]	5.0±0.0 [a]	5.0±0.0 [b]	27.4±0.2 [fg]
GA_3+ BA+Spd	74±2.3 [ı]	4±0.0 [b]	5.0±0.0 [a]	5.0±0.0 [b]	22.4±1.1 [bc]
GA_3+Kin+E	84±0.0 [k]	8±0.0 [c]	5.0±0.0 [a]	5.0±0.0 [b]	24.7±0.5 [d]
GA_3+EBR+E	92±0.0 [oö]	66±2.3 [s]	5.3±0.1 [abc]	6.2±0.0 [ij]	34.5±0.6 [o]
GA_3+TRIA+E	88±0.0 [mn]	40±0.0 [k]	5.2±0.0 [ab]	5.6±0.1 [def]	29.9±0.4 [ij]
GA_3+TRIA+Spd	84±0.0 [k]	48±0.0 [n]	5.1±0.0 [a]	6.0±0.4 [hıij]	33.0±0.4 [n]
GA_3+TRIA+Cad	80±0.0 [j]	48±0.0 [n]	5.1±0.0 [a]	5.3±0.0 [bcd]	26.7±0.2 [ef]
BA+TRIA+E	68±0.0 [f]	0.0±0.0 [a]	5.0±0.0 [a]	0.0±0.0 [a]	21.4±0.2 [a]
BA+TRIA+EBR	76±0.0 [i]	0.0±0.0 [a]	5.0±0.0 [a]	0.0±0.0 [a]	30.2±0.2 [jk]
BA+TRIA+Cad	68±0.0 [f]	0.0±0.0 [a]	5.0±0.0 [a]	0.0±0.0 [a]	22.9±0.1 [c]
BA+TRIA+Spd	56±0.0 [c]	0.0±0.0 [a]	5.0±0.0 [a]	0.0±0.0 [a]	21.7±0.3 [ab]
GA_3+BA+TRIA+Spd	80±0.0 [j]	32±0.0 [i]	5.0±0.0 [a]	5.0±0.0 [b]	28.2±0.2 [gh]
GA_3+BA+TRIA+EBR	80±0.0 [j]	28±0.0 [h]	5.0±0.0 [a]	5.0±0.0 [b]	26.2±0.2 [e]
GA_3+BA+TRIA+E	96±0.0 [p]	28±0.0 [h]	5.0±0.0 [a]	5.0±0.0 [b]	33.5±0.1 [n]
TRIA + Spd+EBR+BA	76±0.0 [i]	18±2.3 [e]	5.0±0.0 [a]	5.0±0.0 [b]	26.2±0.5 [e]
TRIA +Spd+EBR+GA_3	88±0.0 [mn]	58±2.3 [ö]	5.2±0.1 [ab]	5.8±0.3 [fgh]	28.8±0.7 [hı]
TRIA + Spd+EBR+E	80±0.0 [j]	28±0.0 [h]	5.0±0.0 [a]	5.4±0.3 [bcd]	26.2±0.2 [e]

*The difference between values with the same letter in each column is not significant at the level 0.05 (± Standard deviation)

reductive effect of high temperature (Table 3, 4), and that they alleviated its germination-preventive effect on a large scale is very surprising. These regulators may mediate the operation of the basic processes mentioned below and required for germination in the presence of water with the minimum amount up-taken. In the other word, they might have reduced the need of water for the seeds for germination.

On the other hand, all the stimulators used in radish and, GA_3, Kin, EBR and their combinations in barley reached the final germination of the seeds at 100s% and also succeed in alleviating the germination-delaying effect of high temperature (Table 1, 2), i.e. shortened the time required for germination, although they were not able to remove the inhibitive effect of high temperature on the elongation of radicle and some applications partly succeed in shoot elongation (hypocotyl or coleoptile). Moreover, in comparison with the control, the applications mentioned above for barley and many pretreatments for radish caused increases in varying levels reaching 100s% in the percentages of shoot growth (Table 3, 4).

As seen, the used stimulators, in relation to alleviation of high temperature stress on the mentioned parameters of growth, exhibited different modes of effectiveness in barley and radish. One of the best-characterized effects of high temperature is that it can inhibit germination of seed by limiting the availability of energy and nutrients as a result of the fact that it delays and prevents the synthesis and/or activities of hydrolases inducing mobilization and breakdown of food reserves in the seed (Hawker and Jenner 1993). Concequently, the germination may have occured both very slowly and at a low ratio (Table 1, 2). Increases in the amount of abscisic acid (ABA) in seed originated from high temperature stress may also block hydrolytic activity (Lachno and Baker 1986). In addition to gibberellins (Dale 1969), cytokinins (Khan 1969), E (Jacobsen 1973) and EBR (Prusakova et al. 1995) may also ameliorate the germination of seed under high temperature stress by inducing hydrolytic activity, and that also PAs stimulate hydrolytic activity is not far from probability.

The most common response of cell to high temperature is growth inhibition which results from limitation of cell extensibility (Chen et al. 1982) and inhibition of cell division (Sattelmacher et al. 1990). Gibberellins (Galli et al. 1975), cytokinins (Houssa et al. 1990) EBR (Hu et al. 2000, Nakaya et al. 2002) and PAs (Costa and Bagni 1983) might make a counterattack an high temperature by promoting cell division. High temperature is well known to prevent radicle and shoot elongation (Hegarty and Ross 1979). High temperature may also play a preventive role in seed germination by inhibiting synthesis of protein and nucleic acid (Sivaramakrishnan et al. 1990). Alleviation of thermoinhibition of germination by growth regulators used in this work may be accompanied by increases in nucleic acid and protein syntheses. Actually, gibberellins (Akazawa et al. 1988), cytokinins (Ananiev et al. 1987), PAs (Palavan and Galston 1982) and EBR (Bajguz 2000) have been proven to stimulate the syntheses of protein and nucleic acid.

The function of high temperature stress in inhibition of germination might be to prevent these basic metabolic processes which start very soon after the beginning of imbibition. Thus, germination will be prevented in its early stages and dormancy will then be marked by lowered metabolic activity. High temperature might have delayed and/or prevented the germination of the seeds for the reasons mentioned, and in addition, might have reduced the growth of the seedlings. Promoter growth substances used can also overcome these inhibitions by counteracting high temperature.

The similarity of some functions of promoters used in this work seems like insurance for the life of the plant so that if one of them is more effective in a plant, it will succeed in these similar functions. It has been emphasized before that seeds of the same or different species may contain different levels of gibberellins (Taylor and Wareing 1979), cytokinins (Khan 1971), E (Zapata et al. 2004), polyamines (Basu et al. 1988) and brassinosteroids (Schmidt et al. 1997). The seeds, therefore, should not be expected to give the same response to application of any growth regulator. It is not probable that germination and dormancy in nature are governed by absolute presence or absence of a hormone. Perhaps, it is more appropriate to say that individual hormones in a seed, at any one time, are at a physiologically effective or ineffective concentration. These concentrations must depend on many metabolic and environmental factors. Thus, it may be more accurate to think of an effective common pool of growth regulators.

In conclusion, in this work we have shown that EBR, PAs and TRIA, interested researchers for the last two-three decades, were as effective as gibberellins and cytokinins in the alleviation of high temperature stress during seed germination at least for radish. Moreover, we proved that GA_3, Kin, EBR and combinations composed of them became effective in the case of barley as well.

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Yuksek Sicaklik Stresi Altinda Arpa ve Turp Tohularinin Cimlenmesi Uzerine Bazi Bitki Buyume Duzenleyicilerinin Karsilastirilmali Etkileri

Ozet

Arpa ve turp tohumlarinin yuksek sicaklik kosullari altindaki cimlenme ve ilk fide buyumesi uzerine gibberellik asit, kinetin, benziladenin, etilen, 24-epibrassinolit, triakontanol and poliaminlerin (kadaverin, putressin, spermidin, spermin) tek basina ve kombinasyon halindeki etkileri arastirilmistir. Yuksek sicaklik her iki turun cimlenmesini hem engellemis hem de geciktirmistir. Sadece gibberellik asit, kinetin ve 24-epibrassinolit arpa tohumlarinin cimlenmesi uzerindeki yuksek sicakligin etkilerini hafifletebilmistir. Bu uc buyume duzenleyicisinden olusturulan tum kombinasyonlar cimlenme uzerindeki bu olumsuz etkiyi daha basarili bir sekilde uzaklastirmistir. Turp tohumlarinin cimlenmesi uzerindeki yuksek sicakligin etkisi tek ve kombinasyon halindeki tum on uygulamalar ile degisik derecelerde ortadan kaldirilmistir. Soz konusu buyume duzenleyicileri arpa fidelerinin buyumesi uzerinde de basarilarini devam ettirmelerine karsin, kullanilan duzenleyiciler turp fidelerinin buyumesinde genellikle etkisiz olmuslardir.

Anahtar Kelimeler: Yuksek sicaklik stresi, bitki buyume duzenleyicisi, tohum cimlenmesi, fide buyumesi.

