depth to water table increased to at least 76 cm.

Results obtained in these experiments agree with those presented by Goins et al. (1966) in that yields were generally influenced by soil texture as well as by water table depths, and the minimum water table depth required for satisfactory yield varied with species. Williamson et al. (1969) found that root growth of millet was greatly reduced where water tables were maintained at 15 and 30 cm below the soil surface. Low yields of cabbage, squash, and tendergreen in tanks with a 15-cm water table depth were probably due to the effects of a reduced root system and the effects of low soil O_2 on several physiological processes in plants, including nutrient uptake. It appears that with proper management, many horticultural crops can be grown at a higher water table than can most field crops.

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Stimulation of Lettuce Seed Germination at High Temperatures by Ethephon and Kinetin[1]

G. C. Sharples[2]

University of Arizona, Tucson

Abstract. 'GL 659' and 'Vanguard' lettuce seed lots germinated almost completely at 30°C when treated with ethephon (100 mg/liter). Similar treatment at 35°C failed to release seeds from dormancy. Kinetin treatment (10 mg/liter) at 35°C was only moderately effective in breaking heat dormancy, but when ethephon and kinetin were combined at this temperature, the interaction was synergistic and germination was almost complete. The preincubation time requirement at 25°C before maximum germination could occur after transferring to 35°C was nearly eliminated by treating seeds with the ethephon-kinetin mixture. 'Calmar' seeds, which had a lower heat tolerance, could not be induced to germinate completely at high temperature by any treatment.

High temp dormancy of lettuce seed complicates winter lettuce production in southwestern irrigated desert regions. In early fall plantings seed bed (wet soil) temp exceeding 27°C tend to interfere with germination and development of uniform, vigorous stands, the extent of interference depending on the excess over 27°C and the relative lengths of exposures to temp above and below. Germination of even the most heat tolerant cultivars is seriously reduced when the imbibition temp is held constant at 30°C, and at a constant 35°C, germination usually does not occur. Chances for success in current efforts to mechanize lettuce production and harvesting could be increased by development of practical means to improve the germination of lettuce seed under heat stress.

Chemical seed treatments to enhance germination have been the subject of much research, but until recently only thiourea (13) and kinetin (9, 10, 11, 12) have been shown to have any effect on heat induced dormancy of lettuce. Abeles and Lonski (1) found that ethylene, CO_2 or a combination of the 2 could increase the germination at 30°C of photosensitive lettuce, and concluded ethylene action occurred in the initial stages of germination. Negm et al. (7) subsequently showed not only that ethylene increases the fraction of seed that germinates, but that a combination of ethylene and CO_2 can induce complete germination of lettuce seed at 35°C at any time after imbibition and that an interaction between the 2 gases is required. Skinner et al. (11) found that kinetin could stimulate the germination at 30°C of photosensitive lettuce seed and demonstrated that gibberellin and kinetin acted synergistically to increase the germination rate. Porto and Siegel (9) overcame with kinetin the dormancy induced by heating dry seeds to 75°C for 1 hr. Pauli and Harriott (8) increased the germination and subsequent emergence of 'GL 659' and 'Climax' by soaking seed for 8 hr in a kinetin solution containing nutrients. Smith et al. (12) reported that max effects could be obtained with a 3 min dip in 100 mg kinetin/liter followed by washing and drying.

Ethephon [(2-chloroethyl)phosphonic acid] decomposes slowly at pH 4-6 releasing ethylene. Upon absorption into plant tissue ethephon apparently releases ethylene which may then enter into a variety of physiological reactions. Dormancy in peanut and strawberry seeds can be broken by treatment with ethephon (3, 5).

Preliminary tests indicated that germination rate of 'GL 659' seeds in dilute ethephon solutions at 30°C was greater than in water. This suggested that ethephon might be used to investigate ethylene effects on lettuce seed germination at higher temp and point the way toward a practical seed treatment for field use. The following experiments show the effects of ethephon and its interaction with kinetin on the germination of lettuce seed at 30°C and 35°C.

Materials and Methods

Lettuce (*Lactuca sativa* L.) cultivars used and their average lot germination percentages in water at 25°C were: 'GL 659' - 91%, 'Vanguard' - 93%, and 'Calmar' - 82%. Germination was carried out at 30°C or 35°C ± 1°C in polycarbonate Petri dishes containing 2 layers of filter paper moistened with water or test

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[2]Horticulturist, Mesa Branch Experiment Station, Mesa.

solutions. No effort was made to exclude light and germination counts were made under laboratory lighting conditions. For the purpose of this study seeds were considered germinated when radicles protruded 1 mm from beneath the fruit coat. This criterion was arbitrary and convenient for germination, but did not guarantee development into normal healthy seedlings; radicles occasionally ceased growth after reaching greater lengths. Under some conditions, especially at 35°C, a few seeds always germinated cotyledons first. These were classed as atypical and were not counted. Germination was recorded at 24 hr intervals and was essentially complete after 72 hr. Each treatment consisted of not less than 100 seeds and tests were repeated 3 times.

Ethephon (Amchem 68-240 Ethrel) and kinetin (Nutritional Biochemicals Co.) solutions were applied directly to the filter paper medium. In some tests kinetin treated seeds were prepared by the 3 min dip procedure of Smith et al. (12).

Results and Discussion

Ethephon concentration. In preliminary tests 'GL 659' seed lots germinated almost completely in a solution of ethephon (100 mg/liter) at 30°C. Germination occurred also at higher concn but the pH of these solutions generally was too low to allow normal radicle growth.

A systematic study of ethephon concn on total germination of 3 cultivars after 72 hr is summarized in Table 1. The 1000 mg/liter stock ethephon solution (pH 2.3) used in these and following tests was adjusted to pH 6.5 with solid KOH and drop-size vols of 1N KOH before diluting to desired concn. This procedure eliminated pH differences arising from dilution effects and apparently did not cause excessive ethephon decomposition. Max germination response at all 3 temp was obtained with 100 mg of ethephon/liter. At 25°C the response was small or absent with 'GL 659' and 'Vanguard'. At 30°C ethephon increased the germination of these cultivars to values exceeding 90% of those of untreated seeds germinated at 25°C. Germination was low at 35°C but the influence of ethephon was still apparent. Of the 3 cultivars tested, 'Calmar' had the lowest heat tolerance and responded least to ethephon treatment. It could not be induced to germinate at 35°C. Ethephon concn of 500 and 1000 mg/liter tended to suppress germination, possibly because of toxic effects of ethylene or of Cl^- ions released by ethephon decomposition or both. Propylene glycol, used as ethephon solvent by the manufacturer, did not visibly affect seed germination at the concn used (.05 M at 1000 mg ethephon/liter).

Inspection of the germination data on a daily basis indicated germination rates were accelerated by the ethephon treatment and practically all of the rate increase occurred during the initial 24 hr after imbibition started. This was observed by Abeles and Lonski (1) using ethylene gas and taken as evidence that the ethylene triggering action terminating dormancy occurs early in the sequence of events leading to elongation of the radicle.

Ethephon-kinetin interaction. Because of the striking responses of lettuce seed at high temp to kinetin treatment (6, 11, 12) the possibility was strong that ethephon might interact with kinetin to further increase germination. To test this possibility 'GL 659', 'Vanguard', and 'Calmar' seeds were germinated at 30°C and 35°C in dishes containing mixtures of serially diluted ethephon (0 to 100 mg/liter) and kinetin (0 to 10 mg/liter).

Table 2 shows that either 1 or 10 mg kinetin/liter induced almost complete germination of 'GL 659' and 'Vanguard' at 30°C and that 100 mg ethephon/liter was only slightly less effective. Except for 'Calmar', combinations of ethephon and kinetin were no more effective than kinetin alone. The germination of 'Calmar' may have been slightly increased by the combined action of ethephon and kinetin at 30°C.

As before, all 3 cultivars remained substantially dormant at 35°C when treated only with ethephon. The responses due to kinetin alone at this temp were moderate and agree with the results reported for 'GL 659' by Smith et al. (12). Outstanding, however, was the synergistic increase in germination of all 3 cultivars resulting from the combination of ethephon and kinetin. Except for 'Calmar', almost complete germination at 35°C was induced by 100 mg ethephon/liter and 10 mg kinetin/liter. These tests also included kinetin at 100 mg/liter (data not shown), but at this concn germination was depressed, the depression being greater with increasing ethephon concn. Similar tests were conducted with gibberellic acid in combination with ethephon but the results were negative.

Time-temperature relations. Lettuce seed lots can be induced to germinate completely at 30°C or 35°C by preincubating imbibing seeds for 12 hr at 25°C before transferring to the higher temp. Presumably a heat sensitive reaction mechanism which can prevent thermodormancy is completed within this period. The practical value of this property for desert lettuce production was demonstrated by Johnson et al. (4). Simply by arranging the initial sprinkler irrigation set to coincide with the coolest 12 hr of the day, seedling emergence and subsequent stand was improved. To assess the effect of ethephon and ethephon-kinetin mixtures on this temp requirement, untreated

Table 1. Effect of ethephon concn on germination percentage of lettuce seed after 72 hr.[z]

Ethephon mg/liter	'GL 659' 25°C	'GL 659' 30°C	'GL 659' 35°C	'Vanguard' 25°C	'Vanguard' 30°C	'Vanguard' 35°C	'Calmar' 25°C	'Calmar' 30°C	'Calmar' 35°C
0	90	22	0	93	33	0	83	6	0
10	89	55	5	94	72	0	84	50	0
50	91	76	7	94	81	2	82	55	0
100	97	89	10	96	86	5	82	59	0
500	92	83	8	94	82	2	80	56	0
1000	90	83	7	90	73	0	76	51	0

[z]Values are the means of 3 consecutive experiments.

Table 2. Interaction of ethephon and kinetin on germination percentage of lettuce seed after 72 hr at high temp.[z]

Cultivar	Ethephon mg/liter	30°C Kinetin, mg/liter 0	30°C 1	30°C 10	35°C Kinetin, mg/liter 0	35°C 1	35°C 10
GL 659	0	31	93	95	0	34	59
	1	88	93	97	2	30	85
	10	94	96	96	6	84	88
	100	90	94	92	9	88	93
Vanguard	0	35	80	93	1	4	63
	1	74	86	88	0	8	72
	10	69	85	81	0	12	85
	100	73	83	89	2	17	88
Calmar	0	6	66	66	0	1	19
	1	13	61	69	0	4	25
	10	50	71	74	0	23	53
	100	54	75	76	0	44	58

[z]Values are the means of 3 consecutive experiments.

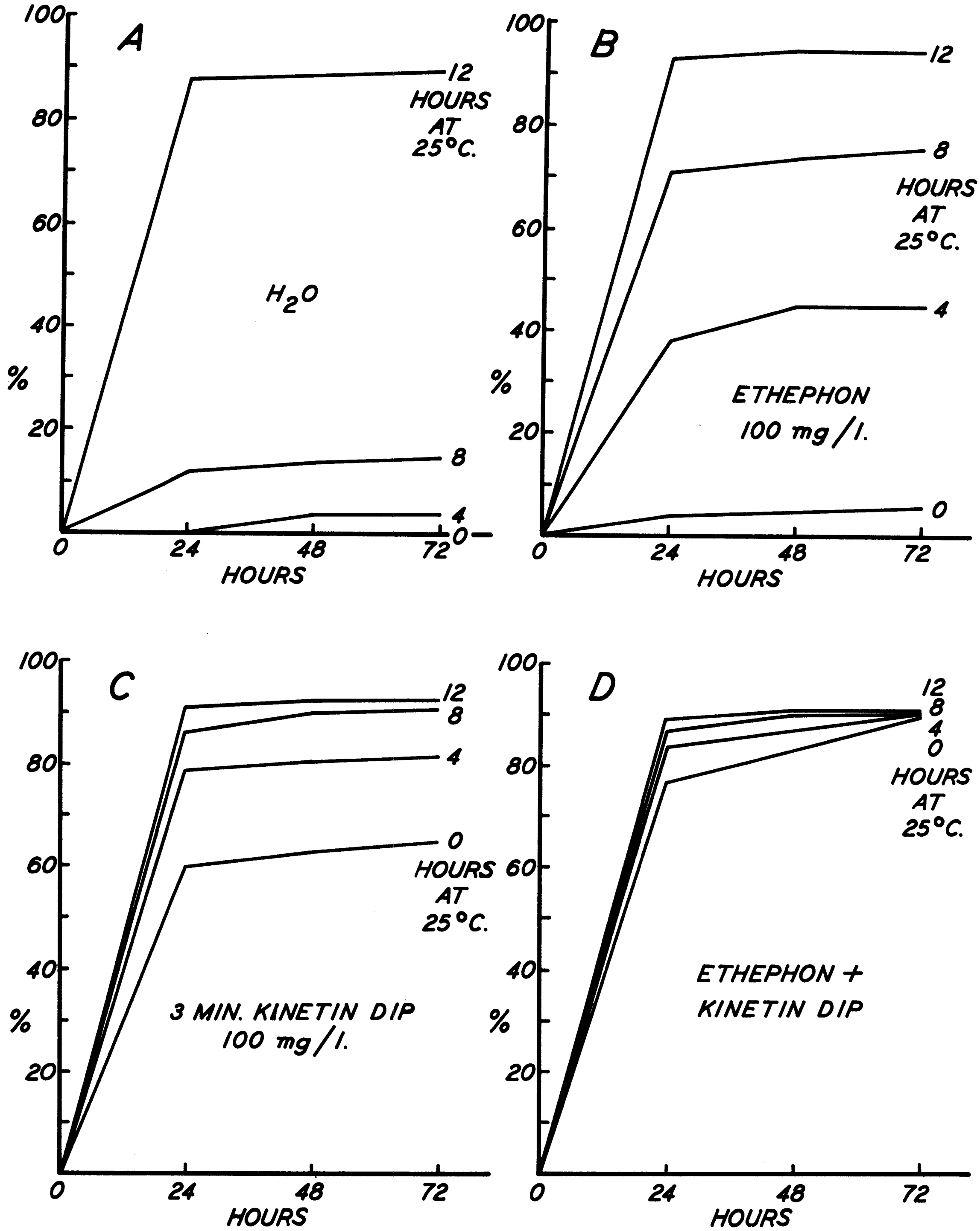

Fig. 1. Cumulative percent germination of 'GL 659' lettuce seed at 35°C in water (A), ethephon (B), kinetin (C) and a combination (D) after preincubating at 25°C for designated no. hr (right side of graphs). The coordinates of each point represent the mean of 3 consecutive tests.

or kinetin treated seeds were imbibed at 25°C in water or in 100 mg ethephon/liter for 0, 4, 8, or 12 hr before transferring to 35°C. Kinetin treated seeds were prepared by the 3 min dip procedure of Smith et al. (12). This kinetin treatment generally produced a response comparable to a 10 mg/liter solution in a Petri dish.

Figure 1 shows that preincubation of imbibing 'GL 659' seed lots for 12 hr at 25°C resulted in nearly complete germination when subsequently transferred to 35°C regardless of chemical treatment. Ethephon treatment (B) tended to reduce slightly the time requirement at 25°C and kinetin treatment (C) reduced it by approx 4 hr. The combination of ethephon and kinetin, however, very nearly eliminated the 25°C preincubation requirement (D). Similar results were obtained with 'Vanguard', but 'Calmar' could not be induced to germinate completely at elevated temp by any treatment.

The roles of ethylene and kinetin in seed germination are not known, but their demonstrated ability to interact synergistically and eliminate the 12 hr preincubation requirement at 25°C suggests they are associated in an early acting heat sensitive mechanism controlling germination. Some workers have suggested that cytokinin may act to end dormancy through stimulation of ethylene production (6). Negm et al. (7) have shown that CO_2 interaction with ethylene is necessary to break thermodormancy in lettuce and that ethylene action depends on CO_2 concn. They cited unpublished data indicating that continual removal of CO_2 from the surrounding atmosphere depressed the germination of kinetin treated seeds. Possibly cytokinin may be more closely associated with respirational function than with ethylene production.

Ethylene effects on seed germination have been studied previously using ethylene gas in closed systems. There have been no suggestions as to how ethylene might be utilized in a field application to improve seed performance under heat stress. Preplanting seed treatment appears not to hold much promise since ethylene action can occur only after a min imbibition period. Seeds soaked in ethephon solutions for up to 8 hr followed by drying or washing and drying did not show typical responses of seeds continuously bathed in ethephon solutions. Ethylene concn in close proximity to the seeds probably cannot be maintained at the optimum level for the required length of time by such procedures.

Dry ethephon preparations are available, are reasonably stable, and suggest the possibility of field application. One approach might be to incorporate ethephon directly into the soil surrounding kinetin treated seeds, but the cost probably would be prohibitive under conventional planting procedures. Another approach, under investigation, is the inclusion of dry ethephon in a vermiculite seed coating or tablet designed for precision mechanical planting.

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Prolonging the Life of Harvested 'McFarlin' Cranberries[1]

Azmi Y. Shawa[2]

Washington State University, Pullman

Abstract. Nutritional foliar sprays 0-10-0 + Mn 7% + Zn 14%, 0-17-0 + Mn 8% + Zn 7%, 0-40-0 + Zn 14%, and 10-12-0 + Zn 2% significantly reduced percentage breakdown in 2 consecutive years. N^6-benzyladenine (N6BA) was the only growth regulator which significantly suppressed respiratory rates. Succinic acid-2,2-dimethylhydrazide (SADH) and 10-12-0 + Zn 2% significantly increased berry size and weight.

A considerable part of the cranberry crop is held each year in common or refrigerated storage for the holidays. Cranberries can be held as fresh fruit for 2 to 3 months at 3°C, thereafter, the berries may shrivel as a result of water loss, discolor, lose their natural luster, and become soft and rubbery (1, 3, 4, 5, 7, 10). Fresh cranberries are seldom available in the market 2 months after harvest because of physiological or pathological breakdown and rot during storage (3, 5, 7). Fresh cranberries bring premium returns to growers and could be developed into an important market channel for the cranberry industry.

From an economic point of view, it would be desirable to find a method to reduce fruit breakdown during storage. Growth retardants and nutritional foliar sprays have been used to reduce fruit breakdown in storage (2, 3, 6, 8). If such an agent can be found, the fresh market season could be extended.

Previous work (3) showed that cold storage alone was not adequate for maintaining high quality cranberries in storage. It was concluded that most spoilage was due to physiological breakdown because of enzymatic activity. Pre-harvest application of certain chemicals slowed down respiration and retarded physiological softening. Bruised cranberries yielded polygalacturonase activity in the soft, but not the sound tissue (7). It was found that both fungal isolability and physiologic softening were associated with cranberry bruising and were independent storage-decay factors (5).

Maleic hydrazide (MH-30) and N^6-benzyladenine (N6BA) sprayed on 'McFarlin' cranberry vines 40 days past full-bloom reduced fruit breakdown significantly, while MH-30, N6BA, and dehydroacetic acid (DAA) suppressed respiration rates below the level of the control (3). Postharvest dip of DAA plus Tween-20 significantly reduced the spoilage of strawberries while N6BA increased the spoilage in strawberries but improved the flesh color of cherries (9).

Succinic acid-2,2-dimethylhydrazide (SADH) (11) applied to apple trees several days after full bloom largely prevented the

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[2]Coastal Washington Research and Extension Unit, Long Beach, Washington.

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