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***Full Length** Research Paper*

# Effects of different osmotic solutions on onion seed emergence

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**This experiment was aimed at the optimisation of emergence with onion seeds. For this reason, onion seeds (*Allium cepa* L.) short-days cultivars (Aki and Alix) and long-days cultivars (Banko and Suluova) were primed with different concentrations of polyethylene glycol (PEG $_{6000}$) in inorganic salts ($KNO_3$ and $KH_2PO_4$) for different periods of time (3 and 6 days or until 1% radicle emergence) at 15°C. After the treatments, the effects of priming on seedling emergence were evaluated at optimal (20°C) and suboptimal (11°C) temperatures, under field conditions. Priming in all $KNO_3$ and $KH_2PO_4$ reduced the days to emergence without significant loss in emergence ratio. In contrast, seed priming with PEG was ineffective. In field experiments, which were conducted in different periods (at two week intervals in February and March for spring and in September and October for autumn), the emergences of primed seeds were not earlier than those of untreated seeds, except 'Alix'. In this variety, seeds primed with $KNO_3$ and $KH_2PO_4$ emerged approximately four days earlier than the control seeds, regardless of the sowing date.**

**Key words:** *Allium cepa* L., polyethylene glycol, potassium salts, priming.

## INTRODUCTION

Onion (*Allium cepa* L.) is a very important economic crop used in different ways and is well known for 5,000 years (Brewster, 1994). Turkey has an important place among the onion producing countries with 2,050,000 tonnes bulb production in 93,200 ha production area (FAO, 2008) in which the Trakya region has an important role in production. In the region, in which the production is generally performed by sets, agricultural inputs and the propagation material (mainly the seeds) have shown rapid increase in cost at the end of the 1980's. Although direct seeding is more economic than by sets, irregularities and delays in germination result in poor plant establishment and yield, especially by the reason of high or low temperatures. In plant species with small seeds and poor seed establishment, perhaps the most promising method of increasing the rate and uniformity of seedling establishment is seed priming that permits the preliminary process of germination but not the final phase of radicle emergence (Heydecker and Coolbear, 1977; Heydecker and Gibbins, 1978). There are several chemicals that have been used for seed priming. Among these, potassium salts and polyethylene glycol (PEG) are the most widely used osmotica. In experiments with onions where only a single variety is used, osmotic potentials and treatment times have greatly differed (Peterson, 1976; Lippe and Skinner, 1979; Frutani et al., 1986; Haigh et al., 1986; Taylor et al., 1988; Bujalski et al., 1989; Suzuki et al., 1989; Ali et al., 1990; Gray et al., 1991; Arin, 1992; Duman, 2002). Heydecker and Coolbear (1977) and Bradford (1986) stated that treatment temperature, time and concentration are three important factors for success, and each must be determined for species, varieties and even for different seed lots. Concerning priming, Ok et al. (2000a) reported that the percentage of germination onion seeds was affected significantly by the seed treatment, priming duration and temperature. It was determined that the germination and vigor of onion seeds decreased as the

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**Table 1**. Some properties of soil mixture.

| N (ppm) | $P_2O_5$ (ppm) | $K_2O$ (ppm) | EC ($\mu S.cm^{-1}$) | pH |
|---|---|---|---|---|
| 100 to 300 | 100 to 300 | 150 to 400 | 350 | 4.4 to 5.9 |

**Table 2.** Soil properties of the experimental field.

| Salt (%) | pH | $CaCO_3$ (%) | $P_2O_5$ (kg $ha^{-1}$) | $K_2O$ (kg $ha^{-1}$) | Organic matter (%) | Texture |
|---|---|---|---|---|---|---|
| 0.066 | 7.4 | 2.60 | 51.4 | 583.0 | 1.67 | Clay-loam |

osmotic potential increased from -1.0 to -1.4 MPa and the imbibition period from 24 to 96 h by Trigo et al. (1999a). In this experiment, the seeds of some important onion varieties, which are widely grown in Trakya region, were treated in different osmotic solutions at different times and different temperatures in the growth chamber for emergence tests to improve seedling establishment.

## MATERIALS AND METHODS

Seeds of two short day ['Aki' (Tat seeds) and 'Alix' (Novartis)] and two long day ['Banko' (May seeds) and 'Suluova' (Agromar)] onion varieties were used for the experiments. Sterile glass containers (30×30×3 cm), with each having a sterile germination paper, were used for the treatments. Seeds were kept in osmotic conditioners containing $KNO_3$, $KH_2PO_4$ and polyethylene glycol (PEG $_{6000}$) with different concentrations (2% $KNO_3$, 4% $KNO_3$, 2% $KH_2PO_4$, 4% $KH_2PO_4$, 2% $KNO_3$+ $KH_2PO_4$, 4% $KNO_3$+ $KH_2PO_4$, -5 bar PEG $_{6000}$, -10 bar PEG $_{6000}$ and -15 bar PEG $_{6000}$) at 15°C for three different times (3 days, 6 days and until 1% radicle emergence). Treatment temperature, concentrations and treatment duration were referred to the results of different investigators (Wiebe and Tiessen, 1979; Furutani et al., 1986; Haigh et al., 1986; Bujalski et al., 1989; Suzuki et al., 1989; Gray et al., 1991; Arin, 1992). Osmotic solutions were replaced every day by new solution to minimize changes in viscosity and prevent toxicity. Time to 1% radicle emergence ranged between 7 and 14 days depending on the variety and concentration of solutions. After priming, the seeds were removed from glass containers and rinsed thoroughly in tap and distilled water in sieve, to remove solutions and dried until they reached their initial moisture content (Brocklehurst et al., 1984; Muhyaddin and Wiebe, 1989). Then, the seeds were treated with 80% thiram tetramethylhiuram disulphide (0.3 kg/100 kg seeds) to prevent fungal growth and stored hermetically in sealed polyethylene bags at 5±1°C during 8 months. Every 2 months, to evaluate the effects of priming on germination during the storage period, four replicates of 100 seeds each from each lot were tested for germination at 20°C (ISTA, 2003). Seeds from each treatment and unprimed seeds were tested for emergence at two different temperatures (20°C optimal and 11°C suboptimal) with four replications. Emergence tests, which were partly followed in growth chambers, were done in 72×19×4 cm plastic containers, having the soil mixture from Rito Seed Company-Antalya, Turkey. Properties of this compost are given in Table 1. Each container had equal amount of compost. The compost were thoroughly moistened and then weighed. The amount of vaporized water from the compost was added each day.

During the emergence tests, every container was checked each day and the number of seedlings emerged from the compost having vertical cotyledon were recorded and pulled out (Harrington, 1962; Bierhuizen and Wagenvoort, 1974). Ratio of emergence and days to emergence were calculated according to Alvarado and Bradford (1988) [Days to emergence = $\Sigma T_i X_i / \Sigma T_i$, where $X_i$ is the number of newly germinated seeds at time $T_i$]. For each variety, three suitable combinations were determined based on these results (solution and time). In deciding these combinations, special attention was given to the results of 20°C for autumn sown short day varieties ('Aki' and 'Alix') and the results of 11°C for spring sown long day varieties ('Banko' and 'Suluova'), because soil temperature in autumn are much higher than early spring.

Soil emergence tests were performed in field conditions. In autumn tests, the seeds of 'Aki' and 'Alix' were sown to the field by two-week intervals at September 5, September 19, October 3 and October 17, and for spring tests, the seeds of 'Banko' and 'Suluova' were sown at February 15, February 28, March 14 and March 29 by fortnight intervals. Meteorological and other ecological conditions were considered effectively in deciding these dates. The experimental layout was the split plot, while the experimental design was the time main plot. Seeds were sown by 25 cm distances between rows and 2 cm distances in rows. Soil properties are shown in Table 2, and air and soil temperatures are shown in Figure 1.

In both seasons, every parcel was visited three times in a week and the seedlings, with erect cotyledons, were recorded and the ratio of emergence (%) and days to emergence were calculated. Data dealing with the emergence ratio were transformed to arc sin before statistical analysis, but they were presented as real values in tables. The data were analysed by analysis of variance (ANOVA), while the means were separated by least significant difference test (LSD).

## RESULTS AND DISCUSSION

The variations in the germination percentage during the storage period were not statistically important for all varieties and treatments, that is, they were not significantly different from the starting value after 8 months of storage.

### Emergence at 20°C

According to the data obtained (Table 3), variety, time, osmotic solutions and interactions between variety and osmotic solutions affected the emergence ratio. 'Alix' has

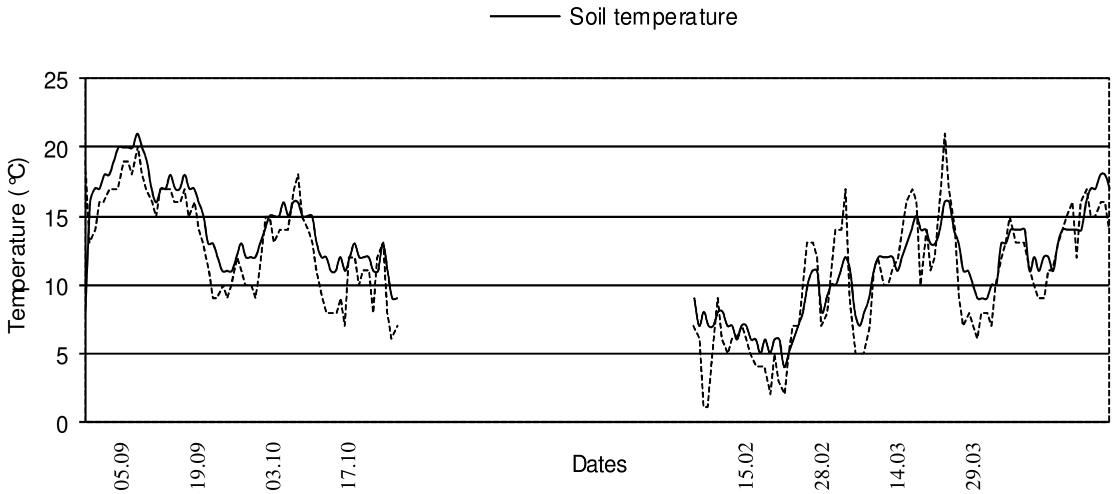


**Figure 1.** Mean air and soil temperatures at emergence period (5 cm).

**Table 3.** Emergence ratio at 20℃ (%).

| Osmotic solution | Variety | | | | Priming time | | | |
|---|---|---|---|---|---|---|---|---|
| | Aki | Alix | Banko | Suluova | 3 day | 6 day | 1% radicle | Main effect |
| 2% $KNO_3$ | 88.3 abcd | 79.6 cdef | 84.6 bcde | 82.5 bcde | 86.9 | 85.0 | 79.4 | 83.8 bcd |
| 4% $KNO_3$ | 84.2 bcde | 78.8 cdef | 81.7 bcde | 77.9 cdef | 81.6 | 79.4 | 80.9 | 80.6 cde |
| 2% $KH_2PO_4$ | 87.5 abcd | 82.1 bcde | 88.8 abcd | 83.3 bcde | 91.6 | 81.3 | 83.4 | 85.4 bc |
| 4% $KH_2PO_4$ | 81.7 bcde | 83.3 bcde | 83.8 bcde | 82.9 bcde | 85.0 | 83.4 | 80.3 | 82.9 bcd |
| 2%$KNO_3$+$KH_2PO_4$ | 80.0 cdef | 85.4 bcde | 90.8 abc | 87.9 abcd | 84.1 | 89.4 | 84.7 | 86.0 b |
| 4%$KNO_3$+$KH_2PO_4$ | 80.8 cdef | 77.9 cdef | 83.3 bcde | 80.0 cdef | 81.6 | 81.9 | 78.2 | 80.5 cde |
| -5 bar PEG $_{6000}$ | 79.6 cdef | 73.3 efg | 79.2 cdef | 75.8 def | 83.4 | 74.1 | 73.4 | 77.0 e |
| -10 bar PEG $_{6000}$ | 83.3 bcde | 67.9 fg | 84.6 bcde | 83.8 bcde | 86.9 | 75.3 | 77.5 | 79.9 de |
| -15 bar PEG $_{6000}$ | 84.2 bcde | 60.8 g | 80.0 cdef | 84.2 bcde | 82.2 | 77.8 | 71.9 | 77.3 e |
| Control | 88.8 abcd | 100.0a | 88.8 abcd | 95.0 ab | 93.1 | 93.1 | 93.1 | 93.1 a |
| Main effect | 83.8 a | 78.9 b | 84.5 a | 83.3 a | 85.6 a | 82.1 b | 80.3 b | |

shown less emergence ratio (78.9%) than other varieties. Priming for three days increased the emergence ratio (85.6%). However, unprimed seeds gave the higher ratio (93.1%) in comparison to other seeds primed in osmotic solutions; PEG $_{6000}$ being the lowest. On the other hand, concerning the variety × solution (including different concentrations) interaction, unprimed seeds of 'Alix' had 100% emergence, but -15 bar PEG $_{6000}$ primed seeds of same variety had 60.8% emergence, being the lowest.

Days to emergence were found to be statistically different, except the interactions of variety × time, variety × time × solutions and solution main effect (Table 4). As in the percentage of emergence, 'Alix' had the longest period for emergence in comparison to other varieties, but three days of priming resulted in the shortest period for emergence. Priming the seeds with PEG $_{6000}$ has resulted in the longest period for emergence compared to other solutions, and same results have been obtained with the different times and concentration of the same solution.

## Emergence at 11℃

Time and osmotic solution main effects were found to be important with respect to emergence ratio (Table 5). All solutions have resulted in a higher percentage than the unprimed seeds (except for PEG $_{6000}$ treatments and 4% $KNO_3$); meanwhile, the longer the time for treatment, the lower the percentage of emergence.

Concerning the days to emergence, variety and solution (including different concentrations) main effects and interactions of solutions × time has given different results, which were found to be statistically important.

**Table 4.** Days to emergence at 20°C (Days).

| Osmotic solution | Variety | | | | Priming time | | | |
|---|---|---|---|---|---|---|---|---|
| | Aki | Alix | Banko | Suluova | 3 day | 6 day | 1% radicle | Main effect |
| 2% $KNO_3$ | 9.9 h | 9.8 h | 9.8 h | 9.6 h | 10.0 cd | 9.5 cd | 9.8 cd | 9.8 |
| 4% $KNO_3$ | 10.2 h | 10.1 h | 10.2 h | 9.9 h | 10.0 cd | 10.0 cd | 10.3 c | 10.1 |
| 2% $KH_2PO_4$ | 9.4 h | 9.5 h | 9.6 h | 9.8 h | 9.8 cd | 9.6 cd | 9.3 d | 9.6 |
| 4% $KH_2PO_4$ | 9.6 h | 10.2 h | 9.9 h | 9.8 h | 10.1 cd | 9.7 cd | 9.7 cd | 9.8 |
| 2%$KNO_3$+$KH_2PO_4$ | 9.8 h | 10.1 h | 9.9 h | 9.8 h | 10.1 cd | 10.0 cd | 9.6 cd | 9.9 |
| 4%$KNO_3$+$KH_2PO_4$ | 9.8 h | 10.1 h | 9.9 h | 9.9 h | 10.1 cd | 10.2 cd | 9.4 cd | 9.9 |
| -5 bar PEG $_{6000}$ | 12.0 fg | 15.6 a | 13.1 cde | 12.4 efg | 12.4 b | 13.6 a | 13.8 a | 13.2 |
| -10 bar PEG $_{6000}$ | 12.5 defg | 15.1 a | 13.4 d | 12.1 efg | 12.1 b | 13.8 a | 14.0 a | 13.3 |
| -15 bar PEG $_{6000}$ | 13.0 cdef | 14.6 ab | 13.7 bc | 11.8 g | 11.8 b | 14.0 a | 14.0 a | 13.3 |
| Control | 9.7 h | 9.8 h | 9.9 h | 9.7 h | 9.8 cd | 9.8 cd | 9.8 cd | 9.8 |
| Main effect | 10.6 c | 11.5 a | 10.9 b | 10.5 c | 10.6 b | 11.0 a | 11.0 a | |

**Table 5.** Emergence ratio and days to emergence at 11°C (%).

| Osmotic solution | Emergence ratio | Days to emergence | | | Main effect |
|---|---|---|---|---|---|
| | | Priming time | | | |
| | | 3 days | 6 days | 1% radicle | |
| 2% $KNO_3$ | 87.8 a | 32.4 cdefg | 31.2 efghi | 29.9 i | 31.2 cd |
| 4% $KNO_3$ | 71.2 cd | 33.1 cdef | 31.1 efghi | 31.8 cdefghi | 32.0 bcd |
| 2% $KH_2PO_4$ | 88.0 a | 30.9 fgh | 29.8 i | 31.9 cdefghi | 30.9 cd |
| 4% $KH_2PO_4$ | 85.1 ab | 31.4 defghi | 31.1 efghi | 30.2 ghi | 30.9 cd |
| 2%$KNO_3$+$KH_2PO_4$ | 85.3 ab | 31.8 cdefghi | 30.3 ghi | 30.1 hi | 30.7 d |
| 4%$KNO_3$+$KH_2PO_4$ | 82.6 abc | 32.4 cdefghi | 32.5 cdefg | 31.6 cdefghi | 32.2 bc |
| -5 bar PEG $_{6000}$ | 72.8 d | 31.9 cdefghi | 33.7 abc | 33.4 bcde | 33.0 ab |
| -10 bar PEG $_{6000}$ | 72.2 d | 33.0 cdef | 33.4 bcde | 35.9 a | 34.1 a |
| -15 bar PEG $_{6000}$ | 76.2 bcd | 33.3 bcde | 33.7 abcd | 35.6 ab | 34.2 a |
| Control | 77.8 bcd | 32.0 cdefghi | 32.0 cdefghi | 32.0 cdefghi | 32.0 bcd |
| **Priming time** | | | **Variety** | | |
| 3 days | 82.8 a | | Aki | 30.4 d | |
| 6 days | 81.8 a | | Alix | 31.3 c | |
| 1% radicle | 77.2 b | | Banko | 32.6 b | |
| | | | Suluova | 34.3 a | |

'Suluova' has taken 34.3 days to emerge, while 'Aki' has taken 30.4 days to emerge. The longest days to emergence, which were more than 34 days, have been obtained from the PEG $_{6000}$ solutions with -10 and -15 bar potentials. Unprimed seed emerged in 32.0 days and the earliest emergence of seedlings was observed in 2% $KNO_3$+ $KH_2PO_4$ with 30.7 days.

## Field emergence

In field trials, emergence was affected by the sowing time and it showed difference in 'Aki' and 'Alix' varieties. Seeds, which were sown in autumn, tend to emerge at a high percentage, but the highest ratio was obtained from the seeds sown at October 17, which later tended to have higher sowing percentage. Same results were obtained for days to emergence and in both periods, more rapid emergence occurred at October 3 sowings in all the varieties (Table 6).

Osmotic solutions and interactions were ineffective for this trial in all the varieties except 'Alix' (Table 6). The seed primed with all solutions completed emergence earlier than unprimed seeds, which emerged at 23.3 days. Days to emergence in field reached 33.5 days for unprimed seeds with September 5$^{th}$ sown seeds.

**Table 6.** Effect of sowing date and osmotic solution on the days to emergence of 'Alix' in the field (Days).

| | Osmotic solution | | | | |
|---|---|---|---|---|---|
| **Sowing date** | **$B_1$*** | **$C_3$** | **$C_5$** | **Control** | **Main effect** |
| 05 September | 22.7 b | 21.9 b | 22.2 b | 33.5 a | 25.1 a |
| 19 September | 23.6 b | 21.4 bc | 20.5 bcd | 21.9 b | 21.9 a |
| 03 October | 15.1 de | 15.4 de | 13.3 e | 16.4 cde | 15.0 b |
| 17 October | 21.8 b | 22.8 b | 22.5 b | 21.3 bc | 22.1 a |
| Main effect | 20.8 ab | 20.4 b | 19.6 b | 23.3 a | |

* $B_1$: 6 days, 2% $KNO_3$; $C_3$: 1% radicle, 2% $KH_2PO_4$; $C_5$: 1% radicle, 2% $KNO_3$+$KH_2PO_4$.

However, the shortest period was obtained from the seeds, which were sown on October 3rd, primed in 2% $KNO_3$+ $KH_2PO_4$ solution until 1% radicle emergence.

The increase in duration results in a somewhat earlier emergence under controlled temperature emergence tests. PEG treatments showed no substantial benefit of priming to onion emergence. Emergence ratio and days to emergence at 20 and 11°C were negatively affected by PEG solutions. The seeds primed in PEG $_{6000}$ solutions have less and later emergence than unprimed seeds. According to the results of some previous research, aeration of treatment solution is important (Peterson, 1976), in that PEG treatment delays and lowers the ratio of germination (Furutani et al., 1986) and aeration increases the germination ratio (Bujalski et al., 1989). In all vegetable seeds in general, there is a benefit of low temperature (15°C) priming in various PEG polymers which enhances germination, whereas in onions, germination ratio decreases with PEG priming, although the time-spread of germination is same with untreated seeds (Gray et al., 1991). Same results of this present research led us to think about the aeration problem again, although the solutions were freshly prepared and changed every day. According to Mexal et al. (1975), $O_2$ exchange capacity of PEG is 90% lesser than water and in some seeds, lower $O_2$ levels promotes anaerobic respiration and probably results in ethanol levels to increase toxic concentrations (Mayer and Poljakoff-Mayber, 1982). Yuri (1988) has also mentioned the toxic effects of same PEG polymers. Duman (2002) stated that $KNO_3$ treatment with bubble-column improved germination and emergence rates faster than both PEG and Petri dishes treatments. Benefits in earlier emergence of seeds primed in different concentrations of potassium salts at 20°C are not enough when compared to unprimed seeds. Time to emergence has only been enhanced in seeds primed at 2% $KH_2PO_4$ (Table 4). At the suboptimal emergence temperature (11°C) tests done in all salt solutions, the ratio of emergence did not increase, but in PEG solutions, the ratio of emergence increased and the time to emergence decreased, except in 4% $KNO_3$+ $KH_2PO_4$ and 4%$KNO_3$. Experimental data similar to our results are those of, for example, Bradford (1986) who mentioned that the $KH_2PO_4$ solution hastened the seedling emergence, and Haigh et al. (1986) working with tomatoes, carrots and onions who found the benefits of priming with $KNO_3$+ $KH_2PO_4$ at 15°C by 14 days. Trigo et al. (2000) stated that onion seeds osmoconditioned in aerated $KNO_3$ exhibited a better performance compared to seeds in PEG $_{6000}$. Ok et al. (2000b) working with osmotic priming chemicals [including $KNO_3$, $KH_2PO_4$, $K_3PO_4$, NaOH, $Ca(NO_3)_2$ and PEG $_{8000}$ ] and their concentration to improve the germination of carrot, lettuce, onion and Welsh onion seeds, found that among the chemicals with no influence on percentage germination, 200 mM $KH_2PO_4$ significantly reduced both 50% of the final germination percentage and the mean number of days to germination. Also, Suzuki et al. (1989) indicated that the priming of some vegetable seeds, including onions in -10 bar $K_3PO_4$ solution, have given better results than Na and Mg salt solutions. Additional data about the different effects of mineral salts come from Haigh et al. (1986) who found the advantageous effects of K salts in comparison to other minerals, and $PO_4$ ion gives an additional extra benefit to these K salts because it is imbibed by the seed itself (Suzuki et al., 1989). Mauromicale and Cavallaro (1997) also pointed out that the embryo and endosperm $K^+$ content of tomato seeds primed in $KNO_3$ + $KH_2PO_4$ was increased by 65 and 33% of the control value, respectively, and by this reason, higher water absorption in seed primed with potassium salt was observed during osmopriming. On the other hand, priming at lower temperatures, has been proved to give more acceptable results than higher temperatures (Szafirowska et al., 1981; Pill and Finch-Savage, 1988).

In this experiment, all the varieties were affected from the sowing date. The emergence at a shortest period was obtained from the third sowing time for all varieties. However, in field emergence tests, priming shortened the time of emergence in only 'Alix' variety. Also, Trigo et al. (1999b) reported that under stress conditions, seed priming with $KNO_3$ improved radicle length and germination rate in only 'Petrolini' variety. This result can easily be explained by the additional factors affecting field emergence and different inherent characteristics of these varieties.

Ultimately, being an extraction from this experiment, onion seed priming in $KNO_3$ and $KH_2PO_4$ solutions for six days or until 1% radicle emergence, has benefits for seedling emergence at low temperatures. Since only the emergence of 'Alix' variety was promoted following priming with $KNO_3$ and $KH_2PO_4$ under field conditions, additional precise tests are required for varietal needs.

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