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POTASSIUM SULFATE IMPROVED EARLY GROWTH OF WHEAT UNDER CONTROLLED CONDITIONS

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ABSTRACT. Experiments were conducted to evaluate NPK fertilizer effects on early growth of wheat (*Triticum aestivum* variety Azar-2). Chemical fertilizers including urea (100, 200, 300, 400, 500 and 1000 mg.L^{-1}), triple superphosphate (10, 20, 30, 30 and 60 mg.L^{-1}) and potassium sulfate (100, 200, 300, 400 and 800 mg.L^{-1}) were used along with control in three replications. The used concentrations imitate possible status of the fertilizers in the soil solutions. The results showed that fertilizers did not alter seed germination percentage. However, there was a significant influence on seedling performance. Seedling growth under potassium sulfate applications was significantly enhanced, which was followed by triple superphosphate, but urea decreased the values. The root to shoot ratio was influenced by potassium sulfate and the ratio was decreased in all concentration. Triple superphosphate did not significant effects on seedling properties, while urea decreased seedling performance. It was concluded that the response of wheat to the fertilizers application was different and among the used materials potassium sulfate could be effective on seedling growth of wheat.

Key words: Fertilizers; Germination; Seedling growth; *Triticum aestivum* L.

INTRODUCTION

Triticum aestivum L. (*Poaceae*) is one of the first cultivated grains which has been mainly used as human food. According to FAO statistics (2014) the average production of the crop in Iran is about 13.5 million tons per year that produce 90% of the country requirements. In small grain crops, seed germination and early seedling growth are very vulnerable to environmental stresses. The success at these stages could enhance crop growth and development, so the plants survive under environmental stresses to better production (Aliloo *et al.*, 2014; Aliloo and Shokati, 2011). Beside environmental stresses, the inputs such as chemical products that frequently are used in agro-systems have a great potential to influence the germination processes. Main chemical inputs are fertilizers, insecticides and

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herbicides that could play as a stress source for seed germination. Nowadays, yield has been mostly increased by fertilizers (FAO, 2005). Fertilizers are superior tools to enhance productivity however, they have disadvantages such as eutrophication (Withers, 2014), increase soil acidity and impact on soil biology (Belay *et al.,* 2002). When fertilizers are used at sowing time or immediately before or after planting the chance will increase to impact on seed germination. Various tests have been reported conflicting effects of fertilizer on seed germination. For example, Bremner (1995) reported that application of urea in soil had an adverse effect on germination of wheat, rye and corn. They also stated that this effect is imposed indirectly by ammonia as a result of urease activity. While, Durrant and Mash (1989) found that potassium nitrate increased hypocotyl growth of sugarbeet seedling. Dürr and Mary (1998) also determined that absorption of mineral were different among species. According their findings, absorption of mineral (N) by sugarbeet started earlier than the wheat seedling which affect hypocotyl elongation. Another important issues at germination time and seedling growth is water potential of the seed bed (Windauer *et al.,* 2012). The decrease of water potential because of dissolved mineral could affect root protrusion and seedling growth. Bouaziz and Hicks (1990), however, reported that relationship between water potential and seed germination of wheat seed was not significant. There are contradictory reports about fertilizers effects on early growth of crop plants. Therefore, the aim of this study was to determine effects of NPK fertilizer on germination and seedling growth of wheat.

MATERIALS AND METHODS

This study was conducted at Agronomy Laboratory of University of Maragheh, Iran, in a completely randomized design (CRD), with four replications during year 2014. The used wheat was *Triticum aestivum* variety Azar-2. In order to disinfection, the seeds were surface sterilized with 1% sodium hypochlorite for 10 min, followed by washing with tap water for three minutes. Seeds were immediately surface dried by filter paper. Twenty five seeds were placed on two layers of filter paper then the following fertilizer solutions include: urea (100, 200, 300, 400, 500 and 1000 $mg.L^{-1}$), triple superphosphate (10, 20, 30, 30 and 60 $mg.L^{-1}$) and potassium sulfate (100, 200, 300, 400 and 800 $mg.L^{-1}$) were poured (10 ml) on the seed bed. The used concentrations imitate possible status of the fertilizers in the soil solutions. To prevent drying of seed beds, the rolled towel papers were put in plastic bags and were kept in the germinator maintained at 20˚C. After 10 days towel papers were removed and characteristics including germination percentage (GP%), normal seedling percentage (NS%), root length (RL), shoot length (SL), seedling length (SEL), root to shoot ratio (R/S), dry weight of root (WR), dry weight of shoot (WS) and seedling dry weight (WSE) were recorded. To calculate seedling vigor index (SV) we used the following formula:

SV = [(G/G0) × (SEL/SEL0)] ×100,
where G – percentage of germinated seeds in the treatment; G0 – percentage of germinated seeds in the control; SEL – average length (cm) of the seedling in the treatment; SEL0 – average length (cm) of the seedling in the control.

For the statistical analysis, the data of germination percentage was transformed to arcsine $\sqrt{x+0.5}$. Appropriate analysis of variance for experiment was conducted, using SAS software and orthogonal analysis was performed among treatments. Means of each trait were compared according to Duncan multiple range test at $p \leq 0.05$.

RESULTS AND DISCUSSION

Results of *Tabs. 1 and 2* revealed that the effects of chemical fertilizers were significant on traits, except for germination percentage and abnormal seedling percentages. The study revealed that the chemical fertilizers did not alter seed germination of wheat (*Table 1*). These findings are in consistence with Monaco *et al.* (2003), who studied the influence of N form and availability on germination and seedling development of two invasive annual grasses, cheatgrass (*Bromus tectorum*) and medusahead (*Taeniatherum caput-medusae*) and six perennial grasses, bluebunch wheatgrass (*Pseudoroegneria spicata*), crested wheatgrass (*Agropyron cristatum* × *A. desertorum*), Sand Hollow and Seaman's Gulch big squirreltail (*Elymus multisetus*), and Little Camas and Little Wood bottlebrush squirreltail (*E. elymoides* ssp. *brevifolius* and *E. elymoides* ssp. *elymoides*, respectively). They found that treatments did not alter germination percentage. The results of germination experiment also agreed with those of other studies on soil N effects, demonstrating modifications in soil N do not alter seed germination of many grass and broad leaf weed species (Riba *et al.*, 2002). They also suggested that the presence of N in seed bed environments only alters germination of dormant seeds. In our study, the dormancy was not observed and all of seeds in control treatments were germinated. Some experiments reported that ammonia toxicity as a result of urea volatilization could be effective on germination of rice (Xiaoli *et al.*, 2012). However, in our study the toxicity of the fertilizers at used concentrations on seed germination did not confirm this effect. Although, it is possible that at higher concentrations the inhibition effects inaugurate and seed germination percentage reduces severely. Again, there was also no difference between the fertilizers and control on abnormal seedlings perhaps supporting the safety of used concentrations. Under chemical stresses, usually the number of abnormal seedling in crop plants tend to be increase (Barro, 2003) and it`s rate depends on chemical concentrations and exposure duration. Hadžić (2005) reported inhibition in seedling growth of *Setaria glauca* when chemical fertilizers reached up to 1%.

Table 1 - Effects of NPK fertilizers on wheat germination and seedling growth

Treatment	GP%	NS%	SL (mm)	RL (mm)	SEL (mm)	R/S (mm)
Control	98.0	96	13.49 gh	16.70 abcd	30.19 def	1.28a
Potassium sulfate (K mg.L^{-1})						
100	100	97.5	24.74 a	19.62 a	44.37 a	0.81de
200	100	100	21.25 abc	18.06 abcd	39.31abc	0.86de
300	100	95	24.12 ab	18.32 abcd	42.45a	0.76e
400	100	100	19.53 cde	18.50 abcd	38.03abc	0.94cde
800	100	95	20.60 bcd	17.71 abcd	38.31abc	0.86de
Triple superphosphate (P mg.L^{-1})						
10	95.0	97.5	14.89 fg	16.35 abcde	31.25 def	1.11abcd
20	100	95	17.85 cdefg	17.40 abcd	35.25 bcd	0.97abcd
30	95	97.5	15.63 efg	15.10 cdef	30.73 def	0.96abcde
60	95	97.5	14.91 hi	15.29 bcdef	30.21 def	1.02abcde
Urea (N mg.L^{-1})						
100	93.3	100	10.63 ghi	9.516 h	20.15h	0.97abcde
200	96.6	89.6	12.98 i	14.32defg	27.30 h	1.10abcd
300	96.3	89.1	9.21h i	11.28 gh	20.50gh	1.23abc
400	96.6	100	10.56 hi	13.20 efgh	23.76efg	1.28a
500	100	100	12.76 ghi	15.68 abcde	28.45h	1.23abc
1000	100	97.5	9.08 i	11.55 fgh	20.64fg	1.27ab
Significance level (ANOVA)						
Treatment	ns	ns	**	**	**	**

Means with different letter have a statistically difference at p≤0.05; *, ** significant at 0.05 and 0.01, respectively; germination percentage (GP%), normal seedling percentage (NS%), shoot length (SL), root length (RL), seedling length (SEL) and root to shoot ratio (R/S).

Regarding to our findings, the fertilizers altered shoot growth of the plant (*Table 1*). Except urea, triple superphosphate and potassium sulfate improved shoot growth and high values was obtained by potassium sulfate concentrations. Orthogonal analysis revealed that effects of potassium sulfate on shoot growth were positively significant in comparison with control while urea decreased this trait remarkably. There was a contradictory result for fertilizer effects on root growth. Analysis of variance showed a significantly difference among treatments for this trait (*Table 1*), but except for urea concentrations that decreased root growth compared to control, the other treatments slightly increased the value and the best result was recorded by potassium sulfate. Nevertheless, the orthogonal analysis for root growth showed noticeably decreasing by urea in comparison with control (*Tabs. 3, 4 and 5*). Regarding to seedling length results potassium sulfate enhanced the value compared to control treatment, however, urea declined seedling growth (*Table 1*).

Table 2 - Effects of NPK fertilizers on wheat seedling growth and growth index

Treatment	WS (mg)	WR (mg)	WSE(mg)	SV
Control	85 cdef	61 abcd	146 bcd	0.96 def
Potassium sulfate (K mg.L^{-1})				
100	100 bcd	65 abcd	165 abcd	1.45 a
200	110 bc	50 cde	160 abcd	1.28 ab
300	155 a	63 abc	219 a	1.38 a
400	102 bcd	52 cde	154 abcd	1.24 abc
800	129 ab	62 abcde	191 ab	1.25 abc
Triple superphosphate (P mg.L^{-1})				
10	57 fg	50 cde	108 cd	0.97 def
20	78 defg	61 abcde	140 bcd	1.15 bcd
30	75 defg	43 e	118 cd	0.95 def
60	73 defg	51 cde	124 bcd	0.94 def
Urea (N mg.L^{-1})				
100	76 defg	54 bcde	130 bcd	0.61 h
200	67 defg	73 ab	149 abcd	0.86 efg
300	76 defg	48 de	124 abc	0.64 h
400	51 g	60 abcde	111 d	0.75 h
500	72 defg	75 a	148 abcd	0.93fgh
1000	91 cde	42 e	133 cd	0.67hg
Significance level (ANOVA)				
Treatment	**	**	**	**

Means with different letter have a statistically difference at p≤0.05; *, ** significant at 0.05 and 0.01, respectively; dry weight of shoot (WS), dry weight of root (WR) and seedling dry weight (WSE) were recorded. To calculate seedling vigor index (SV).

Table 3 - Means comparison of wheat seedling growth affected by potassium sulfate (orthogonal analysis)

Treatment	SL (cm)	RL (cm)	SEL (cm)	R/S	WS (mg)	WR (mg)	WSE (mg)	SV
Control	13.49 b	ns	30.19 b	1.28 a	85 b	ns	146 b	0.96 b
Potassium sulfate	22.05 a	ns	40.40 a	0.84 b	119 a	ns	177 a	1.32 a

Means with different letter have a statistically difference at p≤0.05.

Table 4 - Means comparison of wheat seedling growth affected by triple superphosphate (orthogonal analysis)

Means	SL (cm)	RL (cm)	SEL (cm)	R/S	WS (mg)	WR (mg)	WSE (mg)	SV
Control	ns	ns	ns	1.28 a	ns	ns	ns	ns
Triple superphosphate	ns	ns	ns	1.01 b	ns	ns	ns	ns

Means with different letter have a statistically difference at p≤0.05.

Table 5 - Means comparison of wheat seedling growth affected by urea (orthogonal analysis)

Means	SL (cm)	RL (cm)	SEL (cm)	R/S	WS (mg)	WR (mg)	WSE (mg)	SV
Control	13.49 a	16.70 a	30.19 a	ns	ns	ns	ns	0.96 a
Urea	10.87 b	12.59 b	23.46 b	ns	ns	ns	ns	0.74 b

Means with different letter have a statistically difference at $p \leq 0.05$.

Orthogonal analysis obviously confirmed the findings (*Tabs. 3, 4 and 5*). Root to shoot ratio was decreased by potassium sulfate treatments which had significantly differences with control treatment (*Tabs. 1 and 3*). There were similar results for root dry weights and seedling dry weights for potassium sulfate. All concentrations of potassium sulfate improved seedling dry weights. This increment was due to higher growth for seedling length which was recorded by potassium sulfate (*Tabs. 1, 2, 3, 4 and 5*) but urea and triple superphosphate decreased this value (*Table 2*). The toxicity of urea on young seedling of rice has been reported by Xiaoli *et al.* (2012), who found that urea reduced seed germination and root growth of seedling. Hydrolyzing of urea to ammonia by urease enzymes, could accumulate excess ammonia in seed bed (we used plastic bags to avoid drying) therefore induces ammonia toxicity. Our findings on triple superphosphate not agreed with other published results. Anatomical and biochemical analyses of *Arabidopsis thaliana* have shown that low-P-grown mature roots absence a typical apex. By contrast, the roots of high-P-grown plants have high auxin contents in meristematic cells with high mitotic activity (Liu *et al.*, 2006; Lopez-Bucio *et al.*, 2003). Regulation in root growth by P in our study was only seen at 20 mg.L^{-1} concentration of triple superphosphate. Regarding the change in shoot properties, the results revealed that allocation of reserves to shoot parts under K rich environments was promoted. Potassium sulfate fertilizer improved seedling vigor index, but urea decreased the value compared to the control. Lowest seedling vigor index was seen at higher concentration of urea.

CONCLUSION

In conclusion, we found different responses from wheat germination and seedling growth under fertilizer applications. Germination percentage was not affected by fertilizers, however, seedling growth were significantly increased by potassium sulfate fertilizer. Consequently, high seedling vigor index obtained by potassium sulfate treatments, followed by triple superphosphate at 20 mg.L^{-1} concentration. The experiment also proved the toxicity of urea on seedling growth, especially at high concentrations.

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