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Salicylic acid and oxalic acid stimulates wheat yield components grown under disease conditions

Abstract. *The Republic of Kazakhstan is a major wheat-producing and wheat-exporting country. Wheat is a grain which the most important source of food on earth. It contains 75-80% carbohydrates, 9-18% protein, fiber, many vitamins (especially B vitamins), calcium, iron, and many macro-and micro-nutrients. Fungal leaf diseases, such as leaf blotch caused by Septoria tritici and rust diseases caused by Puccinia graminis, Puccinia striiformis and Puccinia triticina are also a problem for spring wheat production. Despite the dry climate, the cultivation of susceptible varieties results in epidemics of leaf rust in one year out of four on average, affecting more than 1 million hectares, with estimated losses of up to 25-30 percent of yields. Salicylic acid and oxalic acids have the effects of promoting plant growth. We test whether they can positively impact wheat yield under disease conditions. Foliar seed application of Salicylic acid and oxalic acid on wheat cultivar leads to overall better performance of the plants and increases the yield significantly. Effect on wheat yield components of two substances (SA, and OA) in both ways such as seed treatment and foliar spray, believed to have growth-stimulating properties in plants. 0.2 mM OA and 0,5 mM SA+ 0,1 mM OA samples represented a good result in both seed treatment and foliar spray in all yield characteristics of Aray cultivars compaire to control. The results of this study will be useful to control fungal diseases of wheat.*

Keywords: *wheat, disease, rust, systemic resistance, salicylic acid, oxalic acid.*

Abbreviations: *Salicylic Acid – SA, oxalic acid – OA, systemic resistance – SR, induced systemic resistance – ISR.*

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Introduction

Wheat (*Triticum spp.*) is one of the most important staple foods of humankind. About 37 percent of the world's population relies on it as their main cereal; it accounts for some 20 percent of all food calories consumed by humans, and annual world wheat production has risen to over 600 million tonnes, more than one-third of total global cereal output [1]. Central Asia, including Kazakhstan, is a significant player in regional and global food security, producing most of the grain trade in the region, with total area sown to wheat in Kazakhstan representing over 85% of total cereal production [2]. One of the main reasons for the reduction in the yield of wheat in Kazakhstan is the disease of airborne infection. Dominant position, as a part of the pathogenic complex of wheat in Kazakhstan, is taken by rusts (yellow, stem, and leaf rust) [3-6].

Salicylic acid (SA) is a phenolic compound that is a derivative of benzoic acid commonly found in plants at low concentrations (below 1 mg kg^{-1} fresh weight [7]. However, in infected plants its concentration can increase 20-fold, activating the genes responsible for synthesizing defense-related proteins [8]. Both endogenous and exogenous SA induce local resistance, given its role as a signal molecule for the development of systemic acquired resistance [9]. Moreover, SA is an endogenous regulator of plant growth and development [10,11].

Oxalic acid (OA) is an organic acid widely distributed in plants, fungi, and animals, and plays different roles in different living organisms [12]. It is a virulence factor in several phytopathogenic fungi, including the model species *Sclerotinia sclerotium* [13]. In plants, it can play two distinct roles, depending on the concentration. While a high concentration of OA induces programmed cell death and contributes to the progression of fungi, a low concentration gives rise to plant resistance to fungi [14].

Recently, the oxalic acid application has received much attention about induced disease systemic resistance and its antioxidant capability [15-19].

The objective of this study was to investigate the impact of spraying salicylic acid, oxalic acid, individually or in combination on yield and yield components of wheat (*Triticum aestivum* L.) to improve growth, yield, and grain quality under disease stress.

Materials and methods

Growth Conditions, Treatments, and Experimental Design

Field experiments were carried out at the Kazakh research institute of agriculture and plant growing, Kazakhstan during the summer seasons of 2020 (43°13′09′N 76°41′17′E). The soil of the experimental site, located in the village of Almalybak, is represented by irrigated light-chestnut soils with a deep occurrence of groundwater (more than 10 meters), characteristic of the foothill plain of the Zailiyskiy Alatau.

A completely randomized design with different combinations of SA, OA, seed treatment, and foliar spray was conducted during the 2020 year in the field. While the SA levels were 0.25 and 0.5 mM, the OA levels were 0.1 and 0.2 mM, respectively. The treatment combinations were replicated 3 or 4 times.

In this study, grains of wheat variety (*Triticum aestivum* L.) were taken from the Kazakh research institute of agriculture and plant growing, Kazakhstan. The variety of Arai was harvested in July 2019. Wheat seeds were washed twice with sterile distilled water. Seed treatment: the seeds were soaked in acid solutions for 6 hours, soaked, and then germinated in the field; foliar spray: 11-day-old seedlings were sprayed with acid solutions and then germinated in the field. Plants were inaculated with Urediniospores of *Puccinia recondita f. sp. tritici, Puccinia striiformis f. sp. tritici,* and *Puccinia graminis f. sp. Tritici* that causes Leaf, stripe, respectively, after 25 days from sowing the seeds. The plant materials were treated with various concentrations of SA, and OA (Enbridge PharmTech, China). The seedlings were cut After 18 days to estimate the dry weight of shoots (g) and dry weight of roots (g). At harvest, samples of ten plants were taken randomly to estimate the following yield components: Plant height (cm), number of main spikelets (pcs), number of seeds in main spike (pcs), thousands kernel weight (TKW, g).

Results

We used wheat variety to investigate the effect of salicylic and oxalic acid on overall plant performance under disease conditions in the field. We tested whether different concentrations of acids show a basic difference under our experimental conditions and was observed the effect of SA and OA on productivity parameters such as number of the spike (g), number of seeds in the main spike (pcs), thousand kernel weight (TKW, g) dry weight of shoots (g) and dry weight of roots (g). We observed that the grain yield differed significantly in both seed treatment and foliar spray in all the yield parameters that were investigated (Table 1, 2).

Table 1

Basic yield characteristics of Aray cultivar under the growth in disease condition in seed treatment

Salicylic acid and oxalic acid (mM)	Number of the spike, pcs	Number of seeds in main spike, pcs	TKW, g	The dry weight of shoots, g	The dry weight of roots, g
Control	13	27.87	31.2	0.37	0.07
0.25 SA	12.7	23.85	31.5833	0.543	0.0983

0.5 SA	13.133	26.467	28.65	0.472	0.1017
0.1 OA	15.5667	31.03	36.3167	0.572	0.09
0.2 OA	15.3333	29.4	32.917	0.536	0.115
0.25 SA+ 0.1 OA	12.9	23.43	30.75	0.46	0.0873
0.25 SA+ 0.2 OA	11.9333	21,03	29.917	0.565	0.09
0.5 SA+ 0.2 OA	11.3667	22.833	29.083	0.587	0.088
0.5 SA+ 0.1 OA	15.1667	30.933	29.833	0.582	0.088

Table 2

Basic yield characteristics of Aray cultivars under the growth in disease condition in foliar spray

Salicylic acid and oxalic acid (mM)	Number of the spike, pcs	Number of seeds in main spike, pcs	TKW, g	The dry weight of shoots, g	The dry weight of roots, g
Control	13.267	22.367	28.25	0.346	0.067
0.25 SA	13.967	25.267	30.483	0.629	0.098
0.5 SA	13.067	22.667	31.87	0.5297	0.093
0.1 OA	12.133	18.6	24.367	0.585	0.093
0.2 OA	14.367	22.667	32.417	0.538	0.103
0.25 SA+ 0.1 OA	13	18.667	29.37	0.463	0.087
0.25 SA+ 0.2 OA	14.3	21.667	26.65	0.555	0.083
0.5 SA+ 0.2 OA	14.567	19.8	23.833	0.593	0.087
0.5 SA+ 0.1 OA	14.6	23.1	27.083	0.602	0.09

In our study, number of main spike showed the high level in 0.1 mM OA, 0.2 mM OA and 0.5 mM SA+ 0.1 mM OA with 15.6 pcs, 15.3 pcs and 15.2 pcs., respectively, in seed treatment (Table 1) while 0.2 mM OA, 0.25 mM SA+ 0.2 mM OA, 0.5 mM SA+ 0.2 mM OA, and 0.5 mM SA+ 0.1 mM OA with 14.4 pcs, 14.3 pcs, 14.7 pcs and 14.6 pcs, respectively, in foliar spray (Table 2). Number of seeds in main spike more in 0.1 mM OA, 0.2 mM OA and 0.5 mM SA+ 0.1 mM OA such as 31.0 pcs, 29.4 pcs and 30.9 pcs than control of seed treatment. The higher number of seeds observed in 0.25 mM SA and 0.5 mM SA+ 0.1 OA mM at 25.3 pcs and 23.1 pcs compare to control in foliar spray. TKW increased in 0.1 mM (36.3 g) and 0.2 mM OA (32.9 g) in seed treatment as well as in 0.25 mM SA (30.5 g), 0.5 mM SA (31.8 g), 0.2 mM OA (32.4 g) and 0.25 mM SA+ 0.1 mM OA (29.4 g) in foliar spray.

Discussion

Exogenous SA and OA application also showed different effects on plant development, including seed germination, budding, flowering, fruit setting, and ripening, imbibing maize seeds in ~0.3 mM to ~0.9 mM SA showed higher germination speed, percentage, and shoot length [20]. In this study, number of main spike showed the high level in 0.1 mM OA, 0.2 mM OA and 0.5 mM SA+ 0.1 mM OA with 15.6 pcs, 15.3 pcs and 15.2 pcs., respectively, in seed treatment (Table 1) while 0.2 mM OA, 0.25 mM SA+ 0.2 mM OA, 0.5 mM SA+ 0.2 mM OA, and 0.5 mM SA+ 0.1 mM OA with 14.4 pcs, 14.3 pcs, 14.7 pcs and 14.6 pcs, respectively, in foliar spray (Table 2). Research on salicylic acid, oxalic acid, and chitosan as plant protection products and growth stimulants has so far concerned various herbaceous crop plants [11.12.21]. The leaf number, fresh and dry mass per plant of wheat seedlings raised from the grains soaked in lower concentrations (10-5 mM) of salicylic acid, increased significantly [22]. A similar growth-promoting response was generated in barley seedlings sprayed with salicylic acid [23.24] observed a significant increase in growth characteristics, pigment contents, and photosynthetic rate in maize, sprayed with SA. In our study, the best result was obtained to the weight of shoots and roots with all various concentrations of SA and OA, though it was found to stimulate the growth of shoots and roots. The highest number of TKW was observed in 0.1 mM OA seed treatment.

Conclusion

We tested the effect on wheat yield components of two substances (SA, and OA) in both ways such as seed treatment and foliar spray, believed to have growth-stimulating properties in plants. 0.2 OA and 0.5 SA+ 0.1 OA samples represented good results in both seed treatment and foliar spray in all yield characteristics of Aray cultivars compaire to control. To be concluding, the effectiveness of SA and OA must be evaluated in further studies.

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Салицил және қымыздық қышқылдарының ауру жағдайында бидайдың өнімділігіне әсері

Аңдатпа. Қазақстан Республикасы-бидай өндіруші және бидай экспорттаушы ірі мемлекет. Бидай - ең маңызды азықтық дақыл. Оның құрамында 75-80% көмірсу, 9-18% ақуыз, талшық, көптеген дәрумендер (әсіресе В тобының дәрумендері), кальций, темір және көптеген макро және микроэлементтер бар. Жапырақтағы саңырауқұлақ аурулары, мысалы, Septoria tritici тудыратын жапырақтың дағы мен Puccinia graminis, Puccinia striiformis және Puccinia triticina туғызатын тат аурулары да жаздық бидайдың өнімін төмендететін себептер болып табылады. Климаттың құрғақ болуына қарамастан, сезімтал сорттарды өсіру нәтижесінде орташа есеппен төрт жылда бір рет тат эпидемиясы пайда болады, 1 миллион гектардан астам аумаққа әсер етеді және бидай өнімділігін 25-30% дейін төмендетеді. Салицил қышқылы мен қымыздық қышқылдары өсімдіктердің өсуін жақсартатаын әсері бар. Біз осы қышқылдардың ауру жағдайында өскен бидай өнімділігіне оң әсер барма деген сұрақ бойынша зерттеу жүргізді. Салицил қышқылы мен қымыздық қышқылдарын бидайдың жапырағы мен тұқымына қолдану өсімдіктердің жалпы өсіуін және өнімділігін едәуір арттырады. Бидай өнімділігі мен өсуін ынталандыратын қасиеттері бар деп есептелетін екі қышқыл (SA және OA) тұқымдық өңдеу мен жапыраққа бүрку арқылы қолданылды . 0,2 мм OA және 0,5 mM SA+ 0,1 mM OA үлгілері бақылау мен салыстырғанда Арай сорттарының барлық өнімділік сипаттамаларында тұқым өңдеуде де, жапырақты бүркуде де жақсы нәтиже көрсетті. Зерттеу нәтижелері бидайдың саңырауқұлақ ауруларымен күресуде пайдалы болады.

Түйін сөздер: бидай, ауру, тат, жүйелік төзімділік, салицил қышқылы, қымыздық қышқылы.

Қысқартулар: салицил қышқылы - SA, оксал қышқылы - OA, жүйелік қарсылық - SR, индукцияланған жүйелік қарсылық - ISR.

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Влияние салициловой и щавелевой кислот на урожай пшеницы в болезненных условиях

Аннотация. Республика Казахстан - крупный производитель и экспортер пшеницы. Пшеница - это зерно, которое является самым важным источником пищи на Земле. Он содержит 75-80% углеводов, 9-18% белков, клетчатку, множество витаминов (особенно витаминов группы B), кальций, железо и множество макро- и микроэлементов. Грибковые инфекции листьев, такие как пятнистость листьев, вызываемая Septoria tritici, и болезни ржавчины, вызываемые Puccinia graminis, Puccinia striiformis и Puccinia triticina, также представляют эту проблему. Независимо от засушливого климата, рост восприимчивых сортов приводит к эпидемиям листовой ржавчины в среднем через четыре года, поражая более 1 миллиона гектаров с предполагаемыми потерями в 25-30 процентов. Салициловая и сланцевая кислоты способствуют росту растений. Проверяем, могут ли они положительно повлиять на урожай пшеницы в условиях болезни. Внеурочная обработка семян салициловой кислотой и кислотами у сортов пшеницы приводит к повышению общей продуктивности растений и значительному увеличению урожайности. Компоненты двух веществ (SC и OA) влияют на урожай пшеницы в обоих направлениях, при обработке семян и опрыскивании листьев, которые, как считается, обладают свойствами стимулирования роста растений. Образцы 0,2 мМ ОА и 0,5 мМ СК + 0,1 мМ ОА показали хорошие результаты как при обработке семян, так и при опрыскивании листьев по всем характеристикам урожайности сорта Арай по сравнению с контрольными. Результаты этого исследования будут полезны для борьбы с грибковыми заболеваниями пшеницы.

Ключевые слова: пшеница, болезнь, ржавчина, системная устойчивость, салициловая кислота, сланцевая кислота.

Сокращения: салициловая кислота - SA, сланцевая кислота - OA, системная резистентность - SR, индуцированная системная резистентность - ISR.

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