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Research Article

Salicylic Acid as a Safe Alternative to Conventional Fungicides

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Abstract

This literature review aims to analyse the latest research in phytohormones (specifically salicylic acid (SA)) and their application for managing biotrophic pathogens as a safe and economical alternative to synthetic fungicides in an agricultural context. It was found that salicylic acid does induce significant protection from fungal pathogens, particularly when combined with Bacillus subtilis.

Keywords: Salicylic acid; Systemic acquired resistance; Pathogen

Introduction

This review synthesizes data provided by four recent studies into the effectiveness of salicylic acid in controlling pathogens in important crops. Three studies looked at the effects of exogenous applications of salicylic acid on seedlings. One study looked at the inoculation of wheat seed with no further applications after germination.

In all reviewed studies, it was maintained that salicylic acid does aid to reduce the effects of pathogenic stresses to some degree. Two studies compared this reduction against the protection of fungicides.

[6]

Review of Research Literature

Eliwa et al., in their paper *Efficacy of certain fungicide alternatives for controlling sugar beet powdery mildew* tested a number of fungicide alternatives for the control of Sugar beet Powdery mildew. Salicylic acid plus other chemical and plant extracts were compared with plots treated with Bellis®38% WG and a control plot [3].

In Table 1, results are shown for two cultivars, Sirona cv. and FD.0807L. Out of the fungicide alternatives, Salicylic acid is shown to give the best protection against Powdery mildew when applied at 300ppm with 56.7% and 70.6%. The fungicide provided protection of 89.5% and 90%. These outcomes are likely not enough to persuade farmers to switch from the fungicide when looking solely at crop protection.

It may be that the SA concentrations were too low to be a viable alternative and the application too late after germination.

Treatment	Conc. (ppm)	AUPMPC							
		Sirona cv.				FD.0807 L.			
		2014/2015	2015/2016	Mean	Protection (%)	2014/2015	2015/2016	Mean	Protection (%)
Ascorbic acid	100	700	664	682 ±1	2.2	1100	1077	1089 ±1	34.1
	200	648	638	643 ±1	7.8	1003	1013	1008 ±1	39
	300	572	558	565 ±1	19	885	880	882 ±1	46.6
Citric acid	100	604	562	583 ±1	16.4	940	946	943 ±1	42.9
	200	521	503	512 ±1	26.6	782	798	790 ±1	52.2
	300	470	471	470 ±1	32.6	707	718	713 ±1	56.8
Salicylic acid	100	537	516	527 ±1	24.4	813	820	816 ±1	50.6
	200	343	341	342 ±1	51	604	594	599 ±1	63.7
	300	309	295	302 ±1	56.7	485	486	485 ±1	70.6
Bellis® 38% WG		78	68	73 ±1	89.5	191	138	165 ±1	90
Control		721	675	698 ±1	0.0	1652	1653	1653 ±1	0.0
LSD at 0.05 %									
Treatment(T)		40	25.5			32.5	31.1		
Concentration(C)		6.2	15.4			16.6	18.3		
(T x C)		14	34.4			37.2	41		

Table 1: Mean of AUPMPC values to sugar beet (Sirona& FD.0807 cultivars) as affected by foliar spray with antioxidants under field conditions during 2014/2015 and 2015/2016 growing seasons [3].

Nehal S. El-Mougy et al. in their paper *Seed dressing and foliar spray with different fungicide alternative for controlling maize diseases under natural field conditions* studied the effects of Bio-agents, essential oils and chemical inducers (including Salicylic acid) on maize diseases Root rot, Leaf spot, Leaf gray blight, Late wilt and Ear rots. They compared them to the fungicide Rizolex-T 50 WT and a control group. Salicylic acid was foliar sprayed at a concentration of 2% three times onto seedlings at 15-day intervals from 30 days after sowing [5].

Table 2 shows the reduction in disease after application by different alternatives, including salicylic acid, compared to a fungicide. Salicylic acid is shown to provide significant reduction of Leaf spot (86.8%), Leaf gray blight (65.2%), Late wilt (75.1%), and Ear rots (63.6%). Comparatively, Chitosan has provided a strong response against all four diseases, with almost the same reduction as the fungicide Topsin-m 70%WT [5].

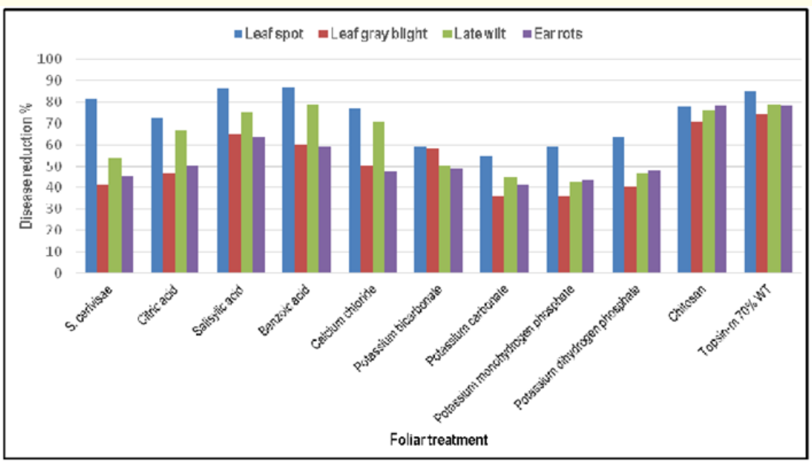

Table 2: Average reduction in Maize foliar diseases in response to plant spray with bioagents and chemical resistance inducers during two growing seasons under field conditions [5].

Table 3 below shows the suppressing effects against fungal infection. Salicylic acid provided high suppression against all four foliar diseases at 4.2, 10.0, 8.5 and 11.4%, proving to be almost on par with chitosan.

When looking at suppression and reduction together, salicylic acid has shown to give significant protection and a substantial reduction of disease after infection. The results show that the fungicide is not providing appreciable control after infection when there are safer alternatives. It would be beneficial to investigate the defence provided by salicylic acid combined with chitosan.

Treatment	Maize root and foliar diseases (%)			
	Leaf spot	Leaf gray blight	Late wilt	Ear rots
S. cerivisae	5.7±1.0 g	16.8±2.2 c	15.7±1.2 de	17.1±1.9 bc
Citric acid	8.5±1.2 e	15.4±2.2 cd	16.4±1.6 d	15.7±0.9 de
Salicylic acid	4.2±0.8 g	10.0±1.5 ef	8.5±1.3 f	11.4±0.9 e
Benzoic acid	4.1±1.0 g	11.5±1.0 e	6.9±1.1 g	12.3±1.0 e
Calcium chloride	7.1±1.0 f	14.4±1.9 d	17.0±0.5 bc	16.4±1.1 d
Potassium bicarbonate	12.8±1.4 c	12.0±1.5 e	17.1±1.0 bc	16.0±1.5 d
Potassium carbonate	14.2±2.0 b	18.5±1.0 b	18.8±1.3 b	18.5±1.5 b
Potassium monohydrogen phosphate	12.8±2.2 c	18.5±3.0 b	18.5±3.0 b	17.1±2.0 bc
Potassium dihydrogen phosphate	11.4±1.2 cd	17.1±2.0 c	17.1±2.0 bc	15.7±0.8 de
Chitosan	6.9±1.2 fg	8.4±0.8 g	7.6±1.0 g	8.4±1.1 f
Topsin M70%	4.6±1.3 g	7.4±7.4 g	6.8±0.2 g	6.6±1.1 g
Control	31.4±1.2 a	28.8±0.9 a	32.2±1.9 a	30.3±2.2 a

Table 3: Average efficacy yeast and chemical inducers as foliar spray against Maize diseases incidence during two growing seasons under field conditions [5].

George Bawa et al. in their paper *Pre-treatment of salicylic acid enhances resistance of soybean seedlings to Fusarium solani* makes the point that salicylic acid is induced by plants to provide defence mechanisms against biotrophic pathogens (feed off living cells) while plants utilize jasmotic acid to defend against necrotrophic pathogens (feed off dead or dying cells) [1].

In these trials, George Bawa et al. foliar treated three-day-old soybean 'Jiuyuehuang' seedlings with salicylic acid at 200µM every 6 hours for 24 hours. Inoculation of the seedlings with Fusarium solani took place 24 hours after treatment.

Disease development was monitored for three days after inoculation. Bawa, G. et al. observed that the stress indicators of MDA (malondialdehyde) and hydrogen peroxide (H_2O_2) was markedly lower in treated seedlings compared to the control group. It was observed that the treated seedlings showed an increase in the antioxidant activity of SOD (superoxide dismutase) and POD (peroxidase), working to neutralize ROS (reactive oxygen species) [1]. Under oxidative stress, increased ROS can damage lipids, proteins and DNA [2], further exposing the plant to pathogen attack.

This experiment has shown that seedlings treated with an exogenous application of salicylic before exposure to F. solani have fewer disease symptoms than the control (up to 70% greater resistance to F. solani).

This study only looked at the effects of SA application before infection and the plant's resistance to pathogen attack. No observation was made on the effects of SA being applied after plant infection.

In their paper *Application of Endophytic Bacillus subtilis and Salicylic Acid to Improve Wheat Growth and Tolerance under Combined Drought and Fusarium Root Rot Stresses* Oksana Lastochkina et al. examined the effect of drought stress and resistance to Fusarium culmorum on wheat and compared a control group with wheat pre-treated with Bacillus subtilis, salicylic acid and a combination of SA and B. subtilis.

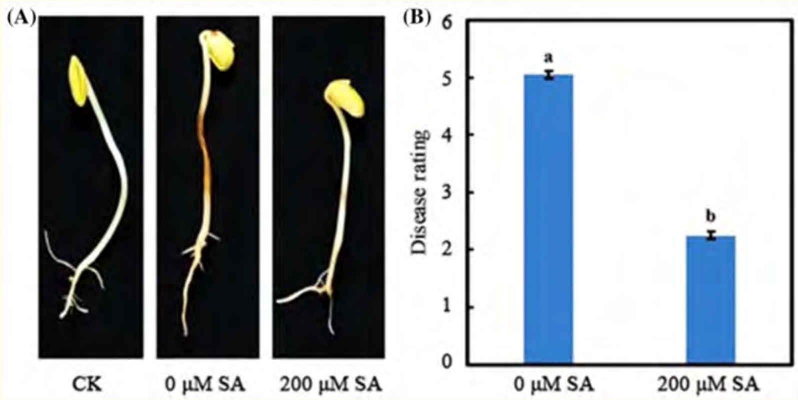

Table 4: Effect of 200 µM salicylic acid (SA) treatment and inoculation of F. solani on soybean seedlings. b Disease resistance in soybean seedlings against Fusarium solani infection at 3 days post-inoculation (dpi). Seedlings were sprayed with 200 µM SA for 24 h before fungal inoculation. Columns represent the mean disease rating on a 1-5 scale. Data bars are the mean ±SD of three replicates. Letters indicate significant differences (P<0.005) according to Duncan's multiple range tests [1].

Wheat seeds (*Triticum aestivum* L., Cv. Omskaya 35) were sterilized and washed. They were then either treated with just *B. subtilis*, just salicylic acid, or *B. subtilis* and SA combined by soaking the seeds in solution. Concentration of salicylic acid was 0.05mM. A control group was soaked in water. After three days the treated seedlings were transferred to a solution of 12% PEG 6000 to induce drought stress. Twenty-four hours later, the pathogen F. culmorum was introduced to all samples. Monitoring occurred at 2, 4, 6, 10 and 14 days after F. culmorum infection [4].

After 14 days the control group had *F. culmorum* incidence of 75%, the SA treated batch had 10% incidence, SA + *B. subtilis* had 0% incidence. The samples under simulated drought stress after 14 days had fusarium incidence of 90% in the control group, SA 20%, SA + *B. subtilis* 2%.

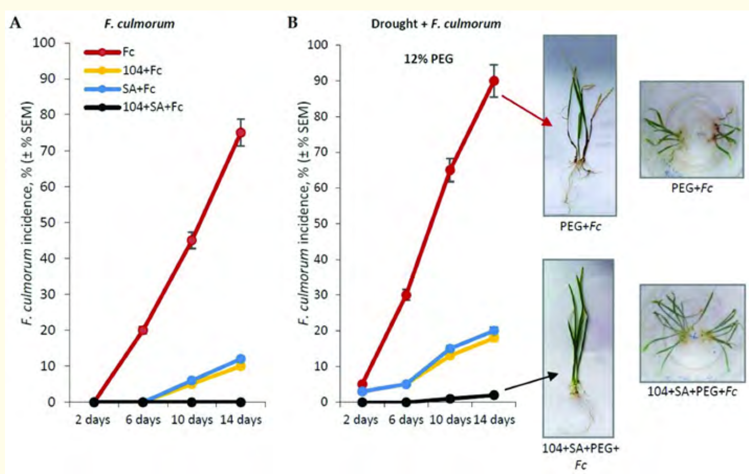

Table 5: The influence of endophytic bacteria B. subtilis 10–4 (104) (105 colony-forming units (CFU) mL−1), salicylic acid (SA) (0.05 mM), and composition of B. subtilis 10–4 + SA (104 + SA) on F. culmorum-instigated root rot (Fc) development in wheat plants under normal (A) and combined drought stress (12% PEG-6000) (PEG+Fc) conditions (B). The error bars show the average of three repetitions ± SEM (n = 50) [4].

It was observed, as shown in Table 5, that plants treated with SA, B. subtilis or both provide significant protection from F. culmorum, with the combined treatment having an absence of symptoms altogether. This indicates the contribution of exogenous SA to enhancing the antagonistic potential of strain 10-4 against F. culmorum – the causative agent of FRR [4].

It was also observed (as shown in Table 6 below) that treated wheat plants are provided with a strong buffer against drought stress, as shown by their lower stress indicators of MDA (malondialdehyde) when compared to the control.

The maximum positive effect on the wheat plants under drought conditions and Fusarium root rot stress was with the combination of B. subtilis and salicylic acid. Plant vigour and turgor were stronger when treated in combination than treated individually or not at all.

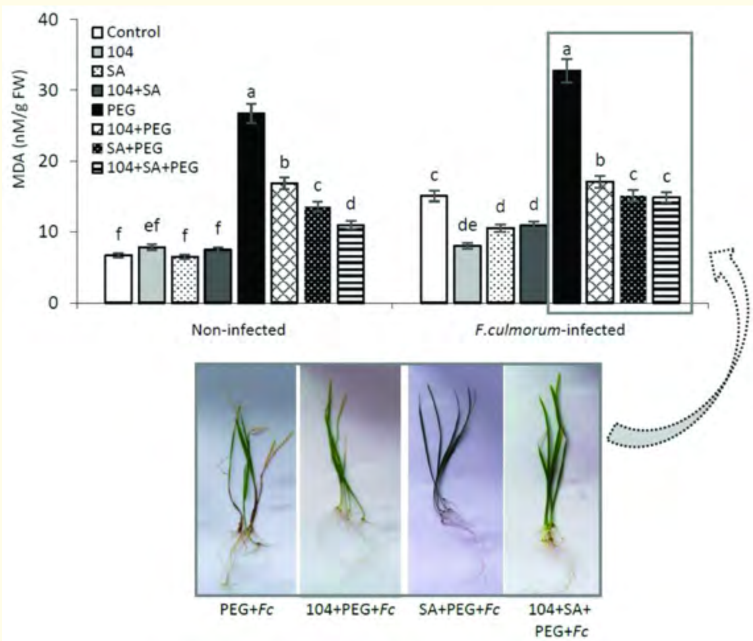

Table 6: Effect of B. subtilis 10–4 (104) (105 CFU mL−1), salicylic acid (SA) (0.05 mM), and composition of B. subtilis 10–4 + SA (104+SA) on the concentration of malondialdehyde (MDA) in non-infected by F. culmorum (non-infected) and infected by F. culmorum (F. culmorum-infected) wheat plants under normal and combined drought stress (PEG) conditions. Fourteen-day-old seedlings; drought stress (12% PEG) exposure time—11 days; time after infection with F. culmorum—10 days. Fc—F. culmorum. The error bars show the average of three replicates ± SEM. Different letters indicate a significant difference between the average values for $p < 0.05$ [4].

Summary

This review has shown that exogenous application of salicylic acid provides a strong defensive response to pathogenic attack - particularly against Fusarium species Oksana Lastochkina et al. observed the greatest response, which was achieved by seed coating with 0.05mM SA and the bacteria Bacillus subtilis prior to planting.

Both Nehal S. El-Mougy et al. and George Bawa et al. encountered strong resistance to pathogen attack as well as a decrease in pathogen biomass as a result of foliar spraying of SA.

Eliwa, M et al. tested the protection SA might induce on Sugar beet against Powdery mildew with unremarkable results. This may be due to concentration, timing or just that SA does not create a suitable defence mechanism against Powdery mildew.

It is recommended that further research be conducted on any negative affects these applications would have on crops - does the exogenous application of Salicylic acid lead to greater plant metabolism, depleting nutrients at a higher rate and are other messaging pathways compromised due to an increase in endogenous SA. It is also recommended that opportunities for bulk supply of material be investigated for commercial use.

References

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