

Role of the Elicitor Compound Methyl Salicylate in Enhancing Allelopathic Potential of Rice for Sustainable Weed Management.



Botany

KEYWORDS: MeSA, Allelopathy, Phytotoxicity

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ABSTRACT

Rice production suffers a major setback through weed pressure world wide. In the present study, exogenous application of elicitor compound methyl salicylate (MeSA), at different concentration, (0.1, 0.2, 0.3mM MeSA) was made as a foliar spray and its effect on allelopathic potential of rice genotypes was assessed.

The experiment was conducted in a split-plot design with the weedy and weed-free treatments in the main plot and three genotypes as the sub-plot treatment with the foliar application of MeSA.Methyl jasmonate (MeJA) and methyl salicylate (MeSA) are important signaling molecules that induce plant defense against insect herbivores and microbial pathogens. We tested the hypothesis that allelopathy is an inducible defense mechanism, and that the MeSA signaling pathways may activate allelochemicals release.

MeSA was found to improve the competitive ability of the genotypes by suppressing weed biomass through enhancements in phenolic acid content (viz. caffeic, o-coumaric and syringic acid) and also in plant growth without any detrimental effect on the host plant, showing that application of MeSA resulted in enhancement of phytotoxic potential of rice genotypes. Spraying of rice plants with 0.2 mM MeSA resulted in highest inhibition of weed dry weight in all the genotypes. Application of MeSA increased also increases Shoot dry matter, grain yield, as well as PAL activity. These results suggest that allelopathy may be an active defense mechanism, and that plant signaling compounds are potentially valuable in its regulation.

INTRODUCTION

About 90% of the world's rice is grown in Asia (Rabbani et al. 2011). Weeds are one of the major constraints to rice production in a range of agroecosystems including rainfed uplands and rainfed and irrigated lowlands (Balasubramanian et al. 2007). Yield losses due to weed competition range from 12-100% (Akobundu 1980, Becker and Johnson 2001a,b, Becker et al. 2003). The higher yield loss is mainly attributed to the limited availability of labor for hand weeding and the unavailability and/or limited effectiveness. Salicylic acid is a well-known inducer of plant systematically acquired resistance in plant-pathogen interactions, which results in resistance to pathogens and is characterized by the induction of defense-related gene expression and synthesis of phenylpropanoids, phytoalexins, and pathogenesis-related proteins (Metraux 2001; Durrant and Dong 2004; De Vos et al., 2005). Salicylic acid also induces the biosynthesis of secondary metabolites in plants (Taguchi et al., 2001). Secondary compounds can enhance the survival of a plant, allowing greater reproduction in stressful environments. It is still unclear, however, whether the release of allelochemicals into the environment is passive or active. It is hypothesized that allelopathy is an actively inducible defense mechanism, and that the JA and SA signalling pathways may activate chemical release (Bi et al., 2007). Authors suggested that application of MeSA induced release of allelopathic compounds which enhance the allelopathic activity of rice. Bi et al. (2007) reported that allelopathy in rice is induced by signaling molecules Methyl jasmonate (MeJA) and methyl salicylate (MeSA). Exogenous application of MeJA and MeSA to rice (*Oryza sativa* L.) enhanced rice allelopathic potential and led to accumulation of phenolics, an increase in enzymatic activities, and gene transcription of phenylalanine ammonia-lyase (PAL) and cinnamate 4-hydroxylase (C4H), two key enzymes in the phenyl propanoid pathway and showed increased inhibitory effects on root and shoot growth of barnyardgrass (*Echinochloa crus-galli* L.). 3,4- hydroxybenzoic acid, vanillic acid, coumaric acid, and ferulic acid that accumulated in the leaves were 5.3-, 31.3-, 2.2-, and 1.7-fold higher in response to MeJA exposure, and 3.3-, 13.1-, 2.0-, and 2.2-fold higher in response to MeSA. It has been suggested that the SA-mediated cascade of reaction in rice, to defend against barnyardgrass attack might be similar to the responses to nutrient deficiency through the regulation of car-

bon-nutrient balance (Bryant et al., 1987). This in turn results in the accumulation of phenolics and more phenolic allelochemicals being released into external environment (culture solution) from the roots to depress the target weed growth including the inhibition of protective enzyme activity and root uptake ability, which was consistent with the previous studies (Lin et al., 2000; Bi et al., 2007; Xiong et al., 2007b; Shen et al., 2008; Song et al., 2008).

MATERIALS AND METHODS

Experimental design:

After analyzing the data of first year performed with ten rice genotypes three cultivars namely UPR 2962-6-2-1, and Govind(Allelopathic)and UPR 2992-17-3-1(non allelopathic) were selected based on their competitive ability.A second experiment was carried out in the second year along with the main experiment to study the effect of MeSA on the competitive ability of rice genotypes. The experiment was laid down in a randomized block design (RBD) with complete randomization of treatments (0.1 mM MeSA, 0.2 mM MeSA, 0.3 mM MeSA and control). Spraying of MeSA was done three times at 5, 15 and 30 days after transplanting. Weeding was not done in this experiment during the period of study, at the Norman E. Borlaug Crop Research Centre, G.B. Pant University of Agriculture and Technology. Weed free conditions were maintained by hand weeding at regular intervals Observations Observations: Morphological parameters such as, biomass production at different time intervals and phenolic acid content determined by HPLC of three rice plants were recorded at different growth stages. Observations on weed flora and weed biomass were recorded at different growth stages. Competitive nature of the genotypes was estimated based on maximum production of phenolic acid content in Weedy genotype compared to weed free condition without compromising with yield reductions and % yield loss under weedy conditions.

Statistical analysis: The statistical analysis for all the parameters was done using analysis of variance for splitplot design with means being tested at $P > 0.05$ using an STPR software designed at the Department of Mathematics, Statistics and Computer Science, CBSH, G. B. Pant University of Agriculture and Technology, Pantnagar.

RESULTS

Estimation and Profiling of phenolic acids of three rice genotypes by High Performance Liquid Chromatography Phenolic acid content of three rice genotypes treated with different concentrations of MeSA (0.1, 0.2 and 0.3 mM MeSA) was determined and a large number of compounds were detected in shoot extract and were analyzed using RT of standard compounds as reference (table 4.39).

A number of phenolic compounds were identified in all the treatments (table 1), among which the MeSA treated plants produced a higher number of phenolic acids in all the genotype at both stages of growth analyzed in comparison to control. A maximum of 6 different phenolic acids (vanillic acid, p-coumaric acid, caffeic acid, o-coumaric acid, salicylic acid and gallic acid) were identified in UPR 2962-6-2-1 at 30 DAT in plants treated with 0.2 mM MeSA, whereas, at 45 DAT 6 compounds were identified in Govind in plants treated with 0.2 mM MeSA.

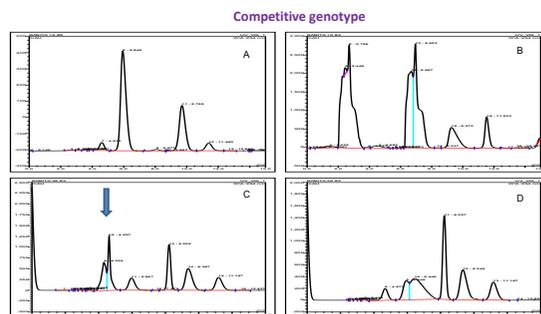
At 30 DAT vanillic, p-coumaric and caffeic acid were exclusively found in the MeSA treated plants, of which p-coumaric acid was found only in the genotype UPR 2962-6-2-1, while, caffeic and vanillic acids were found in both UPR 2962-6-2-1 and Govind, contributing towards their enhanced competitiveness on treatment with MeSA. Also the concentration of phenolic acids was found to be enhanced on treatment with MeSA (table 4.43). In the genotype UPR 2962-6-2-1, treatment of plants with 0.1 and 0.2 mM MeSA resulted in elimination of syringic acid, whereas treatment with 0.3 mM MeSA resulted in production of similar concentration of syringic acid to that of control. Vanillic and p-coumaric acid were produced only in MeSA treated plants and their concentration was fairly higher in 0.2 mM treated plants (viz. 792.8 and 799.0 mM respectively) in comparison to other treatments, protocatechuic acid was totally eliminated by MeSA treatment, and the concentration of gallic acid was found to be highest in the plants treated with 0.1 mM MeSA and it was absent in the control and 0.3 mM treated plants. In Govind syringic acid, 8-hydroxyquinoline and o-coumaric acid were absent in control. The concentration of syringic acid and 8-hydroxyquinoline was highest in 0.2 mM MeSA treatment and that of o-coumaric acid was highest in 0.1 mM MeSA treatment. And in UPR 2992-17-3-1, syringic acid was found only in 0.2 mM and 0.3 mM MeSA treatment, while, caffeic acid was found exclusively in 0.2 mM MeSA treatment and o-coumaric acid occurred exclusively in 0.1 mM MeSA treatment.

At 45 DAT, vanillic acid, p-hydroxy benzoic acid and gallic acid were found only in MeSA treated plants of which, p-hydroxy benzoic acid was found exclusively in the genotype UPR 2962-6-2-1, while, vanillic and gallic acid were found in both UPR 2992-17-3-1 and Govind. In the genotype UPR 2962-6-2-1 vanillic acid and gallic acid were exclusively found in 0.1 mM MeSA treatment while, these were absent in the others. P-hydroxybenzoic acid was found only in MeSA treated plants with its concentration maximum in the 0.1 mM treated plants (409.1 mM), in 0.2 and 0.3 mM treated plants concentration of p-hydroxybenzoic acid was similar, caffeic acid was found in all the treatments with its concentration maximum in 0.1 mM treated plants. In the genotype Govind syringic acid, vanillic acid, p-coumaric acid, caffeic acid, protocatechuic acid and gallic acid were found only in the MeSA treated plants, out of which syringic (49.1 mM) and protocatechuic acid (88.2 mM) were only found in 0.1 mM MeSA treated plants, while, caffeic (263.7 mM) and gallic acid (570.8 mM) were only found in 0.2 mM treated plants and vanillic acid (30.4 mM) was only found in plants treated with 0.3 mM MeSA. And in the genotype UPR 2992-17-3-1, syringic, caffeic and protocatechuic acid were absent in the control, the concentration of syringic and caffeic acid was highest in the plants treated with 0.2 mM MeSA (768.4 mM and 307.5 mM respective-

ly) while, concentration of protocatechuic acid was almost similar in plants treated with both 0.1 and 0.2 mM MeSA.

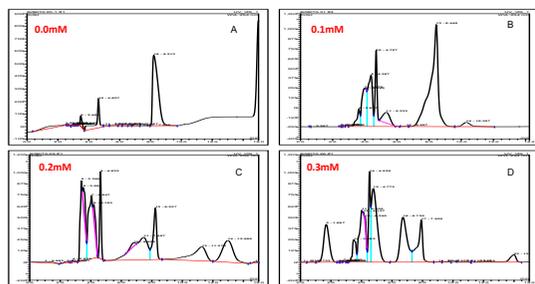
Table 1: Phenolic content in rice shoots under differential application of elicitor compound (MeSA).

Genotypes	Phenolic compounds	Phenolic content (mM)			
		30 DAT			
		Control	0.1 mM	0.2 mM	0.3 mM
UPR 2962-6-2-1	Syringic acid	595.5	x	x	559.7
	Vanillic acid	x	151.5	792.8	366.4
	p-coumaric acid	x	42.4	799.0	X
	Caffeic acid	x	x	411.9	633.3
	Protocatechuic acid	342.6	x	x	X
	o-coumeric acid	106.6	457.9	255.3	55.7
	Salicylic acid	448.2	1028.7	1309.4	669.7
	Gallic acid	x	814.7	66.1	x
Govind	Syringic acid	x	x	321.4	93.3
	8-HQ	x	73.0	146.0	88.2
	o-coumeric acid	x	64.6	31.6	x
	Salicylic acid	11.7	1468.0	1357.5	1609.6
	Gallic acid	743.6	695.4	821.8	152.2
UPR 2992-17-3-1	Syringic acid	x	x	179.6	287.1
	Caffeic acid	x	x	32.7	x
	8-HQ	43.4	38.6	105.4	210.8
	o-coumeric acid	x	17.7	x	x
	Salicylic acid	263.5	719.7	791.3	452.6
UPR 2962-6-2-1	45 DAT				
	Syringic acid	207.9	x	x	x
	Vanillic acid	x	133.2	x	x
	PHB	x	409.1	270.1	280.2
	Caffeic acid	35.0	408.5	223.1	225.9
	8-HQ	12.4	x	169.5	60.6
	Protocatechuic acid	318.6	x	158.3	163.5
	Salicylic acid	x	x	764.6	674.9
Gallic acid	x	426.2	x	x	
Govind	Syringic acid	x	49.1	x	x
	Vanillic acid	x	x	x	30.4
	p-coumaric acid	x	x	383.1	131.5
	Caffeic acid	x	x	263.7	x
	8-HQ	38.6	129.5	86.8	258.3
	Protocatechuic acid	x	88.2	x	x
	o-coumeric acid	17.3	74.3	71.9	99.9
	Salicylic acid	718.9	763.1	472.8	531.4
	Gallic acid	x	x	570.8	x
UPR 2992-17-3-1	Syringic acid	x	560.0	768.4	299.6
	p-coumaric acid	39.5	x	77.3	x
	Caffeic acid	x	x	307.5	x
	Protocatechuic acid	x	341.2	340.0	x
	o-coumaric acid	99.3	106.6	102.4	141.9
	Salicylic acid	755.1	448.1	X	711.7



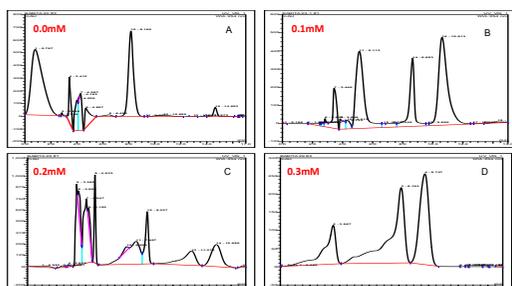
Chromatograms of phenolics analyzed by HPLC in the genotypes UPR 2962-6-2-1 at 0.0 mM (A), 0.1 mM (B), 0.2 mM (C) and 0.3 mM (D) MeSA treatment at 45 DAT.

Competitive genotype



Chromatograms of phenolics analyzed by HPLC in the genotypes Govind at 0.0 mM (A), 0.1 mM (B), 0.2 mM (C) and 0.3 mM (D) MeSA treatment at 45 DAT.

Non Competitive genotype



Chromatograms of phenolics analyzed by HPLC in the genotypes UPR 2992-17-3-1 at 0.0 mM (A), 0.1 mM (B), 0.2 mM (C) and 0.3 mM (D) MeSA treatment at 45 DAT.

the rice genotypes

Table 2: Effect of MeSA on weed population (No./m²) at 30 DAT in three genotypes of rice.

Concentration/ Doses of MeSA	Weed population (No./m ²)								
	<i>Alternanthera sessilis</i>	<i>Caeculia oxillaris</i>	<i>Echinochloa crus-galli</i>	<i>Echinochloa colona</i>	<i>Ammania spp.</i>	<i>Cyperus rotundus</i>	<i>Cyperus iria</i>	Total	
UPR 2992-17-3-1	0.0 mM MeSA	16.5 (2.8)	5.5 (1.8)	8 (2.1)	4 (1.5)	x	6 (1.9)	28 (3.4)	68
	0.1 mM MeSA	19 (2.9)	4.5 (1.7)	14 (2.7)	6 (1.9)	6 (1.9)	x	x	50
	0.2 mM MeSA	8.5 (2.2)	1.5 (0.8)	3 (1.4)	3 (1.3)	x	5 (1.8)	20 (3.0)	41
	0.3 mM MeSA	8.5 (2.1)	11 (2.5)	5 (1.7)	4 (1.6)	x	4 (1.6)	20.5 (3.0)	53
UPR 2962-6-2-1	0.0 mM MeSA	15.5 (2.8)	8 (2.2)	9.5 (2.3)	7.5 (2.1)	x	3.5 (1.5)	16 (2.8)	60
	0.1 mM MeSA	12 (2.5)	x	x	6 (1.8)	5 (1.7)	x	7 (2.1)	30
	0.2 mM MeSA	4 (1.5)	1.5 (0.9)	2 (1.0)	4 (1.6)	x	x	7 (2.0)	19
	0.3 mM MeSA	14 (2.7)	1.5 (0.9)	3 (1.3)	4.5 (1.7)	x	3 (1.3)	12 (2.6)	38
Govind	0.0 mM MeSA	6 (1.9)	3 (1.4)	2 (1.1)	2 (1.1)	x	3 (1.3)	13 (2.6)	29
	0.1 mM MeSA	4 (1.5)	2 (1.1)	x	4 (1.6)	x	2 (1.1)	9 (2.2)	21
	0.2 mM MeSA	3 (1.4)	1 (0.6)	2 (1.1)	3 (1.4)	x	x	4 (1.6)	13
	0.3 mM MeSA	4 (1.6)	3 (1.3)	4 (1.6)	3 (1.4)	3 (1.4)	x	7 (2.1)	24

(Values in parenthesis represent log $\sqrt{x+1}$ transformed values)

Weed flora and weed biomass

Weed dry weight and weed population count are the most important parameters which indicate the competitive ability of the rice genotypes. Weed population of three rice genotypes as affected by different doses of MeSA, at different stages of growth (30, 45 DAT) is presented in table 2 through 3.

All the treatments were able to reduce the weed population significantly in comparison to control. Amongst the treatments, spraying of the plants with 0.2 mM MeSA resulted in maximum reduction in the weed population. It resulted in a reduction of (68, 55, 35%), at 30DAT, (61, 58, 57%) at 45DAT.

Genotypes followed an order UPR 2962-6-2-1> Govind> UPR 2992-17-3-1 in context of reduction of weed population in response to the application of MeSA.

Thus, 0.2 mM MeSA results in about (3.2, 2.2, 1.7 fold at 30 DAT), (2.7, 3.3, 3.1 fold at 45 DAT), (2.6, 2.3, 2.4 fold at 60 DAT) increase in inhibition rate of paddy weeds, compared to control, in UPR-2962-6-2-1, Govind and UPR-2992-17-3-1 respectively.

This was in accordance with Fang et al. (2009) where, the inhibitory rates (IRs) was enhanced with the increase of SA concentration and reached a peak at 0.2 mM with 59.81, 46.76, and 65.28% suppression of root length (RL), shoot height (SH), and dry weight (DW) of barnyardgrass. However, the IR was decreased when the concentration of SA was increased to 0.3 mM.

From the data obtained it was clear that the treatment of rice plants with MeSA resulted in enhancing the competitive ability of all the three rice genotypes under study. Therefore, the reduction in weed dry weight and weed population count of weeds growing in the rice field, upon application of MeSA, directly justifies the role of MeSA in enhancing the competitive ability of

Table 3: Effect of MeSA on weed population (No./m²) at 45 DAT in three genotypes of rice.

Concentration/ Doses of MeSA	Weed population (No./m ²)								
	<i>Alternanthera sessilis</i>	<i>Echinochloa crus-galli</i>	<i>Ammania spp.</i>	<i>Cyperus rotundus</i>	<i>Cyperus iria</i>	Hukuva	<i>Eclipta alba</i>	Total	
UPR 2992-17-3-1	0.0 mM MeSA	6.5 (2.0)	x	x	4.5 (1.7)	18 (2.9)	x	1.5 (0.9)	31
	0.1 mM MeSA	6 (1.9)	6.5 (2.0)	x	x	3 (1.3)	1.5 (0.9)	0.5 (0.4)	18
	0.2 mM MeSA	3 (1.4)	1 (0.6)	x	x	4 (1.5)	x	2 (1.1)	10
	0.3 mM MeSA	2.5 (1.2)	2 (1.1)	1.5 (0.9)	x	9 (2.2)	1 (0.6)	x	16
UPR 2962-6-2-1	0.0 mM MeSA	5 (1.7)	9 (2.2)	x	x	8 (2.1)	1.5 (0.9)	x	24
	0.1 mM MeSA	0.5 (0.4)	2.5 (1.2)	x	2.5 (1.2)	9 (2.3)	x	1 (0.6)	16
	0.2 mM MeSA	3.5 (1.5)	1 (0.6)	2 (1.1)	x	1 (0.6)	1 (0.6)	x	9
	0.3 mM MeSA	7 (2.1)	5.5 (1.8)	x	1 (0.7)	7 (2.0)	0.5 (0.4)	x	21
Govind	0.0 mM MeSA	1 (0.6)	3.5 (1.5)	5 (1.7)	x	20 (3.0)	x	x	30
	0.1 mM MeSA	2 (1.1)	3 (1.4)	4 (1.6)	x	6 (1.8)	3 (1.4)	x	18
	0.2 mM MeSA	5 (1.7)	x	0.5 (0.4)	x	3 (1.4)	0.5 (0.4)	x	9
	0.3 mM MeSA	3 (1.3)	4 (1.2)	2.5 (1.2)	1 (0.6)	11 (2.5)	0.5 (0.4)	x	22

(Values in parenthesis represent log $\sqrt{x+1}$ transformed values)

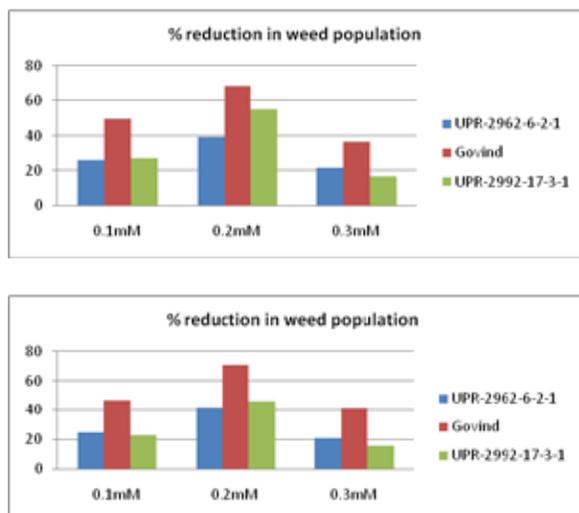


Fig 3.1: Per cent reduction in weed population at 30(A), 45(B), days after transplanting (DAT) in three rice genotypes, under different concentration of MeSA, in the rainy season 2010.

Phenylalanine ammonia-lyase activity

Phenylalanine ammonia-lyase (PAL) that catalyzes the first step in the biosynthesis of phenylpropanoids, contributes to increased accumulation of phenolic acids, and ultimately to enhanced allelopathic potential.

The Phenylalanine ammonia-lyase activity of three rice genotypes as affected by different doses of MeSA, at different stages of growth (15, 30, 45, 60 and 75 DAT) is presented in table 4.

Amongst the genotypes, PAL activity increased from 15 DAT to 60 DAT and declined thereafter. Maximum PAL activity was recorded in the genotypes Govind (58.6 units), followed by UPR 2962-6-2-1 (53.0 units) and UPR 2992-17-3-1 (43.6 units) at 60 DAT. The trend was (Govind > UPR 2962-6-2-1 > UPR 2992-17-3-1) similar in all the growth stages for PAL activity.

The activities of PAL in the leaves treated with MeSA (0.1, 0.2, 0.3 mM MeSA) significantly increased compared with the control. In comparison to the control, PAL activity in the plants treated with 0.1 mM MeSA increased by 14% at 15 DAT, 15% at 30 DAT, 16% at 45 DAT, 12% at 60 DAT and 11% at 75 DAT, while an increase of 31% at 15 DAT, 31% at 30 DAT, 30% at 45 DAT, 28% at 60 DAT and 20% at 75 DAT was recorded in the plants treated with 0.2 mM MeSA, and an increase of 18% at 15 DAT, 14% at 30 DAT, 15% at 45 DAT, 11% at 60 DAT and 10% at harvest was recorded in the plants treated with 0.3 mM MeSA. The treatments followed an order 0.2 > 0.1 > 0.3 mM MeSA, with PAL activity peaking at 0.2 mM MeSA treatment.

Table 4: Effect of methyl salicylate on Phenylalanine ammonia lyase (µg/g FW) activity of three rice genotypes.

		Rice Genotypes			
DAT	Treatments	UPR-2962-6-2-1	Govind	UPR-2992-17-3-1	Mean
15	Control	19.1	21.5	16.3	19.0
	0.1 mM MeSA	22.5	25.3	18.6	22.2
	0.2 mM MeSA	26.6	32.0	24.7	27.8
	0.3 mM MeSA	22.9	26.0	21.1	23.3
	Mean	22.8	26.2	20.2	23.1
	CD (p < 0.05)	0.83			
SEm ±		0.28			

30	Control	29.8	32.8	24.4	29.0
	0.1 mM MeSA	36.2	38.4	28.7	34.4
	0.2 mM MeSA	44.1	48.4	34.9	42.5
	0.3 mM MeSA	35.8	36.7	29.4	34.0
	Mean	36.5	39.1	29.4	35.0
	CD (p < 0.05)	0.96			
SEm ±		0.32			
45	Control	32.1	34.9	26.0	31.0
	0.1 mM MeSA	38.3	40.3	32.8	37.1
	0.2 mM MeSA	46.2	50.9	36.9	44.7
	0.3 mM MeSA	38.3	39.9	32.3	36.8
	Mean	38.8	41.5	32.0	37.4
	CD (p < 0.05)	0.47			
SEm ±		0.16			

Biological yield

Application of MeSA resulted in an increase in the biological yield of rice plants. An increase of 9.0% was observed in the plants treated with 0.1 mM MeSA, while an increase of 28.9% was observed in the plants treated with 0.2 mM MeSA and an increase of 15.3% was observed in the plants treated with 0.3 mM MeSA. Biological yield was found to be significantly increased due to the application of 0.2 mM MeSA as compared to control and other doses of MeSA.

Amongst the genotypes, per cent increase in biological yield was highest (42.6%) in UPR 2992-17-3-1, followed by UPR 2962-6-2-1 (26.9%) and Govind (20.4%) amongst the genotypes in 0.2 mM MeSA.

Table 5: Effect of methyl salicylate on biological yield and harvest index of three rice genotypes.

		Rice Genotypes			
Treatments	UPR-2962-6-2-1	Govind	UPR-2992-17-3-1	Mean	
Biological yield(kg/ha)					
Control	13744	21111	11212	15356	
0.1 mM MeSA	14106	23819	13021	16982	
0.2 mM MeSA	18808	26528	19531	21622	
0.3 mM MeSA	16638	22917	14829	18128	
Mean	15824	23594	14648	18022	
CD (p < 0.05)		2920.2			
SEm ±		995.7			
Harvest index(%)					
Control	47.1	46.6	43.6	45.8	
0.1 mM MeSA	50.0	46.2	45.6	47.3	

0.2 mM MeSA	49.1	48.4	46.1	47.8
0.3 mM MeSA	47.8	42.7	45.5	45.3
Mean	48.5	46.0	45.2	46.6
CD (p< 0.05)	1.38			
SEm ±	1.85			

1.2 Grain yield

Application of MeSA resulted in an increase in the grain yield of rice plants (fig 5.1). An increase of 12% was observed in the plants treated with 0.1 mM MeSA, while an increase of 31% was observed in the plants treated with 0.2 mM MeSA and an increase of 13% was observed in the plants treated with 0.3 mM MeSA. Grain yield was found to be significantly increased due to the application of 0.2 mM MeSA as compared to control and other doses of MeSA.

Amongst the genotypes, per cent increase in grain yield was highest (46.2%) in UPR 2992-17-3-1, followed by UPR 2962-6-2-1 (29.0%) and Govind (23.2%) amongst the genotypes in 0.2 mM MeSA.

Results obtained in the present investigation and their comparison with the earlier observations has made it clear that application of MeSA to rice have increased the competitive ability without compromising with yield.

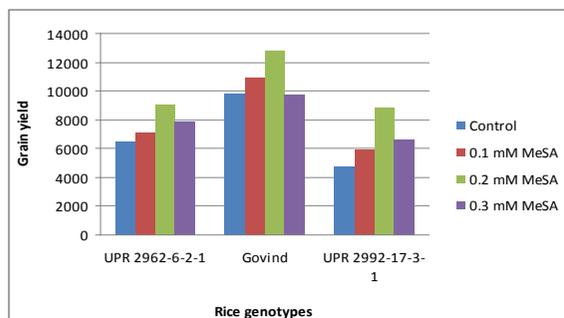


Figure 5.1: Effect of methyl salicylate on grain yield of three rice genotypes.

Shoot dry matter accumulation

The above ground biomass of three rice genotypes, as affected by different doses of MeSA, at different stages of growth (viz. 15, 30, 45, DAT) is presented in the table 6. Treatment with different concentrations of MeSA has resulted in a significant increase in the shoot dry matter at all the growth stages amongst all the genotypes.

Maximum promotory effect by the application of 0.2 mM MeSA, was seen during initial days i.e. 30, 45 DAT, which resulted in a 27.3%, 22.4% and 25.3% increase in dry matter in the genotypes UPR 2962-6-2-1, Govind and UPR 2992-17-3-1, respectively at 30 DAT and an increase of 20.3%, 29.3% and 22.9% in the genotypes UPR 2962-6-2-1, Govind and UPR 2992-17-3-1, respectively at 45 DAT. However, a slightly lower tendency to promote the increase in shoot dry weight was found when the concentration of MeSA applied was 0.3 mM and 0.1 mM, it showed only about 9%, 16%, 15%, 10% and 10% increase in dry matter at 15, 30, 45, 60 and 75 DAT respectively.

Amongst the genotypes, UPR 2962-6-2-1 responded well with the application of different concentrations of MeSA, followed by Govind and UPR 2992-17-3-1. However, maximum shoot dry matter

was recorded for UPR 2962-6-2-1 (37.2 g/plant), followed by Govind (36.4 g/plant) and UPR 2992-17-3-1 (36.1 g/plant). The genotypes followed an order UPR 2962-6-2-1> Govind = UPR 2992-17-3-1 in production of dry matter and the treatments followed an order 0.2 mM MeSA> 0.1 mM MeSA = 0.3.

Table 6: Effect of methyl salicylate on shoot dry matter (g plant-1) of three rice genotypes.

		Rice Genotypes			
DAT	Treatments	UPR-2962-6-2-1	Govind	UPR-2992-17-3-1	Mean
15	Control	6.0	5.5	5.4	5.6
	0.1 mM MeSA	7.0	5.9	6.1	6.3
	0.2 mM MeSA	7.3	6.7	6.6	6.9
	0.3 mM MeSA	6.9	6.0	5.8	6.2
	Mean	6.8	6.0	6.0	6.3
	CD (p< 0.05)	0.32			
SEm ±		0.10			
30	Control	13.3	12.1	12.4	12.6
	0.1 mM MeSA	16.2	14.1	14.3	14.9
	0.2 mM MeSA	18.3	15.6	16.6	16.8
	0.3 mM MeSA	16.3	13.8	14.8	15.0
	Mean	16.0	13.9	14.5	14.8
	CD (p< 0.05)	0.65			
SEm ±		0.22			
45	Control	23.1	18.6	19.5	20.4
	0.1 mM MeSA	26.3	24.9	22.0	24.4
	0.2 mM MeSA	29.0	26.3	25.3	26.9
	0.3 mM MeSA	26.2	24.0	21.8	24.0
	Mean	26.2	23.4	22.2	23.9
	CD (p< 0.05)	2.02			
SEm ±		0.69			

Discussion

In the present study, exogenous application of elicitor compound methyl salicylate (MeSA), at different concentration, (0.1, 0.2, 0.3mM MeSA) was made as a foliar spray and its effect on allelopathic potential of rice genotypes was assessed.

The signaling compound methyl salicylate (MeSA) has been reported to result in higher accumulation of phenolics acids, enhancing their phytotoxic affects against weeds.

In the present investigation, both a higher number as well as a higher concentration of phenolic acids were found in the genotypes UPR-2962-6-2-1 and govind (6 compounds each) after treatment with MeSA. Treatment of rice plants with MeSA resulted in production of some unique phenolic compounds in the rice genotypes under study. For example p-coumaric acid was found only in UPR 2962-6-2-1 and caffeic acid and vanillic acid were found in both UPR 2962-6-2-1 and Govind at 30 DAT. In the genotype UPR 2962-6-2-1 the concentration of vanillic and p-coumaric acid was higher in 0.2 mM MeSA treated plants. Similarly, in Govind, treatment with 0.2 mM MeSA resulted in enhancement of syringic acid and 8-HQ and in UPR 2992-17-3-1

treatment with 0.2 mM MeSA resulted in enhancement of concentration of caffeic acid and 8-HQ, although no unique compounds were found in this genotype.

In the present investigation, among different concentrations of MeSA used, maximum phenolic acid production was found in 0.2 mM MeSA treatment compared to 0.1 and 0.3 mM MeSA treatments, in all the genotypes, the results obtained are in congruence to Fang et al. 2009 who also reported that treatment of plants with MeSA resulted in increasing their competitive ability.

weed dry weight was found to be markedly reduced upon application of MeSA in comparison to control. Inhibitory rates of upto 36% was observed for the genotype UPR 2962-6-2-1. In other genotypes also higher inhibitory rates of 34% and 22% were observed upon treatment with 0.2 mM MeSA, suggesting the potential role of MeSA in increasing the competitive character of rice genotypes.

PAL activity was found to be 20-30% enhanced in comparison to control which is almost twofold greater compared to 0.1 and 0.3 mM MeSA treatments in all the genotypes. This is in accordance with Fang et al. (2009), where phenylalanine ammonia-lyase activities in the leaves treated with MeSA or MeJA was increased by 56 and 32%, respectively, compared with the control.

Increasing phenolic content and enzymes activities without compromising the yield of the crop plants is necessary for increasing the competitiveness of the genotypes. In the present investigation, biological yield was increased by around 28% and grain yield by around 31% in plants treated with 0.2 mM MeSA. The application of elicitor compound MeSA has resulted in an increase in phenolic content of the rice genotypes and has substantially reduced the weed pressure, and has also enhanced the yield of the genotypes.

Accumulation of more biomass at early stages is an important parameter for selection of weed competitive rice cultivars (Saito et al. 2010). In the present study shoot dry matter was found to be 20-25% higher in 0.2 mM MeSA treatment in all the genotypes at all the growth stages and shoot dry matter at higher dose of MeSA i.e. 0.3 mM was at par with control, this is in accordance with (Farouk et al. 2008) who reported that SA at higher concentration (400 mg L⁻¹) recorded the lowest values of yield and its components compared to their corresponding controls. Thus judicious application of appropriate dose of MeSA (in this study it was 0.2 mM) parameters related to yield and competitiveness can be enhanced without compromising the yield.

Conclusion

Spraying of rice plants with different concentrations of MeSA resulted in an overall enhancement in the growth potential of the rice plants. An increase in grain yield was observed, which could have resulted due to improvement in growth of the crop or due to enhancement in the allelopathic potential of the crop plants. Thus, use of elicitor compounds in appropriate concentration can be suggested to enhance the allelopathic potential of the crop and to increase its yield.

Amplifying the production of allelochemicals used for weed suppression would make allelopathic plants more plausible for use in typical agricultural systems. "If the trend of increasing dependence on heavy use of chemicals for weed control is to be reversed, more alternative strategies against weeds have to be developed. The possibility of application of elicitor compound into improved cultivars would enhance the competitive ability of the crops, and thereby reduce or delay the need for applying herbicides"

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