Research Article

Plant Defence Related Enzymes in Rice (Oryzae sativa L.,) Induced by Pseudomonas sp VSMKU2

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Abstract

In recent days, antibiotic producing fluorescent pseudomonads (FPs) has been used as a bioorganic tool for the control of sheath blight disease of rice. Combined application of antagonistic microorganism showed that significant bio control activity and enhances plant growth by induced systemic resistance (ISR). The present study, we carryout morphological, physiological and biochemical analysis and then identified, the selected isolate VSMKU2 is Pseudomonas sp. Maximum level of phenylalanine ammonia lyase (PAL) was quantified in the treatment of Pseudomonas sp VSMKU2 + R. solani on the 7th day (97.50 nmol trans-cinnamic acid/min/g). Similarly, the cell free culture filtrate of VSMKU2 challenged with R. solani demonstrated lower level of PAL activity on 7th day (91.76 nmol trans-cinnamic acid/min/g) compared to control. Peroxidase (PO) and polyphenoloxidase (PPO) gave higher activity in Pseudomonas sp VsMKU2 challenged with R. solani on 7th day (0.94 and 0.95 unit/min/g of protein respectively) but 14th and 21st day after challenged inoculation of R. solani had been reduced (0.92, 0.75 and 0.82, 0.65 unit/min/g of protein) compared to control. The total phenol content activity was significantly increased with Pseudomonas sp VSMKU2 (148.27 µg catechol/mg/g of protein) and cell free culture filtrate of VSMKU2 (137 µg catechol/mg/g of protein) treated in rice seedlings on 7th day after challenged inoculation of R. solani compared to control. The results obtained in the current study imply to Pseudomonas sp VSMKU2 was able to rise defence response, thereby contribute resistance to sheath blight disease.

Keywords: Pseudomonas sp VSMKU2, R. solani, Rice seedlings, defence related enzymes.

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INTRODUCTION

Sheath blight of rice (ShB) is a critical disease caused by *Rhizoctonia solani*. Rice yield was condensed up to 69% in tropical Asian countries like India and China. For management of ShB of rice using chemical fungicides cause severe threat to the environment and public health. Earlier days, chemical fungicides are used for control of soil borne fungal pathogens, but these chemical fungicides persist in the agriculture ecosystem and cause toxicity to beneficial microbes and develop resistance to the plant pathogens. Hence, we need to find out alternative approach for control of plant disease through bio control methods without causing any environmental problems and health hazards. In recent days, biological control is one of the best choices and extensively documented as both safe and consistent clarification for sustainable agriculture. Bio control method is ecofriendly approach to minimize the risk of possible resistance under selection pressure. Recent findings reported many microorganism considered as potential biocontrol agents such as *Pseudomonas aeruginosa* MML2212, *Burkholderia*, *Ceratobasidium*, *Bacillus pumilus* MTCC7615 and *Streptomyces aurantiogriseus* VSMGT10143,5-8. Among different beneficial microbial population, fluorescent pseudomonads have drawn much attention worldwide, since, it has plant growth promotion efficiency and major biocontrol potential for fungal pathogens. Moreover it does not cause any environmental problems and health hazards. Fluorescent pseudomonads (FPs) are reported to be a major associated bacteria, FPs demonstrates has the ability to produce IAA, ACC deaminase, siderophore, hydrogen cyanide and lytic enzymes. Previous report showed that FPs strains facilitate to raise seed germination, plant growth and yield 11. *Pseudomonas* spp are activates systemically in the plant system through induced systemic resistance (ISR). Recent report demonstrated that, plant growth promoting rhizobacteria (PGPR) activating defence genes encoding chitinase, POX, PPO and PAL in plants 12. *P. fluorescens* is providing plant growth promotion against plant diseases such as sheath blight, sheath rot, blast of rice, bacterial blight of cotton, ground nut, *Pythium* disease of tomato and hot pepper 13-16. The ISR induced by *Pseudomonas* sp was established in bean, carnation, rice, cucumber and raddish 13,17-20. Previous reports showed, the seed treatment with soil application of *P. fluorescens* DABBV4 enhanced seed germination and vigour index. Further, wilt disease was considerably reduced by *P. fluorescens* treated seeds challenge with *R. solanacearum*. The objectives of the current study deal with the identification of selected isolate VSMKU2. To carry out green house experiment for sheath blight of rice with treatment of VSMKU2 and their cell free culture filtrate against *R. solani*. After 1-3 weeks of *R. solani* inoculation, we examine PAL, PO, PPO activity and total phenol content.

MATERIALS AND METHODS

Antagonistic and Pathogenic culture collection and maintenance

The culture collection and maintenance of selected antagonistic isolate VSMKU2 and pathogen *R. solani* were obtained from our lab culture collection in the Department of Microbial Technology, School of Biological Sciences, Madurai Kamaraj University, which was isolated from rice rhizosphere. Sheath blight disease causing *R. solani* was used in this study. The selected antagonistic isolate VSMKU2 and *R. solani* were kept at 4°C in King’s B and Potato Dextrose Agar (PDA) for regular research work. For long time storage, the isolate VSMKU2 was stored in 40% glycerol at -80°C.

Morphology and Biochemical analysis

The selected isolate VSMKU2 was identified by colony morphology, cells shape, including gram staining and pigmentation. The pyocyanin pigment was observed on King’s B medium. Isolate VSMKU2 was observed as rod shape under light microscope by staining with Grams reaction. Biochemical analysis was performed by Bergey’s Manual of Determinative Bacteriology 21.

Green house experiment

The greenhouse experiments were performed in earthenware pots with rice seedling in complete randomized block design (CRBD) with triplicate. Wet nursery was organized in earthenware pots filled with sterilized field soil and rice seeds of IR-50 were sown as per the treatments. After 25 days, rice seedlings were transplanted to bigger pots for various treatments.
**Pseudomonas sp VSMKU2** treatment and challenge inoculation with *R. solani* in green house

*Pseudomonas* sp VSMKU2 was used for defence reaction against *R. solani*. The treatments included (1) Healthy control (IR-50 seeds treated with sterile distilled water) (2) Inoculation of 25g of *R. solani* hull/rice seedlings (3) *Pseudomonas* sp VSMKU2 treated in seeds + soil application (25 mL bacterial cells, 7 x 10⁸ CFu/ml) with *R. solani*. (4) A 25 ml of cell free culture filtrate of *Pseudomonas* sp VSMKU2 and *R. solani*. The treatments were duplicated for three times. In 21 days’ time course of study, every one week interval; the samples were taken from all the treatments for defence related stress enzymes assay such as PAL, PO, PPO and total phenol.

**Preparation of rice leaf extracts**

Defence related enzyme assay was performed using rice leaf extracts. Rice leaves were collected on 7th, 14th and 21st days after challenged inoculation of *R. solani* and were stored at -80°C until extract was prepared. From all the treatments, rice leaves were collected every three rice seedlings about 10cm.

**Phenylalanine ammonia lyase (PAL)**

Phenylalanine ammonia lyase estimation was performed according to Dickerson et al. (1984)²³. Briefly, One gram of rice leaves were taken and homogenized then followed by the above said method.

**Peroxidase (PO)**

Peroxidase activity was carryout at 30°C by the method of Hammerschmidt et al.²⁴. Briefly one gram of rice leaves were homogenized using 2ml of 0.1 M phosphate buffer (pH 7.0) at 4 °C and then followed the above said method.

**Polyphenol Oxidase (PPO)**

Polyphenol oxidase activity was examined by the method of Mayer et al. (1965)²⁵. One gram of rice leaf tissues were homogenized using two ml of 0.1 M sodium phosphate buffer (pH 6.5) and centrifuged at 16,000 g for 15 min at 4 °C and then followed by the above said method.

**Total phenol content**

Total phenol content was quantified according to Mayer et al., (1966)²⁶. One gram of fresh leaf tissues were homogenized with 10 ml of 80% methanol and then followed the above mentioned method.

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**Table 1. Physiochemical and biochemical characteristics of Pseudomonas sp VSMKU2**

| Test                                   | Results                                      |
|----------------------------------------|----------------------------------------------|
| Biochemical test                       | -                                            |
| Gram's Staining                        | -                                            |
| Motility                               | Motile                                       |
| Colony                                 | small, circular and yellow in colour         |
| Pigment production                     | +                                            |
| Optimum temperature for growth         | 37°C                                         |
| Optimum pH for growth                  | 7                                            |
| Salt tolerance for growth              | 0.1-1M                                       |
| Indole test                            | +                                            |
| Methyl red test                        | -                                            |
| Voges-Proskauer                        | -                                            |
| Citrate utilization                    | +                                            |
| Gelatin liquefaction                   | +                                            |
| Nitrate reduction                      | +                                            |
| TSI                                    | acid butt, alkaline slant, H₂S production    |
| Catalase                               | +                                            |
| Oxidase                                | +                                            |

**Carbohydrate utilization test**

| Glucose                               | +                                            |
| Fructose                              | +                                            |
| Sucrose                                | +                                            |
| Mannitol                               | +                                            |
| Lactose                                | -                                            |
| Maltose                                | -                                            |
| Xylose                                 | -                                            |
| Arabinose                              | -                                            |

**Lytic enzyme Production**

| Amylase                                | +                                            |
| Cellulase                              | +                                            |
| Gelatinase                             | +                                            |
| Protease                               | +                                            |
| Chitinase                              | -                                            |
| Pectinase                              | -                                            |

Note: - absence, + presence.

**Statistical analysis**

The pot experiments were carryout in a randomized design. The enzyme activity was presented as means ± standard deviations (S.D.) All treatments were repeated in triplicates with three plantlets per pots.

**RESULTS AND DISCUSSION**

**Identification of VSMKU2 and Characterization**

PGPR have the ability to improve plant growth promotion and indirectly control fungal
pathogens like *R. solani*, *Pythium aphanidermatum*, *Colletotrichum orbiculare*, *Fusarium oxysporum*\(^3,27-29\). In the same way the current study, discover the potential antagonistic rhizobacterium enhance rice defence related stress enzymes in the inoculation and noninoculation of pathogen *R. solani*. Based on the plant growth promotion and bio control potential against fungal pathogen *R. solani* by the isolate VSMKU2 (data not shown) was selected for defence related stress enzymes in rice plants and its role for the management of sheath blight of rice.

**Morphology**

Isolate VSMKU2 exhibited good growth on King’s B agar medium with fluorescent colonies (Fig.1). It secretes a variety of pigments, including blue-green (pyocyanin) in different growth media. Light microscopic visualization revealed that the VSMKU2 is a rod-shaped bacterial cell. The light microscope images of VSMKU2 exhibited a detailed structure showing a rod shape.

**Biochemical characteristics**

Biochemical tests exposed that the isolate VSMKU2 is a Gram negative organism. It demonstrates positive reactions such as oxidase, catalase, citrate utilization, indole production, nitrate reduction and triple sugar iron (acid butt, alkaline slant, H\(_2\)S production) tests. It exhibited negative reactions to MR and VP tests (Table 1). The isolate VSMKU2 effectively fermented for various carbon sources like glucose, fructose, sucrose and mannitol. However, it did not ferment arabinose, lactose, maltose and xylose (Table 1). The hydrolytic enzyme assay on different substrate amended medium was exposed, the VSMKU2 isolate secrete only amylase, cellulase, gelatinase and protease, however not produced pectinase and chitinase (Table 1) compared to control.

*Fig. 1.* Morphology of *Pseudomonas* sp. VSMKU2. Culture plate showing fluorescent pigment production under UV-transilluminator at 365 nm.

*Fig. 2.* Phenylalanine ammonia lyase (PAL) activity profile of rice leaves variety IR-50 in different treatments. T1- Healthy control (rice variety IR-50 treated with sterile distilled water); T2- Disease control (rice seed inoculated with *R. solani*); T3- *P. aeruginosa* VSMKU2 culture + *R. solani*; T4- *P. aeruginosa* VSMKU2 culture filtrate + *R. solani* at 7\(^{th}\), 14\(^{th}\) and 21\(^{st}\) day. The data represent the mean values based on three replicates in each treatment, Vertical bar indicate standard error.
present findings coherence with previous results 30-32.

**Induction of defence related stress enzymes**

Isolate VSMKU2 belongs to genus *Pseudomonas* sp were involved for the control of fungal and bacterial plant pathogens through antagonism, competition and by developing straight communications with host plants through Induced systemic resistance (ISR). In this study, we discuss the following defence related stress enzymes such as PAL, PO, PPO and total phenol.

**Phenylalanine ammonia lyase (PAL)**

The seed treatment and soil application of *Pseudomonas* sp VSMKU2 significantly induced maximum level of PAL activity (97.50 nmol trans-cinnamic acid/min/g) on 7th day inoculation of *R. solani*, whereas 14th and 21st day after inoculation of *R. solani*, the PAL activity reduced compared

![Image of graph showing PAL activity](image1.png)

**Fig. 3.** Phenol oxidase (PO) activity profile of rice leaves variety IR-50 in different treatments. T1- Healthy control (rice variety IR-50 treated with sterile distilled water); T2- Disease control (rice seed inoculated with *R. solani*); T3- *P. aeruginosa* VSMKU2 culture + *R. solani*; T4- *P. aeruginosa* VSMKU2 culture filtrate + *R. solani* at 7th, 14th and 21st day. The data represent the mean values based on three replicates in each treatment, Vertical bar indicate standard error.

![Image of graph showing PO activity](image2.png)

**Fig. 4.** Polyphenol oxidase (PPO) activity profile of rice leaves variety IR-50 in different treatments. T1- Healthy control (rice variety IR-50 treated with sterile distilled water); T2- Disease control (rice seed inoculated with *R. solani*); T3- *P. aeruginosa* VSMKU2 culture + *R. solani*; T4- *P. aeruginosa* VSMKU2 culture filtrate + *R. solani* at 7th, 14th and 21st day. The data represent the mean values based on three replicates in each treatment, Vertical bar indicate standard error.
to control (Fig. 2). But, the cell free treatment of *Pseudomonas* sp VSMKU2 about 20 to 30% reduction of PAL activity was observed for all three consequent days of evaluation compared to pathogen and untreated control. Similar result was reported by Reshma *et al.* (2018)\(^{33}\), showed that seed treatment and root dipping of *Pseudomonas* sp maximum in PAL activity on 7th day of challenge inoculation of *R. solani* in rice plants. Numerous fluorescent pseudomonads were showed to induce ISR\(^ {33}\). Similarly, ISR condensed infection and enhanced plant growth promotion was reported in several crops\(^ {34}\). Since, PAL is the primary enzyme in phenylpropanoid metabolism and phenolics and phytoalexins which reduced the development of pathogen\(^ {35}\). The present study showed increased PAL activity due to *Pseudomonas* sp VSMKU2 action, which has the capacity to prevent the establishment of *R. solani* in rice roots and leaves. PAL has been involved a significant task in phenylpropanoid pathway, since lignin is a major product. Lignin accumulation is a provoke defence mechanism and strengthening against infection development. Superior PAL activity by *Pseudomonas* spp was reported in tomato\(^ {16}\), pearl millet\(^ {37}\), cucumber\(^ {12}\), tomato\(^ {16, 20}\) and mulberry\(^ {38}\).

**Peroxidase (PO)**

Peroxidase is the principal enzyme during biosynthesis of lignin. Due to production of PO, it gives strengthening to plant tissues and avoids pathogen entry in to the plants. PO could afford fortification from oxidative stress, through which lipid peroxidation ensuing in damage to the macromolecules, thereby inhibiting photosynthesis and other enzyme activities. In our study, PO activity has been increased on 7th and 14th days of challenged inoculation of *R. solani* with *Pseudomonas* sp VSMKU2 as seed and soil treatment in rice seedlings compared to control. Whereas, in the cell free culture filtrate treatment showed significant activity of PO on 14th days after challenge inoculation of *R. solani* in comparison to other two (7th and 21st) consequent days (Fig. 3). In concurrence with our result, Podile and Lakshmi (1998)\(^ {39}\) reported that PO activity was increased in pea plants treated by *Bacillus subtilis* against *Fusarium udum* after 7 day of inoculation. On the other hand, PO level has been improved after immunization of pathogen and accomplish its greatest at 9th hours after *Ralstonia solancearum* inoculation in tomato plants. Similarly, PAL and PO lower activity was observed in tomato seedlings treated with *R. solani*.

**Fig. 5.** Profiling of total phenol content in rice leaves variety IR-50 in different treatments. T1- Healthy control (rice variety IR-50 treated with sterile distilled water); T2- Disease control (rice seed inoculated with *R. solani*); T3- *P. aeruginosa* VSMKU2 culture + *R. solani*; T4- *P. aeruginosa* VSMKU2 culture filtrate + *R. solani* at 7th, 14th and 21st day. The data represent the mean values based on three replicates in each treatment, Vertical bar indicate standard error.
**Polysaccharides**

Polysaccharides are known to be synthesized by many rhizobia and contribute to plant-microbe interactions. In our study, the polysaccharide content of *Pseudomonas sp VSMKU2* treated rice seedlings was significantly higher compared to the control (untreated) plants. This indicates a possible role of these compounds in enhancing plant defense against *R. solani*.

**Phenolic compounds**

Phenolic compounds are known to play a crucial role in plant defense mechanisms. In our study, the level of phenolic compounds was found to be significantly higher in *Pseudomonas sp VSMKU2* treated rice seedlings compared to the control (untreated) plants. This finding supports the hypothesis that these compounds contribute to the enhanced resistance of the treated plants against *R. solani*.

**CONCLUSION**

The use of *Pseudomonas sp VSMKU2* as a bioinoculant could be a promising strategy for the management of sheath blight of rice. Further studies are needed to understand the mechanisms by which these rhizobacteria induce plant defense responses against soil-borne pathogens.

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**CONFLICT OF INTEREST**

The authors declare that there is no conflict of interest.

**AUTHOR’S CONTRIBUTION**

KN, contributed the data and drafted the manuscript. VS interpretation supervised and reviewed the manuscript. NB helped for preparation of figures, interpretation and draft improvisation. KN, VS and NB read and approved the manuscript.

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**DATA AVAILABILITY**

All datasets generated or analyzed during this study are included in the manuscript.

**ETHICS STATEMENT**

Not applicable.

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