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Allelopathy: Potential Role to Achieve New Milestones in Rice Cultivation

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Abstract: Rice fields are ecosystems with many types of plants, microbes, invertebrates, birds and animals. The rice farming protects the biodiversity of the region and maintains the ecosystem for the benefit of environment. Some rice varieties release biocidal allelochemicals which might affect major weeds, microbial and pathogenic diversity around rice plants, even soil characteristics. A large number of compounds such as phenolic acids, fatty acids, indoles and terpenes have been identified in rice root exudates and decomposing rice residues, as putative allelochemicals which can interact with surrounding environment. Since these allelopathic interactions may be positive, they can be used as effective contributor for sustainable and eco-friendly agro-production system. Genetic modification of crop plants to improve their allelopathic properties and enhancement of desirable traits has been suggested. Development of crops with enhanced allelopathic traits by genetic modification should be done cautiously, keeping in view of the ecological risk assessment (non-toxic and safe for humans and ecosystem, crop productivity, ratio of benefit and cost, etc.).

Key words: rice; allelopathy; crop improvement; weed management; disease management; microbe; soil

In nature, microorganisms grow with multi-species communities and regulate their growth and also get influenced by them. They are rarely present as isolated species. Since ancient time, the direct and indirect chemical effects of one plant species on development of neighboring plants have been well documented. Theophrastus (300 B.C.) stated that beside reinvigorated effect of other leguminous crops on agriculture fields, *Cicer arietinum* have negative effect on weeds and *Tribulus terrestris*. Such an antipathy was also noticed between grape and cabbage plants (Culpeper, 1987). These series of observation during early time lead to the concept of allelopathy coined by Molisch (1937). According to his definition, allelopathy refers to both inhibitory and stimulatory reciprocal biochemical interactions between plants including microorganisms. However, Rice (1974) defined the term as any direct or indirect harmful effect by one plant (induding microorganisms) on another through production of chemical compounds that escape into the environment. In 1984, additional experiments and literature surveys convinced that if not all but most organic compounds that are inhibitory at some concentrations are stimulatory to the same processes at low concentrations (Rice, 1984). Further, he also differentiated allelopathy (effect depends on addition of chemical compounds in environment) from competition, which involves the removal or reduction of some factors from the environment (Rice, 1995). In 1996, the International Allelopathy Society recommended the following definition of allelopathy as: Any process involving the secondary metabolites produced by plants, microorganisms, viruses, and fungi that influence the growth and development of agricultural and biological system (excluding animals), including positive and negative effects (Torres et al, 1996).

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It is now realized that complex genetic and chemical systems regulate the interactions of individual organisms within communities. The biocontrol methods based on the heavy use of synthetic chemicals have great impact on the environment. Therefore, establishing more eco-friendly methods utilizing allelopathy is one of the features for improving cultivation practices of several crops.

Inderjit and Weiner (2001) suggested that allelopathy is not just plant-plant interference but also involves soil-mediated chemical intervention. Allelopathy of soil may get influenced by many factors (physical, chemical, and biological), including the climatic conditions and presences of other plant species in the vicinity.

Rice is the most important crop worldwide, with about more than 1.5×10^8 hm^2 of land being cultivated for its production. Globally, rice provides approximately 20% of the caloric intake to more than 50% of the population in the world. Although rice is cultivated at such a massive scale, its yield is prone to significant loss because of infestation by weeds, pests and diseases. Out of these, yield loss because of weed infestation was reported to be more than the total loss caused by diseases and pests (Asaduzzaman et al, 2010). Therefore, in order to reduce the yield loss of rice due to weed infestation, different herbicides are reported to be incorporated in rice fields (Fig. 1; Ravi and Mohankumar, 2004). Since, extensive area is covered by rice cultivation, heavy pesticide (insecticides-1.02 a.i/hm^2, herbicide-0.19 a.i/hm^2, fungicides-0.51 a.i/hm^2) load enters the environment and get accumulated via leaching and biomagnifications (Shende and Bagde, 2013).

Rice fields have versatile ecotones that comprises of aquatic habitats as well as drylands and a large group of biodiversity (Fernando, 1995). In addition to the economic benefits, paddy field ecosystem helps maintain nutrient recycling, trophic structure balance, water recharge and most importantly, harbours diverse plant communities (Dhyani et al, 2007).

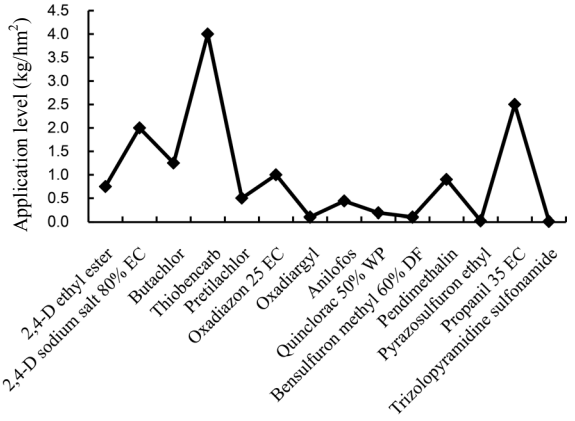

Fig. 1. Herbicides applied for rice cultivation.
Data are from Ravi and Mohankumar (2004).

A few rice varieties or rice straws left in the fields after harvesting produce and release allelochemicals into the fields which suppress the growth of neighboring or successive crops/plants (Inderjit et al, 2004). Allelopathy plays a relatively better role in the competitive outcome later in the season because allelopathic interactions increase with age and density of rice. The environmental stress increases the allelopathic strength of a given plant (Waller and Einhellig, 1999). It has been observed that the amount of allelochemicals released per plant is lesser during allelopathic interaction with increased weed density (Olofsdotter, 2001a).

The objective of the present review is to discuss some physiological and molecular aspects of allelopathy which has relatively scanty information available with respect to the importance of allelochemicals in crop cultivation, particularly focusing on the possible interactions in rice field ecosystem, as well as its potential advantage in agriculture.

Agricultural practices and allelopathy

The suppressing effect among crops is mainly due to interference i.e. competitive and allelopathic interactions between the plant species (Sanjerehei et al, 2011). In agroecosystems, the competition for growth resources (like sunlight, soil moisture, nutrients and space) starts few days after the emergence of seedlings and becomes severe with time. The competition may be inter-species and/or intra-species. The intra-species competition generally occurs in pure crop, while inter-species competition occurs between different plant species i.e. between the component crops in mixtures/intercropping systems and/either between the crops and weeds or between the plants of the same crop sown in narrow rows or at high plant density (Narwal and Haouala, 2013).

Zero tillage in rice-wheat cropping system might have major benefits, such as improved water usage efficiency, reduced investment cost, higher yield, reduced weed population and a positive environmental effect (Mann et al, 2008). Besides, the cropping system is expanding as new crops are involved in rotations which may help to break disease and insect