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Relationship Between Allelopathic Effects and Functional Traits of Different Allelopathic Potential Rice Accessions at Different Growth Stages

XU Gaofeng[1], SHEN Shicai[1], ZHANG Fudou[1], ZHANG Yun[2], Kato-Noguchi HISASHI[3], Roy Clements DAVID[4]

([1]*Institute of Agricultural Environment and Resources Research, Yunnan Academy of Agricultural Sciences, Kunming 650205, China;* [2]*Food Crops Research Institute, Yunnan Academy of Agricultural Sciences, Kunming 650205, China;* [3]*Department of Applied Science, Faculty of Agriculture, Kagawa University, Miki, Kagawa 761-0795, Japan;* [4]*Department of Biology, Trinity Western University, 7600 Glover Road, Langley, British Columbia V2Y1Y1, Canada*)

Abstract: In this study, effects of temperature, light and their interactions on allelopathic effects and the functional traits specific leaf area (SLA) and stem mass fraction (SMF) of different allelopathic potential rice accessions at different growth stages were analyzed. The main results were as follows: Allelopathic responses to temperature and light varied with different allelopathic potential rice accessions at different growth stages. With the rise of temperature and the extension of photoperiod, allelopathic effect increased firstly and then decreased at 2–3 leaf stage, but increased constantly at the 4–5 and 7–8 leaf stages in strong allelopathic rice accessions [*O. longistaminata*, F_1 (*O. longistaminata* × RD23), F_2 (RL159 and RL169)]. Temperature had significant impact on allelopathic effect without considering light factors, but light showed little effect on rice allelopathy at the same temperature conditions. The greatest allelopathic effect was attained with moderate temperature and long photoperiod at 2–3 leaf stage in strong allelopathic rice accessions, but all the rice accessions showed weak allelopathic effects at the low temperature condition (15 ºC/10 ºC), and the influence of different factors on allelopathy followed a general trend as temperature > leaf stage > light, indicating that among the multiple factors impacting rice allelopathy, temperature was the main factor. Allelopathic characteristics of F_1 and F_2 to various temperature and light were similar to *O. longistaminata*, showing that allelopathic genes from wild rice can be expressed in its descendants. Temperature and light also had significant effects on SLA and SMF, and rice allelopathy was closely correlative to SLA in strong allelopathic rice accessions at the 4–5 and 7–8 leaf stages, but there was no correlation between rice allelopathy and SMF at different growth stages. These results suggested that rice adjust the relationship between allelopathy and SLA and adapt to the varied environments, and that high temperature and long photoperiod can enhance rice allelopathic activity.

Key words: rice; allelopathy; environment change; functional trait; specific leaf area; stem mass fraction; temperature-light interaction

Rice paddy weeds, especially barnyard grass (*Echinochloa crus-galli*), generally cause significant loss in yield and quality of rice. To prevent the large loss in yield, contemporary cultivation methods largely rely on the application of herbicides, which imposes accompanying economic, environmental and human health costs (Sweet and Kostov, 2014). Allelopathy refers to a phenomenon whereby plants produce

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Corresponding author: ZHANG Fudou (fdzh@vip.sina.com)

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natural products that suppress the growth of their neighbors (Khanh et al, 2007). Growing allelopathic rice to control paddy field weeds may significantly reduce dependency on herbicides and contribute to effective protection of environment and biodiversity, and therefore, facilitate the sustainable development of agriculture (Kim 2001; Kong et al, 2008; Duke, 2010). However, the weed control of allelopathic rice is often low in the field, and even high allelopathic potential rice frequently exhibits poor control on rice paddy weeds (Zhou et al, 2005; Xu et al, 2014). How to improve the allelopathic efficacy is essential for sustainable agricultural production.

Rice allelopathy can be regulated by various environmental factors (Kong et al, 2004; Wang et al, 2011). Knowledge of environmental allelopathic effects has been taken as one of the key methods for improving allelopathic efficacy. In the aspect of ecological chemistry, previous studies showed that environmental changes are able to affect the synthesis and type of rice allelochemicals which regulate rice allelopathic effects (Kong et al, 2008). For example, Shen et al (2015) showed that phenolic acid synthesis of allelopathic rice can be regulated by *OsMYB*. As well as affecting the synthesis of rice allelochemicals, environmental factors, i.e., temperature, illumination, soil condition, exogenous hormones and nutrient levels may also affect their activity (Bastiaans et al, 1997; Gibson et al, 2001; Wang et al, 2003; Olofsdotter and Malik, 2011; Zhang et al, 2011). In the aspect of molecular ecology, studies showed that rice allelopathy is a quantitative trait mediated by both genetic and environmental factors. Quantitative trait loci (QTLs) for allelopathy are found mainly on chromosomes 2, 3, 8, 9 and 10 significantly interacting with the additive × additive epistatic effects and the environment (Lin et al, 2003, 2010; Xiong et al, 2007). These studies have led to a better understanding of the impact of environment on the rice allelopathic effects. However, no research on rice allelopathic effects from resource allocation standpoint has been reported.

Plant functional trait has been broadly applied to analyses of species traits, and the meaning of the term has varied when applied across scales of ecological organization. Plants can perceive different external and internal signals from their surroundings, while environmental change can affect plant allelopathy and its functional trait (Kong et al, 2004; Rivoal et al, 2011). Huang et al (2015) demonstrated *Merremia boisiana* can adjust its resource allocation to allelopathy and leaf functional traits to adapt to various environments. As one of the key factors affecting plant allelopathy and the functional traits, environmental change has long been considered critical. However, the relationship between rice allelopathy and its functional trait has received little attention.

In previous studies, we demonstrated the allelopathic potential of wild rice (*O. longisatminata*), and also proved that its allelopathic effects can be regulated by temperature, illumination, soil water, N-levels and exogenous hormones (Guo et al, 2004, 2005; Zhang et al, 2004, 2011; Xu et al, 2014). However, previous studies on allelopathy of wild rice focused on single environmental factor, and the relationship between allelopathic effect and its functional trait of different allelopathic potential rice is still unclear. Here, based on our former studies (Zhang et al, 2004, 2008; Xu et al, 2010, 2014), the present research examined how environmental change (temperature-light interactions) affects allelopathic effect and functional traits specific leaf area (SLA) and stem mass fraction (SMF) of different allelopathic potential rice at different growth stages, and analyzed their relationship. Results of our study aided to understand allelopathic characteristics of wild rice and its descendants, and provide practical implications for improving allelopathic efficiency.

MATERIALS AND METHODS

Plant materials

RD23, an *indica* cultivar of *O. sativa* from Thailand, wild rice *O. longisatminata* accession (S37), F_1 accession (*O. longisatminata* × RD23) and F_2 accessions (RL219, RL169 and RL159) were obtained from the Rice Research Institute, Yunnan Academy of Agricultural Sciences (YAAS), Kunming, China. The biological characteristics and allelopathic effect at 2-leaf stage of all rice accessions have been tested and reported (Zhang et al, 2004; Guo et al, 2005; Xu et al, 2014; Shen et al, 2016), and detailed data is shown in Supplemental Table 1. The seeds of barnyard grass (*E. crus-galli*) were collected from the farm of YAAS in Kunming in 2014 and stored at room temperature.

Temperature and light treatments

The impacts of temperature and light on rice allelopathy and leaf functional trait are studied by using climatic chamber in 2015. Temperature levels were set separately in different artificial climate