Guttation: A potential yield enhancing trait in rice

Food is the basic need for human survival and existence. Rice (*Oryza sativa* L.) is the staple food for about half of the world's population[1]. Naturally, in view of the limited land resources to support the ever-rising human population, multipronged efforts are called for enhancing rice productivity aimed at aiding the world food security[2]. As a result, enhancement in rice production over the last few decades has come from new rice plant architecture with greater yield sink potential and better production management[3]. However, concerted efforts are being continually made the world over by rice scientists, including geneticists, breeders, physiologists, biochemists, nutritionists and biotechnologists for the search and creation of rice varieties possessing desirable traits for further quality improvement and quantum jump in rice productivity under sustainable agriculture[4]. The results reported herein demonstrate one such possibility for further improvement in rice yield through discriminating a large number of germplasms consisting of breeding materials and selecting desirable genotypes having high rates of guttation therefrom by measuring their rate of guttation, which is non-invasive, simple, accurate and quick to perform.

Rice leaves guttate through structures called hydathodes situated along the margins and tips[5]. The guttational exudate being a carrier of numerous organic and inorganic constituents of metabolic significance[6–8], prompted us to examine the possibility of genotypic variability in this trait with a view to harnessing its economic value in rice. Thirty-day-old seedlings of six cultivars, NDRH 2, NDR 80, NDR 359, NDR 2030, Type 3 and Mahsuri, belonging to similar maturity group of 125–135 days under irrigated rice ecosystem were transplanted at three seedlings/hill, maintaining plant spacing of 20×15 cm during rainy season and were fertilized at 120 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha. Efforts were made to keep the field ponded with about 5 cm standing water during active growth period. After careful vigil, exuded droplets from the top leaf of individual cultivars at pre-heading stage were collected on blotting paper pieces held by forceps, before they trickled down from the exuding sites (Figure 1) and placing them immediately into small, airtight weighing glass vials in the evening during daylight hours between 4:30 and 6:30 pm, i.e. 2 h before sunset under conditions of clear sky, still air, 30–32°C temperature and 80–85% relative humidity. The amount of fluid exuded was determined gravimetrically; but for the sake of simplicity it was expressed volumetrically, ignoring the solute contents present therein. The collection of guttational fluid in the evening ensured that it did not mix with dew sometimes deposited on droopy leaf portions in the morning.

Genotypic variability in the ability of guttation from a single leaf was high, ranging from 62 to 110 µl during half an hour period, with cultivars NDRH 2 registering the highest and Mahsuri the lowest values respectively (Figure 2). More importantly, the rates of guttation exhibited by various cultivars were positively correlated ($r = 0.94^{**}$ at $P < 0.01$) with their panicle weights, i.e. yield sink potential, which is a direct measure of grain yield productivity. Thus, the higher the volume of exuded fluid by the varieties, the greater their panicle weights. The exudation of fluid through the hydathodes is primarily attributed to the root pressure[5,6,9], and perhaps a similar pressure developed higher up as well[10]. Thus, guttation is in fact thought to be the manifestation of root pressure pushing the fluid up to the leaves and panicles. Lately, the cells surrounding the vein ending and the epithem cells of hydathodes have been found to possess wall ingrowths similar to those of transfer cells[11]. These cells may be helpful in retrieving some of the organic solutes like soluble carbohydrates, organic acids, vitamins, hormones, enzymes, amino acids and other nitrogenous substances[12,13] and inorganic solutes such as Ca, Mg, K, Na, SO_4, CO_3 and Cl often present in guttational fluid and root exudates[5,6,14], which upon reaching the panicles and the leaves in turn feed the substrates and the products to the panicles, exert positive and stimulatory effect on overall grain growth potential, i.e. grain number and grain filling, thereby increasing the yield sink capacity. Our findings are supported by a recent report demonstrating a positive relation between bleeding potential in the neck of the spike and source–sink quality of rice[10]. Thus, the bleeding of guttational fluid could be, among other factors, under the control of aquaporins and hormones probably evolved in due course of evolution, as a strategy for improving plant water balance[15–19]. Further, being carriers of numerous organic and inorganic ingredients of metabolic importance, it might have also acquired the dimension of a beneficial mechanism for enhancing grain yield[7,8,12–14].

These findings on guttation in rice are novel. Its measurement is easy, simple, accurate, non-invasive and quick to perform. This technique does not need costly and cumbersome equipment and requires much less time than other known laboratory or field methods/techniques of

Figure 1. The guttational water drops oozing out of hybrid rice leaf (cv. NDRH-2).

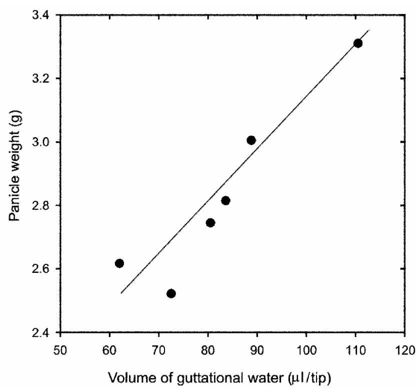

Figure 2. Relationship for six rice cultivars between the rate of guttation and their panicle weights (the yield sink potential). $Y = 1.4718 + 0.1064x$ ($r = 0.94^{**}$).

selecting and breeding crop varieties for yield improvement. Therefore, it holds out good promise for selecting; for example, by setting a lower limit at 90 µl in the present case, genotypes exhibiting guttation rates higher than the cutoff point, from a large pool of germplasm for yield advancement[4]. Further, these findings provide opportunity for mapping the genes controlling this trait and using them for creating efficient rice plants with increased guttation as success has been achieved in increasing and regulating the expression of recombinant proteins in plants that further increase efficiency of phyto-secretions[20,21].

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