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Characterizing stress effects on rice grain development and filling using grain weight and size distribution

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Abstract

Abiotic stresses such as salinity affect rice yield components and grain quality. Among these components, 1000-grain weight (TGW) is thought to be quite constant due to a rigid hull whose size is genetically determined, but chilling and salinity stresses have been reported to strongly reduce TGW. A new, automated methodology is presented to analyze grain weight, length and width distributions for grain samples. Frequency distribution analyses on the basis of histograms generally gave bimodal patterns for grain weight (filled and unfilled grains) and monomodal patterns for grain dimensions. These histograms permit the distinction of unfilled, partially filled and fully filled grains. Peak shape and location on the histogram provide further information potentially useful for the diagnosis of physiological stresses affecting grain hull development, spikelet fertility and filling, and may be of value in breeding and grain quality research. The methodology was applied to rice grain samples taken from farmer's fields having different levels of soil salinity in the Camargue delta region in France. High salinity levels were associated with an increased fraction of unfilled spikelets and reduced grain dimensions and weight, which point at salinity affects taking place before flowering during hull development. The methodology is being further developed with a biometric tool for histogram analysis, and will be extended to other stresses and germplasm.

Keywords: *Oryza sativa* L.; Spikelet sterility; Rice grain quality; Source-sink relationships; Salinity

1. Introduction

Rice is known for its relatively constant 1000-grain weight (TGW) irrespective of environment, thought to be a result of (1) a rigid hull limiting grain size and (2) variable proportions of spikelet sterility that are apparently regulated according to available assimilates (Yoshida, 1981). For example, different levels of competition for resources caused by population density and N application has no effect of TGW in rice (Dingkuhn et al., 1992), whereas high population density reduced TGW in pearl millet (Van Oosterom et al., 2002).

Earlier research on irrigated rice in the Sahel documented the extreme sensitivity of spikelet sterility to low temperatures and heat (Dingkuhn et

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al., 1995) and to a lesser extent to salinity (Asch et al., 1999). Salinity effects on rice spikelet sterility were also reported by Zaibunnisa et al. (2002). The most striking effect of salinity on rice yield components, however, appears to be a strong reduction in TGW, particularly during the tropical dry season when high transpiration rates led to increased plant salt uptake (Asch et al., 1999).

Environment effects on grain development can affect spikelet fertility, degree of filling or the size and maximal weight of the filled grain. Histograms of individual grain weight at maturity taken from a population of panicles showed that maximal grain weight decreases under heat stress, whereas a large proportion of grains is only partially filled under cool conditions (Cissé, 1994). Furthermore, Siband (IRRI, 2000, unpublished) using the same methodology found that in certain rice genotypes, assimilate source limitations caused by leaf pruning lead to highly variable (unregulated) grain weight, whereas in other genotypes the histogram remains divided into two sharp peaks (filled and unfilled: regulating types). A previously unpublished example of such genotypic responses using a heterotic hybrid (regulating) and a breeding line (poorly regulating) of IRRI is shown in Fig. 1. It was concluded that the degree of bimodality and the shape and position of the peaks on the frequency versus weight histogram might be of diagnostic value for stress effects and genotypic behaviour.

This paper introduces an improved, automated methodology to establish histograms of weight, length and width distributions for grain populations, as well as first results obtained with irrigated rice in the Camargue region in France exposed to different levels of salinity in farmer's fields.

2. Materials and methods

A combined methodology was developed to measure, for a population of rice grains, the individual weight, length and width in order to study the distribution of these parameters. The method was then applied to grain samples (cv. Ariete; oven dried rough rice including unfilled spikelets) taken at maturity from two farmer's fields in the Camargue delta region (France) in summer 2002, and from six fields in summer 2003. The fields were known for having different levels of soil salinity, and this was quantified with measurements of soil solution electrical conductivity (EC) measured on 0–20 cm soil core samples taken at crop maturity at exactly the locations where panicles were collected. Ten grams of dry soil were extracted with 50 ml water for EC measurement. Mean field EC was between 284 and 981 $\mu S\ cm^{-1}$.

On each field, 5 sub-samples of 50 panicles each were taken in different places. Panicles were threshed by hand and a representative sample of 20 g (ca. 600 grains) was taken for analysis from each sub-sample. After drying until constant weight at 60 °C, individual grain weight distribution was measured with a combination of a custom made grain separator using a vibrating bowl and a Precisa XT 220-A precision balance having a resolution of 0.1 mg (grain weight

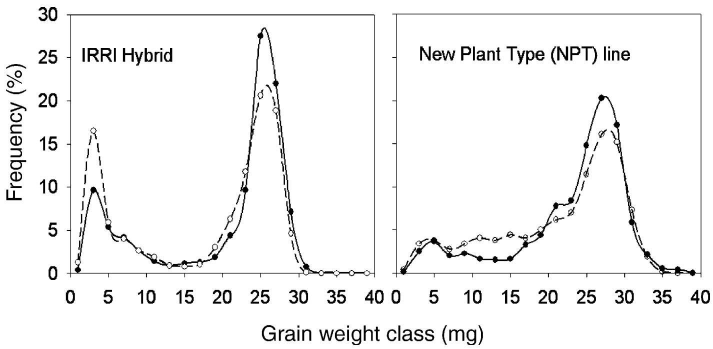

Fig. 1. Example of grain weight histograms obtained for two contrasting breeding lines at IRRI, grown without constraints (solid lines) and with leaf pruning at flowering (broken lines).