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Rice (Oryza sativa L.) plant traits dissection for early vigor and competitiveness with late watergrass *Echinochloa phyllopogon* (Stapf) Koss. I. Characterization of watergrass and rice seedling vigor.

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ABSTRACT - Rice early vigor could contribute for developing competitive cultivars, a crucial component in an integrated weed management. Plant breeders require knowing which most relevant early traits are needed for selection. Plant height has likely been the most referenced plant trait associated to plant vigor, however mechanistically other traits would be involved. We analyze a set of vegetative traits that allows clustering of vigor rice cultivars, then would be suitable for breeding competitive genotypes.

KEY WORDS- rice seedling vigor; vegetative traits; competitiveness.

I. INTRODUCTION

INTEGRATED weed management (IWM) approaches including non-chemical weed control alternatives and reduced herbicide use could overcome agronomic and environmental concerns associated to excessive herbicide use as well as could help reducing crop production costs. IWM is a key component for organic crop production. Breeding more competitive genotypes could contribute to IWM. Research on rice has attempted the identification of relevant plant traits conferring crop competitiveness to develop selection criteria to breed for competitiveness. Rice plant traits contributing to competitiveness with weeds would improve yielding stability across environments with variable weed infestation levels. It is well known that weed competition with rice is critical during early stages of crop growth [1], and most rice traits identified as conferring competitiveness are early expressed. Competitiveness has been related to rapid seedling shoot and root growth [2]. This implies rapid resource preemption and is often referred to as plant vigor. Thus defined, vigor involves a suite of early growth traits, such as seedling emergence [3], leaf area growth rate [4], biomass partitioning to leaves [5], or vegetative biomass accumulation [6], [2]). Early biomass accumulation is relevant for rice to compete with watergrass [7]. Therefore, traits should be identified that are the primary components of rice early vigor; their interrelationships should be understood as well as their relative contribution to resource preemption by rice seedlings. Those traits would be targeted in breeding for more vigorous plants.

II. MATERIALS AND METHODS

Plant vigor studies were conducted in 2000 and 2001 in a greenhouse at the Rice Experiment Station (RES) near Biggs, CA. Seeding dates were August 3 2000 and June 4 2001. Treatments were arranged within a randomized complete design with five replications. Traits related to early vigor were characterized in 21 rice genotypes and compared with those of late watergrass (WG). Thirteen experimental lines (EL) were from the rice population DX221 (M-202/O.nivara//M-202///M-202). Two EL were from the population DX236 originated from a multiple cross including the Indian landrace FR13A (submergence tolerant) and backcrosses to M-202 [8]. The Californian varieties M-202 and A-301 were included as checks. Three destructive harvests were conducted for growth analysis during the seedling and vegetative period at 12 DAS (4-5 leaf stage), 24 DAS (early tillering) and 36 DAS (mid to late tillering). The following parameters were measured at each sampling: number of tillers per plant (TPP), length of the main culm from the soil surface to the tip of the youngest fully extended leaf (SL), leaf area (LA), leaf dry weight (DW) (LW), sheath DW (ShW), total aboveground DW (STW), root DW (RW) and total DW (TotW). Root DW was determined after gently washing of soil over a 1 mm mesh. Root length (RL) was measured only at 12 DAS. Leaf area was measured using a LI-3100 leaf area meter. Specific leaf area (SLA, $cm^2\ g^{-1}$), leaf area ratio (LAR, $cm^2\ gr^{-1}$), and leaf weight ratio (LWR, gr. gr^{-1}) were calculated from these measurements.

III. RESULTS AND DISCUSSION

Comparison of rice and WG seedling traits

WG and rice seedlings exhibited different early growth profiles. At establishment, rice seedlings had larger values for most growth traits. However, WG had superior growth rates for height and gradually became taller than the semidwarf genotypes included in our study (Fig 1). SLA was the second largest WG phenotypic early trait compared of those of rice.

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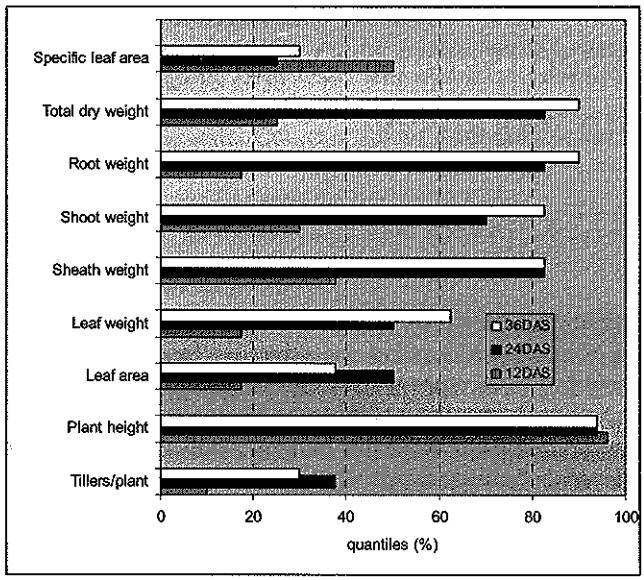

Fig. 1. Quantiles (%) of WG phenotipic values of traits at three sampling times (12, 24 and 36 Days after seeding, DAS) when compared with same traits of rice cultivars.

Principal components (PC) analysis of rice seedling traits

In both years, the first three PC captured about 80 to 90% of the total multivariate variation at each sampling time considered; while, the first PC explained about half of the total variation in both years. By definition, variables showing higher eigenvectors associated with PC1 reflect the main factors underlying early rice seedling growth. At 12DAS, in both years, biomass-related variables (leaf, sheath, shoot, root, and total plant weight) and LA were associated with PC1, while variables related to biomass allocation to leaves (SLA, LAR, LWR) were associated with PC2, and were thus rather independent of early total biomass accumulation. This was also true in the subsequent samplings (24 and 36DAS), except that LA became related to PC2 together with SLA and LAR.

Early vigor clustering of rice genotypes

Variables included in this analysis were selected according to their importance in the preceding PC analysis, low co-linearity, and previous references as causative variables of early vigor [7]. In our cluster study, k=3 was set a priori for clustering into three initial groups named here as High (HVG), Low (LVG) and Intermediate (IMVG) vigor groups. Traits which allow for cluster's discrimination were some of those measured at 24 DAS like leaf area and below and aboveground biomass (Table I). Tillering at that time contributed marginally in 2000 (P = 0.074). By the last sampling (36DAS) most of the same traits differentiated groups of vegetative vigor (i.e. ability for seedlings to rapidly accumulate biomass). The ability to accumulate biomass was represented by shoot and root weight. Traits expressing the ability for light capture, including a measure of the efficiency to use biomass to develop leaf area (SLA) were good early vigor discriminators among genotypes.

Table I. *F* values and probability (p) associated to k-means cluster analysis in two years.

	2000		2001	
Traits	F	p	F	p
TPP12	0.199	0.820	4.1723	0.018
SL12	0.601	0.550	0.5401	0.584
LA12	0.887	0.415	6.1198	0.003
STW12	0.738	0.481	4.9432	0.009
RW12	1.708	0.186	0.9208	0.401
SLA12	1.179	0.312	2.5807	0.081
TPP24	2.665	0.074	17.6394	0.000
SL24	9.003	0.000	1.3833	0.255
LA24	21.710	0.000	78.6492	0.000
STW24	11.402	0.000	27.2540	0.000
RW24	9.984	0.000	5.3815	0.006
SLA24	0.503	0.606	0.3352	0.716
TPP36	0.127	0.881	7.3200	0.001
SL36	17.550	0.000	0.3168	0.729
LA36	262.789	0.000	42.6193	0.000
STW36	17.419	0.000	4.7957	0.010
RW36	1.601	0.207	14.2835	0.000
SLA36	33.188	0.000	3.0291	0.053

TPP = number of tillers per plant, SL = length of the main culm, LA = leaf area, STW = total aboveground DW, RW = root DW, SLA = Specific leaf area. 12, 24 and 36 are days after seeding.

Discussion

Under simultaneous emergence with WG, rice genotypes would be unable to overtop and shade neighboring WG plants making WG suppression through rice competition difficult. As a C4-metabolism plant, *Echinochloa* spp. can be critically affected by light deprivation [1]. Therefore, a combination of delayed WG emergence, early weed control, and vigorous rice seedling growth can effectively impair early WG growth and establishment. Although a desirable trait for weed suppression [7], seedling height was not associated with the clustering of genotypes into vigor groups. Contrary to this, early LA was relevant for clustering, possibly through its contribution to light capture and biomass accumulation. Leaf area also contributes to early canopy closure, which prevents further weed establishment. Early tillering was associated to fast growing genotypes, and was correlated with root biomass, total biomass and leaf area. These results corroborate our earlier studies with a restricted set of genotypes [7] and suggest that rice early vigor, as a component of overall competitiveness, can be enhanced through selection for leafier, rapidly elongating, and highly tillering plants. All these traits correlated well with seedling biomass accumulation. Our method for traits clustering would be useful for selection of genotypes with superior vigor and likely competitiveness.

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