



SHORT COMMUNICATION

CHANGE OF ADAPTIVE PLASTICITY OF *ORYZA RUFIPOGON* GRIFF. IN RESPONSE TO VARIATION OF GROWTH HABITATS

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Received on 19th March, 2010, Revised on 30th Aug., 2010

We assessed the margin of plasticity in assimilate partitioning between plant organs in three ecotypes of *Oryza rufipogon* Griff. living in dryland, lowland and deep water habitats and in each ecotype grown in three simulated habitats resembling the natural habitats. Growth duration, biomass and grain yield and assimilate concentration of reproductive organs were low in the dryland ecotype, but high in the other two ecotypes, although the proportion of biomass partitioned to panicle declined. Simulated habitats were beneficial for shoot dry matter production of dryland ecotype but not always for the other two; shoot biomass did not improve, when deep water ecotype was placed in simulated conditions. The pattern of distribution of assimilates or dry matter between the organs of the ecotypes did not differ between the natural and simulated conditions. Thus, difference in morphological attributes of the ecotypes was mostly determined by variation of environmental conditions irrespective of any variation accrued in the genotype owing to adaptation in the habitat. The adaptive plasticity of *Oryza rufipogon* resulting in morphological divergence of the species across the gradation of habitats may be a trait useful for rice agronomy.

Key words: Adaptive plasticity, assimilate partitioning, ecotypes, *Oryza rufipogon*

The cultivated Asian rice originated from the land races intermediate between the annual and perennial wild rice *Oryza rufipogon* Griff. (Vaughan 1994). The cultivated rice diffused into a wide spectrum of habitats around the globe, such as, aerobic upland, rain-fed lowland, rain-fed deep water, irrigated and very deep water agro-ecosystems (Huke and Huk 1990). The cultural types remained obligatory to the conditions of the growing environments and lost ability of culture in environments other than their own.

Subjected to environmental fluctuations, rice plant strongly regulates its source and sinks relationships (Yoshida 1981) which determine partitioning of

assimilates to different organs. However, the variation in partitioning of assimilates between organs of rice across gradation of habitats has not been tested as an index of tolerance to the sub-optimal conditions. Lack of such studies precludes knowledge on genotypic permissibility of the cultural types for phenotypic plasticity in response to environmental stresses. *Oryza rufipogon*, the progenitor of the cultivated rice is more amenable for adaptation. Thus, the margin of plasticity in assimilate partitioning between plant organs in three ecotypes of the species living in different habitats, was assessed in natural and simulated growth conditions. This species is distributed in Asia from Pakistan to China. Morphological intergrades of the species vary between

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the annual and perennial types. The annual ecotype lives in the summer parched temporary marshes, while the latter inhabits deep swamps (Oka 1991).

In this experiment, three ecotypes of wild rice species *Oryza rufipogon* Griff. growing naturally in dryland, lowland and deep water habitats around the Sambalpur University campus (21.25°N; 83.52°E; altitude 160 m) were used. Ecotypes growing in the first two habitats were annual, while the last one was a perennial. The annual ecotypes are often named *Oryza rufipogon* (annual form) or *Oryza nivara* Sharma et Shastry (Vaughan 1994). In the experiment, growth of the ecotypes was observed in their natural habitats. Simultaneously, 30 days old seedlings of the ecotypes were uprooted carefully from the field and transplanted to each of the manipulated growth habitats, such as, dryland, lowland and deep water conditions at the Adaptive Research Station, Chakuli, Sambalpur, Orissa, India during the wet season of 2003. In the simulated conditions, the plants were grown in three replicates in a randomized block design with the plot size of 3 x 4 m² and spacing 20 x 10 cm. Similarly, three replicate plots were selected at random in each habitat of the natural environment. After transplanting, commercial fertilizers containing N, P and K were applied at the ratio of 60:30:30 in split doses, whereas no commercial fertilizers were applied to the plants grown under natural condition. Un-interfered water accumulation in both natural habitats and manipulated conditions were measured (data not shown). The annual ecotypes were erect, photo-insensitive, upland rice adapted to either dryland or medium lowland habitats under natural conditions, whereas the deep water ecotype was perennial, multi-tillering, prostrate and highly photo-sensitive and adapted to submerged soils of deep water habitats. The perennial type behaves as annual type when cultivated in simulated conditions and flower in the same season.

Plants with uniform growth and development were screened and tagged both in natural and simulated habitats. The dry weight of plant parts were measured at the time of booting, anthesis and maturity. The ratio between the weights of panicle and total biomass (shoot+panicle) of main shoot was calculated and grain yield of main shoot was determined at maturity. The

soluble carbohydrates (Buysee and Merck, 1993) and total free amino acids (Yemm and Cocking, 1955) concentrations of plant parts of the main shoot were determined in aqueous methanolic extractions.

In the natural condition, the dryland ecotype possessed the lowest number of tillers per plant and grain yield of the main shoot was very low (Table 1). Compared to that, panicle weight and grain number of main shoot were more than two times high in the deep water ecotype. This ecotype had the longest vegetative growth period and amassed the largest biomass. Number of tillers of deep water ecotype was significantly higher than the dry land ecotype, but not larger than the lowland type. The ratio between grain weight and total biomass of main shoot was the highest in the dryland ecotype and lowest in the deep water ecotype. Transplantation of dryland ecotype from the natural to simulated condition improved tiller number and shoot biomass in all the three habitats significantly, while the increases in panicle dry weight or spikelet number were not as much significant. The pattern of biomass distribution between plant organs of the ecotype in the three simulated habitats was similar to that of the natural conditions. Also, variation in the panicle weight and total biomass weight ratio of the mainshoot of the plants in simulated habitats was similar to that of the natural habitats. The cultivation of the lowland ecotype reduced overall biomass of all organs in the simulated dry land condition. In contrast, number of tillers and shoot biomass improved significantly in the other two simulated situation, although no change was noticed in the reproductive structure of the main shoot. Tillering improved in deep water ecotype when transplanted in to the dry or low land habitats, but biomass of mainshoot or panicle declined in all the three simulated habitats. The pattern of dry matter distribution between vegetative and reproductive parts of the mainshoot in the three simulated habitats was similar to that of the natural habitats for both the lowland and deep water ecotypes. Among the three ecotypes, vegetative and reproductive growth durations of the dryland and deep water ecotypes were the shortest and longest respectively. Vegetative and reproductive growth durations increased, when the ecotypes were transplanted to the simulated conditions in dry and low land ecotypes; but the durations decreased in the deep water ecotype.

Table 1. Morphological and phenological features of three ecotypes of *Oryza rufipogon* growing in natural and three different simulated (*) habitats; dryland, lowland and deep water. Observations were recorded at maturity.

Wild rice eco-types	Growing habitats	No. of tillers	Dry wt. of main shoot (g)	Dry wt. of panicle on main shoot (g)	Grain number of panicle on main shoot			100 grain weight (g)	Panicle wt/total shoot wt	Growth duration (days)	
					Fertile	Sterile	Total				
Dry	Natural	1.66±0.47	0.85±0.11	0.433±0.03	21.33±2.05	09.33±0.471	30.670±1.672	1.220±0.011	0.337	44	27
Dry	Dry*	4.33±0.42	1.16±0.40	0.493±0.012	22.33±2.054	08.33±1.632	30.667±0.816	1.616±0.069	0.298	51	27
Dry	Low land*	9.67±1.24	1.78±0.23	0.519±0.021	23.67±0.942	07.67±0.471	31.333±1.247	1.680±0.057	0.226	59	32
Dry	Deep*	6.67±0.47	2.47±0.37	0.580±0.032	28.00±2.449	09.00±0.816	37.000±2.160	1.760±0.131	0.190	67	39
Low land	Natural	4.67±0.47	1.78±0.21	0.610±0.04	28.67±4.49	10.33±2.052	38.990±2.451	1.513±0.082	0.255	55	30
Low land	Dry*	4.67±0.64	1.45±0.50	0.503±0.012	18.00±1.632	07.67±0.471	25.667±1.247	1.523±0.061	0.258	60	32
Low land	Low land*	6.33±0.71	3.97±0.72	0.580±0.032	25.00±1.414	08.67±0.471	33.667±1.632	1.740±0.048	0.128	63	34
Low land	Deep*	4.67±0.82	5.27±0.98	0.603±0.021	30.00±1.632	09.67±1.247	39.667±2.247	1.843±0.069	0.103	68	39
Deep	Natural	4.33±0.47	8.03±0.11	1.041±0.11	61.67±6.18	14.00±1.411	75.670±4.780	1.401±0.011	0.115	85	44
Deep	Dry*	7.67±1.02	1.51±0.40	0.469±0.092	19.67±1.128	07.67±1.247	27.333±3.599	1.540±0.032	0.237	65	34
Deep	Low land*	6.33±0.91	4.75±0.87	0.610±0.040	34.00±4.546	13.00±0.816	47.000±4.080	1.640±0.089	0.114	70	39
Deep	Deep*	4.67±0.47	5.36±0.76	0.636±0.065	38.00±2.816	16.33±1.247	54.333±4.942	1.810±0.073	0.106	79	42

Change over to simulated conditions, however, did not alter the pattern of difference in growth duration between the ecotypes growing in their respective natural habitats. In the natural condition, the deep water ecotype continued elongation for a longer time period and achieved the longest shoot height. But extension growth ceased much early in the dryland ecotype resulting in a much smaller shoot height. The simulated situation also elicited similar responses from the ecotypes.

Dry weight of the main shoot increased with passage of time in the deep water ecotype in natural condition, it stopped much earlier in the other two ecotypes (data not shown). Among the ecotypes, biomass of the main shoot was highest and lowest in the deep water and dry land ecotypes respectively. Change over to the simulated situation improved shoot biomass accumulation in the dry and low land ecotypes. In contrast, biomass growth declined in the deep water ecotype, when subjected to simulated situation. The hierarchies in main shoot biomass accumulation were similar for both natural and simulated conditions. The same hierarchy between habitats was noticed in biomass accumulation of the panicle on the main shoot of the ecotypes. Change over to simulated situation from the natural condition elicited higher biomass fixation for the dryland ecotype, but not for the others.

Soluble carbohydrates and free amino acids (assimilates) concentrations of the plant parts of the main shoot, such as, panicle, stem, leaf sheath, lamina and roots fluctuated temporally; the concentration increased from booting stage to anthesis and declined thereafter until maturity (data not shown). At the anthesis stage, the concentration of assimilates was high in the plant parts of deep water ecotype and it was quite low in the dry land ecotype in the natural habitat (Fig. 1). The concentrations improved in all the ecotypes, when grown in the three simulated habitats but, the hierarchies in the concentration of assimilate of plant organs between the habitats were similar to that of the natural habitats.

Our experiment revealed close physiological similarities between the annual and perennial ecotypes of *O. rufipogon* (Oka and Morishima 1997). Both the ecotypes exhibited considerable variation in growth,

phenology and assimilate partitioning while growing in their natural habitats. Change over to the simulated situation often improved vegetative and reproductive growth of the annual ecotypes, but the impact of simulated environment on plants was not different from that of the natural environment. This observation revealed the broad phenotypic permissibility of the ecotypes in response to environmental stimulus.

In addition to this, the results provided valuable information on the variations in biomass production and nature of assimilate partitioning in response to the interaction between ecotype and habitat. Both biomass and assimilate concentration of the plant organs changed in response to change of habitat. Soluble carbohydrates and free amino acid concentrations and dry weight of panicle were quite low, main shoot biomass was poor and the plant completed life cycle early in the natural dryland habitat. Similar physiological, morphological and phenological features were evident in the other two ecotypes when transplanted to the dryland habitat. Early partitioning of biomass in favour of reproductive growth resulted in high ratio between panicle dry weight and total biomass weight of the main shoot in this habitat. In contrast, the deep water or lowland ecotypes grew in relatively stable environments and enjoyed an extended period of life cycle. The anaerobic conditions of the submerged soil might have allowed provision of exchangeable form of many essential elements like nitrogen, potassium, phosphorus, iron, manganese and silicon (Mahapatra et al. 1985) to the plant for increasing vegetative and reproductive growth durations, but the ratio between dry masses of panicle and total main shoot declined significantly (Table 1). The decline of this ratio under relatively more favourable environment was further confirmed, when the plants were shifted to the simulated conditions. Variation in adaptive strategy reiterated high phenotypic plasticity of wild rice in the changed environments; K-selection occurred with low reproductive allocation in stable environment and r-selection with high reproductive allocation under unstable situation (Oka and Morishima 1997). Transplantation of all the three ecotypes to either lowland or deep water condition elicited similar responses in each of the ecotypes. In our experiment, measurements of soluble carbohydrates and amino acids (Fig.1) of the plant parts

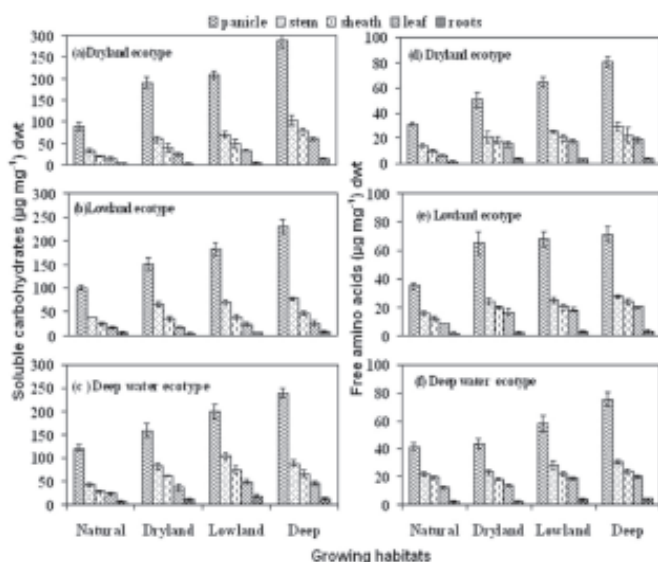


Fig.1. The concentration of soluble carbohydrates and free amino acids of different plant organs of *O. rufipogon* Griff. at anthesis grown under three natural habitats and in each ecotype grown under simulated habitats resembling the natural conditions. Vertical bars represent \pm SD values (n =3).

of the three ecotypes indicated the influence of environmental conditions in the regulation of assimilate partitioning to plant organs and the morphological features varied between the ecotypes accordingly. The plants growing in dryland and deep water habitats accumulated the lowest and highest biomass as well as assimilate respectively irrespective of variation of ecotype.

Partitioning of assimilates in favour of reproductive structures is the most important feature in agriculture, because it determines grain yield. As of today, physiology of environmental effects on the partitioning process is not understood clearly. Environment influences both source and sink activities and maintains a balance between them, and any effect on the former can not be viewed in isolation from the latter (Bancal and Soltani 2002). In our study, fluctuation of growing condition influenced both source and sink organs of the ecotypes across a gradation of habitats, such as dry land, lowland and deep water situation. In the process, the balance between source (shoot) and sink (panicle) organs changed because of variation in assimilate

partitioning. The influence of environment was similar on both assimilate concentration and biomass of the plant organs in the natural and simulated conditions. This essential attribute may be useful for developing an ideotype beneficial for deriving yield stability in either unstable or widely fluctuating habitats. The wild rices constitute a major gene pool for improvement of the cultigen *O. sativa* (Vaughan 1994). Our discovery supplements their versatility.

ACKNOWLEDGEMENT

PKM acknowledges the support given by Council of Scientific and Industrial Research, New Delhi under the Emeritus Scientist project.

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