Yield advantage of hybrid rice induced by its higher control in tiller emergence

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Abstract

Tiller senescence occurs in most tillering crops since maximum tiller number produced during the vegetative phase is higher than the number of tillers that will be productive at maturity. The assimilate stored in senescent tillers are, however, mostly wasted as few translocation of assimilate between tillers of the same plant occurs. The opportunity to improve grain yield through an increase in tiller fertility rate was addressed in a high tillering crop like rice by comparing two genotypes, an improved inbred line and a hybrid rice with different tillering strategy but similar crop duration. Seedlings were grown in seedling trays and wet-bed nurseries and transplanted 7, 14 and 21 days after sowing at 25 or 50 pl m^{-2}. Early plant development of both varieties during wet and dry seasons did not differ until mid-tillering, as plant tiller number and leaf and stem dry weight per plant were similar. From mid-tillering onwards, shoot dry weight per plant was again similar for both genotypes, but the tillering emergence rate of IR72 was maintained whereas the hybrid stopped its tiller emergence earlier. This reduced the number of tillers in hybrid rice that were likely to senesce as productive tiller number per plant at maturity was similar for both varieties. Grain yield was then significantly higher for hybrid rice as hybrid increased assimilate allocation towards productive tillers. The higher efficiency in assimilate partitioning reported for hybrid suggests that crop management that could improve control in tiller emergence will increase grain yield in rice significantly.

Media summary

The grain yield advantage of hybrid rice over one conventional variety is rather due to its higher control in tiller emergence than its early vigour.

Key Words

Hybrid rice, grain yield, assimilate partitioning, tiller senescence, assimilate wastage

Introduction

Tillering in favorable environments allows the plant to rapidly close the canopy and compensate its heterogeneity in order to maximize light interception. Grain yield is generally stable in these conditions over a wide range of plant densities as the tillering dynamics respond to the level of resources available. Tiller density at maturity is therefore relatively independent of initial sowing density (Kataoka *et al*., 1991). As a result, tillering dynamics did not receive great attention in the past years, whereas tiller senescence during plant competition may involve half of the emerged tillers. Lauer and Simmons (1988) reported, however, few assimilate remobilization in barley from senescent tillers to growing tillers, then considering tiller senescence mostly as a wastage of assimilate. In sorghum, grain yield was increased from 9 to 11 ton ha^{-1} in high density plots by removing all tillers of the plant as soon as they appeared, which, for most of them, became finally unproductive in the control plot (Lafarge *et al*., 2002). In rice, tillering plays a key role as tiller number per plant as high as 40 and tiller senescence rate as high as 50% can be observed (Peng *et al*., 1994). The objective of this study was to check if it could be realistic to increase grain yield of a rice genotype from a better control in tillering dynamics. This was analyzed by comparing two genotypes with similar crop duration but different tiller production strategy, one conventional variety and one hybrid.

Materials and methods

Field experiments were conducted in the wet and dry seasons of 2003 at the lowland area of the IRRI experimental farm, Los Ba?os, Philippines. IR72 (I1) and hybrid rice IR75217H (H1) were grown in nurseries at 3000 seeds m^{-2}, either in wet-bed (WB) or seedling trays (ST), transplanted in 4 replications at 25 or 50 pl m^{-2} after 7 (WB07-25 and ST07-25), 14 (WB14-25) and 21 (WB21-25 and WB21-50) days after sowing. The seeds were sown in the nursery on 26 December 2002 (dry season) and 10 June 2003 (wet season). Water and nutrient management was optimum. Destructive plant measurements were performed weekly from transplanting until maximum tillering, then every second week until flowering and at mid-grain filling (dry season only). Measured plant growth parameters included tiller number, leaf and stem dry weight, yield components, from 2 locations per plot of 0.12 m^2 area, and grain yield from a 5m^2 harvest area.

Results

Grain yield observed for H1 was higher by 1 ton in average to the one observed for I1, for wet and dry growing seasons, for seedling tray and wet-bed nursery, for transplanting age of 7, 14 and 21 days, and for plant density of 25 and 50 pl m^{-2} (Table 1). The productive tiller number at maturity was, however, higher in I1 than in H1. The difference varied from 0.7 tiller per plant when seedlings were transplanted at 50 pl m^{-2} to 3.4 tillers per plant when seedlings grown 7 days in seedling trays were transplanted at 25 pl m^{-2} (Table 1). The advantage in grain yield of H1 compared to I1 was mainly due to its higher harvest index : it varied from 0.51 to 0.55 in the dry and 0.33 to 0.42 in the wet season for H1, whereas for I1 it varied from 0.43 to 0.46 in the dry and 0.30 to 0.35 in the wet season (Table 1) : even though the stem dry weight in H1 was often higher at maturity, the filled grain dry weight per tiller in H1 was considerably higher, from 0.33 g in WB21-25 in the wet season and from 1.02 g in ST07-25 in the dry season (Table 1). This difference was mostly explained by a higher filled grain number per productive tiller, as grain size and grain fertility rate were almost unchanged across genotypes. This seems to indicate that the growth strategy of these genotypes had an impact on the establishment of grain number, which occurred as early as close after panicle initiation. These advantages in yield components for H1 were observed despite its similar, or even shorter, crop duration by 2 days in the wet season and 4 days in the dry (Table 1).

Table 1. Variation in grain yield (t ha^{-1}) and main yield components between H1 and I1 for contrasted growing periods, nursery management and plant density. PtilNB for productive tiller number per plant, StDW Ptil for stem dry weight per productive tiller (g), FiGrDW for filled grain dry weight per productive tiller (g), HI for harvest index, FiGrNB for filled grain number per productive tiller, C dur for crop duration.

TRT	VA Var	GGrain Yield		PTilNB		StDW Ptil		FiGrDW, g		HI		FiGrNB		C dur
		mmean	ststdev	mean	stdev	mean	stdev	mean	stdev	mean	stdev	mean	ststdev	days
							Wet season 2003							
ST07-25	H1	6.73	0.04	12.02	1.48	2.02	0.06	1.98	0.26	0.38	0.03	85.94	14.25	104
ST07-25	I1	5.27	0.18	15.38	0.55	1.73	0.12	1.35	0.09	0.34	0.01	59.01	4.54	108

WB07-25	H1	6.62	0.22	11.88	0.26	1.86	0.07	2.18	0.32	0.42	0.04	93.42	15.89	104
WB07-25	I1	5.32	0.09	15.21	1.02	1.72	0.16	1.42	0.02	0.35	0.02	62.76	2.76	108
WB14-25	H1	6.02	0.13	13.06	0.57	1.72	0.09	1.92	0.13	0.41	0.01	76.96	7.07	106
WB14-25	I1	5.14	0.06	14.42	1.52	1.77	0.03	1.40	0.02	0.34	0.00	60.22	5.13	111
WB21-25	H1	5.89	0.06	14.36	1.15	1.80	0.07	1.57	0.18	0.35	0.03	66.52	7.54	111
WB21-25	I1	5.18	0.10	15.64	0.59	1.72	0.20	1.24	0.14	0.32	0.02	55.91	6.72	115
WB21-50	H1	5.84	0.12	9.31	0.69	1.88	0.25	1.50	0.05	0.33	0.03	61.08	1.03	111
WB21-50	I1	5.32	0.10	10.00	1.66	1.51	0.06	1.04	0.12	0.30	0.03	45.98	6.41	115

Dry season 2003

ST07-25	H1	7.75	0.10	14.79	1.06	1.63	0.10	2.91	0.26	0.52	0.02	121.11	8.08	107
	I1	6.99	0.23	17.08	1.34	1.51	0.06	1.89	0.08	0.43	0.01	81.00	3.53	109
WB14-25	H1	6.98	0.12	14.13	0.63	1.42	0.10	2.88	0.15	0.55	0.01	117.60	5.21	107
	I1	6.34	0.15	15.77	1.12	1.48	0.19	2.00	0.10	0.46	0.01	84.61	4.55	108
WB21-25	H1	6.97	0.06	16.08	1.04	1.45	0.19	2.45	0.15	0.51	0.02	102.57	7.62	107

I1	6.06	0.21	17.88	1.25	1.28	0.10	1.82	0.08	0.46	0.01	76.91	3.43	111

The increase in tiller number per plant in the wet season was the same for H1 and I1 from emergence to mid-tillering when plants had 6 tillers (Fig. 1a). From that time, increase in tiller number per plant was significantly greater in I1, with maximum tiller number per plant observed for both genotypes at 40 DAS higher than 30 in I1 and close to 20 in H1. Fertility rate of these tillers was significantly higher for H1, 67%, than for I1, 48% (Fig. 1a). The same trend was observed during the dry season : tillering dynamics was the same for both genotypes until 35 DAS and then departed in favor to I1 (Fig. 1b). Maximum tillering was higher (28 compared to 20), and tiller fertility rate was lower (56% compared to 69%), for I1. In contrast, the increase in shoot dry weight per plant in the dry season was similar for both genotypes until 90 DAS, as plant stem and leaf dry weight were similar (Fig. 1d). This observation was also valid for the wet season (Fig 1c). In fact, both stem and leaf dry weight per productive tiller of H1 were higher than those of I1 as early as 30 DAS (Fig. 1e, insert), just from the time when tiller dynamics of both genotypes started to depart (Fig. 1a). Both leaf and stem dry weight per tiller were higher until the start in panicle growth, when the difference in dry weight was then mainly expressed in the increase in panicle size (Fig. 1e). The weight of the panicle of H1 at maturity, 2.4 g, was then 0.6 g higher that that of I1. The same trend was observed in the dry season : the increase in leaf and stem dry weight per productive tiller in H1 compared to that in I1 was observed as soon as tiller emergence rate in H1 departed from that in I1 (Fig. 1d and insert).

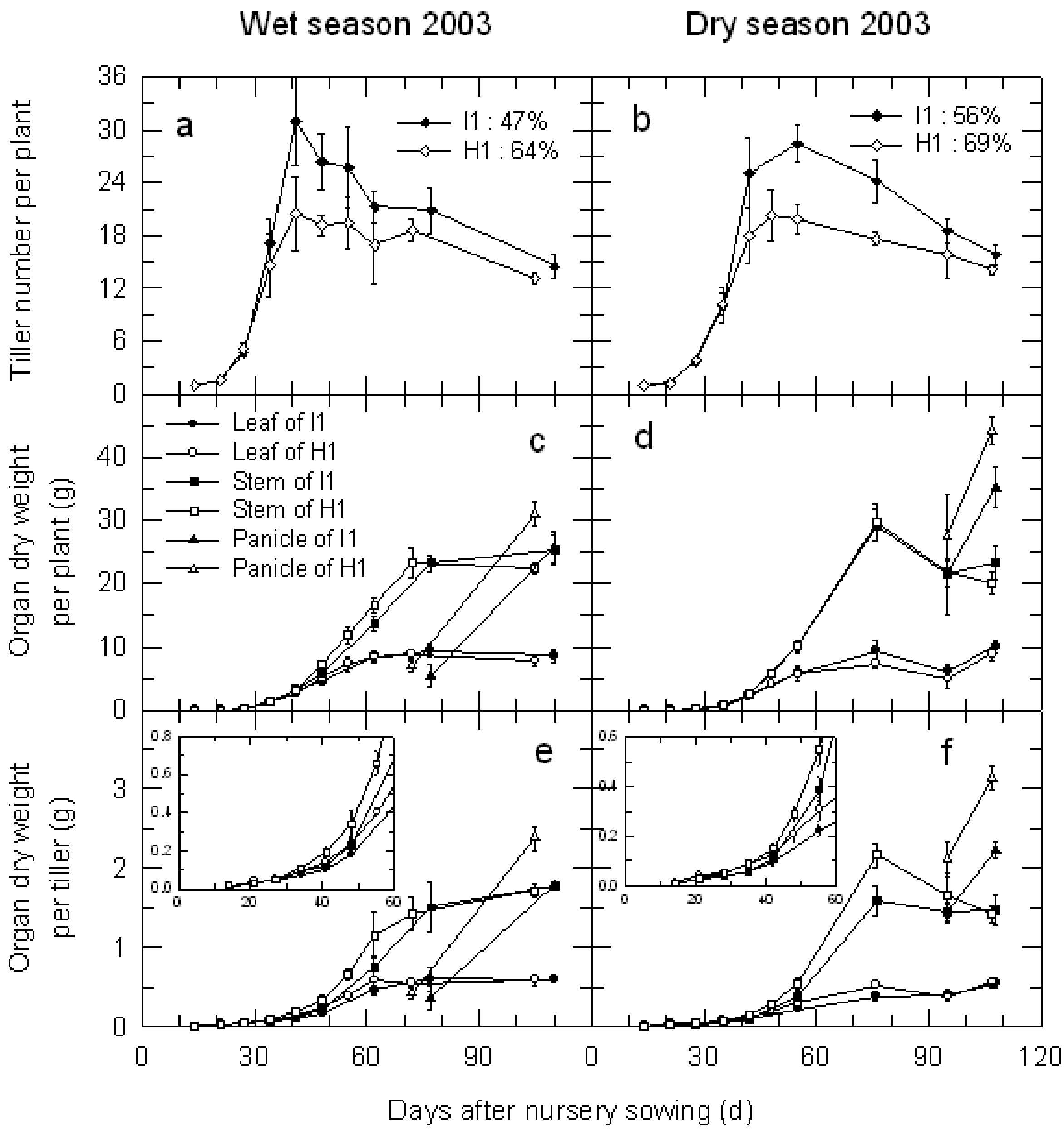

Fig. 1. Change, with days after nursery sowing, in tiller number per plant (a and b), organ dry weight per plant (c and d) and organ dry weight per productive tiller (e and f), for the wet (a, c and e) and the dry (b, d and f) seasons. In a and b, percentages indicate the percentage of tillers at max tillering that produced grain at maturity. In e and f, inserts, zoom of change in organ dry weight per productive tiller.

Conclusion

The higher efficiency in assimilate partitioning of hybrid rice compared to that of IR72 was the main reason for its observed advantage in grain yield : this hybrid stopped the emergence of new tillers earlier than IR72, thereby increasing the partition of newly gained assimilate to the existing tillers, while IR72 was still allocating part of the newly gained assimilate to the production of new tillers. This difference in growth strategy between these two genotypes was observed during both wet and dry seasons on genotypes with similar crop duration. Tiller senescence was lower for H1 than IR72 as both genotypes were characterized by similar productive tiller density at maturity. This more efficient control in tiller dynamics observed in H1 increased tiller fertility rate and reduced assimilate wastage (Peng *et al*., 1994), considering that Lauer and Simmons (1988) reported that remobilization of assimilate in the barley plant from senescent tillers was low. This efficient control in tillering induced a higher filled grain number per panicle at maturity as a consequence of the likely more active grain formation process from panicle initiation.

References

Kataoka M Ibaraki K Tokunaga H (1991). Population regulation of rhodesgrass cultivars in a sward conditions. II. Tiller density. Journal of Applied Ecology 28, 842-854.

Lafarge T Broad IJ Hammer GL (2002). Tillering in grain sorgum over a wide range of population densities: identification of a common hierarchy for tiller emergence, leaf area development and fertility. Annals of Botany 90, 87-98.

Lauer JG Simmons SR (1988). Photoassimilate partitioning by tillers and individual tiller leaves in field-grown spring barley. Crop Science 28, 279-282.

Peng S Khush GS and Cassman KG (1994). Evolution of the new plant ideotype for increased yield potential. In: Cassman KG (ed.), Breaking the yield barrier. Proceeding of a workshop on rice yield potential in favorable environments, IRRI, 29 November-4 December 1993. IRRI, Manila, Philippines, 141 pp.