Crop establishment, water management, and plant type characteristics: moving toward more productive cultural practices

Flooded rice is estimated to take up 3,000 L to produce 1 kg of grain and its consumption of irrigation water on earth is about 1 trillion m^3 yr^{-1}. In one theoretical calculation from FAO, a 1% increase in water productivity in food production will make available an extra 24 L a day per head of population. At the time when it is required to grow rice with less water and less labor input, and to cope with transient water shortage in less favorable conditions, it is essential to identify plant types appropriate to promising crop management approaches. An evaluation of a wide set of six contrasting genotypes was conducted under transplanting, wet and dry direct seeding, and aerobic management.

Materials and methods

Transplanted rice (E1, 25 kg seeds ha^{-1}, 100 plants m^{-2}), wet (E2, 80 kg ha^{-1}) and dry (E3, 80 kg ha^{-1}) row seeding, both continuously flooded after crop establishment, and aerobic rice (E4, 80 kg ha^{-1}), were evaluated for six contrasting genotypes: IR72 as an elite inbred line for favorable conditions (I1), IR71676-90-2-2 as a second-generation new plant type (N1) and four elite aerobic genotypes, as three inbred lines APO (I21), PSBRc 80 (I4) and IR77298-14-1-2 (I8), and 1 hybrid rice Magat (H4). Germination dates were similar (seed soaking for wet sowing did occur when the first rainfall watered the dry seeds in the dry fields) and nitrogen application was optimal (140 kg N ha^{-1}).

Results

Effect of crop establishment and genotypes on grain yield (t ha^{-1}), productive tiller number, filled grain number, and percent filled grain, 2004 wet season, IRRI, Philippines.

	Genotypes						
Crop method	I4 (PSBRc 80)	I21 (APO)	I1 (IR72)	I8 (IR77298-14-1-2)	N1 (IR71676-90-2-2)	H4 (Magat)	Mean
	Grain yield (t ha^{-1})						
E1	6.89 B a	5.64 B b	6.60 B ab	5.51 C b	7.37 B a	6.92 C a	**6.49**
E2	8.65 A a	7.27 A bc	7.84 A ab	6.99 ABc	8.19 A ab	8.04 ABa	**7.83**
E3	8.41 A a	7.81 A a	7.62 A a	7.63 A a	7.73 ABa	8.63 A a	**7.97**
E4	5.50 C b	5.96 B b	5.38 C b	6.34 B b	6.17 C b	7.70 B a	**6.18**
	Productive tiller number (no. m^{-2})						
E1	467 B ab	366 B c	506 ABa	403 B bc	524 ABa	550 B a	**469**
E2	630 A ab	455 A c	734 A a	513 A bc	633 A ab	725 A a	**618**
E3	474 B c	365 B d	676 A a	504 A bc	561 ABb	553 B b	**522**
E4	401 B bc	333 B c	414 B bc	384 B c	438 B b	566 B a	**423**
	Filled grain number (no. $prod^{-1}$)						
E1	60.50 A ab	67.10 B a	48.60 A b	52.40 A b	56.40 A ab	59.60 A ab	**57.43**
E2	52.15 B b	67.00 B a	47.40 A b	52.30 A b	49.40 ABb	52.00 BCb	**53.38**
E3	62.52 A b	83.40 A a	49.90 A c	55.60 A bc	54.60 ABbc	57.70 ABbc	**60.62**
E4	52.20 B b	76.40 A a	49.00 A b	58.50 A b	48.00 B b	50.10 C b	**55.70**
	Harvest index						
E1	0.37 ABab	0.31 B c	0.38 A ab	0.30 B c	0.41 A a	0.35 C bc	**0.35**
E2	0.41 A ab	0.34 ABbc	0.34 A c	0.33 ABc	0.44 A a	0.38 BCabc	**0.37**
E3	0.43 A ab	0.37 A b	0.31 A c	0.36 Abc	0.40 A ab	0.45 A a	**0.39**
E4	0.34 B b	0.31 B b	0.33 A b	0.35 A b	0.40 A a	0.42 ABa	**0.36**

In a column, means followed by different capital letters are significantly different at the 5% level by LSD test (n=4).
In a row, means followed by different small letters are significantly different at the 5% level by LSD test (n=4).

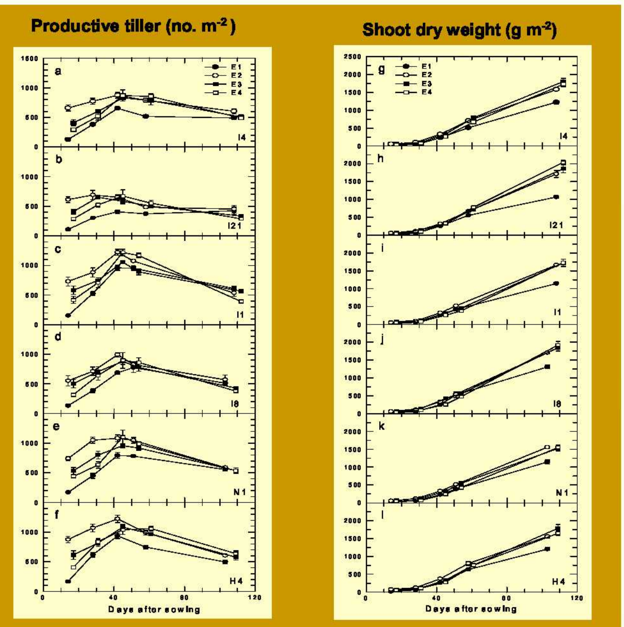

Fig. 1. Change with time of the density of productive tiller number (a to f) and of shoot dry weight per field area (g to l) among crop management methods for each genotype, IRRI, 2004 WS.

Wet and dry row seeding (E2 and E3) appreciably outyielded transplanting and aerobic management (E1 and E4), regardless of genotype, by about 1.5 t ha^{-1} on average (see table).

Wet row seeding (E2) was characterized by quicker early growth and higher maximum tillering (Figs. 1a to f) than transplanting (E1), because of higher seedling vigor associated with higher seed density, and than aerobic rice (E4), because of higher germination rate.
Higher grain yield in E2 was directly supported by quicker increase in shoot dry matter (Figs. 1g to l), higher productive tiller number and higher harvest index (see table).

Dry row seeding (E3) had the tendency to be more productive than wet row seeding (E2) for three genotypes (I8, H4, I21, see table). Higher harvest index seemed to have played a role while compensation of productive tiller number with filled grain number per tiller generally occurred.

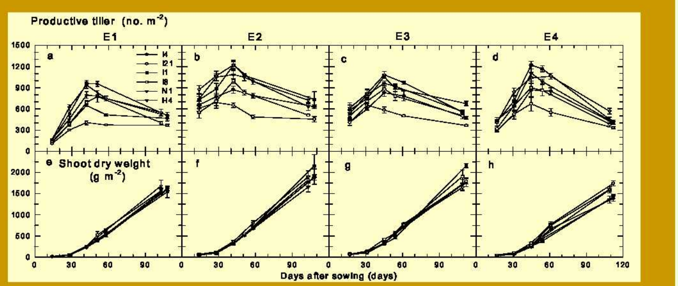

Fig. 2. Change with time of the density of productive tiller number (a to d) and of shoot dry weight per field area (e to h) among genotypes for each crop management method, IRRI, 2004 WS.

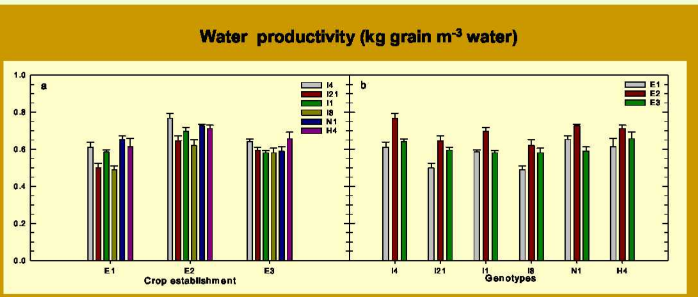

Fig. 3. Water productivity (kg grain m^{-3} water) among genotypes in each crop management method (a) and among crop management methods for each genotype (b), IRRI, 2004 WS.

The best genotypes under E1 (N1, H4, and I4), E2 (I4, N1, and H4), E3 (H4, I4) and E4 (H4) were those with the highest harvest index and often those with the highest number of productive tillers (see table). In most cases, they were not characterized with the quickest early growth and highest maximum tillering (Fig. 2a to d).

Dry matter accumulation rate of H4 was maintained under E4 compared with E3, while I4 and N1 dropped theirs (Fig. 2e to h). I4 mainly dropped its harvest index whereas N1 mainly dropped its tiller dynamics.

Water productivity was observed higher in E2 than in E3, regardless of genotype (Fig. 3). This was mostly due to the greater amount of water applied to E3 at the end of the dry establishment. Water productivity was also higher in E2 than in E1 mainly due to its higher grain yield (Fig. 3). Water productivity in E4 was not calculated because seepage and percolation were not controlled and evaluated (absence of plastic bunds).

Conclusions

■ Wet and dry row seeding outyielded conventional transplanting by 1.5 t ha^{-1}, regardless of genotype, but considering that land levelling and water input were finely tuned.

■ Early tillering and early crop vigor in direct seeding were essential in achieving high dry matter accumulation at panicle initiation and then in supporting higher grain yield, probably with help of a better seed coverage of the field area than in transplanting.

■ Good performance in dry establishment and aerobic conditions seemed supported by an increase in plant harvest index, possibly due to an increase in sink strength.

■ Dry crop establishment, however, did not appear promising for increasing water productivity significantly in the soil conditions of the IRRI farm.

■ Harvest index appeared as a key trait to support the performance of the best genotypes and reinforce the plan to focus further studies on plant assimilate partitioning strategies.

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