Yield performance of temperate and tropical rice varieties in the Ord

Siva Sivapalan

Department of Agriculture and Food, Durack Drive, Kununurra, WA, 6743, siva.sivapalan@agric.wa.gov.au

Abstract

Seven temperate and 20 tropical rice varieties, sourced from 9 countries (Australia, USA, Korea, Indonesia, Japan, India, Philippines, China and Vietnam), were evaluated in field trials for their yield performance in the Ord River Irrigation Area, during the dry season between 2009 to 2014. Two irrigation methods were tested, aerobic rice on raised-bed system compared with the traditional flooded system. Other agronomic features tested include date of planting, rate of sowing, rate of basal fertiliser, rate of topdressing, irrigation scheduling (aerobic only), and planting configuration (flooded only). A total of 23 individual trials were conducted over the 6-year period to test different hypotheses. Minimum air temperatures less than 15°C can affect varietal performance. Cold damage during the months of June and July warrants selection of varieties with cold tolerance for this environment, especially for the aerobic rice system. Ponded water provides a 4-8°C advantage over air temperature, thus providing some protection against such cold damage. This has resulted in higher yields under the flooded system. Planting dates, varying from late-February to late-May, can play a crucial role for plants to escape the low temperature damage at critical growth stages. Among the varieties tested, selected tropical varieties yielded higher than the temperate varieties. Yunlu 29 has been identified as the best variety adapted for aerobic rice system in the Ord. NTR 426 was found to outperform all other tested varieties under the flooded system in this environment.

Keywords

Variety × environment interaction, specific/wide adaptation, multi-criteria decision aids, PROMETHEE and GAIA methods

Introduction

Studies into adaptation of rice varieties to a range of environmental conditions are important to select varieties with yield stability and optimum grain production level. Adaptation is a complex process and very difficult to measure. The local environment, in which the rice plants grow, varies significantly from year to year. Crop management factors such as planting date, weed control, fertiliser application, and water management can also influence the growing environment. These factors can modify the length of the crop cycle, from seed to harvest, or the time taken by each variety to reach crop maturity. Variety by environment interaction, that is how each variety interacts with each environment, is the main focus in an adaptation analysis. The highest yielding variety in an environment may not be the preferred variety for that location. A variety's ability to produce consistently high yields, i.e. yield stability, at each location is more important. Since varietal performance is influenced by a range of factors, adaptation analysis is required to understand the complex variety by environment interactions. The overall objective of this analysis is to identify locally adapted rice varieties with good yield stability characteristics for the Ord River Irrigation Area.

Methods

Rice variety trials were conducted at the Frank Wise Institute of Tropical Agriculture at Kununurra in northern WA from 2009 to 2014. Twenty seven varieties were tested over the six years during the dry season, which resulted in 23 environments. Varieties included 7 temperate and 20 tropical varieties, which were sourced from different countries (Table 1). Different environments were created by: the year in which the trials were conducted; irrigation method, raised-bed/flushed/flooded; planting date; rate of top dressing; and rate of basal dressing (Table 1). Variety by environment matrix for grain yield was unbalanced due to not testing all varieties in all environments. Mean grain yield of 27 varieties tested in 23 environments was analysed using preference ranking organization method for the enrichment of evaluations (PROMETHEE) and graphical analysis for interactive aid (GAIA) analysis as described by Sivapalan et al. (2007). Visual PROMETHEE 1.4 software was used for this purpose (VPSolutions 2013). Data for aerobic (raised-bed and flushed) system and flooded system were first analysed separately to identify specific adaptation of varieties

© 2015 *"Building Productive, Diverse and Sustainable Landscapes "*

for each system. Analysis of combined data was performed to identify broad adaptation of varieties for both systems. The PROMETHEE II Complete Ranking based on the net preference flow (Phi) was used to rank the varieties.

Table 1. Number of varieties used in each trial which created a unique environment

Varieties	Origin	Environments*																							
		09-FO-135	10-FO-053	10-FO-082	10-RB-090	10-FU-098	10-FO-098	11-RB-108-050	11-RB-108-100	11-RB-108-200	11-FO-108-050	11-FO-108-100	11-FO-108-200	12-RB-123	12-FO-123	13-RB-112	13-RB-128	13-RB-141	13-FO-112	13-FO-128	13-FO-141	14-RB-137	14-FO-141-525	14-FO-141-310
Temperate																									
Amar	Australia	●	●	●	●	●	●	●	●	●	●	●	●												
oo	Australia	●	●	●	●	●	●	●	●	●	●	●	●	●	●										
Quest	Australia	●	●					●	●	●	●	●	●	●	●										
Doong	Australia	●	●					●	●	●	●	●	●	●	●					●	●				
ara	Australia							●	●	●	●	●	●							●					
Langi	Australia			●	●	●	●							●	●	●	●	●							
Jarrah	Australia													●	●										
Tropical																									
Fin	Australia							●	●	●	●	●	●	●	●										
Lemont	Texas, USA		●	●	●	●	●	●	●	●	●	●	●	●	●										
Tachiminori	Japan		●	●	●	●	●	●	●	●	●	●	●	●	●										
Vandana	India		●	●				●	●	●	●	●	●												
Milyang 23	Korea		●	●				●	●	●	●	●	●												
Muncul	Indonesia		●	●				●	●	●	●	●	●												
Takanari	Japan		●	●				●	●	●	●	●	●	●											
Pandan	Indonesia		●	●				●	●	●	●	●	●	●	●				●	●	●				
Pandan	Indonesia		●	●				●	●	●	●	●	●												
B6144F-MR-	Indonesia							●	●	●	●	●	●	●											
IR72	IRRI, Philippines							●	●	●	●	●	●	●	●										
NTR 426	IRRI, Philippines							●	●	●	●	●	●	●	●				●	●	●		●	●
PSBRC 9	IRRI, Philippines							●	●	●	●	●	●												
ULP R17	Philippines							●	●	●	●	●	●												
Yunlu 29	Yunnan, China							●	●	●	●	●	●	●	●	●	●	●				●			
IR 64	IRRI,													●	●										
NTR 587	Philippines													●	●				●	●	●		●	●
Viet 1	Vietnam													●	●				●	●	●				
Viet 4	Vietnam													●	●										
Viet 5	Vietnam													●	●	●	●	●							

* first two digits represent the year; FO=flooded; FU=flushed; RB=raised-bed; three digits after the alphabet represent calendar day of planting; last three digits represent three different rate of top dressing in 2011 and two rates of basal dressing in 2014. IRRI=International Rice Research Institute.

Results and discussion

GAIA uses Principal Components Analysis and the resulting bi-plots are shown in Figures 1 and 2. Each variety is represented by a point in the GAIA plane. Varieties with similar performance are closer to each other. The position of individual varieties on the bi-plots for the aerobic and flooded systems is different. This is due to the environmental conditions that prevailed in the aerobic system being different to that under the flooded system. Since most axes for the environments are aligned to the right, most favoured varieties are located on the right and least favoured ones on the left. There is no clear separation of temperate varieties from tropical varieties for their performance in both aerobic and flooded systems. In decreasing order, varieties Yunlu 29, Tachiminori, B6144F-MR-6, Quest and Langi were identified as best adapted to the aerobic system. Similarly, varieties NTR 426, Jarrah, ULP R17, Tachiminori and PSBRC 9 were identified as best adapted to the flooded system, in that order. Quest, Langi and Jarrah are temperate varieties from NSW. Among the top performing five varieties, Tachiminori is the only variety common for both systems.

Considering all the varieties tested, the rank order shows that selected tropical varieties seem to outperform most of the temperate varieties. It has been observed that night time air temperatures below 15°C can negatively influence growth and yield of rice at this location. However, ponded water in the flooded system can provide some degree of protection against such low temperatures. Therefore, cold sensitive varieties, such as NTR 426 and NTR 587, are ranked lower for the aerobic system and ranked higher for the flooded system. They are positioned on the right for the flooded system but on the left for the aerobic system.

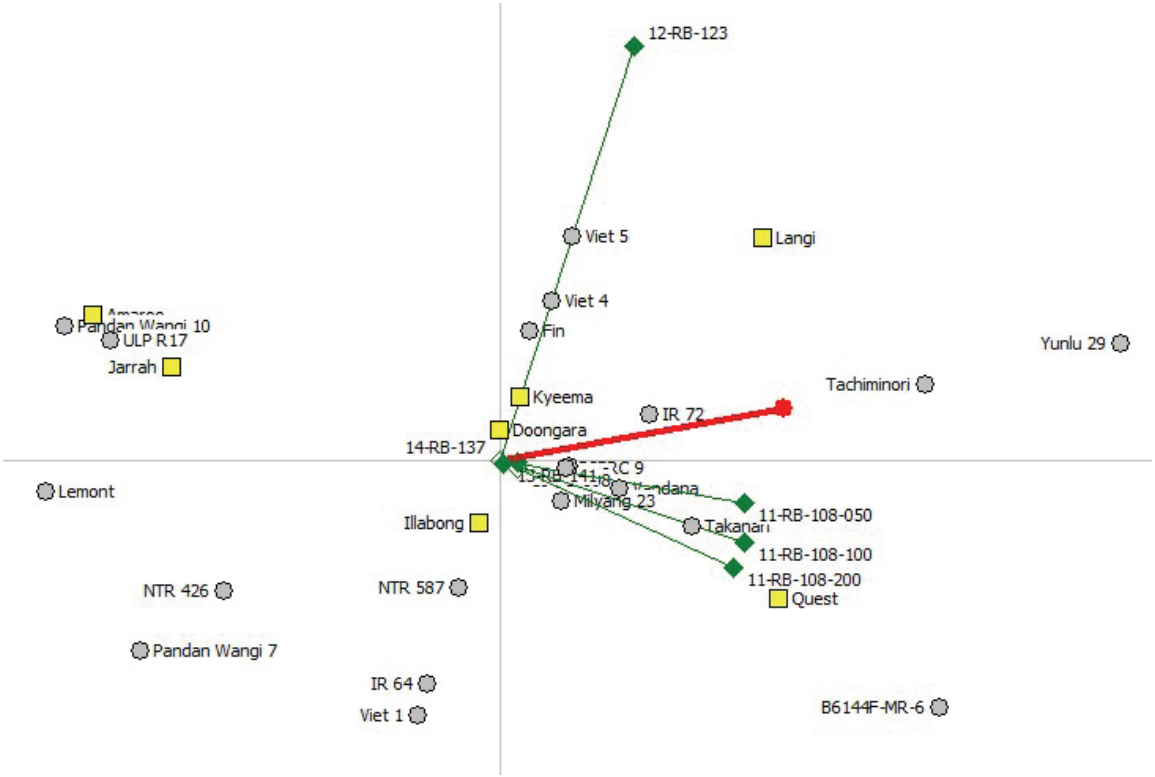

Figure 1. GAIA plots of varieties and environments for aerobic system. Green=environments, yellow=temperate varieties, grey=tropical varieties, red=decision axis.

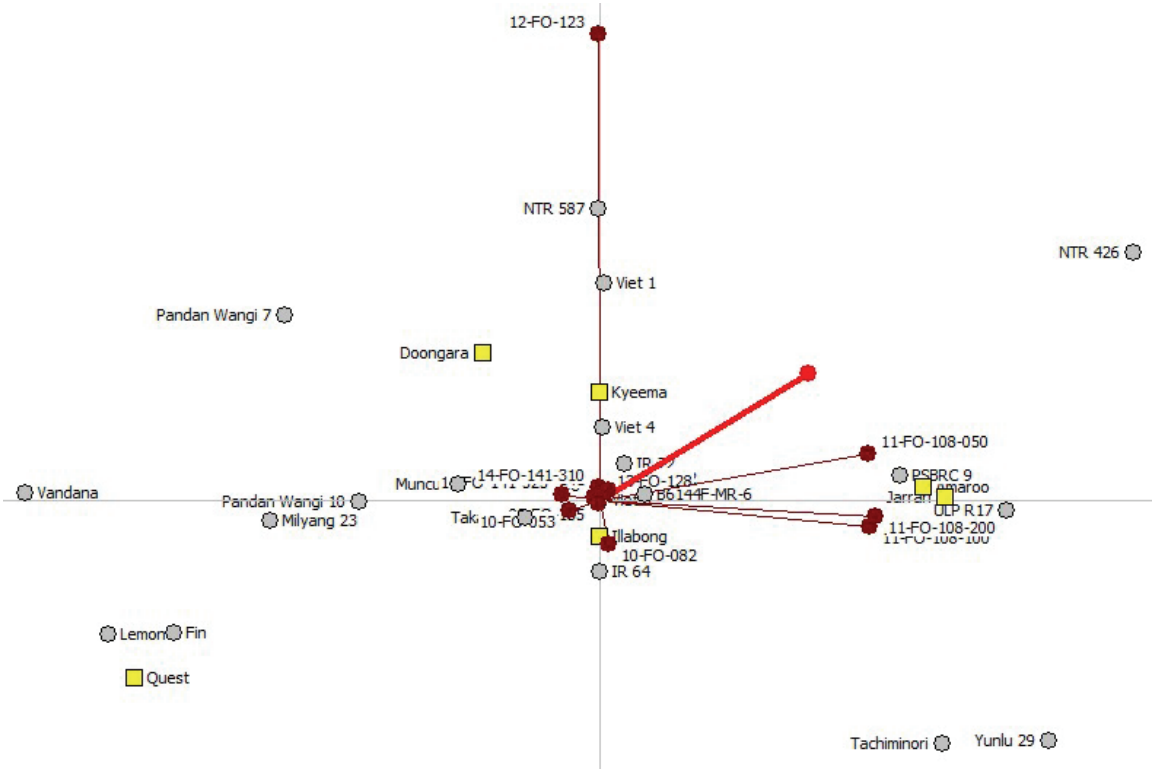

Figure 2. GAIA plots of varieties and environments for flooded system. Brown=environments, yellow=temperate varieties, grey=tropical varieties, red=decision axis

Each environment in Figures 1 and 2 is represented by an axis drawn from the centre of the GAIA plane. The orientation of these axes indicates how closely the environments are related to each other. For example, the three rates of top dressing in 2011 created environments which were similar for both aerobic and flooded systems. However, the environments in 2011 and 2012 were different as their axes are located away from each other. Date of planting failed to identify a pattern among the environments. This may be due to other factors, such as low night temperatures, which dominated each variety's performance. The length of the environment axis is also relevant; the longer an axis the more discriminant the environment. It is the case in 2011 and 2012 when the number of varieties tested varied from 17 to 20 which were higher than in other environments (Table 1). Thus the environments in 2011 and 2012 were more discriminant in this investigation. The orientation of an environment axis indicates where the best varieties for this environment are located. Note that varieties Kyeema, Illabong, IR 64 and Viet 4 were tested only in 2012, therefore they are aligned with these environment axes. Other notable cases are where Takanari and Quest which align with environment axes 11-RB-108-100 and 11-RB-108-200, respectively. This may suggest that Quest requires higher rate of top dressing than Takanari in the aerobic system.

The decision axis (thick red axis in Figures 1 and 2) is a representation of the weighting of the environments. Thus shorter decision axes are less reliable. The orientation of the decision axis indicates which environments are in agreement with the PROMETHEE rankings and which are not. The top ranked varieties Yunlu 29 and Tachiminori are located along the decision axis for the aerobic system, and NTR 426 for the flooded system. These varieties exhibit good yield stability across a range of environmental conditions. A combined analysis of aerobic and flooded systems could identify varieties adapted to both systems (Yunlu 29, Tachiminori, B6144F-MR-6, Langi and PSBRC 9 in that order) at the expense of maximum potential yield achievable in each environment. Therefore, for economic reasons, varieties with specific adaptation to each system must be considered rather than broad adaptation for both systems. Therefore, among the tested varieties, Yunlu 29 for the aerobic system and NTR 426 for the flooded system seem better varieties suited for the Ord River Irrigation Area. Grain quality must be tested before undertaking large area production with the selected varieties.

Conclusion

The yield performance of temperate and tropical rice varieties tested in this study was influenced by the environmental conditions imposed by factors such as growing season, water management, date of planting and basal and top dressing. Aerobic growing system was found to be completely different compared with flooded system in discriminating the varieties. Broad adaptation of varieties for both systems was considered as not preferred for economic reasons. Varieties with specific adaptation to each system have been identified for the Ord River Irrigation Area. Varieties originated from tropical regions might be better suited for this region compared with varieties from the temperate regions. Cold air temperatures during the night is a major issue which may impact the selection of appropriate varieties with cold tolerance. Grain quality of each variety under different environmental conditions needs to be evaluated before undertaking commercial plantings in the region.

Acknowledgements

Financial assistance from Rural Industries Research and Development Corporation (RIRDC) and Rice Research Australia Pty Ltd (RRAPL), technical advice from Peter Snell (DPI, NSW) and Russell Ford (RRAPL), and assistance from Mark Warmington (DAFWA) are gratefully acknowledged.

References

Sivapalan S, Batten G, Goonetilleke A and Kokot S (2007). Yield performance and adaptation of some Australian-grown rice varieties through multivariate analysis. Australian Journal of Agricultural Research 58, 874–883.

VPSolutions (2013). Visual PROMETHEE 1.4 Manual. 152 pages, published September 5, 2013. http://www.promethee-gaia.net/assets/vpmanual.pdf. Accessed 19 March 2015.