

Crop establishment options for lowland irrigated rice in relation to weed infestation and grain yield

(Perkaitan pilihan penapakan tanaman untuk sawah padi berpengairan dengan infestasi rumpai dan hasil padi)

M. Azmi* and D.E. Johnson**

Key words: weed management, water seeding, wet seeding, drum seeding, transplanting

Abstract

Field experiments were conducted over three consecutive seasons to determine the effect of crop establishment methods on rice yield and weed growth. The options included wet seeding (WS), dry seeding (DS), drum seeding (WDS), seedling broadcasting (BCS), water seeding (WTS) and manual transplanting (TPR). Population densities of weedy rice were substantial (mean density 35 panicles/m²) in the main season 2005/06 but considerably lower in off season 2006 and main season 2006/07. Across seasons, in the unweeded plots, weeds caused 37% rice yield loss and there were no significant interactions with establishment method. In the three seasons, rice yields from BCS did not differ from TPR under weed free condition. In each season, the lowest yields were from DS. In off season 2006, yields from WS and WTS were not different from TPR and BCS and in main season 2006/07, yields from WS, WDS, WTS, TPR and BCS were almost similar. In the main season 2005/06, weedy rice infestations were highest in the DS and WS and in these treatments panicle densities of weedy rice were more than twice those in BCS and almost three times those in WTS. In the subsequent seasons weedy rice infestations were much lower, irrespective of treatments. Weed dry weights recorded in the unweeded plots in the off-season 2006 and main season 2006/07 revealed weed growth to be greatest in DS followed by WS and least in WTS. Water seeding, or the broadcast of pre-germinated seed into standing water (5–10 cm deep), significantly reduced weedy rice populations and other weed growth compared to DS or WS and gave yields that were comparable to TPR in two out of three seasons. Where water supplies are adequate, with soils having low infiltration rates and well-levelled fields, WTS appears to be an effective method of crop establishment to address the problems of serious weedy rice or grassy weeds infestations.

*MARDI Station, Seberang Perai, Locked Bag 203, 13200 Kepala Batas, Pulau Pinang, Malaysia

**International Rice Research Institute, DAPO Box 7777, Manila, Philippines

Authors' full names: Azmi Man and D.E. Johnson

E-mail: azmiman@mardi.gov.my

©Malaysian Agricultural Research and Development Institute 2009

Introduction

Increasing costs of labour and the widespread availability and use of selective herbicides have led to a major shift from conventional transplanting method to direct seeding in countries like Malaysia, Vietnam, Thailand, Sri Lanka and the Philippines (Azmi et al. 2005). Currently, about 23% of the global rice area is direct-seeded (Rao et al. 2007). Direct seeding refers to the rice crop being established from seeds sown in the field rather than transplanting seedlings. The introduction of direct seeding in Malaysia, however, has resulted in a shift in the weed species to the grassy weeds such as weedy rice (*Oryza sativa* complex), barnyard grass [*Echinochloa crus-galli* (L.) Beauv.], red sprangletop [*Leptochloa chinensis* (L.) Nees.] and wrinkle grass (*Ischaemum rugosum* Salisb.) that are difficult to control (Azmi et al. 2005). Weedy rice, in particular, has become an important constraint in DS rice in Malaysia. Infestation of rice fields by weedy rice results in economic losses because of reduced quality and lower yields. In addition, there is no selective herbicide that can be used against weedy rice.

While labour shortages have spurred the transition to either dry or wet direct seeding in many places, there are a number of different ways by which lowland rice can be established. Dry seeding (DS) describes the sowing of dry seeds on dry (unsaturated) soils. Wet seeding (WS), however, has been more widely adopted in Malaysia and this involves broadcast sowing pre-germinated seed onto wet (saturated) puddle soils either by hand or with “backpack” motor blowers.

A modification of WS adopted in Vietnam is drum seeding (WDS) in which a hand-drawn seeder drops pre-germinated seeds in rows on puddle soils to give a more homogenous rice plant stand than is commonly possible with broadcasting. The sowing in rows also facilitates interrow weeding by hand.

Water seeding (WTS) describes the broadcasting of pre-germinated seeds into standing water and this has been introduced

in Malaysia in an effort to overcome the problems of grassy weeds especially weedy rice. For effective WTS, rice seed must be heavy enough to sink below standing water to enable anchorage at the soil surface. Modern techniques of water-seeding include aerial sowing using aircraft in the United States and Australia, seed broadcasting using tractor-mounted seeders in Italy (Rao et al. 2007).

Seedling broadcasting (BCS) is practised in China (Tang 2002) and this involves broadcasting small bunches of seedlings (usually 2–4 plants) on to puddled and drained soil. Some soil remains attached to the roots of the seedlings being broadcast and with the momentum of the fall allows the base of the seedling to slightly penetrate the mud. After a few days, new roots develop and the plants upright themselves.

This paper reports a field study to evaluate the impacts of several rice establishment methods on weed infestations, especially weedy rice and rice yield.

Materials and methods

The experiment was conducted at MARDI Rice Research Station, Seberang Perai, Malaysia over three cropping seasons [main season 2005/06 (MS06), off season 2006 (OS06) and main season 2006/07 (MS07)]. The field used for the experiment was heavily infested by weedy rice in the season prior to the first experiment (off season 2005). These studies were carried out using recommended cultural practices (Anon. 2002). Soil fertility status of experimental site as shown in *Table 1*.

Table 1. Soil fertility status of experimental site

pH	4.73
Organic carbon	1.06%
Nitrogen	0.18%
Soluble Phosphorous	7.90 ppm
Cation Exchange Capacity	8.42 me (%)
Ex Potassium	0.20 me (%)
Ex Sodium	0.45 me (%)
Ex Calcium	2.08 me (%)
Ex Magnesium	1.00 me (%)

Six rice crop establishment methods were tested:

- 1) DS – dry rice seeds (120 kg/ha) were broadcast on the soil surface prior to the final tillage
- 2) WS – pre-germinated seeds (120 kg/ha) were broadcast onto saturated puddled soil
- 3) WTS – pre-germinated seeds (150 kg/ha) were sown directly into 5–10 cm water depth
- 4) WDS – pre-germinated seeds (24-h soaking and 12-h incubation to limit root length) are sown onto puddled soil one day after land levelling, using a drum seeder. The distance between rows was 20 cm. Water was drained before seeding and the soil was firm enough to support the seeder and to make shallow furrows for sowing; the seed rate was at 70 kg/ha
- 5) Transplanting (TRP) under 5–10 cm water depth – manual transplanting of 20-day-old seedlings
- 6) BCS – 15-day-old rice seedlings, with some soil still attached to the roots, were broadcast onto puddled soil

At the start of each season, dry tillage was carried out 15 days after the harvest of the previous rice crop. This was followed by wet tillage of saturated soil 10 days later for treatments WS, WTS, WDS, TPR and BCS. Soil levelling was done 7 days after wet tillage using pedestrian tractor following conventional farmer practices. A total of 60 plots, each measuring 7 m x 8 m, were laid out in a split-plot design with five replications; each plot was isolated by 0.5 m high levees to prevent movement of irrigation water. A 1.0 m wide channel between replicates was used for irrigation and drainage purposes.

The irrigation regimes differed for the various establishment methods. In DS, the plots were irrigated at 10 days after sowing (DAS) to a depth of 5–10 cm and the flooding maintained at this depth. In WS and WDS, the plots were irrigated at 7 DAS to a depth of 5–10 cm and the flooding

maintained at this depth. In BCS, the plots were irrigated at 5 days after broadcasting to a depth of 5–10 cm depth and the flooding maintained at this depth. In TRP and WTS the water was maintained at the 5–10 cm depth.

Each crop establishment method was tested under two weed control regimes i.e. weed free (W1) and unweeded conditions (W0). In MS06, weeds in W0 plots other than weedy rice were controlled with a combination of cyhalofop butyl (100 g ai/ha) + bensulfuron (50 g ai/ha) applied at 12 DAS or transplanting. The same herbicides were applied in W1 plots followed by manual weeding at 40 DAS or transplanting. In OS06 and MS07, however, these herbicides were applied in W1 plots only and then followed by bentazon/MCPA (2 litres product/ha) applied at 40 DAS or transplanting and no manual weeding was undertaken. Weeds were allowed to emerge and grow in association with the rice crop in W0 plots and no herbicide application or manual weeding was undertaken.

Rice variety MR 219 was used in this study. The equivalent of 100 kg/ha N and 40 kg/ha P₂O₅ and K₂O kg/ha, with two-thirds of the N and all the P and K applied at 15 DAS or transplanting in all plots. The remaining N was applied at rice panicle initiation stage. Trebon (ethfenprox 10%) and sumicidin (fenvalerate 3%) were used for insect control. Drat (chlorophacinone) mixed with rice grains as rat bait was placed at 3 m intervals on the bund along the perimeter of the experimental plot 1–2 days before sowing.

The number of weedy rice panicles/plot were recorded before harvest for MS06 study. In OS06 and MS07, dry weight of weeds (excluding weedy rice) were recorded at 60 DAS from four 1 m² quadrats per unweeded plot placed outside a central 5 x 5 m area reserved for yield determination. Rice yield data were taken from the central area and corrected to 14% moisture content.

Results and discussion

Across the seasons, the percentage of yield losses due to weeds were least in WTS and BCS and greatest in DS. In the plots with weed control (W1), rice yields were greatest in BCS followed by TPR, WTS, WS, WDS and DS with yields respectively at 3.96, 3.92, 3.73, 3.31, 2.95 and 2.39 t/ha (SED \pm 0.20). There were, however, interactions between the treatment effects and seasons ($p < 0.01$).

In MS06, BCS gave the highest yield irrespective of the level of weed control and this was followed by TPR and WTS methods (Figure 1). WDS, WS and DS resulted in a similar trend in yields in both the unweeded and the weed free plots. Across the establishment treatments, the rice grain yield loss due to competition with weedy rice was 40%. There were, however, significant interaction effects ($p < 0.001$) with yields in DS and WS losing about 60% to weed competition in W0 compared to W1, while losses in TPR and BCS were 30% or less. Highest panicle density of weedy rice was found in the DS plots, followed by WS and WTS had the least. There was a five fold difference in the panicle densities between DS and WTS. The densities in the WDS, TPR and BCS were almost similar. Correlation between the weedy rice panicle densities and rice yield losses was not significant at the 5% level ($r = 0$, $n = 30$).

Across establishment methods in OS06, rice grain yield in the unweeded (W0) plots were only 60% of those (2.1 v. 3.5 t/ha) where weeds were controlled (Figure 1). Yield losses were greatest in the DS and WDS plots, and the highest grain yields were from TPR and WTS in weed free plots. Weedy rice infestations were much lower (experiment mean = 1.4 panicles/m²) compared to the previous crop (35 panicles/m²). There were no significant differences in the density of weedy rice panicles or the weed biomass between the rice establishment treatments.

In MS07, across establishment methods, rice yield were 33% lower in W0

than in W1. Rice grain yields were least for DS irrespective of whether weeds were controlled or not, while rice yields for WTS, WDS, TPR, BCS and WS were comparable within either W1 or W0 (Figure 1). Weed biomass was greatest within DS and WS and least in WTS.

Rice establishment method had a considerable influence on weed growth. The presence of standing water (5–10 cm depth) in WTS and TPR during early crop establishment significantly reduced weed dry weight. Greater weed infestations were associated with DS in particular and this was likely related to the aerobic soil conditions prevailing early in the crop growth. Flooding reduced weed infestations in rice and for example, WTS had one third the weed dry weight (70.3 g/m²) of DS (222.8 g/m²) in OS06 (Figure 1). Similar trends were found in the subsequent season (Figure 1). Such effects however are species-specific and while flooding, as in WTS and TPR, may suppress the incidences of some species and may lead to a higher prevalence of aquatic weeds (Baki and Azmi 1994). Further, Ho (1998) cited that the use of WS for crop establishment in the Muda rice granary of Peninsular Malaysia as a primary reason for the increase in weed infestation.

Prior to the introduction of direct-seeding in early 1980s, weed infestation was less problematic among farmers who at that time were mainly transplanting rice seedlings into standing water followed by hand weeding. Baki and Azmi (1994) noted higher incidence and greater intensity of grasses such as *E. crus-galli*, *L. chinensis* and *I. rugosum* with continuous WS compared with the transplanting. Reports of less weed growth with TPR were made by De Datta (1979) from studies in India where full-season competition reduced grain yields 11% in TPR, 20% in WS rice, and 46% in DS rice.

DS, WS and WDS necessitate that the soil conditions to remain aerobic until the rice seedlings are established (i.e. 2–3 leaf stage) which also provides an opportunity

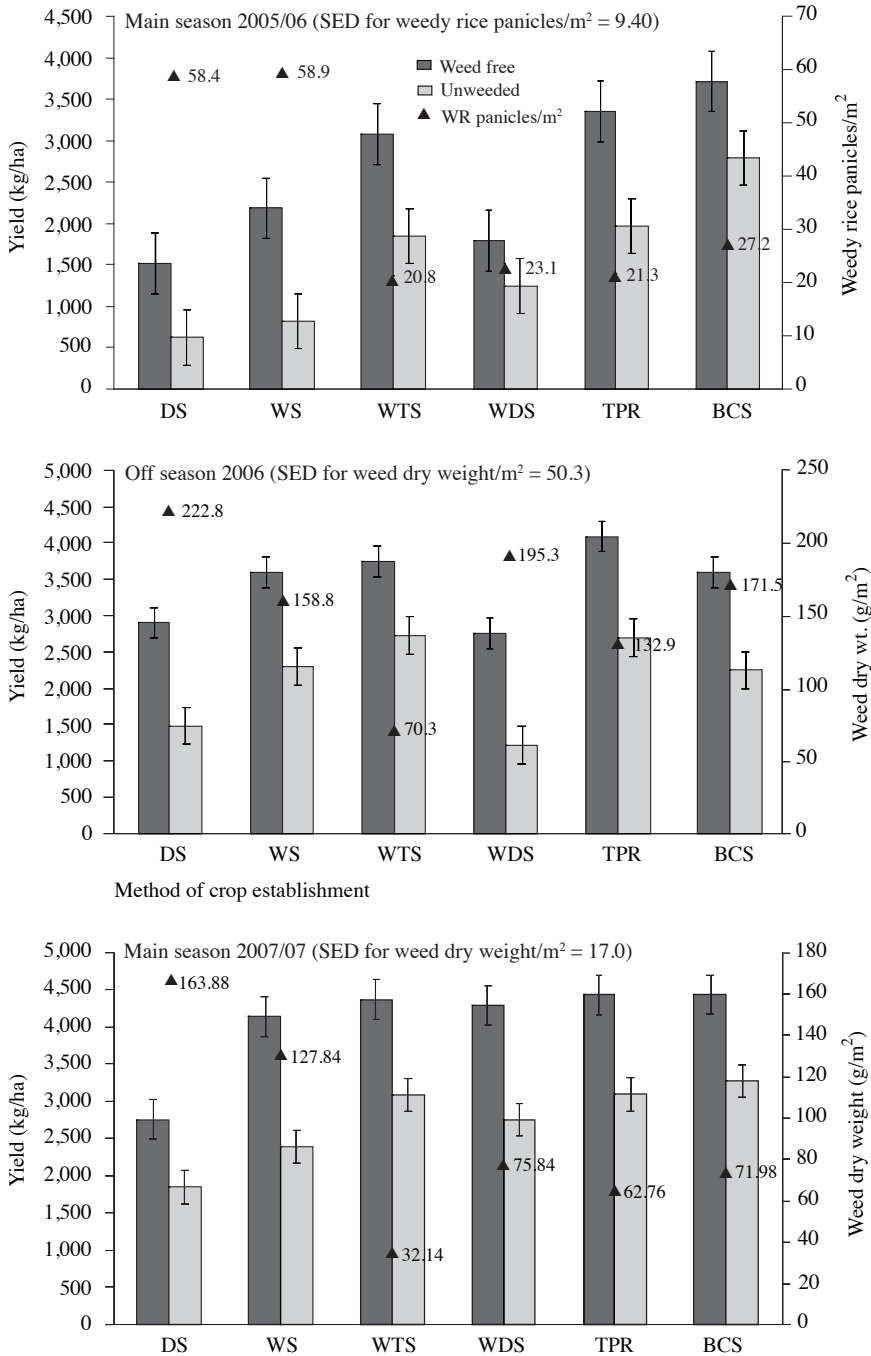


Figure 1. Effect of crop establishment methods on weed infestation and rice yield, main season 2005/06, off season 2006 and main season 2006/07, MARDI Seberang Perai (SED for weed dry weight/m² = 17.0). The bars indicate Standard Error

for a wide range of weeds to emerge and compete with the crop. Weed competition in such conditions can be severe and, if not controlled, can result in serious yield losses. The use of selective herbicides rather than hand weeding is almost indispensable under Malaysian conditions where labour costs are relatively high. Manual weeding is very difficult and time consuming especially under broadcast DS and WS techniques where the rice plants are randomly placed. WDS, however, offers the advantages that it is easier to monitor the growth of weeds, as the crop is sown in rows, and this provides easier access for weeding and allows the use of hand tools such as the hoe or push weeder. In contrast, the anaerobic conditions in WTS and TPR methods are likely to reduce the weed growth.

The high cost of transplanting is the main disadvantage and WTS may be a good alternative particularly in weedy rice infested areas. WTS, however, requires good land preparation, level fields and better management of irrigation water to produce acceptable crop establishment. The advantage of WTS is water from rainfall can be retained for water seeding, which reduces wastage compared to WS where water is drained before the pre-germinated seeds are broadcast. Grassy weeds and some sedges can be suppressed by standing water under WTS and TPR system resulting in reduced herbicide application and environmental pollution. In addition, WTS can prevent damages caused by rats and birds on pre-germinated seeds

Water availability and cost of labour are major determinants of choice in crop establishment methods. Pandey and Velasco (2005) suggest a low wage rate and adequate water supply favour transplanting. When the water supply is plentiful and the wage rate is high, WS is more to be an option of choice. Whether WS is by drum seeding or broadcasting will depend in part on the availability of labour and the need for manual weeding subsequent to herbicide application.

With WDS, some manual weeding is possible and also farmers can employ practices such as a push weeder to reduce the labour costs. As selective herbicides are not available, the presence of weedy rice has increased the need for some supplementary hand weeding in order to reduce infestations. Likewise, the widespread infestation of weedy rice requires researchers and farmers use alternative cultural measures to help reduce weedy rice infestations. In these respect, these studies also demonstrate that WTS provides an alternative to TPR of rice in weedy rice infested areas and, in suitable conditions, can provide an effective means of crop establishment.

Acknowledgement

The authors are grateful to Mr Chew See Eng for helping implementing the experiments. The project was funded by MARDI under the R-IE032-0903 Research Grant, Ministry of Science, Technology and Environment, Malaysia and Irrigated Rice Research Consortium of the International Rice Research Institute (Kod 80202).

References

- Anon. (2002). *Manual teknologi penanaman padi berhasil tinggi*, 48 p. Serdang: MARDI
- Azmi, M., Chin, D.V., Vongsaraj, P. and Johnson, D.E. (2005). Emerging issues in weed management of direct-seeded rice in Malaysia, Vietnam, and Thailand. *Proceedings of the World Rice Research Conference*, (Theme: Rice is life: scientific perspectives for the 21st century), (Toriyama, K., Heong, K.L. and Hardy, B., eds.), p. 196–198. Los Banos: IRRI and JIRC
- Baki, B.B. and Azmi, M. (1994). Integrated management of paddy and aquatic weeds in Malaysia: Current status and prospects for improvement. In: *Integrated management of paddy and aquatics weeds in asia*, (Shibayama, H., Kiritani, K. and Baypeterson, J., eds.), p. 78–86. Wallingford, UK: CABI
- De Datta, S.K. (1979). Weed problems and methods of control in tropical rice. *Proc. symposium on weed control in tropical crops*, p. 9–44. Weed Science Society of the Philippines Inc., & Philippines Council for Agriculture & Resources Research Publication

- Ho, N.K. (1998). The rice agroecosystem of the Muda Irrigation Scheme: An overview. In: *Rice agroecosystem of the Muda Irrigation Scheme, Malaysia* (Nashriyah, B.M., Ho, N.K., Ismail, B.S., Ahyaudin, B.A. and Lum, K.Y., eds.), 24 p. Kuala Lumpur: MINT and MADA
- Pandey, S., and Velasco, L. (2005). Trends in crop establishment methods in Asia and research issues. Proceedings of the World Rice Research Conference, (Theme: Rice is life: scientific perspectives for the 21st century), (Toriyama, K., Heong, K.L. and Hardy, B., eds.), p. 178–181. Los Banos: IRRI and JIRC
- Rao, A.N., Johnson, D.E., Sivaprasad, B., Ladha, J.K. and Mortimer, A.M. (2007). Weed management in direct-seeded rice. *Advances in Agronomy* 93: 153–255
- Tang, S. (2002). Seedling broadcasting in China: an overview. In: *Direct seeding: Research and opportunities*, (Pandey, S., Mortimer, M., Wade, L., Tuong, T.P., Lopez, K. and Hardy, B., eds.), p. 177–184. Los Banos: IRRI

Abstrak

Kajian ladang dijalankan selama tiga musim berturut-turut untuk menentukan kesan penapakan tanaman terhadap infestasi rumpai dan hasil padi. Kaedah penapakan tersebut ialah tabur terus basah (WS), tabur terus kering (DS), tabur terus drum (WDS), tabur terus anak benih (BCS), tabur terus dalam air (WTS) dan mencedung (TPR). Kepadatan populasi padi angin adalah tinggi (purata 35 tangkai/m²) pada musim utama 2005/06 tetapi rendah pada luar musim 2006 dan musim utama 2006/07. Semasa musim-musim tersebut, rumpai menyebabkan kerugian hasil 37% pada petak tanpa kawalan dan tidak berlaku interaksi dengan kaedah penapakan. Dalam ketiga-tiga musim, hasil padi BCS tidak berbeza dengan TPR pada keadaan bebas daripada rumpai. Pada setiap musim, hasil terendah ialah DS. Pada luar musim 2006, hasil daripada WS dan WTS tidak berbeza dengan TPR dan BCS dan pada musim utama 2006/07, hasil daripada WS, WDS, WTS, TPR dan BCS hampir sama. Pada musim utama 2005/06, serangan padi angin adalah tinggi pada DS dan WS dengan bilangan tangkai padi angin dua kali daripada BCS dan hampir tiga kali daripada WTS. Pada musim berikutnya, serangan padi angin berkurangan bagi semua rawatan. Berat kering rumpai pada luar musim 2006 dan musim utama 2006/07 pada petak tanpa kawalan rumpai menunjukkan serangan rumpai adalah kuat pada DS diikuti WS dan paling kurang WTS. Menabur benih pracambah dalam air bertakung (5–10 cm dalam) semasa penapakan tanaman dapat mengurangkan populasi padi angin dan pertumbuhan rumpai lain berbanding dengan DS atau WS dan memberikan hasil setanding dengan TPR pada dua daripada tiga musim. Sekiranya bekalan air mencukupi, dengan tanah mempunyai kadar infiltrasi yang rendah dan rata, WTS akan menjadi kaedah penapakan yang berkesan untuk mengatasi masalah serangan padi angin ataupun rumpai daun tirus yang serius.