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Water Productivity of Irrigated Rice under Transplanting, Wet Seeding and Dry Seeding Methods of Cultivation

N. S. Murali[1] & R. Thabonithy

Keywords : Land preparation - Percolation - Seepage - Labour requirement.

Summary

Water productivity (WP) of irrigated lowland rice was determined during the 1994 dry (January to May) and wet (August to December) seasons on a heavy clay acid sulphate soil. Treatments consisted of three cultivation methods: transplanted rice, pregerminated seeds broadcasted on puddled soil (wet seeding) and dry seeds broadcasted on unpuddled soil (dry seeding). In wet and dry seeded plots, continuous standing water condition was initiated 17 days after sowing.

Total water requirement for rice production was highest in transplanted plots (755 mm in wet season and 1154 mm in dry season) and was lowest in dry seeded plots (505 mm in wet season and 1040 mm in dry season). Dry seeding required no water for land preparation but transplanting and wet seeding methods required 18 - 20 % of total water requirement in dry season and 27 - 29 % in wet season. Total percolation was maximum (99 mm in wet season and 215 mm in dry season) in dry seeding method and was minimum (62 mm in wet season and 94 mm in dry season) in transplanting method. In dry and wet seeding methods, daily percolation gradually decreased with the age of the crop. Total seepage loss did not show any significant difference between the cultivation methods in the two seasons. Grain yield was not affected by the three cultivation methods in both seasons. Water productivity (the ratio between grain yield and total amount of water used in production) was 3.5 - 4.1 kg ha^{-1} mm^{-1}, 3.8 - 4.4 kg ha^{-1} mm^{-1} and 4.1 - 5.5 kg ha^{-1} mm^{-1} in transplanted, wet seeded and dry seeded rice, respectively. Labour requirement for land preparation and sowing was maximum in transplanted (219 - 226 man-hours ha^{-1}) followed by wet (104 -112 man-hours ha^{-1}) and dry seeded (94 - 99 man-hours ha^{-1}) methods. However, in wet season extra labour (77 man-hours ha^{-1}) was required for weeding after crop establishment in dry and wet seeding methods. Crop maturity was 20 days earlier in wet and dry seeding methods compared to transplanting. Dry seeding was considered the best rice cultivation method on heavy clay soils

Résumé

La productivité de l'eau dans l'irrigation de la basse terre pour le riz a été determinée pendant la saison sèche (de janvier à mai) et pendant la saison humide sur sol lourd argileux acide. Les traitements ont consisté en trois types de culture: le riz transplanté, semis sur sol bourbeux (semailles humides) et semis sur sol non bourbeux (semailles à sec). Sur les parcelles semées mouillées et sèches, une condition de submersion ininterrompue a été installée 17 jours après les semailles.

Le besoin total en eau de la production du riz a été meilleur sur les parcelles avec riz transplanté (755 mm pendant la saison humide et 1.154 mm pendant la saison sèche) et elle était la plus basse dans les parcelles avec les semailles à sec (505 mm pendant la saison humide et 1.040 mm pendant la saison sèche). Les semis à sec n'ont pas exigé d'eau pour la préparation du sol, mais les méthodes de transplantation et de semis à sec ont exigé 18 - 20 % d'apport d'eau pendant la saison sèche et 27 - 29 % pendant la saison humide. La percolation totale a été maximale (99 mm pendant la saison mouillée et 215 mm pendant la saison sèche) avec les semis à sec et minimale (62 mm pendant la saison humide et 94 pendant la saison sèche) avec la méthode par transplantation. Dans les méthodes de semis secs et mouillés la percolation journalière a diminué peu à peu avec l'âge de la culture. La perte totale par suintement n'a pas montré de différence importante entre les méthodes de culture pendant les deux saisons. Le rendement de la récolte n'a pas été influencé par les trois méthodes de culture pendant les deux saisons. La productivité de l'eau (les rapports entre le rendement en grains et la quantité totale d'eau utilisée dans la production) a été de 3.5 - 4.1 kg ha^{-1} mm^{-1}, 3.8 - 4.4 kg ha^{-1} mm^{-1} et 4.1 - 5.5 ha^{-1} mm^{-1} pour le riz transplanté et pour les semis mouillés et à sec respectivement. L'exigence de travail pour la préparation du sol et pour les méthodes des semis étaient au maximum pour la transplantation (219 - 226 heures de travail ha^{-1}) suivies par les semis mouillés (104 - 112 heures de travail ha^{-1}) et les semis

[1] Asian Institute of Technology. IREM Program, GPO Box 2754, Bangkok 10501, Thailand.
Present address: Danish Institute of Plant and Soil Science, Lottenborgvej 2, 2800 Lyngby, Denmark.
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with expanding type of clay minerals to save water and labour cost.

à sec (94 -99 heures de travail ha-1). Cependant au cours de la saison humide un travail supplémentaire (77 heures de travail ha-1) a été nécessaire pour désherber après l'établissement de la récolte dans les méthodes de semis mouillés et à sec. La maturité de la récolte a été plus précoce de 20 jours avec les méthodes de semis mouillés et à sec en comparaison avec la transplantation. La meilleure méthode de culture du riz sur sol lourd et argileux avec argiles gonflantes a été la méthode de semis à sec pour économiser l'eau et le coût de travail.

Introduction

In lowland rice cultivation, puddling of soil has been practised to increase soil water holding capacity, reduce percolation and seepage, and control weeds. However, it is time consuming and needs large amounts of water, energy and labour. Furthermore, due to the destruction of soil structure, puddling is undesirable for crops that follow lowland rice (11). On the other hand, dry seeding cultivation (broadcasting seeds onto unpuddled, levelled soil and then maintaining ponded water condition from 3-4 leaf stage) may be suitable for clay soils with expanding type of clay since expansion of clay lattice could reduce losses by percolation and seepage. Furthermore, dry seeding method require less labour during preparatory cultivation since puddling is not required. Hence, to investigate the suitability of dry seeding cultivation method on heavy clay soil and to determine and compare the water productivity (WP) of transplanted, wet seeded and dry seeded rice, field experiments were conducted during two consecutive seasons.

Material and Methods

Field experiments were conducted at the Regional Experimental Centre, AIT, located 14°04'N and 100°30'E with an elevation of 2.27 m above mean sea level. The soil is a heavy clay (72% clay) acid sulphate soil with smectite clay mineral (8). There were 14 rainy days with a total of 204 mm precipitation during the dry season (January - May 1994) while during the wet season (August - December 1994) the number of rainy days was 21 with a total of 358 mm precipitation. Minimum and maximum temperatures ranged from 19.8 - 26.3 °C and 31.4 - 38.2 °C in dry season and they were 16 - 25 °C and 29 - 34 °C in wet season.

Experimental treatments in dry and wet seasons consisted of three cultivation methods : i) transplanted rice in puddled soil (transplanting); ii) pregerminated seeds broadcasted on puddled soil (wet seeding); and iii) dry seeds broadcasted on unpuddled soil (dry seeding). High yielding Thai rice cultivar Suphanburi-90 from the Suphanburi Rice Research Station was used in both seasons. The experiment was laid out as a completely randomised design with four replicates in dry season and as a randomised block design with six blocks in wet season. Each plot was of 10 m × 10 m and 13 m × 10 m in dry and wet seasons, respectively. In both seasons, experiments were conducted on the same location. Bunds separating dry seeded plots from wet or transplanted plots were made water tight to prevent seepage by installing 0.8 mm plastic sheets to a depth of 250 mm all along the length of the bund. Earlier study on the site has shown that the method is effective in preventing seepage across bunds (9).

Wet seeded and transplanted plots were individually flooded prior to puddling. Nursery bed of 25 m^2 for transplanted rice was prepared separately and pregerminated seeds were sown. Transplanting at a spacing of 250 × 250 mm with two seedling per hill was done in puddled plots when the seedlings were 26 days old. For wet seeding, pregerminated seeds were sown at the rate of 110 kg (dry seeds) ha^{-1} on puddled soil after draining the standing water. Plots allocated for dry seeding were sown at the rate of 110 kg (dry seeds) ha^{-1}. Sowing in the main field or nursery was done on the same day in all three methods. After transplanting, permanent ponding water was maintained around 30 mm for 5 days and thereafter a depth of 50 mm. When wet and dry seeded rice reached the 3-4 leaf stage (17 days after sowing - DAS) permanent standing water (50 mm depth) was maintained. During seedling establishment period (17 days) in wet season, no irrigation was given as there were two precipitations. However, in dry season two irrigations were given. Nitrogen and phosphorous were applied at the Department of Agriculture, Thailand, recommended rates (30 kg N ha^{-1} plus 16.25 kg P ha^{-1} as basal and 32.8 kg N ha^{-1} as top dressing applied a week before panicle initiation). Weeds were controlled by a single application of herbicide Propanil (6 ml l^{-1}) 13 DAS or by hand weeding.

Measurements for total water requirement, percolation and seepage losses were taken daily. Water application to each plot for irrigation and land preparation was made from the tertiary irrigation channel using 2 - 3 plastic hose pipes of 50 mm Ø and 2 m long. The volume of water applied was calculated from the hydraulic head difference between the plot and the irrigation channel, application duration and rate of discharge. Total amount of water applied included water for saturation, initial flooding, percolation and evapotranspiration (ET) from the main field and nursery. On the irrigation day, readings were taken before and after irrigation. Sloping gauges were used to measure daily total water loss and N type meters to measure losses through ET and percolation (14). For measurement of percolation, a quick percolation measuring apparatus was used (14). The apparatus measured percolation at a location as a variation in water volume over a short time. Measurements were made at 2-3 locations in each of the plots. Border seepage was calculated from the difference in the readings of slope gauge and N type meter. Results were normalised to the total length of bunds in each plot since the number of bunds with plastic sheet varied from plot to plot.

Grain and straw yields were obtained by harvesting total area of plots excluding 1 m from the bunds. Grain and straw moisture contents were measured after oven drying the samples at 60 °C for 48 hours. Yields were converted to 14 % moisture content. WP was calculated as the ratio between grain yield (kg ha^{-1}) and the total amount of water used in production (mm).

Components of total water requirement, yields and WP were analysed by single factor Anova (cultivation method) in dry season and by two factor Anova (block x cultivation method) in wet season. Differences between treatment means were separated using LSD at 0.05 probability level. Statistical software package Statgraphics Version 7.0 (Statistical Graphics Corporation) was used in the analysis.

Results and Discussion

Total Water Requirement

Total water requirement in transplanting method includes water used for land preparation, nursery preparation and nursery stage irrigation. In wet seeding method it includes only land preparation in the main field. In dry seeding method, total water requirement includes two irrigations given prior to submergence in dry season. During wet season, no irrigation was given to the nursery or for soil saturation in dry seeding method. In both seasons, total water requirement was lower in dry seeding than in transplanting or wet seeding methods (Table 1). The major component that reduced total water requirement in dry seeding was the lack of land preparation water requirement due to unpuddled soil conditions.

Table 1.
Total Water Applied for Rice Under Three Cultivation Methods in Two Seasons.

Treatment	Total water applied (mm)[a]	
	Dry season	Wet season
Transplanting	1154 ± [b] 5.4 b	755 ± 5.1 c
Wet seeding	1105 ± 5.1 b	678 ± 2.1 b
Dry seeding	1040 ± 3.2 a	505 ± 8.6 a

[a] Data includes land preparation, nursery stage requirement and irrigations prior to submergence but excludes precipitation overflow.

[b] ± indicate 1 SE. Means in the same column followed by same letter are not significantly different at 0.05 probability level using LSD.

Land Preparation Water Requirement

The amount of water applied during land preparation to transplanted and wet seeded plots ranged from 191 - 230 mm in dry season and 184 - 196 mm in wet season. This corresponds to 18 - 20 % of the total water requirement in dry season and 27 - 29 % of the total water requirement in wet season. The amount of water applied for land preparation was near to the range recommended by the Royal Irrigation Department of Thailand (144-200 mm) (6) and was consistent with the average amount (220 mm) used by farmers nearby (10). In dry season, water requirement for nursery land preparation was 51.2 mm and three nursery irrigations required a total of 37.5 mm. But in wet season, no irrigation was given for the nursery or the saturation of soil in dry seeding method as there was enough precipitation. Dry seeding method required no water during land preparation and thus saved a large amount of water compared to wet seeding and transplanting methods.

Percolation Losses

In dry season, the daily percolation losses in dry and wet seeded plots were significantly higher than in transplanted plots until the maturity stage, but during the maturity stage the differences were not significant (Table 2). In wet season, percolation was significantly

Table 2.
Daily Percolation Losses (mm day^{-1}) During Different Stages of Rice Growth and Total Percolation (mm) for Three Cultivation Methods in Two Seasons.

Treatment	Growth stages			
	Vegetative	Reproductive	Maturity	Total
	Daily percolation losses (mm day^{-1})			(mm)
Dry Season :				
Transplanting	1.30 ± [a] 1.03 a	0.6 ± 1.4 a	0.25 ± 1.3 a	93.9 ± 1.1 a
Wet seeding	1.75 ± 1.05 b	1.8 ± 1.1 b	0.62 ± 1.2 a	128.9 ± 1.1 b
Dry seeding	3.00 ± 1.04 c	2.8 ± 1.0 b	0.92 ± 1.0 a	214.7 ± 1.0 c
Wet season:				
Transplanting	0.7 ± 0.002 a	0.9 ± 0.008 a	1.0 ± 0.01 a	61.9 ± 0.23 a
Wet seeding	1.1 ± 0.007 b	1.1 ± 0.005 a	1.0 ± 0.003 a	82.2 ± 0.37 b
Dry seeding	1.3 ± 0.001 c	1.1 ± 0.002 a	1.0 ± 0.005 a	97.9 ± 0.07 c

[a] ± indicate 1 SE. Means in the same column within one season followed by same letter are not significant at 0.05 probability level using LSD.

higher in dry and wet seeded plots only during the vegetative stage. The differences in percolation among the cultivation methods and at various stages of growth could be attributed to the differences in soil condition. Expanding type of clay minerals, on swelling, seals cracks as well as block the continuous macropores when water is in continuous ponded condition (4). Dispersion and disintegration of soil aggregates also occur and thus the percolation rate gradually decreases with time. The low percolation rate in transplanting and wet seeding compared to dry seeding method is also due to soil puddling. Puddling results in decreased macroporosity due to the destruction of soil structure and thereby increases water holding capacity and reduce hydraulic conductivity (1). In wet season, moist soil condition due to precipitation was also responsible for the reduction in percolation rate in dry seeded plots.

Higher percolation in wet seeding compared to transplanting was due to the formation of cracks in the soil three days prior to permanent submergence. Wet seeded plots were kept without irrigation till 17 DAS. The main cause of crack formation was the shrinkage of clay minerals and changes in soil structure caused by swelling and shrinkage phenomenon (3). Furthermore, Iwata (4) reported that the volume change by swelling and shrinkage is greater in smectite (montmorillonite) than the non-expanding type clay mineral, which results in deep cracks. Smectites are the dominant clay fractions in the experiment field.

Percolation was highest in dry seeded plots and this was due to the non-puddled condition. Kawasaki (7) reported a 60 % reduction in percolation on clay soil due to puddling compared to non puddled soils. In the present study, the reductions were 56 % and 37 % in dry and wet seasons, respectively. The low value in wet season was due to wet conditions at the beginning of experiment because of precipitations.

The total percolation losses in the main field for the entire period of growth were found to be significantly different between cultivation methods in both seasons. Dry seeding and transplanting rice had the maximum and minimum total percolation losses, respectively. Percolation was based on the observations made from the day of permanent submergence in the field. In all three cultivation methods, total percolation was lower during the wet season than during the dry season primarily due to wet field conditions at the beginning of the season.

Seepage Losses

Total seepage losses in dry season varied from 76 - 86 mm and in wet season from 30 - 42 mm. The losses were not significantly different between cultivation methods in both seasons. Furthermore, seepage losses did not change with the stage of crop. These results are in contrast to the findings of previous workers (5,12). They observed a gradual decrease in lateral seepage because of the compaction of bunds. Probable reason for non significant results in the present study could be due to maintenance of bunds in wet condition throughout the experiment by frequent irrigations and precipitations at the beginning of the experiment.

Grain Yield and Water Productivity

Grain yields were not significantly different between cultivation methods in both seasons (Table 3). However, WP based on grain yield was higher for dry seeded rice compared to transplanted rice in both seasons. There were no significant differences in WP between transplanted and wet seeded rice. WP in the present experiment are little higher than the results reported at IRRI (2.5 kg ha^{-1} mm^{-1}) on a clay loam soil (13). However, they are much lower than WP of 8.05 kg ha^{-1} mm^{-1} on a clay loam soil in Indonesia (2). The results show that dry seeding method was the best among the three cultivation methods for saving water without causing yield reductions.

Crop Duration

Crop duration of transplanted rice was 118 days in dry season and 125 days in wet season. While in the dry and wet seeding methods crop duration was 86 days in dry season and 105 days in wet season. The normal duration of Suphanburi-90 cultivar is 120 days under transplanting. In dry and wet seeding, crops were harvested at least three weeks earlier than transplanting even though they were all sown at the same time. Early harvesting would thus give more time available for land preparation or early planting of the next season crop. Furthermore, shorter duration would reduce the risk of crop damage due to natural causes.

Savings on Labour

The major differences in the labour requirement between the three cultivation methods were during the

Table 3.
Grain Yield and Water Productivity (WP) of Rice Under Three Cultivation Methods in Two Seasons.

Treatment	Grain yield (t ha^{-1})		WP (kg ha^{-1} mm^{-1})	
	Dry season	Wet season	Dry season	Wet season
Transplanting	4.09 ±[a] 0.03 a	3.07 ± 0.10 a	3.54 ±[a] 0.04 a	4.07 ± 1.05 a
Wet seeding	4.21 ± 0.25 a	3.03 ± 0.12 a	3.81 ± 0.26 ab	4.38 ± 1.02 a
Dry seeding	4.30 ± 0.13 a	2.79 ± 0.19 a	4.13 ± 0.04 b	5.49 ± 1.12 b

[a] ± indicate SE. Means in the same column followed by same letter are not significant at 0.05 probability level using LSD.

land preparation and sowing. In dry season, land preparation and sowing required 226, 112 and 99 man-hours ha^{-1} in transplanted, wet seeded and dry seeded rice, respectively. In wet season, they were 219, 104 and 94 man-hours ha^{-1}. In both seasons, two irrigations were saved in wet and dry seeding compared to transplanting during crop establishment and thereby 19 man-hours ha^{-1} were saved. The low labour requirement for land preparation in dry seeding method implies that dry seeding saves on labour costs while minimising physical effort.

There was no difference in the labour requirement for cultural practices in all three cultivation methods after the establishment of the crop. However, in wet season, wet and dry seeded rice required an additional 77 man-hours ha^{-1} for weeding. Though chemical weed control was used it was not effective due to frequent precipitations. In spite of the extra labour required for weeding the total labour requirement in dry seeding was still lower than transplanting.

Conclusions

Total water requirement for lowland rice was lowest in dry seeding method because of lack of land preparation water requirement. Furthermore, WP was highest and labour requirement was lowest for dry seeding method. Thus, dry seeding method can be recommended as the best among the three rice cultivation methods to save water and labour on heavy clay soils with expanding type of clay minerals. Furthermore, crop duration was also shorter with dry seeding method.

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N.S. Murali, Danish. Ph.D. in Plant Nutrition, Danish Institute of Plant and Soil Science, Lottenborgvej 2, 2800 Lyngby, Denmark.
R. Thabonithy, Sri Lankan. M.Sc in Irrigation Engineering, Eastern University, Chenkalady, Sri Lanka.

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