Rice root distribution under various systems of soil management on rainfed Vertisols in Southern Lombok, Eastern Indonesia

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Abstract

Root distribution and yield of crops depend on the physical properties of soil, which in turn depend on soil management. The root distribution, shoot:root ratio and yield of rice (*Oryza sativa*) under four soil management treatments within two years on a rainfed Vertisol in Southern Lombok, Indonesia (annual rainfall 700 mm to 1300 mm) were studied during the 2002/2003 wet season. The treatments were rice, grown on: a) raised beds with no tillage, not flooded (M1), b) raised beds with tillage, not flooded (M2), c) flat land with no tillage, flooded (M3), and d) flat land with tillage, flooded (M4, the conventional system *gogorancah*). In each treatment, the root distribution varied with depth, with fewer roots at 15 to 20 cm depth than higher in the profile. There were no significant differences in concentration of roots between treatments at each depth. The shoot:root ratio was at least 3.2 in treatments with tillage (M2, M4), and was no more than 2.6 in treatments without tillage (M1, M3). In this climate with low rainfall, the yield of rice was not related to root distribution, but was higher in the conventional flooded system M4 (6.0?t/ha), than the yield on unflooded raised beds (M1, M2, mean 5.0?t/ha). Further study is needed on Vertisols in this semi-arid climate to determine the long-term effects of unflooded raised beds on root distribution and crop performance of wet-season crops and of secondary crops.

Media summary

After one year, root growth of rice was not affected by tillage, or raised beds versus flat land. Yield seemed to depend on water supply.

Keywords

No-tillage, paddy, soil strength, shoot growth.

Introduction

Root distribution is controlled by soil properties, such as porosity, compaction, water content and concentration of organic matter, which in turn are affected by the system of soil management. In Indonesia, rice (*Oryza sativa*) is widely grown on flooded flat land. In Timor, a rice cropping system with unflooded raised beds produced a yield equivalent to that on a flooded system (Borrell et al. 1998). In their study, grain yield, above-ground dry mass, and other components of yield were not significantly different between the raised beds and the flooded system. However, Borrell et al. (1998) did not report the effect of soil management on root distribution. Therefore, we studied the distribution of roots and performance of rice under several systems of soil management (unflooded raised beds or flooded flat land, with and without tillage) in Southern Lombok, Indonesia. This information will assist in the planning of nutrient management of rice, particularly when grown in rainfed Vertisols on raised beds.

Material and methods

Experimental site

A field study on root distribution was conducted in the second year of an experiment on a rice-based (*Oryza sativa*) cropping system on rainfed Vertisols, in the wet season of 2002/2003 at Wakan (8 44`S,116 30`E) Southern Lombok, Indonesia. The average rainfall at this semi-arid site ranges from 700 to 1300 mm, falling over 3?months from November/December to February/March. The Vertisol (USDA 1998) was dominated by montmorillonite, and contained 668 g clay /kg soil.

Treatments

The root distribution, shoot and root biomass, and yield of rice were observed in an experiment on soil management, set up in 2001 in a Randomized Block Design, with three replicates (Table 1).

Table 1. Treatments in an experiment with rice on a Vertisol **at Wakan, Lombok in 2002/2003.**

	Treatments
M1	Raised beds, no tillage, not flooded
M2	Raised beds, tillage, not flooded
M3	Flat land, no tillage flooded
M4	Flat land, tillage, flooded

Plots (each 10 m long and 6 m wide) were separated by border bunds (0.2 m high, 0.5 m wide). The drainage channels between treatments were each 0.5 m wide and 0.25 m deep, and those between blocks were each 1 m wide and 0.30 m deep. In each of M1 and M2 (Table 1), four adjacent raised beds (each 1.2 m wide and 0.2 m high) were formed from soil excavated from the furrows, and placed on the untilled surface of soil. Water in the furrows between the raised beds (M1, M2), and on the flat land (M3, M4) was kept at a depth of 10 cm and 5 cm respectively. In each treatment, rice (wet season) and soybean (*Glycine max*, dry season) were each direct-seeded (row spacing of 20 x 20 cm) in holes made by a stick.

Sampling and measurements

At harvest, five hills of rice plants were cut at the surface of the soil from within a)?one quadrat (1?x?1.5 m) in each of the two middle beds of each treatment M1 and M2, and b)?two quadrats (each 1 x 1.5 m) in the middle of each treatment M3 and M4. The oven-dry biomass (70^{o} C) of the shoots and grain (yield) of rice were determined in each treatment.

Two days after the rice plants were harvested, a block of soil (15 cm x 15 cm) was cut with a knife from beneath each of the harvested hills, at depths of 0-5, 5-10, 10-15 and 15-20 cm. The five samples of soil at each depth were made into a composite sample. Each composite sample was soaked overnight in 2 L of water containing 50?mL of 5% NaOH, then stirred with an electric mixer. Each suspension was allowed to settle overnight, sieved (<?0.125 mm), and the oven-dry mass (70^{o}C) of roots at each depth determined, enabling the total mass of roots (0-20 cm depth) to be calculated. The shoot:root ratio was determined from the total mass of above-ground dry mass/total mass of roots in each treatment.

The volume of roots (V_R) from each sample was determined by displacement in water. The total volume of soil (V_C) in each sample from each depth was 125 cm^3. The root concentration at each depth in each treatment was calculated from V_R/V_C.

Throughout the growing season, the soil strength was measured at five different points in each of two middle raised beds in M1 and M2, and in the middle of each treatment on flat land (M3 and M4). Soil strength was measured with a cone penetrometer (type Remic CP^{TM}) 20 at intervals of 2 cm to the bottom of the rooting zone (0 to 60?cm depth).

An Analysis of Variance, including the standard error of the mean (SE_{mean}), was determined on data from each measurement.

Results and discussion

The root distribution (by volume) at each depth was not significantly different between treatments (Table?1), with mean: 0.15 cm^3 root/cm^3 soil at 0–5 cm depth, and 0.14 cm^3 root/cm^3 soil at each of 5–10 cm, 10–15 cm, and 15-20 cm depth. However, Figures 1 to 4 show that the concentration of roots was higher at a depth of 0-5 cm than that at 15-20 cm in three of the four treatments (M1, M2, M3). Throughout the season, penetrometer resistance was not significantly different between the treatments. At 10, 20, 40 and 60 cm depth, mean penetrometer resistance was 232, 392, 612 and 1098 kPa, respectively, so should not have restricted roots.

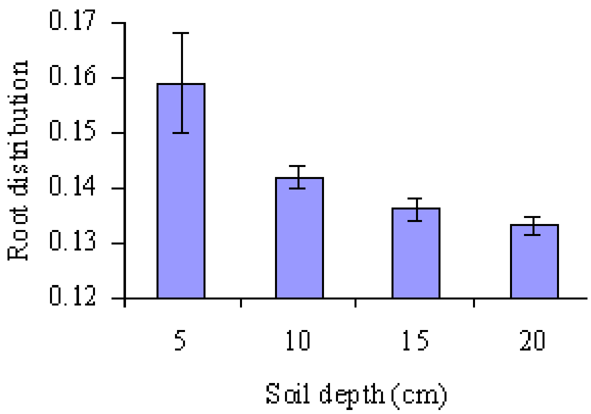

Figure 1. Root distribution of rice (cm^3?root/cm^3 soil) at various depths in a Vertisol at Wakan, Lombok in M1 (Table?1) in 2003. Error bars = 2 x SE_{mean}.

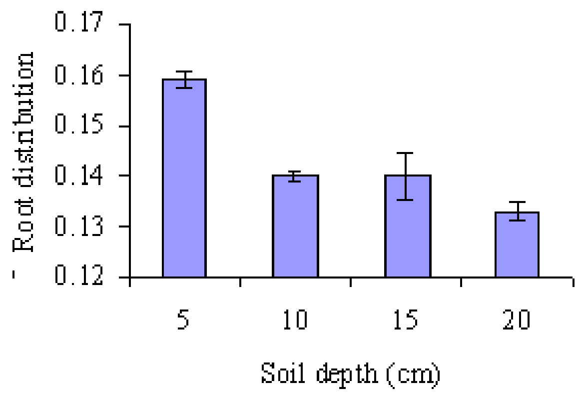

Figure 2. Root distribution of rice (cm^3?root/cm^3 soil) at various depths in a Vertisol at Wakan, Lombok in M2 (Table?1) in 2003. Error bars = 2 x SE_{mean}

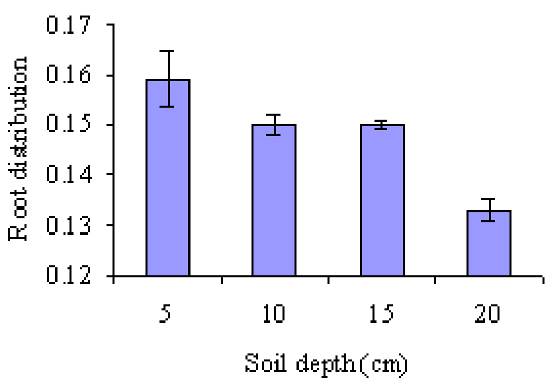

Figure 3. Root distribution of rice (cm^3?root/cm^3

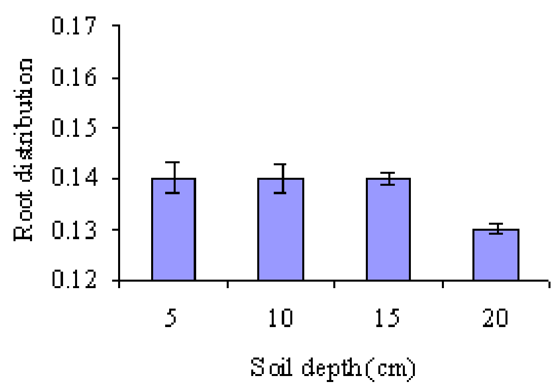

Figure 4. Root distribution of rice

soil) at various depths in a Vertisol at Wakan, Lombok in M3 (Table?1) in 2003. Error bars = 2 x $SE_{mean.}$

(cm^3?root/cm^3 soil) at various depths in a Vertisol at Wakan, Lombok in M4 (Table 1) in 2003. Error bars = 2 x $SE_{mean.}$

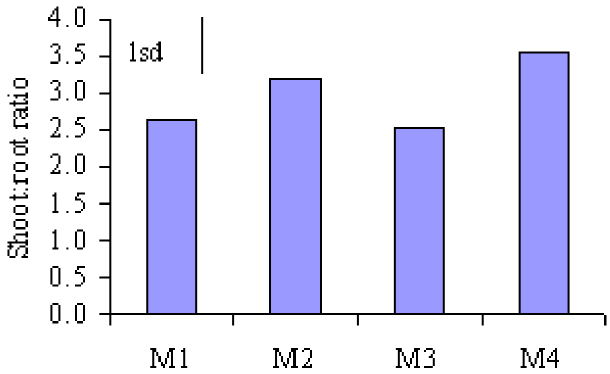

Figure 5. Shoot:root ratio (biomass) of rice in various systems of soil management (Table 1) in a Vertisol at Wakan, Lombok.

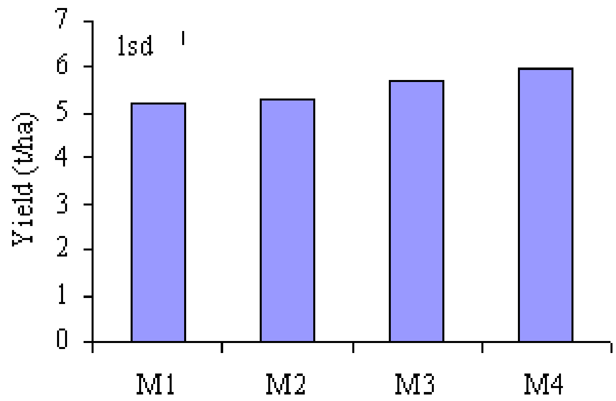

Figure 6. Yield of rice under various systems of soil management (Table 1)in a Vertisol at Wakan, Lombok, in 2003.

The shoot:root ratio (Figure 5) in treatments M2 and M4 (with tillage) was higher than that of M1 and M3 (without tillage). The yield of rice was higher (Figure 6) in flat flooded treatments (M3, M4) than that in unflooded raised beds (M1, M2). Hence the yield of rice was not related to the root distribution (Figures 1 to 4), but was shown elsewhere to depend on the supply of water to the roots (Mahrup et al. 2004).

Conclusion

New systems of soil management (tilled or untilled, flooded flat land or unflooded raised beds) on rainfed Vertisols of Southern Lombok in Eastern Indonesia did not greatly affect the root distribution of rice within two years. However, grain yield was not related to root distribution, but depended on the supply of water related to the roots. Further study is needed on these soils to determine the long-term effects of unflooded raised beds on root distribution and performance of wet-season and secondary crops.

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