Title of dissertation				
Adaptation of nutrient management for rainfed lowlands in the Philippines				
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Rainfed lowland rice ecosystems, occupying one-third of the total rice area in the Philippines, face various bio-physical constraints in relation to the fluctuation of water availability in the field. While significant progress has been made on nutrient management in irrigated rice ecosystems, nutrient management for rainfed lowland rice remains ineffective and inefficient. The objectives of this thesis were to assess and adapt nutrient management for drought-prone rainfed lowlands in the Philippines, based on the concept of site-specific nutrient management (SSNM). It also involved specific research questions on nutrient management for new drought-tolerant cultivars and for dry direct seeding under rainfed lowland conditions, and on the farmers' perspectives on nutrient management based on plant growth conditions.

1.On-farm assessment of site-specific nutrient management for rainfed lowland rice in the Philippines

On-farm trials were conducted in the wet seasons of 2011–2014. Average application rate of N, P and K in researcher practice (RP) based on SSNM was 82, 10 and 21 kg ha^{-1}, respectively, while the application rate was 93, 11 and 18 kg ha^{-1} in farmer practice (FP) (n = 93). Grain yield in FP, which ranged from 1.82 to 6.49 t ha^{-1}, was enhanced by RP by 6% on average (4.48 vs. 4.22 t ha^{-1}). The yield difference was mainly associated with the different N application regimes in RP and FP. Average number of N applications was 1.94 in FP with 52% of total N applied during the first 15 days after transplanting, while there were 2.63 applications in RP with 29% applied during the first 15 days after transplanting and 44% at panicle initiation, respectively. Total cost for fertilizer was comparable or lower in RP than FP, and consequently, the net income was increased by 154 US$ ha^{-1}.

2. Comparison of yield-related characteristics in farmers' practices vs. site-specific nutrient management for rainfed lowland rice

Nutrient management can increase crop yield and income, but its effects on yield-related growth characteristics are rarely dissected in on-farm trials. We compared yield components under researcher practice (RP) based on SSNM and farmer practice (FP) at 69 sites across nine provinces over three years. The sink size (spikelets m^{-2}) was most closely associated with grain yield in all years. Panicle size (spikelets per panicle) increased by 10.4% and 13.0% in 2011 and 2012, respectively, in RP. N application around the early reproductive stage was < 25 kg N ha^{-1} in FP, while 30–33 kg N ha^{-1} in RP. Higher N application during seedling establishment in FP (55 kg N ha^{-1}) than in RP (22 kg N ha^{-1}) did not increase panicles m^{-2} in any year. Our results suggested that enhancing sink size should be the major target of nutrient management in rainfed lowland rice, and N application is most important during the early reproductive stage to increase panicle size.

3. Assessment of adaptive nutrient management for drought-tolerant cultivars under rainfed lowland conditions

Recent advances in rice breeding in tropical Asia led to the release of high-yielding drought-tolerant cultivars for rainfed

lowlands. The objectives were to evaluate cultivar differences in the responses of crop growths to fertilizer application regimes. Thirteen drought-tolerant rice cultivars were compared with two irrigated rice cultivars under three nutrient management conditions in irrigated and rainfed lowlands during the wet seasons of 2014 and 2015. Drought stress was mild in both years, with a yield reduction of 11% to 12%, and there was no significant cultivar × nutrient management interaction in yield. The drought-tolerant cultivar NSIC Rc282 proved fertilizer-responsive and had similar yield to those of the popular high-yielding cultivar NSIC Rc222 under all conditions. An ancillary experiment in 2016 confirmed that NSIC Rc282 was more drought-adapted than NSIC Rc222, with 11% to 37% higher yield under stress. In order to maximize the yield, NSIC Rc282 required N application only when the drought ended, whereas NSIC Rc222 required additional N during the drought. This shows that the details of drought-adaptive nutrient management differ between irrigated and drought-tolerant cultivars. N application at the cessation of drought was important to promote recovery growth in drought-tolerant genotypes.

4. Nutrient management for dry direct-seeded rice in rainfed lowlands of the Philippines

Dry direct-seeded rice (DDSR) is an adaptive practice used in rainfed lowlands of tropical Asia where insufficient rainfall at the onset of the wet season. However, basic guidelines for nutrient management to support DDSR are lacking. In the study, crop growth and yield were evaluated in DDSR with different N fertilizers (ammonium sulfate, urea, and coated compound fertilizer) applied at different timings. The total N rate was fixed at 100 kg ha^{-1}. In the on-station trials, ammonium sulfate did not increase yield compared with urea and coated compound fertilizer in either year. Application of N fertilizers at sowing promoted plant N uptake and early shoot growth, but the effect of the timing of N application on yield was not significant. The on-farm trials showed that a uniform N management recommendation is unlikely to be effective in DDSR. Yield increased significantly with coated compound fertilizer relative to the uncoated fertilizers in clay and silty clay soils, but not in other soil types. Flexible timing of the first application of N, ranging from 0 to 30 days after sowing, had no significant effect on yield, but the omission of N application at sowing reduced yield by 13–25% in two trials on sandy soils with a low nutrient-holding capacity.

5. Deciphering plant growth factors associated with farmer's decisions on nutrient management in rainfed lowland rice

Farmer participatory trials were conducted in irrigated and rainfed lowlands in the Philippines during the wet seasons of 2014, 2015, and 2016. Each year, 30 participating farmers made decisions on nutrient management for plots with different seedling ages and planting densities. These treatments greatly changed the canopy appearance and affected farmer decisions on nitrogen (N) management, particularly in the first year. We found that plant height and leaf greenness were the major determinants of their decisions in irrigated lowlands. Under rainfed conditions, the risk of drought made farmers focus on tillering rather than plant elongation and leaf color during early growth stages, and on canopy cover and plant elongation during later stages. Across years and water regimes, farmers applied 78% more N than researchers without generally increasing grain yield. Since crop diagnosis is a key for successful management by farmers, guidelines for efficient nutrient management should include numerical targets for the traits emphasized by farmers.

General discussion and conclusions

This study showed that the concept of site-specific nutrient management developed for irrigated rice can be also applied to rainfed lowland rice but with some modification. Split N application, particularly N topdressing around panicle initiation, increased yield without increasing the total N input. However, the challenges remain in nutrient management under moderate to severe drought. We found N input can be saved under drought by using a recent drought-tolerant cultivar, otherwise additional N is needed for recovery growth when a dry spell terminates. Adaptation of nutrient management is also needed for dry direct seeded rice: fertilizers for seedling vigor at crop establishment should be a primary consideration, particularly under fluctuating water availability. Lastly, researchers' ideas on nutrient management do not necessarily match farmers' perspectives, and that some interface, such as standard growth characteristics for in situ crop diagnosis, should be prepared for better technology adoption by farmers in rice extension programs.

Photos

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