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Spatial variability of fertilizer management and response in rainfed rice of Nepal

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ABSTRACT

To develop improved nutrient management options for rainfed rice farmers in Nepal, we conducted two surveys and a field experiment on-farm during 2009 and 2010 in the Mid-hills, Lamjung district, and in the Inner Terai, Chitwan district. The objectives were to (i) initially distinguish together with farmers different recommendation domains for rainfed rice within the landscape, (ii) document farmers' respective management practices, and (iii) test existing fertilizer options in these different recommendation domains with farmers' participation. Based on the surveys and structured group discussions, four major field categories were distinguished: fields on upper or lower terraces and fields far from or close to the house. These categories did not define clearly different soils, but the trend was that soils close to the house were the most fertile and fields far from the house were the least fertile. Almost all farmers applied less fertilizer in fertile fields. Organic fertilizer was preferably applied in fields close to the house and to non-rice crops in the dry season, whereas inorganic fertilizer was preferably applied to rice and in lower fields and fields far from the house. Upper fields received little inorganic fertilizer in the Mid-hills but normal rates in the Inner Terai. No clear preference for fertilizer use in drought-prone versus wetter fields was found. In the Mid-hills, across both experimental seasons and all fertilizer treatments, rice yields were highest near the house (4.38 t ha^{-1}), similar in lower fields and far from the house (3.86 and 3.35 t ha^{-1}, respectively), and lowest in upper fields (2.78 t ha^{-1}). A medium fertilizer rate tested (60–30–20 N–P_2O_5–K_2O kg ha^{-1}) increased average yields by 1 t ha^{-1} compared with the control (no fertilizer applied), and by 0.5 t ha^{-1} compared with the farmers' practice. Yield gains and agronomic efficiency of N were similar in both seasons, and the highest values for both indicators were found for fields near the house, whereas the lowest values for both characteristics were found in upper terrace fields. We conclude that grain yields can be substantially increased with applications of medium fertilizer rates, and that inorganic fertilizer use is most profitable in fields near the house, followed by lower terrace fields and fields far from the house. The application of organic and little inorganic fertilizer seems to be the best option in drought-prone upper fields.

1. Introduction

In Nepal, agriculture contributes about 32% to the total gross domestic product and employs around 66% of the economically active population according to the Ministry of Finance (MoF, 2008). About 21% (or 3.2 million hectares) of the total land area is used for crop cultivation, and the principal crops are rice (45%), maize (20%), wheat (18%), millet (5%), and potatoes (3%) (Gautam, 2008). Since 2001, Nepal has achieved a positive food balance; nevertheless, 55 of the 75 districts (mostly mountainous and hilly districts) reported some food deficits because of transportation and access problems (Gautam, 2008). Rice is the most important cereal crop and, according to the FAOSTAT database for 2010, was grown on 1.48 million hectares, producing 4.02 million tons of paddy, corresponding to an average productivity of 2.71 t ha^{-1}. However, total production as well as productivity are highly variable in time and space (Basnet, 2008). High yearly fluctuations are mainly caused by the variability of the amount and distribution of the annual monsoon rain, and because about 65% of the total rice area is rainfed; only 35% of the rice area is at least

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partially irrigated according to the Ministry of Agriculture and Cooperatives (MoAC, 2010). Given that all the potential arable land is already under cultivation and the rapid population growth continues, stable and improved productivity of all cropping systems needs to be an essential element of agricultural development (Sherchan and Karki, 2006).

The three main geographic regions distinguished in Nepal are the Terai (<330 m amsl), the Mid-hills (330–2000 m amsl), and the Mountains (>2000 m amsl). The Inner Terai valleys are several elongated valleys, situated between the Himalayan foothills and the Terai plains. Rice is mainly cultivated in the Terai (70%) and in the Mid-hills (30%), even if some rice is grown up to 3050 m amsl. The climate in the main rice-growing regions is tropical to sub-tropical, even temperate in the higher parts. According to a land resource mapping project conducted countrywide in 1986, the most common soil orders following the USDA soil taxonomy are Entisols, Inceptisols, Mollisols, and Alfisols (Pariyar, 2008). Entisols occur on recent alluvial or colluvial deposits, Inceptisols with distinct subsoil weathering are found on more stable grounds, and Alfisols with clay-enriched subsoils are typical on stable slopes and terraces of the Mid-hills and high-hill regions (Mollisols occur usually under grassland above the tree line). Rainfed lowland rice, which is not defined by its altitude but as rainfed rice grown in bunded fields with water saturation for at least part of the season, reaches from the Terai plains to terraced rice fields high up on steep mountain slopes in the Mid-hills. It experiences too little or too much water regularly, contributing to the relatively low grain yield average of 2.34 t ha^{-1}, which is below the national average (Pandey et al., 2007). Apart from these predominant abiotic stresses, low yields are also attributed to sub-optimal crop management practices, and in particular to sub-optimal nutrient management (Sherchan and Karki, 2006). The same authors wrote that the last effort for comprehensive recommendations on economical fertilizer use for various crops in Nepal was made in 1975 by Joshy and Deo (1976). Current nutrient management recommendations disseminated differ only between irrigated rice, for which the application of 100:60:40 kg ha^{-1} N:P_2O_5:K_2O is recommended, and rainfed lowland rice, for which 60:30:20 kg ha^{-1} N:P_2O_5:K_2O is recommended. Such recommendations are very general and rarely followed in farmers' fields (Joshy and Rajbhandari, 2001). They also do not address the very diverse rice-growing environment in Nepal, characterized by strong topographic differences and a range of soils, soil fertility, water availability, field accessibility, and cropping systems. Pariyar (2008) and Desbiez et al. (2004) found that farmers have systematic criteria for distinguishing soils according to landform position, based on slope, elevation, drainage, and many more factors. According to them, topsoil color, texture, and terrace type are the predominant criteria for local land classification and soil fertility management. Thus, farmers use their own knowledge and experience for fertilizer management in rainfed lowland rice cultivation, partly also because they have only little or no access to information from farmer advisory services. But, farmers' practices are usually highly variable, and they have varying levels of skills, knowledge, and insight into their production environment. In order to provide all farmers with better advice on nutrient management, the combination of participatory on-farm research and a detailed analysis of their practices and experience seemed most promising. Particularly in complex environments, the study of farmers' knowledge and their practices should be of high value for any attempt to improve their management. Consequently, our objectives were to (i) initially distinguish together with farmers different recommendation domains for rainfed rice within the landscape, (ii) document farmers' respective management practices and crop performance, and (iii) test existing fertilizer recommendations in these different recommendation domains with farmers' participation.

2. Materials and methods

2.1. Survey description

For the surveys, four neighboring villages were selected in the Mid-hills (MH) in Lamjung district (Tarku, Khatrithanti, Handetar, Thakle), and four in the Inner Terai (IT) in Chitwan district (Mangalpur, Rampur, Dhaddaghari, Fulbari) (Fig. 1). In the MH, the villages were located about 3 to 15 km west of the Institute of Agriculture and Animal Sciences (IAAS), Lamjung Campus of Tribhuvan University, in Sundarbazar. In the IT, the selected villages surround the main IAAS campus of Tribhuvan University at Rampur, Chitwan, at about 2 to 10 km distance. In the MH and in all four villages, most of the fields were terraced on the mountain slopes. The fields were usually narrow strips (from a few meters to 20–30 m wide) and the terraces were constructed a long time ago. In contrast, Chitwan district in the IT was previously a forest area, settled from 1951 onward when the government granted the land to landless people from the MH regions after the eradication of malaria. The rice field topography there ranged from rainfed or irrigated lowland fields to terraced fields on the sloping hills.

Two different surveys were conducted (Table 1). The purpose of the initial survey before and during the wet season 2009 was to determine with the farmers useful field categories with respect to crop nutrient management and to get an overview of farmers' nutrient management practices in rainfed rice. It was conducted in all eight villages using group discussions and individual questionnaires. In each village, five randomly chosen farmers were participating. The second survey of farmers' actual fertilizer management in specific fields was conducted in two villages each season (Tarku and Mangalpur in 2009 and Khatrithanti and Fulbari in 2010). In each village, 20 farmers participated with 5 farmers/fields in each field category. Observed were general crop management practices (variety used, timing of seeding/transplanting/harvesting), the actual amounts of different fertilizers used, and the grain yields achieved. Grain yields were measured by researchers for a 6-m^2 area in all fields surveyed. Particular local units used by the farmers and in the surveys were Ropani (20 Ropani = 1 ha, preferred in the MH) and Katta (30 Katta = 1 ha, preferred in the IT), and rice yield was measured in Muri (2 Muri = 100 kg), but a correction factor (0.8) was used to adjust the moisture content to 14% and to account for impurities. Farmyard manure (FYM) application was measured in "doko", a backpack containing on average 25 kg FYM fresh weight. Dry matter of the FYM was estimated assuming an average water content of 75%.

2.2. Experimental setup

Fertilizer experiments for rainfed lowland rice in the MH were conducted at Tarku village, Lamjung. The village is located at 645 m amsl, and at 28°8′37.68″ North latitude and 84°24′5.04″ East longitude. Although this region is called "Mid-hills" in Nepal, this is relative to the Himalayan Mountains behind it, and it is actually quite mountainous with steep slopes and narrow valleys. Predominant soils in the upper and middle terraces were shallow to medium-deep, mostly developed in colluviums on the mountain slopes. The lower rice terraces often had medium-deep soils developed in old alluvial river terrace deposits above the river banks. The climate at the site is sub-tropical. Minimum temperatures are 6–10 °C and even during the coldest months, December–January, they never drop to the freezing point. Maximum winter temperatures rise to 25 °C. The hottest months of the year are April, May, and June, when maximum temperatures reach 39 °C. The rainy season usually starts in June and continues until September. June and July normally receive the highest amount of rainfall, and the