

FARMERS' FERTILIZER APPLICATION GAP IN RICE-BASED CROPPING SYSTEM: A CASE STUDY OF NEPAL

B.R. Baral^{1*}, K.R. Pande², Y.K. Gaihr³, K.R. Baral⁴, S.K. Sah², and Y.B. Thapa²

¹Nepal Agricultural Research Council, Regional Agricultural Research Station, Banke, Nepal

²Agriculture and Forestry University, Rampur, Chitwan, Nepal

³International Fertilizer Development Centre, Dhaka, Bangladesh

⁴Department of Agroecology, Aarhus University, Blichers Allé 20
POBox 50, 8830 Tjele, Denmark

ABSTRACT

Low adoption of improved agricultural practices is one of the major challenges to improve food security. A case study was carried out to assist the farmer's fertilizer application gap in rice cultivation in Nepal. To collect data a household survey was conducted in 2017 by selecting 90 households randomly from rice growing pocket area of Banke district of Nepal. The rates of fertilizers use were assessed in relation to farm size, crop variety, irrigation etc. The applications of both organic and mineral fertilizers vary highly by farmer type. Small and medium farmers applied twice the amount of organic manure compared to large farmers. For inorganic fertilizer use, large farmers applied higher amounts of nitrogen (N) fertilizer compared to medium and small farmers. Across farmer types, a higher amount of N and P fertilizers was used for hybrid varieties than inbred varieties and in irrigated fields than in rainfed fields. The use of potassium (K) fertilizer was low and not affected by farmer type or variety. Overall, farmers used a lower amount of N and K and a higher amount of P than the recommendation. The imbalanced use of fertilizers was associated with poor access to agricultural extension services. Variations of fertilizer use among farmers and the role of extension in the adoption of improved practices are still under-researched, and hence this study exposes the need to investigate in-depth knowledge, determinants of fertilizer use and role of extension education. Results from this study could be important to develop an innovative extension program using multiple channels to increase farmers' access to and awareness regarding balanced use of fertilizers to increase soil fertility and crop productivity.

Keywords: Farmers' fertilizer application, Inorganic fertilizer, Manure, Rice-based system

* Corresponding author: bandhu.baral@gmail.com

INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food for more than half of the world's population and ninety percent of it produced and consumed in Asia (FAO, 2013). In Nepal, agriculture contributes one third of gross domestic product (GDP) and provides employment to more than 60% of the population, while rice alone contributes 21% in agricultural GDP (MoF, 2016). However, despite the introduction of high yielding improved varieties, the average rice yield remained almost stable ($<3.5 \text{ t ha}^{-1}$) over the last decade (MOAD, 2017). Fertilizer alone could contribute more than 50% yield increase (Bindraban et al., 2018). Although Agriculture Prospective Plan (APP) of Nepal, identified fertilizer as a key to increase food security and had envisaged an increase in its use from 31 kg ha^{-1} of the base year 1995 to 131 kg ha^{-1} by 2017 (APP, 1995), the average fertilizer use rate was only 51 kg ha^{-1} during 2014 (AIMS-MOAD, 2016), which is relatively lower compared to neighboring countries.

The Government of Nepal (GON) had recommended fertilizer dose for rice under rainfed condition $60:20:20 \text{ kg N P}_2\text{O}_5\text{K}_2\text{O ha}^{-1}$ and under irrigated condition $100:30:30 \text{ kg N P}_2\text{O}_5\text{K}_2\text{O ha}^{-1}$ along with organic manure 6 t ha^{-1} for both conditions (AICC, 2016). On the one hand, these recommendations are very old and should be updated to address site, crop and variety-specific nutrient requirements. On the other hand, the majority of farmers have not adopted government recommendations (Raut and Sitaula, 2012). The fertilizer trade of Nepal shows imbalance uses; for example, in the year 2015, consumption of urea, Di-ammonium Phosphate (DAP) and Muriate of Potash were 64%, 34%, and 2%, respectively (MOAD, 2015). However, no comprehensive farmer survey was conducted about farmer's adoption of fertilizer practices and their associated barriers for adoption.

A detailed study is needed to understand the farmers' fertilizer application practice which helps to develop appropriate extension strategies on effective and efficient use of organic inputs and inorganic fertilizers in a balanced way. Therefore, this study was conducted to identify the farmer's fertilizer application gap in rice-based system in Nepal. The findings of this study have implications for appropriate policies formulation and implementations for increasing rice productivity by the fertilizer management.

MATERIALS AND METHODS

Study site description

The study was conducted in Banke district of mid-western development region of Nepal (27°N to $28^\circ20'\text{N}$ longitude and 81°E to $82^\circ08'\text{E}$ latitude). The study site has subtropical climate and is drought prone rain-fed rice growing area of Nepal. Dodhuwa Rural municipality, Rapti sonari Rural municipality, Belhari and Belbhar area of Nepalgunj Sub Metropolitan City were selected purposively within the rice growing pocket areas to address the research questions.

The site has diversified land sizes and social and economic groups of farmers. The annual temperature of the study area was ranged from 5.4°C to 46°C, and rainfall ranged from 937 mm to 2149 mm, with a long-term average (1950 to 2016) annual rainfall of 1317 mm. Over 80% of rainfall occurs during monsoon season which last from June to September.

Sampling techniques and data recording

A household survey was conducted with a semi-structured questionnaire during October to November 2017. A total of 90 households were selected purposively. The interview questionnaires were both close-ended and open-ended types to explore the farmers' perception about the fertilizer application and soil fertility management practices. Household survey was supplemented by key informants' interview (10 persons each site) and focal group discussions (10 persons each site). In addition to primary information, secondary information were collected regarding recommended fertilizer application and soil management practices, agro-climate data etc. from published reports. Farmers were categorized as small, medium and large based on the land holding size of <0.5 ha, ≥ 0.5 to <2.0 ha and ≥ 2.0 ha, respectively. Among the interviewed farmers 35%, 33%, and 22% were small, medium and large categories, respectively. The categorization was carried to link between farmer's socio-economic status and technology adoption linkage.

Data analysis

The data were analyzed by descriptive as well as inferential statistical tools, using SPSS 20. The descriptive statistics tools comprised of simple proportions, percentages, and frequencies of all studied variables. Differences in organic manures use within farm type, and inorganic fertilizer application within farm types, varieties (hybrids and inbred), and irrigation type (irrigated and rainfed) were determined through independent T-test. Prior to the analysis, the data were tested for model assumption i.e., homogeneity of variance and normal distributions. The least significance difference of means was analyzed at 0.05 and 0.01 significance level.

RESULTS

Farm characteristics

The dominant (67%) cropping patterns in the study site were rice-wheat and rice-rapeseed + lentil-maize. The average farm size (i.e, land holding) of interviewed farmers ranged from 0.22 ha to 3.28 ha. In this study, land was categorized into two groups irrigated and rainfed based on irrigation facility. Medium landholding farmers had more cattle and buffaloes as compared to large farmers.

Besides fertilizer management practices, farmers were asked about crop productivity. The average rice productivity was 4.12 t ha⁻¹, which is varied with farm type. Medium size farmers recorded higher yield (4.98 t ha⁻¹) compared to the large (3.75 t ha⁻¹) and small farmers (3.63 t ha⁻¹) (Fig. 1).

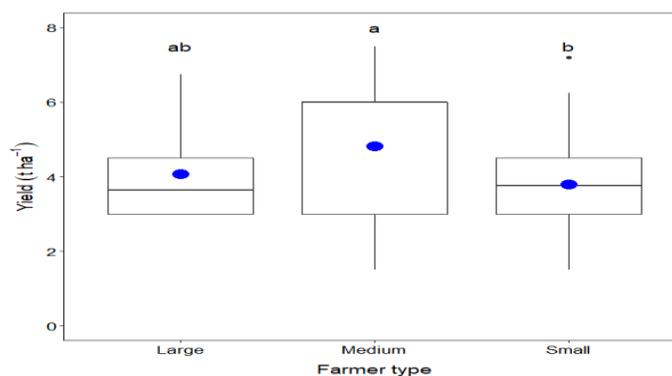


Figure 1. Rice yields at survey site of Banke district. The upper and lower limits of each box represent the 25th and 75th percentiles of the crops yield. The horizontal line in the center of the box indicates the median. The solid circle indicates mean values. Different lowercase letters indicate significant difference among farmers type ($p < 0.05$).

Use of organic inputs

Application of organic inputs (FYM and compost) varied with crops and farmer type. Eighty six (86%) percent of the surveyed farmers used organic manures in rice. On average, farmers used 10 t ha⁻¹ manure, but the magnitudes of use varied with farm-type. Small and medium farmers used higher amount (12.50 t ha⁻¹) compared to the large farmers (6.10 t ha⁻¹) (Fig. 2). During field application, farmers delivered manure to field several weeks and left open in the field prior to incorporation into the soils. About 65% of surveyed farmers left organic manure open in the field for more than two weeks to a month. This suggests that the large amount of nutrient, particularly N could be lost through leaching (depending on rainfall) and volatilization due to sun drying.

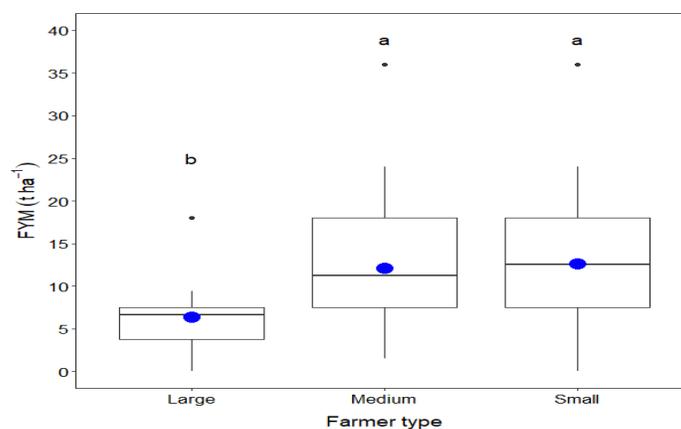


Figure 2. Manure used by farmers in rice production at survey sites. The upper and lower limits of each box represent the 25th and 75th percentiles. The horizontal line in the center of the box indicates the median. The solid circle indicates mean values. Different lowercase letters indicate significant difference among farmers type ($p < 0.05$).

Use of inorganic fertilizers

Farmer's fertilizer application practices varied considerably across farm types, varieties, and irrigation facilities. On average, farmers used 55:39:15 kg N:P₂O₅:K₂O ha⁻¹ (Fig. 3). These nutrients were supplied from urea, DAP, and MOP. In general, farmers' fertilizer uses were found imbalanced. The amount of N fertilizer use ranged from 0 kg ha⁻¹ to 138 kg ha⁻¹. Large farmers applied in the higher rate (73 kg ha⁻¹) compared to medium (57 kg ha⁻¹) and small farmers (41 kg ha⁻¹). Moreover, the magnitude of N fertilizer use varied by rice varieties. Farmers used a higher amount of fertilizers in hybrid (78 kg ha⁻¹) than in inbred (54 kg ha⁻¹). For hybrid, farmers applied 22% less, while 30-59% less for inbred (30%, 44% and 59% for small, medium and large farm, respectively) than the recommended rate. Similarly, N fertilizer application rate was affected by the availability of irrigation facilities. Among the interviewed farmers, only 62% had irrigation facility for rice and they were found to be applied a higher amount of N fertilizer (65 kg ha⁻¹) than rainfed farmers (39 kg N ha⁻¹). Regardless of varieties and irrigation facility, the average N fertilizer application was substantially lower than the recommended rates. Only 21% of the farmers used higher than the recommended rate (100-138 kg ha⁻¹), and 46% of the farmers used less than 50 kg N ha⁻¹.

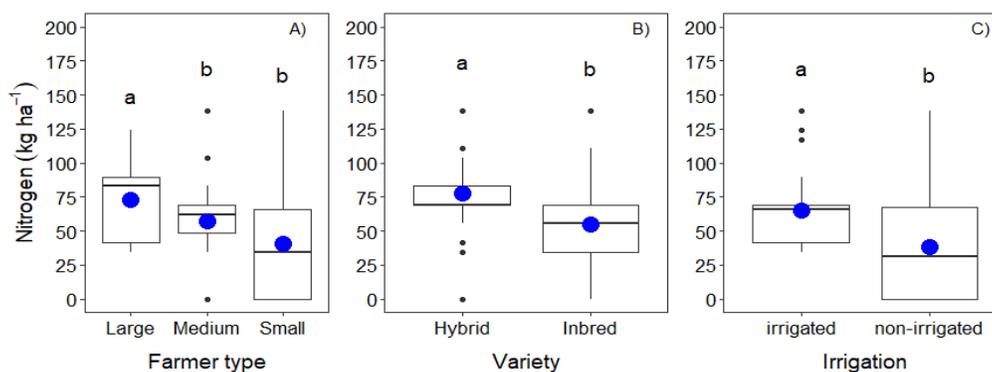


Figure 3. Nitrogen fertilizer application rate in rice field by farmers based on A) farmer types, B) crop varieties and C) irrigation facilities. The upper and lower limits of each box represent the 25th and 75th percentiles. The horizontal line in the center of the box indicates the median. The solid circle indicates mean values. Different lowercase letters indicate significant difference among farmers type ($p < 0.05$).

In contrast with N fertilizer, the average use of P fertilizer was slightly higher (38 kg P₂O₅ ha⁻¹) than the recommended rate (30 kg P₂O₅ ha⁻¹). The amount of use varied with variety which ranged from 0 kg ha⁻¹ to 103 kg ha⁻¹ (Fig. 4). The average use for hybrid and inbred varieties was 50 kg and 36 kg ha⁻¹, respectively. Among the total farmers, 67% and 19% of them applied higher than the recommended rate for hybrid and inbred, respectively. Use of P varied with irrigation and a higher use (46 kg P₂O₅ ha⁻¹) was reported under irrigated condition than rainfed condition (27 kg P₂O₅ ha⁻¹).

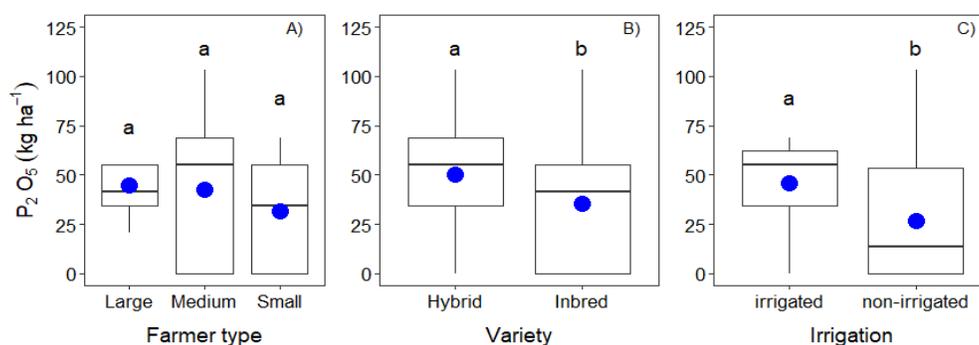


Figure 4. Phosphorus fertilizer application rate in rice field by farmers based on A) farmer types, B) crop varieties and C) irrigation facilities in the study site. The upper and lower limits of each box represent the 25th and 75th percentiles. The horizontal line in the center of the box indicates the median. The solid circle indicates mean values. Different lowercase letters indicate significant difference among farmers type ($p < 0.05$).

Unlike N and P fertilizer, only about 43% of the respondents used K fertilizer, yet the average amount of use was 50% ($15 \text{ kg K}_2\text{O ha}^{-1}$) of the recommended rate ($30 \text{ kg K}_2\text{O ha}^{-1}$) (Fig. 5). While farm type and irrigation had no effects, the use of K was found varied with rice variety. On average, farmers applied 40% ($18 \text{ kg K}_2\text{O ha}^{-1}$) and 57% ($13 \text{ kg K}_2\text{O ha}^{-1}$) less K fertilizer compared to the recommended rate ($30 \text{ kg K}_2\text{O ha}^{-1}$) for hybrid and inbred rice, respectively. In general, farmers were not using micro nutrients except Zinc (Zn), which was supplied as zinc sulfate ($4.5 \text{ kg Zn ha}^{-1}$). Use of Zn was not affected by either farm size or rice variety.

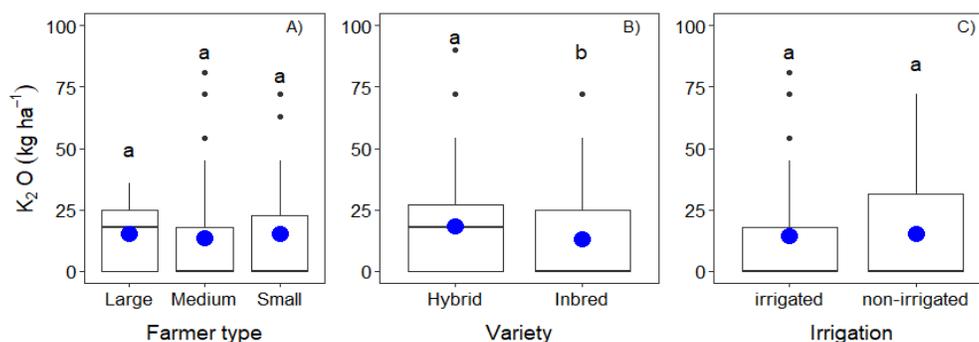


Figure 5. Application of potassium fertilizer in rice field by farmers based on A) farmer types, B) crop varieties and C) irrigation facilities. The upper and lower limits of each box represent the 25th and 75th percentiles. The horizontal line in the center of the box indicates the median. The solid circle indicates mean values. Different lowercase letters indicate significant difference among farmers type ($p < 0.05$).

Effects of extension activities on use of fertilizers

Besides fertilizer use, farmers were inquired about sources of extension support they received, and their effects on the adoption of agricultural technology in general and fertilizer use in particular. The majority of the farmers (40%) were found to receive technical information from fellow farmers followed by government extension workers (23%), agrovet (16%), research station (8%) and mass media (3%). About 10% of the farmers had no access to any of the above information sources and used to cultivate crops based on their own experience.

Only 11% of the interviewed farmers attended the training on rice production, among which all of them were large and medium farmers but no one small farmer received training on rice production. Trained farmers used consistently higher amount of N (59%) and P (35%) fertilizers compared to farmers without training (Fig. 6)

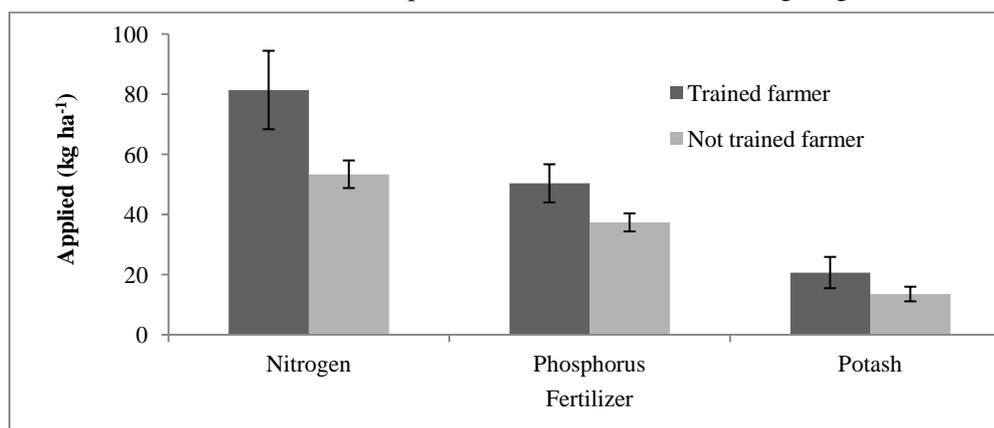


Figure 6. Bar diagram showing application of Nitrogen, Phosphorus and potassium fertilizer in rice field by trained and not trained farmers. The vertical lines indicate the standard error

Changes in fertilizer application behaviors

Besides current fertilizer use practices, farmers were asked about their fertilizer application practices in the past to see the trend of fertilizer use. Among the respondent farmers, 51% of the farmers reported decreasing use of organic manure, while only 25% reported increasing use. Contrary to organic manure, 54% of the farmers reported increasing use of chemical fertilizers and only 17% reported decreasing use. In addition, farmers reported that the main production constraints in this region was irrigation (32% farmers) followed by the availability of improved variety (27% farmers) and fertilizers (27% farmers). Concerning the extension service, lack of technical information regarding improved methods of fertilizer use was one of the main reasons for low adoption.

DISCUSSION

Our survey results indicated that farmers' fertilizer use is imbalanced, they are using lower amount of N and K fertilizers and the higher amount of P fertilizers under both irrigated and rainfed conditions compared to the government recommended rates (Table 1). The imbalance use of fertilizer indicated that farmers' awareness about importance of balanced fertilization is poor, although they use higher amount of N and P fertilizers in hybrid compared to inbred varieties and in irrigated rice compared to rainfed rice (Fig. 3 and 4).

Table 1. Recommended rates and application methods organic inputs and inorganic fertilizers for rice cultivation in Nepal

Fertilizers	Application rate (kg ha ⁻¹)	Application method	Application time
Irrigated rice			
Organic manures	6,000	Soil incorporation	2-4 weeks before planting
Nitrogen (N)	100	Broadcast	Three splits—50% basal and 25% each at maximum tillering and panicle initiation stages
Phosphorus (P ₂ O ₅)	30	Soil incorporation	Final land preparation
Potassium (K ₂ O)	30	Soil incorporation	Final land preparation
Zinc (ZnSO ₄)	25	Soil incorporation	Final land preparation
Rainfed rice			
Organic manures	6,000	Soil incorporation	2-4 weeks before planting
Nitrogen (N)	60	Broadcast	Three splits—50% basal and 25% each at maximum tillering and panicle initiation stages
Phosphorus (P ₂ O ₅)	20	Soil incorporation	Final land preparation
Potassium (K ₂ O)	20	Soil incorporation	Final land preparation
Zinc (ZnSO ₄)	25	Soil incorporation	Final land preparation

Source: AICC (2016)

In general, Nepalese farming is of subsistence type and plant nutrients are mostly supplied from organic inputs such as farm yard manure (FYM), compost, crop residues etc. with very low use of inorganic fertilizers (Sherchan and Karki, 2006). The decreasing use of organic inputs over past five years was associated with reduced in number of cattle (labor shortage), lower availability of forage or organic biomass for animal bedding, decreasing grazing lands, closure of community forest for fodder collection and increasing crop intensity (Poudel and Thapa, 2001). The higher amount

of organic manures used by small and medium farmers ($\sim 12 \text{ t ha}^{-1}$) compared to the large farmers ($\sim 6 \text{ t ha}^{-1}$) could be associated with higher availability of organic manure per unit land and farm near to house (data not shown). The large farmers had lower availability of organic manure per unit land and their farms were far distant from the house or animal shed. Furthermore, resulting declined to apply thus, small amount of organic manures for their large cultivated area. Survey results showed that most farmers (86%) used organic manure in rice. This study confirmed that farmers used sufficient amount of organic inputs to maintain soil organic matter as recommended. However, farmer's knowledge about the quality of organic manures (preparation and storage) and their field application method should be improved through different extension interventions. During field application, farmers deliver the manure several days prior to incorporation in the soils. These manure management techniques results in loss of nutrients, particularly N in groundwater and atmosphere due to high rainfall and temperature.

Although farmers reported use of inorganic fertilizer is increasing over the past five years, the overall use is lower than the government recommended rates. Large farmers tended to use higher N fertilizer compared to medium and small farmers, probably due to higher financial resource (Takeshima et al., 2016) and lower availability of organic inputs. Zingore et al. (2007) also observed similar results in western Kenya. Farmers also used relatively higher amount of N fertilizer for hybrid compared to inbred varieties and for irrigated rice compared to rainfed. However, their knowledge on crop nutrient requirement, the amounts of nutrients supplied by organic manures and nutrient that should be supplemented by inorganic fertilizers was inadequate. It was evident from the lower use of N and K fertilizers compared to the recommendation. A higher amount of P fertilizer than the recommended rate was due to using of both urea and DAP as N sources. Farmers opined that K fertilizer use was only for improving soil structure. Therefore, they used a very low amount of K fertilizers. Farmers were not able to recognize the importance of micronutrients in crop production. Only a few farmers used Zinc (Zn), which was also lower than the recommended rate. These results confirm that farmers' fertilizer use is imbalanced due to inadequate access to extension services. They used fertilizers based on their own experience or following neighbor techniques rather than following soil test reports. This type of practice gap was also reported in other countries such as in Kenya (Barrious et al., 2012). Training had positive impacts on adoption of new practices as trained farmers (11%), used higher amount of fertilizers than untrained farmers.

Farmers had insufficient knowledge of amounts and timing of fertilizer use. In this study, 67% of interviewed farmers top dressed urea even when the field did not have sufficient moisture. They applied urea based on counting fixed days after transplanting rather than observing soil moisture status due to poor awareness in the importance of moisture for top dressing. This suggests that improvement in Nitrogen use efficiency (NUE) under rainfed rice cultivation is very challenging and needs

sufficient research on it. Changing the application method from broadcast (multiple splits) to deep placement, which is a one-time application after rice transplanting, increase NUE and crop productivity under irrigated conditions (Gaihre et al., 2015). More research is needed to evaluate the performance of these forms of fertilizers across different agro-ecological zone in Nepal under both irrigated and rainfed conditions.

Although, the large farmers applied higher amounts of mineral N fertilizer compared to medium and small farmers, rice yields were higher in medium farmers, probably the application of a higher rate of organic manure along with inorganic fertilizers supplied sufficient plant nutrients (Fig. 2). Use of organic manure improves the soil bio-physical properties like soil respiration, water and nutrient retention and many others (Das et al., 2017). Resource poor farmers who cannot afford groundwater irrigation schemes, the addition of higher organic matter at least can support the yields. However, the importance of organic manure for water and nutrient retention in addition to nutrient *per se* need to be informed to farmers in to increase rice productivity, particularly in the rainfed conditions.

CONCLUSIONS

Most farmers used a sufficient amount of organic manures to maintain soil organic matter, but the quality of manure was poor, and the application method was inefficient. The use of inorganic fertilizers, particularly N and P, varied with farmer type, variety and irrigation facility. The large farmers used higher amounts of N fertilizer than the medium and small farmers. Similarly, farmers used more N, P and K fertilizers in hybrid compared to inbred varieties. Farmers used more N, and P fertilizer in irrigated condition compared to rainfed. Overall, the rates of N and K were below the government recommended and the rate of P fertilizers was slightly higher than government recommended dose. This imbalanced use of fertilizers was associated with inadequate access to extension services. The study showed that effective mobilization of extension approaches, such as field demonstrations of balanced fertilizer management practice, and strengthening extension services and private sector agri-inputs supplier (agro-vets, fertilizer retailers and dealers) may lead to improve farmers' fertilizer application practice. Improved fertilizer application practice, ultimately will improve food and nutrition security as envisioned by the Agriculture Development Strategies (ADS) of Nepal.

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REFERENCES

- AICC. (2016). *Krishi Diary*, Agriculture Information and Communication Centre, Harihar Bhawan, Lalitpur. P 337.
- AIMS-MoAD. (2016). Agriculture Inputs Management Section (Annual Progress report), Ministry of Agricultural Development, Singhadurbar, Kathmandu.
- APP. (1995). Agriculture Perspective Plan (Final Report). National Planning Commission, Agricultural Projects Service Centre, Kathmandu, Nepal.
- Bindraban, P.S., Dimkpa C.O., Angle, S. and Rabbinage, R. (2018). Unlocking the multiple public good services from balanced fertilizers. *Food Security*, 10: 273-285.
- Das, S., Jeong, S.T., Das, S. and Kim, P.J. (2017). Composted Cattle Manure Increases Microbial Activity and Soil Fertility More Than Composted Swine Manure in a Submerged Rice Paddy. *Frontiers in microbiology*, 8: 1702-1702.
- FAO. (2013). FAOSTAT. Food and Agriculture Organization of the United Nations, Rome. Retrieved November 23, 2018 from <http://www.fao.org/faostat/en/#data>
- Gaihre, Y.K., Singh, U., Islam, S.M.M., Huda, A., Islam, M.R., Satter, M.A., Sanabria, J., Islam, M.R. and Shah, A.L. (2015). Impacts of urea deep placement on nitrous oxide and nitric oxide emissions from rice fields in Bangladesh. *Geoderma*, 259–260: 370–379.
- MoAD. (2015). Statistical information on Nepalese agriculture, Government of Nepal. Ministry of Agriculture and Development, Agribusiness Promotion and Statistics Division, Singha Durbar, Kathmandu, Nepal.
- MoAD. (2017). Statistical information on Nepalese agriculture, Government of Nepal. Ministry of Agriculture and Development, Agribusiness Promotion and Statistics Division, Singha Durbar, Kathmandu, Nepal.
- MoF. (2016). Economic survey of Nepal for the fiscal year 2014/2015. Government of Nepal, Ministry of Finance.
- Paudel, G.S. and Thapa, G.B. (2001). Changing farmers' land management practices in the hills of Nepal. *Environmental Management*, 28(6): 789-803.
- Raut, N. and Sitaula, B.K. (2012). Assessment of fertilizer policy, farmers' perception and implications for future agricultural development in Nepal. *Sustainable Agriculture Research*, 1: 188-200.
- Sherchan, D.P. and Karki, K.B. (2006). Plant nutrient management for improving crop productivity in Nepal. P.257. In: *Food and Agriculture Organization, Improving Plant Nutrient Management for Better Farmer Livelihoods, Food Security and Environmental Sustainability*. FAO, Rome, Italy.
- Takeshima, H., Adhikari, R.P., Poudel, M.N. and Kumar, A. (2016). Farm Household Typologies and Mechanization Patterns in Nepal Terai: Descriptive Analysis of Nepal Living Standard Surveys. *IFPRI Discussion Paper 01488*. Washington, DC: International Food Policy Research Institute.
- Zingore, S., Murwira, H.K., Delve, R.J. and Giller, K.E. (2007). Influence of nutrient management strategies on variability of soil fertility, crop yields and nutrient balances on smallholder farms in Zimbabwe. *Agriculture, Ecosystems & Environment*, 119: 112-126.