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Nutrient responses of wheat and rapeseed under different crop establishment and fertilization methods in contrasting agro-ecological conditions in Nepal

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ABSTRACT

In Nepal, low fertilizer application rate is the primary factor contributing to poor yields of wheat (*Triticum aestivum* L.) and rapeseed (*Brassica campestris* var. Toria) crops. Cash constraints among the smallholders who commonly cultivate these crops necessitate economically-efficient approaches for improving yield. To that end, research was conducted to document current production practices and to assess indigenous soil fertility and responses to nitrogen (N) fertilizer applied at different rates. Fifty-five on-farm experiments (31 in wheat and 24 in rapeseed) were conducted in 2012 and 2013 in two contrasting production agro-ecologies (rainfed Hill ecology- Palpa District and irrigated plain Terai ecology- Nawalparasi District), with nutrient responses in two crop establishment methods, i.e., conventional tillage (CVT), broadcast seeding, and no residue retention on soil surface contrasted to those under 'low soil disturbance' conservation (strip) tillage (CST), line seeding, and loose residue on soil surface. Household surveys ($N = 71$ wheat, $N = 49$ rapeseed) indicated that 73% of farmers did not apply farm yard manure (FYM) at any time during the year. In Nawalparasi, over 33% of wheat farmers did not apply N, phosphorous (P), and potassium (K) fertilizers. Similar use patterns were documented for rapeseed. In Palpa, a higher percentage of farmers did not apply fertilizer and, among those that did, the mean application rates were lower than in Nawalparasi. CST and CVT crop establishment methods did not influence response to N or estimates of indigenous soil fertility in either crop or ecology. On average, yield responses to full rates of N, P, and K fertilizer were 2.2, 1.1, and 0.5 t ha^{-1} in wheat, respectively, and 0.3, 0.2, and 0.1 t ha^{-1} in rapeseed. Except for K in wheat, the yield responses to full rates of all three nutrients were higher in Palpa than in Nawalparasi, which could be due to higher yield potential or higher efficiency of use in Hill. Due to insufficient fertilizer use among farmers, the attainable yield gap that can be attributed to nutrient limitations was 2.6 and 0.34 t ha^{-1} in Palpa (Hill) and 1.9 and 0.18 t ha^{-1} in Nawalparasi (plain Terai) for wheat and rapeseed, respectively. Despite short term, this yield gap analysis showed wheat yield could be increased by 144–336% in Hill and by 95–184% in Terai and rapeseed yield over 100% in Hill and over 47% in Terai through the balanced nutrients and best-crop management practices (BMP). The comparatively low partial factor productivity (PFP) and agronomic efficiency (AE) suggests that gains in efficiency also help to close the fertility-related yield gap. This study supports findings from many other long-term and more ecologically diverse studies and provides additional justification for prioritizing increased fertilizer use coupled with management approaches that increase use efficiencies in order to close yield gaps for both crops in both agro-ecological conditions in Nepal.

1. Introduction

Nepal has three major ecological regions, i.e., Terai (plain, < 700 m a.s.l.), Hill (700–4000 m a.s.l.) and Himalayas (> 4000 m a.s.l.). In the country, wheat (*Triticum aestivum* L.) and rapeseed (*Brassica campestris* var. Toria) are the second major food and first major oilseed crops, respectively. Both crops are grown during winter season, wheat (November–April) and rapeseed (September–March) (Mishra and Chaudhary, 2013). Combined over all regions, wheat is grown on 0.76 M ha and rapeseed in 0.21 M ha area (FAOSTAT, 2018). Hill ecology dominantly has maize-based cropping systems in *Bari* lands (unbunded, broad slopes, often found in upper landscape positions) and

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in rice-based cropping systems in *Khet* lands (bunded leveled fields), while rice-based cropping systems is dominant in Terai region (GoN, 2015).

Agriculture is mostly small-scale and subsistence-oriented but still the mainstay of the economy in Nepal. Along with the increasing population (1.7% growth rate) and the need of feed for livestock and poultry, the demand for food is increasing by 11% per annum (DoA, 2014). However, annual productivity increment rate of wheat and rapeseed crops was almost stagnant, i.e., only 0.31% in wheat and 0.84% in rapeseed in the last 56 years. In the same period, the productivity increment rate of wheat was 5% in Bangladesh and 4% in India, and rapeseed 1.3% in Bangladesh and 2.9% in India (FAOSTAT, 2018). The productivity increment rate is even lower in rainfed ecology than under irrigated (Rockstrom et al., 2010; Tiwari et al., 2004).

In the country, the national average yield of wheat is 2.3 t ha^{-1} (FAOSTAT, 2018) and rapeseed 0.7 t ha^{-1} (MOAC, 2013), while the experimental station yields of wheat is 5 t ha^{-1} (NARC, 2014) and rapeseed (Tori) 1.3 t ha^{-1} (Mishra and Chaudhary, 2013) with the recommended fertilizer rate of 100:50:25 kg $N:P_2O_5:K_2O$ ha^{-1} for wheat and 60:40:20 kg $N:P_2O_5:K_2O$ ha^{-1} for rapeseed (GoN, 2015; MOAC, 2013) with researchers' management for the experimental station yield, and approximately 1/3rd amount of these recommended fertilizer rates and farmers' management for the national average yield, indicating a significant attainable yield gap exists in both crops mainly due to low fertilizer application and poor crop management practices. The other major reasons for the higher yield gap of these crops includes, poor crop establishment and management (Devkota et al., 2015b), declining soil fertility due to: -less mineral and organic fertilizer application (Becker et al., 2007; Pandey and Joshy, 2000), -unbalanced and blanket fertilizer application (Devkota et al., 2016), -excessive soil erosion coupled with occasional heavy rainfall and intensive soil tillage (Mandal, 2002; Turton et al., 1997), and -competing uses for crop residues and animal manures (Paudyal et al., 2001). In this context, narrow down the attainable yield gap through demand-based and science-led innovations for example by optimizing soil and nutrient management practices is needed to meet the future food demand in the region. Many factors could contribute for closing yield gap but under low fertilization and poor crop management production systems, grain yield could either be limited by the nutrient (nutrient-limited yield gap) or by both nutrient- and crop-management practices (Evans and Fischer, 1999; van Ittersum and Rabbinge, 1997). Understanding indigenous soil fertility, yield response to applied nutrients, and nutrient use efficiencies are important for precision nutrient management and closing the yield gap (Dobermann, 2007; Pasuquin et al., 2014).

In the current production system, both wheat and rapeseed crops are grown by performing multiple tillage operations for seeding leading to increased production cost, poor crop establishment due to delayed seeding, and declining soil fertility due to soil erosion. The youth migration, labor scarcity, increasing labor wage rate, and declining profitability (DoA, 2015, 2018) are threatening for the continuation in the cultivation of these crops in the region. Strip tillage (< 30% soil is tilled in the planting row with the rest retaining undisturbed residue) can be considered as one of the conservation tillage (CST) practices (Peigné et al., 2018; Vaitauskienė et al., 2017). Conservation tillage reduces soil erosion (Peigné et al., 2018), enhances soil biological activity (Schlatter et al., 2017), provides better economic returns (Derpsch, 2011), saves labor and time (Erenstein and Laxmi, 2008), reduces management related yield gap by 14–47% for wheat (Jat et al., 2011), and is also suitable for the upland and rainfed crops and cropping systems (Govaerts et al., 2007).

Inadequate and unbalanced use of fertilizers are decreasing the nutrient use efficiency (Devkota et al., 2016; Sapkota et al., 2014) and calling for maximizing yield through the adoption of optimum nutrient rate (Becker et al., 2007) and site-specific nutrient management (Dobermann, 2007). Improved nutrient management strategy, for example nutrient omission has been proposed to improve nutrient use efficiency by providing site-specific fertilizer recommendation (IPNI, 2017). Research carried out in South Asia suggests that further improvement in nutrient use efficiency is possible through the balanced application of nitrogen (N), phosphorus (P), and potassium (K) fertilizers, and by rational use of organic manures in the systems (Jat et al., 2014). In Hill and Terai ecologies of Nepal, optimal nutrient management in CST-based system has not been fully understood, but evidence suggests that soil carbon and nutrient dynamics can be affected (Bauer et al., 2002). Less disturbed soil reduces soil organic carbon oxidation and prevents soil erosion (Pes et al., 2011), both of which ultimately affect nutrient response and use efficiencies. In addition, nutrient stratification and dynamics differ with tillage methods, climatic condition, soil type, and the cropping systems (de Oliveira Ferreira et al., 2013). Thus, the objectives of this study were to determine the N, P, and K responses and nutrient use efficiencies of wheat and rapeseed under CST and conventional tillage (CVT) and different fertilization methods across contrasting agro-ecological conditions of Nepal.

2. Materials and methods

2.1. Site description

The study was conducted in two different ecologies, i.e., Hill (high altitude, terraced, Palpa district, 27°46′42″ to 27°55′30″ latitude, 83°32′26″ to 83°27′57″ longitude, and 700–1700 m a.s.l. altitude) and Terai (low altitude, plain, Nawalparasi district, 27°31′84″ to 27°39′28″ latitude, 83°49′54″ to 83°18′17″ longitude, and 110–300 m a.s.l. altitude) for two years (2012–2013) during the wheat and rapeseed seasons (Fig. 1). In Palpa, on-farm experiments were conducted in four sites, viz. Madiphat (*Khet* land) and Laguwa, Harthog and Chhandibhanjang (*Bari* land), wheat experiments were conducted in *Khet* land and rapeseed in *Bari* land. In Nawalparasi, the studies were conducted in Sunwal in *Khet* land. The on-farm experiments were conducted within 10 km range in Nawalparasi and 25 km range in Palpa. In Nepal,

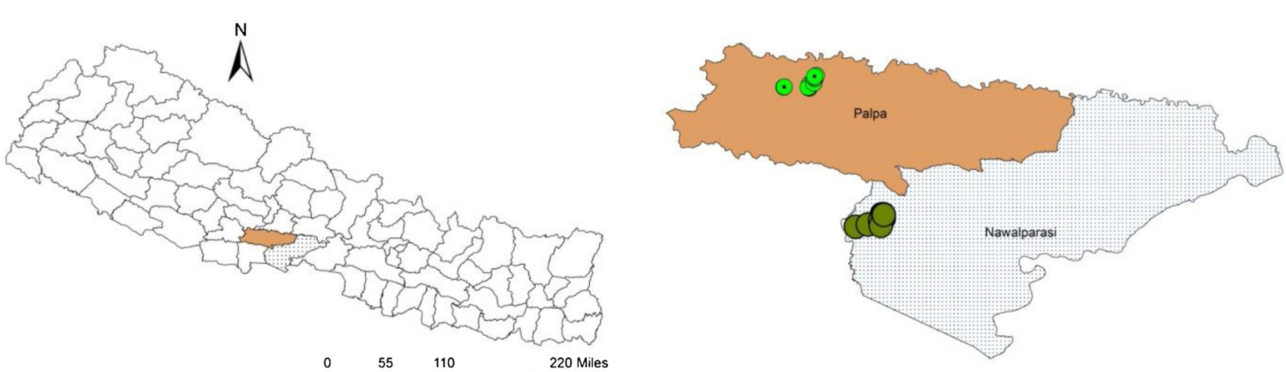

Fig. 1. On-farm experimental sites (A) and two study regions Palpa (Hill) and Nawalparasi (Terai) (B) agro-ecologies of Nepal, 2012-2013.