Influence of nutrient sources and inclusion of mungbean on productivity, soil fertility and profitability of organic rice-wheat cropping system

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Key words: basmati rice, biofertilizers, crop residue, farm yard manure, organic farming, vermicompost

Abstract

Rice–wheat cropping system (RWCS) occupies 13.5 million hectares in the Indo-Gangetic Plains (IGP). Recent years have witnessed a slowdown in the yield growth rate of RWCS. A long-term field experiment evaluated the effect of including mungbean in RWCS with different organic nutrient management practices at Indian Agricultural Research Institute, New Delhi. Averaged across seven years, rice-wheat-mungbean cropping system (RWMCS) produced 12.5 and 8.0% higher grain yields of basmati rice and wheat crops, respectively over RWCS. Overall, the basmati RWMCS was more profitable over the traditional RWCS. On the basis of seven years of investigation we conclude that application of vermicompost + crop residue + biofertilizers (BGA + cellulolytic culture + PSB in rice, Azotobacter + cellulolytic culture + PSB in wheat, Rhizobium + PSB in mungbean) was most productive and FYM + crop residue + biofertilizers was most profitable for nutrient need of basmati rice-based cropping systems.

Introduction

The rice–wheat cropping system (RWCS) is one of the largest agricultural production systems of the world, occupying 13.5 million hectares of cultivated land in the Indo-Gangetic Plains (IGP) in South Asia and several million hectares in China (Ladha et al. 2009). Presently, the IGP contributes nearly 42% to the total food grain production in India with the rice-based cropping systems (Shibu et al. 2012). However, during recent years, a significant slowdown in the yield growth rate of RWCS has been observed. Key issues associated with the sustainability of this system include decline in soil organic matter (SOM) due to reduced inputs of bio-resources and lack of an adequate rotation (Shibu et al. 2010); negative macro and micro-nutrient balances leading to depletion of soil fertility and nutrient deficiencies (Timsina et al. 2006); overexploitation of groundwater resources leading to a decline in the groundwater table (Hira 2009); increased energy cost of pumping water, and deterioration of groundwater quality, increasing salinity (Tiwari et al. 2009); the development of herbicide resistance and a shift in weed flora and pest populations (Hobbs et al. 1997); poor management of crop residues, leading to their burning, and finally decreased total factor productivity or input-use efficiency, increased cost of cultivation and reduced profit margins (Hobbs and Morris 1996). Overcoming these interacting abiotic constraints requires adoption of more integrated farming systems that build-up and maintain SOM, need less water and improve nutrient use efficiency (Prasad 2005). Furthermore, the demand of rice and wheat crops for nutrients, especially nitrogen, is very high. One option is to include a dual purpose summer legume in the rotation and supply nutrients through organic sources to sustain the cropping system.

Adoption of organic farming practices in basmati rice and wheat crops would also enhance income to the farmers as organic products fetch higher prices than conventional ones. During year 2010-11 the share of organic basmati rice was 7.51% to the total volume of organic products' export from India. Thus research on organic farming opens new vistas in Indian Agriculture. Organic farming often has to deal with a scarcity of readily available nutrients in contrast to conventional farming which rely mostly on chemical fertilizers. The aim of nutrient management in organic systems is to optimize the use of on–farm resources and minimize losses. This study evaluated the effect of including mungbean (*Vigna radiata* L.) in rice-wheat cropping system on productivity and profitability of basmati rice and wheat crops. Further aim of the study was to find out the most promising nutrient management practices for better yields, returns and improved soil fertility.

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Material and methods

A long-term field experiment on organic farming of basmati rice-based cropping systems was started in year 2003 and is on-going. The initial three years were considered as transitional (2003-2005) period and a truly organic experiment started since year 2006 onwards. This experiment is located on the research farm of Indian Agricultural Research Institute, New Delhi, India (28.4°N latitude, 77.1°E longitude, and elevation of 228.6 metres above the msl). The soil of the experimental field is classified as a typical Ustochrept (sandy clay loam texture). Soil had 52.06% sand, 22.54% silt and 25.40% clay at the beginning of the experiment. It had medium levels of organic carbon (5.1 mg kg^{-1} soil), low levels of available nitrogen (73.1 mg kg^{-1} soil) and medium levels of available phosphorus (8.42 mg kg^{-1} soil) and available potassium (108.87 mg kg^{-1} soil) and had a pH 8.16 at the start of experiment. The experiment was laid out in a strip plot design with three replications. Treatments consisted of 2 rice-based cropping systems (basmati rice-wheat and basmati rice-wheat- mungbean) in columns, six combinations of different organic materials and biofertilizers [farmyard manure equivalent to 60 kg N ha^{-1} (FYM), vermicompost equivalent to 60 kg N ha^{-1} (VC), FYM + crop residue of preceding crop @ 3 t ha^{-1} for each rice, wheat and mungbean (CR), VC + CR, FYM + CR + biofertilizers and VC + CR + biofertilizers] and control (no fertilizer applied) in rows. These treatments were applied to both rice and wheat, whereas, mungbean in rice-wheat-mungbean cropping system was grown on residual fertility. For biofertilizers, blue green algae (BGA), phosphate solubilizing bacteria (PSB) and cellulolytic culture used in rice, Azotobacter, PSB and cellulolytic culture in wheat and Rhizobium + PSB in mungbean.

Results

Averaged across seven years, rice-wheat- mungbean cropping system (RWMCS) produced 12.5 and 8.0% higher grain yields of basmati rice and wheat crops, respectively over RWCS (Table 1). Furthermore, RWMCS also gave 0.88 t ha^{-1} additional seed yield of mungbean besides a significant improvement in soil fertility over RWCS. With respect to profitability, the basmati RWMCS was more profitable over the traditional RWCS (Figure 1). Hence, inclusion of mungbean, a legume, in RWCS enhanced the yield, profits and soil fertility. All the nutrient management practices increased the grain yield of rice and wheat crops significantly over the control. The increase was most when biofertilizers and crop residues were combined either with farmyard manure (FYM) or vermicompost (VC). Furthermore, application of vermicompost + crop residue + biofertilizers (BGA + cellulolytic culture + PSB in rice, *Azotobactor* + cellulolytic culture + PSB in wheat, *Rhizobium* + PSB in mungbean) was most productive and FYM + crop residue + biofertilizers was most profitable (Figure 1) for nutrient need of basmati rice-based cropping systems. Both these combinations also resulted in a significant improvement in soil chemical and biological properties.

Table 1. Mean grain yield of basmati rice, wheat and mungbean crops in organic rice-wheat and rice-wheat-mungbean cropping systems

Year	Rice-Wheat (yield in t/ha)				Rice-Wheat-Mungbean (yield in t/ha)				
	Rice	Wheat	Total	Mean	Rice	Wheat	Total	Mean	Mungbean
2006-07	4.26	3.57	7.83	3.92	4.55	3.82	8.37	4.19	0.86
2007-08	4.51	4.47	8.98	4.49	4.91	4.83	9.74	4.87	0.90
2008-09	4.30	3.71	8.01	4.01	4.60	3.80	8.40	4.20	0.98
2009-10	3.94	3.81	7.75	3.88	5.10	4.04	9.14	4.57	0.81
2010-11	4.49	3.38	7.87	3.94	5.18	3.78	8.96	4.48	0.95
2011-12	3.71	3.52	7.23	3.62	4.08	3.97	8.05	4.03	0.83
2012-13	3.88	3.61	7.49	3.75	4.33	3.87	8.20	4.10	0.87
Mean	4.16	3.72	7.88	3.94	4.68	4.02	8.69	4.35	0.88

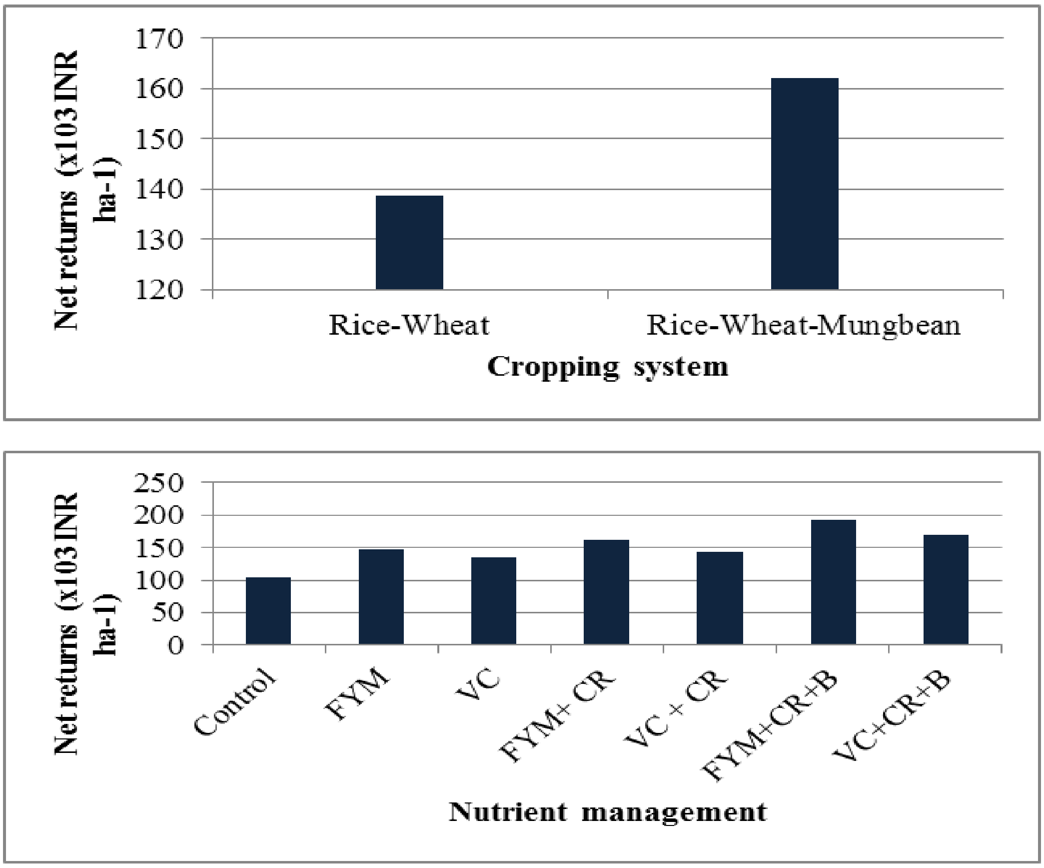

Figure 1. Net returns (x10^3 Indian Rupees ha^{-1}) as affected by cropping systems and nutrient management during 2011-12

Discussion

Inclusion of mungbean in rice-wheat cropping system (RWCS) was quite advantageous. Levels of organic carbon, total N, available nitrogen, phosphorus, potassium and micronutrients increased significantly and substantially due to inclusion of mungbean in RWCS. Simultaneously the soil microbiological properties, viz., microbial biomass carbon, microbial biomass nitrogen and enzymatic (alkaline phosphatase, acid phosphatase, dehydrogenase, glucosidase, FDA hydrolysis, etc.) activities were also significantly higher in soils of rice-wheat-mungbean cropping system (RWMCS) than in RWCS. Some earlier studies on organic grain production identify legume crops as a proficient way of providing nitrogen (N) to high N-demanding grain crops (Casagrande et al., 2009). Their capacity to fix atmospheric N and make it available to non-fixing plants (Fustec et al., 2010) has made them of increasing interest in organic grain systems subject to N deficiency (David et al., 2005). Combined use of either vermicompost or farmyard manure with crop residues and biofertilizers improved grain yields of rice and wheat crops, besides improvement in soil fertility. The increased activity of soil microbs was also notice under this situation. On the basis of seven years of investigation we conclude that inclusion of mungbean in RWCS enhanced grain yield, soil fertility and profits over RWCS. Use of FYM with crop residues and biofertilizers gave maximum profits and sustained soil fertility. Hence, organic systems are sustainable if legume is included in intensive rice-wheat system with appropriate organic nutrition.

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