

Effect of different agricultural practices on yield, profitability and soil properties under maize (*Zea mays*) – barley (*Hordeum vulgare*) cropping system

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Summary

The present study was conducted to quantify the effects of natural, organic, and integrated farming methods on yield, profit, and soil properties of maize (*Zea mays*) + soybean (*Glycine max*) – barley (*Hordeum vulgare*) + vegetable pea (*Pisum sativum*) cropping system. The mean data of two years recorded 54% and 62% higher maize yield and net profit with applied NPK+FYM. Such increase in yield and net profit of barley was 48% and 47%. Soil properties showed a significant improvement due to applied NPK+FYM over FP and observed an increase of 23%, 14%, 8%, 30% and 16% for soil OC, MBC, available N, P and K, respectively. The availability of micronutrients in soil was maximum under organic and SPNF practice than other treatments. The study also revealed that SPNF practice was statistically at par with FP but these were found inferior to rest of the practices suggesting that natural and organic farming need to be practice for a longer period for better yield, profit, and soil environment.

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Introduction

Green Revolution technology has been proved as a double-edged sword for the Indian agriculture system as well as for the entire globe. Although it intensified Indian agriculture from a food-scarce to a food-surplus country, it has also thrown several challenges in the form of declining factor productivity, depleting natural resources, low water, and nutrients, and adverse impacts on climate change as well as on human health (Bharucha et al. 2020, Bhattacharyya et al. 2020, Kitamura et al. 2021)^{1,2,7}. Overuse of chemical fertilizers depletes soil nutrients, reduces the yield, and poisons the whole ecosystem (Li et al. 2020)¹⁰. In the past, several management practices, such as biofertilizers/biopesticide application, use of vermicompost, FYM, etc., have been intended to mitigate the negative impact of chemical fertilizers and pesticides (Ray et al. 2020)¹⁶. Despite the continuous efforts of the scientific community, to date there has yet to be a proven method that can replace chemical-based fertilizers/pesticides providing sustainable results. Although organic farming seems to ease the above-mentioned effect by cutting greenhouse gas emissions (by ~65%) and comforting climate change, it creates a challenge in the form of low productivity and a difficult certification process (Timsina 2018; David Israel Mansingh & Suresh 2019)^{25, 28}.

The un-proportionate use of fertilizers, increase in nutrient gap between plant use and fertilizer application and mining of native soil nutrients has posed adverse

effect on plant growth and yield (Panaullah et al. 2006, Rijpma & Islam 2015)^{12,18}. Presently, farmers are applying chemical fertilizers without FYM resulting negative nutrient balance. Therefore, to halt the nutrient depletion, it is necessary to follow conjoint use of organic and inorganic sources of plant nutrients which would reduce the negative nutrient in near future (FRG 2018)⁴. Recently, efforts have been made in our agricultural practices to reduce the dependency on using mineral fertilizers by developing organic manures produced from natural materials. Majority of the Indian farmers practice conventional type of farming with imbalanced fertilizer use. Hence, the present study was conducted to quantify the effects of natural, organic, conventional, and integrated farming methods on yield, and soil properties of maize (*Zea mays*) + soybean (*Glycine max*) – barley (*Hordeum vulgare*) + vegetable pea (*Pisum sativum*) cropping system.

Materials and Methods

The study was carried out for two years (2019-20 to 2020-21) under rainfed condition at the experimental farm of CSK Himachal Pradesh Krishi Vishvavidyalaya, Hill Agricultural Research & Extension Center, Bajaura, Kullu, India. The experiment consisted of five treatments comprising of organic, natural, conventional, INM and farmers' practice which were replicated thrice in a randomized block design. The maize crop was sown on June 21 and 18 in the year 2019 and 2020, respectively. The sowing of barley was carried out on 16 and 21 November during 2019 and 2020, respectively. The harvesting of maize was done on 26 and 29 October in 2019 and 2020, respectively. The barley was harvested on June 23 and 28 in the year 2020 and 2021, respectively. The crops were provided fertilizer doses as per the treatments. In case of natural farming, seeds of

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maize and barley were treated with beejamruth prior to sowing and application of jeevamruth (500L/ha) was done along irrigation water at 15 days interval and ghanjeevamruth (250 kg/ha) was applied at the time of sowing. The grain yield of crops was recorded every year and expressed in q/ha. Surface soil samples from 0-0.15 m after harvest of barley crop in 2021 were collected and analysed for soil OC, MBC and available NPK using standard procedures. The economics of each treatment was work out considering prevailing market price of inputs and output using the formula:

Gross returns=Yield*Rate

Net returns=Gross Returns-Cost of cultivation

Benefit Cost ratio= Net returns/Cost of cultivation

The average market sale price of maize and barley grain was INR 2500/q and INR 3700/q, respectively.

Statistical Analysis

The data for two years was pooled, and means were presented. OPSTAT software (Sheoran et al. 1998)²² was used to analyse the data in randomized block design. The means were separated by least significant difference at 0.05. The Microsoft excel software was used to prepare error bar diagram.

Results and Discussion

Crop yield and economics: The study over two consecutive years showed that recommended dose of fertilizers and farmyard manure (NPK+FYM) recorded highest grain yield of maize (34 q/ha) and barley (28 q/ha) (Figure 1). However, the crop yield under RDF and INM was statistically equal.

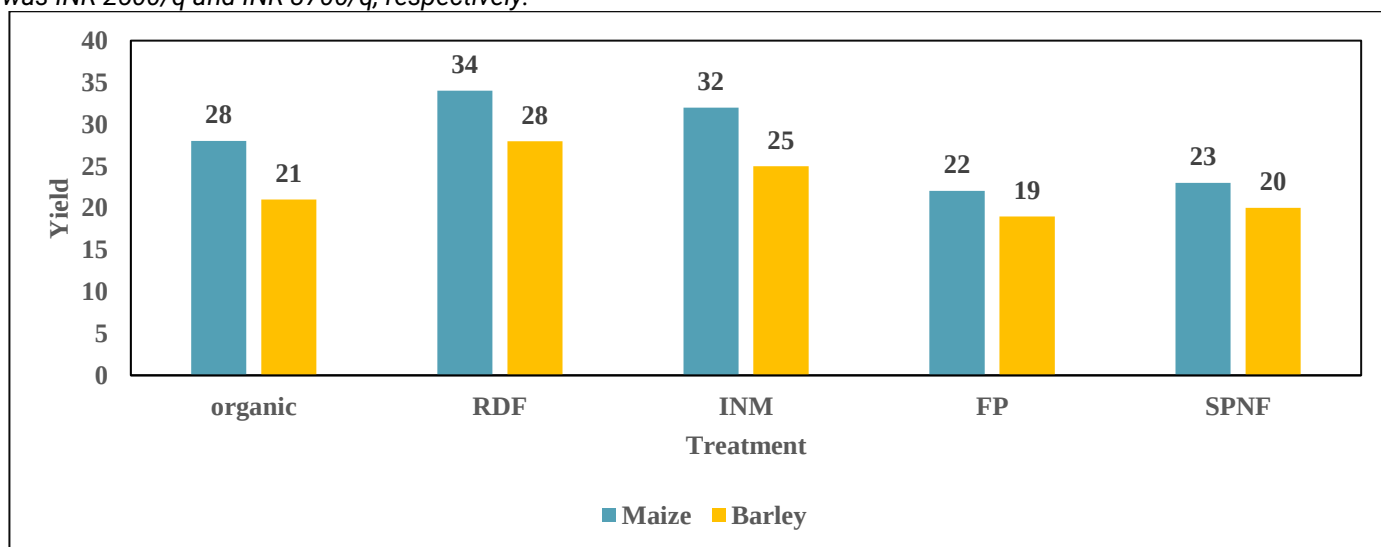


Figure 1. Maize and Barley Grain Yield (q/h)

Likewise, maize grain yield was similar in farmers' practices and natural farming treatment. The barley yield was maximum (28q/ha) in RDF but like INM treatment (25q/ha). Also, the yield level in organic, natural and farmers' practices was same (Figure1). The maximum net returns and B:C of Rs. 47,800/ha and 1.77 and Rs. 39,154/ha and 1.96 were recorded for maize and barley, respectively (Figure 2 & 3). The significant increase in maize and barley yield might be attributed to better growth and development of plant which is due to uptake

of nutrients from both organic and inorganic sources. The highest grain yields were obtained when farmyard manure was applied along with inorganic fertilizers and this may be ascribed to the immediate supply of nutrients after application, while organic fertilizers release nutrients slowly through microbial mineralization which ensure that the nutrient availability at vital growth stage of crops (Simarmata et al. 2016, Vishnupandi & Thangaselvabai 2019)^{23, 29}.

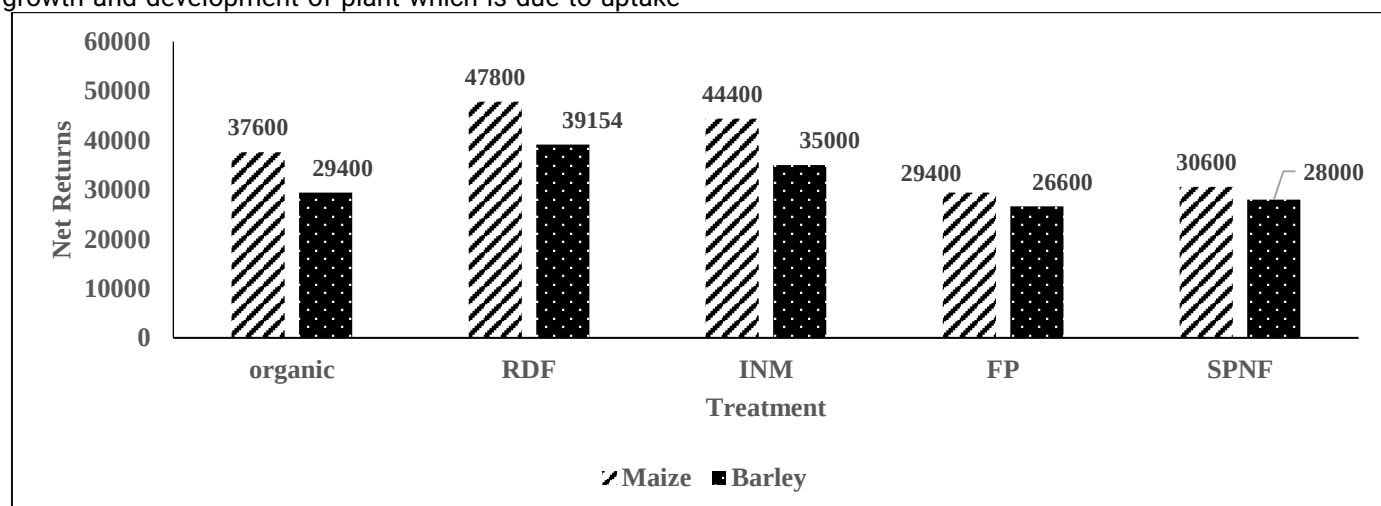


Figure 2. Net returns (Rs/ha)

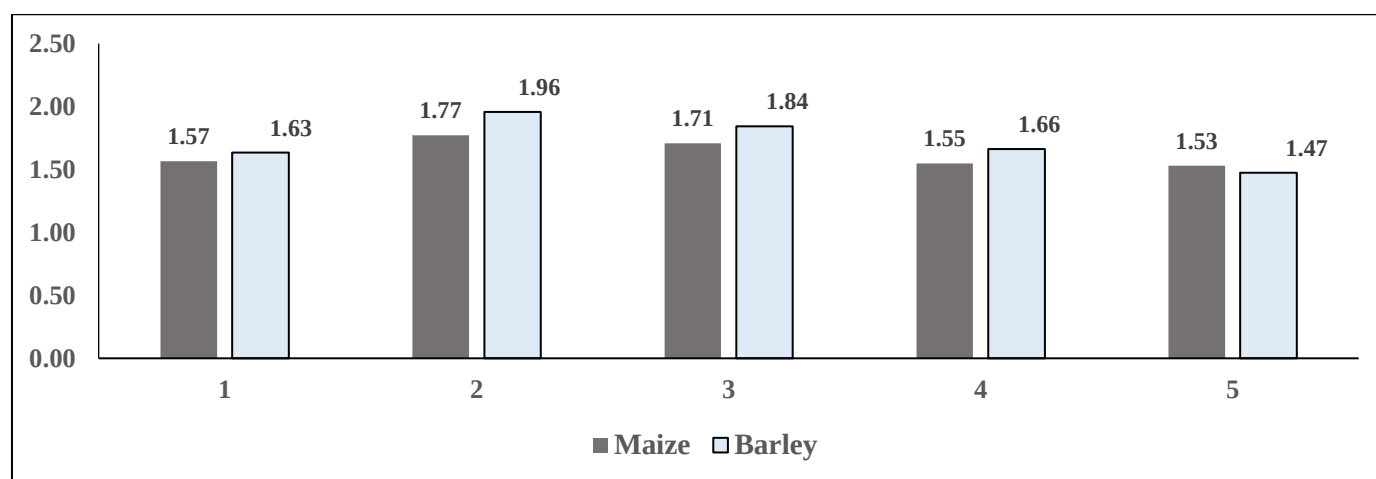


Figure 3. Benefit-cost ratio

The use of organic manures and inorganic fertilizers is primarily based on providing nutrients to plants, sustaining plant growth and development, and increasing yield (Riba et al. 2018)¹⁷. Many researchers have also reported the yield enhancement from the combined application of organic manures and chemical fertilizers (Singh et al. 2018)²⁴. The maximum profit and benefit-cost ratio in INM farming resulted from improved crop growth and soil physical, chemical and biological environment, as was noticed in the current study.

Soil properties: The application of recommended NPK+FYM recorded highest soil OC (0.86%), microbial biomass carbon (98 µg/g soil), available N (241 kg/ha), P (26 kg/ha) and K (195 kg/ha) in comparison to FP which had low value of soil OC (0.70%), microbial biomass carbon (86), available N (223 kg/ha), P (20 kg/ha) and K (168 kg/ha), respectively. The SPNF and FP were recorded at par values of above soil properties (Figure 4).

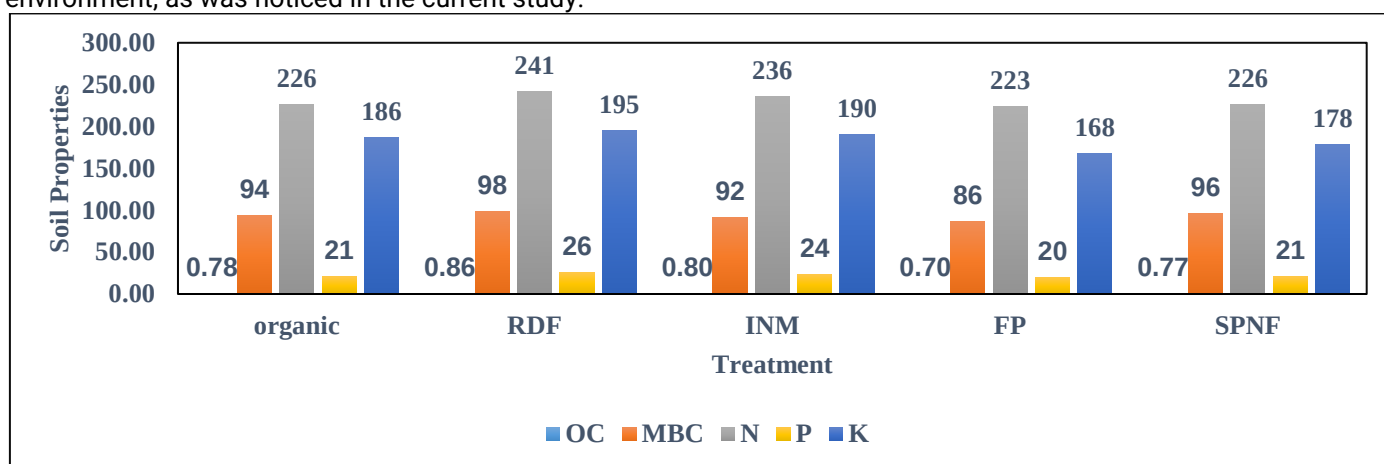


Figure 4. Soil Properties under different agricultural practices

Earlier researchers have observed that conjoint use of organic manures and mineral fertilizers has the tendency to enhance soil organic carbon (Nesgea et al. 2012, Yavarzadeh & Shamsadini 2012)^{11,26}. The higher build-up of available N due to the addition of FYM and chemical fertilizers resulted from enhanced multiplications of microbes, which helped convert organically bound N to inorganic form. The addition of FYM also helped in a higher rate of N mineralization leading to the build-up of higher available nitrogen. These results also contradict those of Kumari & Tripathi (2018)⁸. The higher phosphorus availability in NPK+FYM practice might be due to the release of organic acids during the decomposition of organic matter, which facilitates the release of phosphorus ions in the soil solution through its solubilizing action (Prasad et al. 2010)¹³. These results are also in conformity with Kumar & Singh (2010). Increased availability of K due to applied NPK+FYM is likely due to reduced K fixation and release of K due to the interaction of organic matter with clay (Sharma et al.

2001, Sachin et al. 2019)^{21,30}. Sahu et al. (2017)¹⁹ and Ram et al. (2016)¹⁵ also documented improved soil K status with conjoint use of NPK+FYM.

The highest availability of soil micronutrients was recorded in organic practice, followed by SPNF practice (Table 1). The value of Fe, Mn, Zn, Cu and B among different practices varied from 13-19 ppm; 11-21 ppm; 0.5-2.2 ppm; 0.4-1.3 ppm and 0.32-0.49 ppm, respectively. The higher Fe content in organic practice was due to the production and direct addition of organic acids and chelating agents to the soil, which increased the solubilization of native Fe, which reduced Fe adsorption, fixation, and precipitation, resulting in enhanced availability (Kher 1993)⁶. Microbial decomposition of organic matter leads to reducing conditions by utilizing oxygen from the soil atmosphere and produces CO₂, which is known to be largely responsible for the oxidation and reduction of manganese compounds and increased availability of Mn (Gadd 2004)⁵.

Table 1. Effect of farming methods on soil available micronutrients (ppm)

Treatment	Fe	Mn	Zn	Cu	B
Organic	19	21	2.2	1.0	0.49
RDF	17	15	1.2	0.7	0.39
INM	15	15	1.1	0.6	0.37
FP	13	11	0.5	0.4	0.32
SPNF	16	18	1.8	1.3	0.43
CD(5%)	1.0	2.6	0.15	0.09	0.03

Higher availability of Zn under organic practice increased the crop yield which left a large amount of crop residues and root mass in the soil, thereby, increased the organic matter content in the soil (Priyanka et al. 2017)¹⁴ and Zn is known to form strong complexes with organic matter in the soil and formation of organometallic complexes with ligands, mineralization, and solubilization from organic manures results in increased Zn in plots receiving manures (Dhaliwal & Dhaliwal 2019)³. The higher content of Cu was due to the chelation of Cu with organic ligands produced through the decomposition of organic manures and due to the release of Cu from manures themselves (Shambhavi et al. 2020)²⁰. The higher content of Mn in plant-available form might have solubilized Mn from precipitated and occluded forms thereby increasing its content in soil (Dhaliwal and Dhaliwal 2019)³. Addition of FYM caused an increase in soil organic C that could mobilize B from soil minerals and subsequently chelate it through formation of B-diol complexes and enhanced B availability in soil (Yermiyahu et al. 2001)²⁷.

Conclusions

The study confirmed that application of 100 % of recommended NPK fertilizers and farmyard manure proved to be a good choice for higher yield, and soil health improvement. The study also revealed that the natural farming and organic farming should be practiced for a longer period for the realization of economic and ecological benefits.

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Declaration of interests

The authors have no conflict of interest to declare.

Data sharing

All relevant data are within the manuscript.

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