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Consequences of Organic and Inorganic Fertilizer Application on Secondary Nutrients under Rice-wheat and Agroforestry Systems

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ABSTRACT: After green revolution era India agriculture encountered the several problems of soil health, slightly stagnation of food grain production, reduce the ecological resilance etc. resulting overall declining in the system productivity. Integrated application of nutrients for rice-wheat (RW) and agroforestry system is necessary for maintaining soil properties. In sequence to assess the impact of various nutrient management approaches on RW and agroforestry field experiment was conducted during 2016-17 and 2017-18 in which four treatments were taken in an ongoing Long Term Fertilizer Experiment (LTFE), and two treatments from Agroforestry system *i.e.* Poplar and Eucalyptus based agroforestry systems. Results showed that the organic soil carbon, nitrogen, phosphorus and potassium content increased by 92.41 and 97.60%, 0.396 and 0.390%, 56.34% and 54.84%, 60.39 and 65.06% and 31.99 and 28.68%, respectively over 100% NPK application in R-W cropping system for surface soil in both *kharif* and rabi season. Agro forestry system improves organic soil carbon, available N, P and K by 78.48 and 45.57%, 14.37 and 4.32%, 23.31 and 1.55%, 23.30 and 7.28%, respectively over the 100% NPK for R-W cropping system for the surface soil in kharif season. Overall, fertilizer application along with organics improves the soil properties in both the R-W and Agroforestry based cropping system.

Keywords: Soil organic carbon, nitrogen, phosphorus, potassium, LTFE, Agroforestry.

INTRODUCTION

After green revolution era India agriculture encountered the several problems of soil health, slightly stagnation of food grain production, reduce the ecological resilance etc. resulting overall declining in the system productivity (Singh *et al.,* 2013). Soil organic matter play a crucial role in the improvement of all biological, physical and chemical properties of soil. Agriculture has been the cornerstone of the Indian economy. Indian climatic and soil condition is benignant for agriculture because it provides favorable conditions. There are plain areas, well fertile soil and long crop growing season and broad variation in climatic condition *etc.* India has been regularly making innovation endeavors with the help of science and technology to increase the farm production and productivity as well. In India different types of cropping patterns, cropping and farming systems are adopted by farmers. India has the highest fertile soil in the entire world in the Indo-Gangetic region.

In the country paddy-wheat cropping system are very popular in Indo-Gangeticplains, which occupies about 13.5 million hectares. Paddy-wheat cropping system mostly dominated in Punjab, U.P., M.P. and Haryana, states of the country and contributes approximate 75 per cent of the country food grain production (Sapkota *et al.*, 2017; Jat *et al.*, 2014). In this system, paddy crop is grown in spring season and follow excessive tillage in paddy-wheat systems which requires much labour, water and energy, thus increasing the cost of cultivation which resulting in decreased net returns (Aryal *et al*., 2015). Agroforestry is an aggregative form of land utilization and technologies where woody perennials (shrubs, palms, trees, bamboos, etc.) are consciously used on the same land- units as crops and/or animals, in some form of the spatial arrangement and/or temporal sequence (Solanki *et al*., 2016; FAO, 2015). In Indo Gangetic plain poplar (*Populus deltoids*) and eucalyptus (*Eucalyptus globulus*) based agroforestry systems have been adopted by the farmer (Rabha *et al*., 2019).

Wheat, maize, sorghum, oats, sugarcane, berseem, turmeric, ginger and potato can be easily grown as an intercrop in poplar and eucalyptus plantations. Declining farm productivity, soil and environment quality, and water table, while increasing water logging and salt affected soils have serious problems in this Indo-Gangetic region which requiring immediate contemplation (Solanki *et al*., 2018a). Agroforestry systems in this area has splendid potential to address the issues of soil degradation and sustainability (Pathak *et al.,* 2014). In Indian's Indo Gangetic Region (IGR), poplar based agroforestry systems have been proven to be compatible with agriculture crops and profitable to farmers. Soil organic materials (SOM) are intrinsic and essential components of soil acts as a storehouse for nitrogen, phosphorus, potassium and all other essential micro and trace nutrients.

MATERIALS AND METHODS

A. Experimental site

The field experiment was conducted during 2016-17 at Norman E. Borlaug CRC of GBPUA&T, Pantnagar, four treatments were taken from ongoing Long Term Fertilizer Experiment, which is being carried out at since *Kharif* 1971 and Agroforestry Research Centre of GBPUA&T, Pantnagar in which two treatments were taken from Eucalyptus and Poplar based agroforestry systems. Experiment location represents the *Tarai* belt of Uttarakhand and is situated at an altitude of 243.83 m, 29°N latitude and 79.5°E longitude. The soil of experimental area is fined loamy in texture. These soils are originated from alluvial sediments. The climatic condition of the region is humid sub-tropical. The average annual precipitation is 1020 mm. During summer season, temperature exceeds 40°C while in winters season the minimum temperature seldom touches 0° C.

B. Experimental Details

The experiments were conducted in randomized block design (RBD). The treatment was executed at two sites in cropping year 2016-17 and 2017-18. The first site was long term fertilizer experiment at N. E. Borlaug C.R.C. in which rice–wheat cropping system is followed since 2002 along with a fallow plot. Four treatments were executed in this site in an open condition i.e. without presence of any tree. The second site of experimentation was at AFRC Patharchatta where two treatments were executed under eucalyptus and poplar based agroforestry systems. All the treatments were replicated four times in a RBD design.

Treatments and Detail:

Treatments at long term fertilizer experiment at N. E. Borlaug CRC in rice wheat system

T1- Control (no manures and fertilizers)
T2- 100% NPK to rice and wheat both
T3- 100% NPK to both crops + FYM @ 15 t ha^{-1} (to wheat only)
T4- Fallow (without crop)

Treatments at FRC Patharchatta under agroforestry system

T5- 100% NPK to soybean-wheat in 2016-17 and foxtail millet-wheat in 2017-18 under Poplar trees
T6- 100% NPK to wheat in both years under Eucalyptus trees

Crops at both the sites were managed with scientific package of practices as per the university recommendations. T4 treatment in N. E. Borlaug CRC was kept fallow without any crop and in T6 under Eucalyptus based agroforestry systems at AFRC Patharchatta was kept fallow during kharif season in both the years.

Collection of soil samples processing. Soil samples at two soil depths (0-15 and 15-30 cm) from each plot of the experimental field from both the experimental sites were collected after *kharif* and *rabi* seasons in both the years. From each individual plot, soil samples were collected from 3 different spots by moving in a zigzag manner after scrapping off the surface litter, if any, without removing soil. Collected soil samples from all three spots of an individual plot were mixed together thoroughly by hand on a clean polythene sheet or clean cemented floor. Soil samples were then brought to the laboratory; air dried in shade and passed through 0.2 to 0.5 mm sieve for organic fractions and 2-mm sieve for other parameters. Bulk soil samples were reduced to about 500 g by quartering procedure and representative samples obtained through this method were collected in polythene bags and then analyzed for Physico-chemical and biological properties.

RESULTS AND DISCUSSION

A. Soil organic carbon (%)

The pool data on soil organic carbon (SOC) given in Table 1 revealed that both the surface and sub-surface SOC was significantly affected by all various treatments after *kharif* and *rabi* seasons at both the experimental sites. After *kharif* season, the highest SOC content in surface soil was observed under 100 % NPK + 15 t FYM ha^{-1} (T3), followed by poplar agroforestry (T5), Fallow (T4) and eucalyptus agroforestry (T6) system whereas, the lowest was observed under the control (T1). The SOC increased by 82.05 and 47.44 per cent in popular (T5) and eucalyptus (T6) based agroforestry, respectively over 100 % NPK under rice-wheat system (T2). Likewise, the SOC content in sub-surface also follow similar trend. The value of SOC content in sub-surface varied from 0.49 percent in control to 1.19 percent in 100 % NPK + 15 t FYM ha^{-1}.

SOC content in popular agroforestry (T5) and eucalyptus agroforestry system (T6) increased by 38.33 % and 15.00 %, respectively than SOC in 100 % NPK under rice-wheat system. Similarly, SOC content varied from 0.57% in control to 1.63 % in 100% NPK + 15 t FYM ha^{-1} after *rabi* seasons (Table 1). Application of 100 % NPK under popular (T5) and eucalyptus (T6) agroforestry system increased SOC by 76.54 and 46.91 per cent, respectively than application of 100 % NPK under rice-wheat system (T2). The higher level of organic soil carbon content with the long-term fertilizer application (180-80-40 NPK) along with FYM may be due to improve root growth, resulting in more organic residue in the soil. Similar results were also observed by Solanki *et al*. (2017a); Bora *et al*. (2018); Solanki *et al*., (2017b). Paudel *et al*. (2014) also evaluated that the soil organic carbon (SOC) at both two different depths were analyzed to accomplish the annual SOC deposition under various treatments of the continuous trial of the paddy-wheat system. The mean SOC content at the upper 0-15 cm depth was 17.25 g kg^{-1} soil before paddy crop season at 2012 and 17.58 g kg^{-1} soil after the wheat crop season at 2013. In a 100 year study on poplar, Sierra *et al.* (2013) observed a linear positive correlation of soil organic matter (SOC) content with time. An increase of 88% higher SOC stock in poplar based agro-forestry system than the paddy-wheat system was observed by Benbi *et al*. (2012).

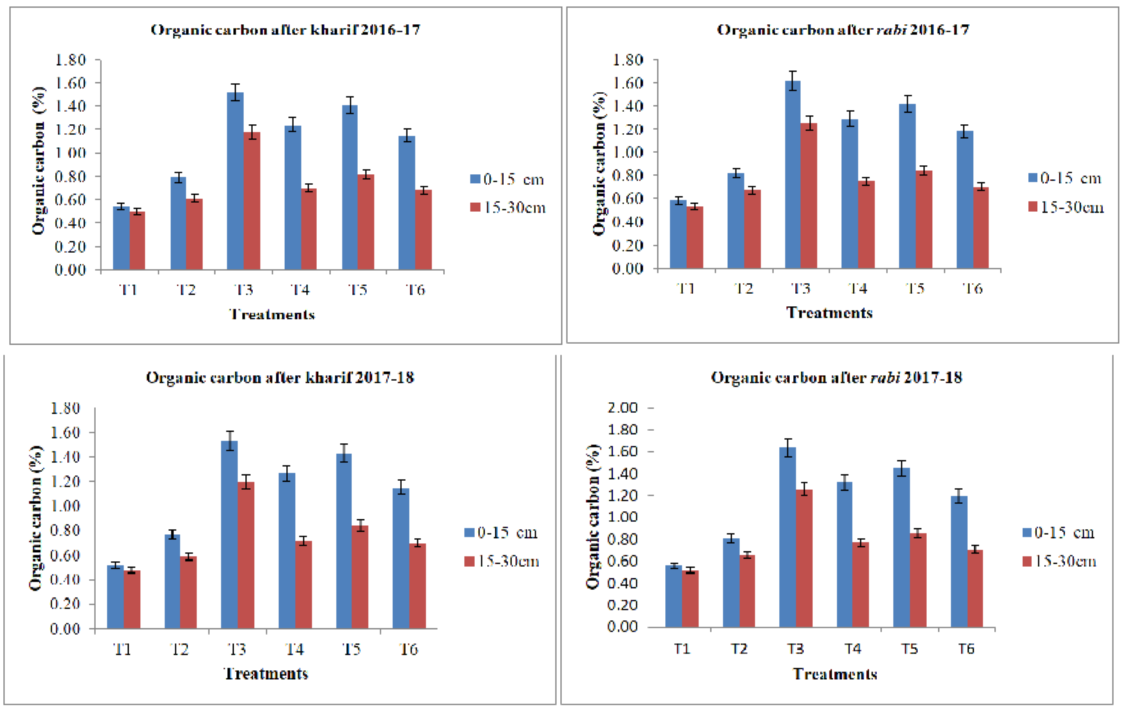

Fig. 1. Effect of long term use of organic manure manures and inorganic fertilizers on organic carbon (%) under different cropping systems after *kharif* and *rabi* seasons during 2016-17 and 2017-18.

Table 1: Effect of long term use of organic manure manures and inorganic fertilizers on organic carbon (%) and pH under different cropping systems after *kharif* and *rabi* seasons during 2016-17 and 2017-18.

Treatments	Organic carbon (%)				Soil pH			
	After Kharif 2016 17	After Rabi 2016-17	After Kharif 2017-18	After Rabi 2017-18	After Kharif2016 17	After Rabi 2016-17	After Kharif 2017-18	After Rabi 2017-18
	0-15 cm							
T1- Control	0.54^{f}	0.58^{f}	0.52^{f}	0.56^{f}	7.66^{a}	7.73^{a}	7.67^{a}	7.71^{a}
T2- 100% NPK (LTFE)	0.79^{e}	0.82^{e}	0.77^{e}	0.81^{e}	7.58^{a}	7.66^{a}	7.57^{a}	7.66^{a}
T3-100% NPK+FYM (LTFE)	1.52^{a}	1.62^{a}	1.53^{a}	1.64^{a}	7.62^{a}	7.69^{a}	7.60^{a}	7.68^{a}
T4- Fallow (LTFE)	1.24^{c}	1.29^{c}	1.27^{c}	1.32^{c}	7.64^{a}	7.70^{a}	7.63^{a}	7.70^{a}
T5- Poplar (Agroforestry)	1.41^{b}	1.42^{b}	1.43^{b}	1.45^{b}	7.76^{a}	7.84^{a}	7.74^{a}	7.84^{a}
T6- Eucalyptus (Agroforestry)	1.15^{d}	1.18^{d}	1.15^{d}	1.20^{d}	7.68^{a}	7.72^{a}	7.67^{a}	7.72^{a}
	15-30 cm							
T1- Control	0.50^{e}	0.53^{e}	0.48^{e}	0.52^{e}	7.81^{a}	7.94^{a}	7.80^{a}	7.94^{a}
T2- 100% NPK (LTFE)	0.61^{d}	0.67^{d}	0.59^{d}	0.66^{d}	7.76^{a}	7.82^{a}	7.75^{a}	7.82^{a}
T3-100% NPK+FYM (LTFE)	1.18^{a}	1.25^{a}	1.20^{a}	1.26^{a}	7.78^{a}	7.86^{a}	7.77^{a}	7.85^{a}
T4- Fallow (LTFE)	0.70^{c}	0.75^{c}	0.72^{c}	0.77^{c}	7.80^{a}	7.90^{a}	7.80^{a}	7.91^{a}
T5- Poplar (Agroforestry)	0.82^{b}	0.84^{b}	0.84^{b}	0.86^{b}	7.84^{a}	7.96^{a}	7.84^{a}	7.97^{a}
T6- Eucalyptus (Agroforestry)	0.68^{c}	0.70^{cd}	0.70^{c}	0.71^{d}	7.82^{a}	7.92^{a}	7.81^{a}	7.92^{a}

Rice-Wheat in LTFE, Soybean-Wheat in Poplar and Fallow-Wheat in Eucalyptus (2016-2017).
Rice-Wheat in LTFE, Foxtail-Wheat in Poplar and Fallow-Wheat in Eucalyptus (2017-2018).

B. Soil pH

The pH of the soil pooled data of surface and sub-surface during kharif and rabi season was not significantly influenced by different treatments (Table 1). After *kharif* season, The highest pH content in surface soil was recorded under Poplar (Agroforestry) (T5) followed by Fallow (LTFE) T4, Eucalyptus (Agroforestry) T6 and 100% NPK+FYM (LTFE) T3 system whereas, the lowest was observed under the 100% NPK (LTFE)(T2). The pH increased by 2.24 and 1.19 per cent in popular (T5) and eucalyptus (T6) based agroforestry, respectively over 100 % NPK under rice-wheat system (T2). Likewise, the pH content in sub-surface also follow similar trend. The value of pH content in sub-surface varied from 7.76-7.82 which does not differ significantly. The soil pH was decrease with application of acid forming fertilizer i.e. ammonium sulphate, ammonium nitrate and urea. Similar findings were also reported by Uthappa *et al*. (2015) observed that the maximum (8.55) and significantly higher soil pH was recorded in 30-60 cm soil depth, whereas than lower pH was recorded from 0-15cm (8.24) soil depth. Singh *et al*. (2017) also evaluated that the continuous cropping and chemical fertilizer application over the years lower the soil pH, except the treatment involving the use of lime.

Table 2: Effect of long term use of organic manure manures and inorganic fertilizers on electrical conductivity (dSm^{-1}) and available nitrogen (kg ha^{-1}) under different cropping systems after *kharif* and *rabi* seasons during 2016-17 and 2017-18.

Treatments	Electrical conductivity (dSm^{-1})				Available nitrogen (kg ha^{-1})			
	After *Kharif*-2016-17	**After *Rabi* 2016-17**	**After *Kharif* 2017-18**	**After *Rabi* 2017-18**	**After *Kharif*2016-17**	**After *Rabi* 2016-17**	**After *Kharif* 2017-18**	**After *Rabi* 2017-18**
	0-15 cm							
T1- Control	0.29^{e}	0.28^{c}	0.29^{e}	0.27^{d}	188.15^{e}	192.34^{d}	183.97^{e}	188.15^{d}
T2- 100% NPK (LTFE)	0.32^{d}	0.32^{b}	0.33^{d}	0.33^{c}	242.51^{cd}	250.87^{b}	232.88^{d}	248.19^{bc}
T3-100% NPK+FYM (LTFE)	0.35^{c}	0.33^{b}	0.36^{c}	0.35^{b}	359.58^{a}	363.77^{a}	363.77^{a}	367.95^{a}
T4- Fallow (LTFE)	0.33^{d}	0.32^{b}	0.34^{d}	0.33^{c}	250.88^{bc}	255.06^{b}	252.61^{bc}	257.32^{b}
T5- Poplar (Agroforestry)	0.40^{a}	0.38^{a}	0.42^{a}	0.40^{a}	263.67^{b}	259.24^{b}	265.52^{b}	262.06^{b}
T6- Eucalyptus (Agroforestry)	0.37^{b}	0.37^{a}	0.38^{b}	0.39^{a}	229.79^{d}	234.15^{c}	240.17^{cd}	238.33^{c}
15-30 cm								
T1- Control	0.27^{e}	0.27^{d}	0.27^{d}	0.26^{e}	125.42^{e}	129.62^{e}	121.25^{e}	126.34^{e}
T2- 100% NPK (LTFE)	0.30^{d}	0.29^{c}	0.31^{c}	0.30^{d}	196.52^{d}	203.63^{d}	194.20^{d}	200.70^{d}
T3-100% NPK+FYM (LTFE)	0.33b^{c}	0.32^{b}	0.34^{b}	0.32^{c}	259.24^{a}	271.78^{a}	263.42^{a}	275.96^{a}
T4- Fallow (LTFE)	0.31^{cd}	0.30^{c}	0.32^{c}	0.30^{cd}	213.27^{c}	217.69^{c}	215.42^{c}	219.52^{bc}
T5- Poplar (Agroforestry)	0.37^{a}	0.35^{a}	0.38^{a}	0.37^{a}	234.15^{b}	229.97^{b}	236.29^{b}	232.42^{b}
T6- Eucalyptus (Agroforestry)	0.35^{b}	0.34^{a}	0.36^{b}	0.35^{b}	200.70^{d}	204.88^{d}	202.79^{cd}	207.34^{cd}

Rice-Wheat in LTFE, Soybean-Wheat in Poplar and Fallow-Wheat in Eucalyptus (2016-2017).
Rice-Wheat in LTFE, Foxtail-Wheat in Poplar and Fallow-Wheat in Eucalyptus (2017-2018)

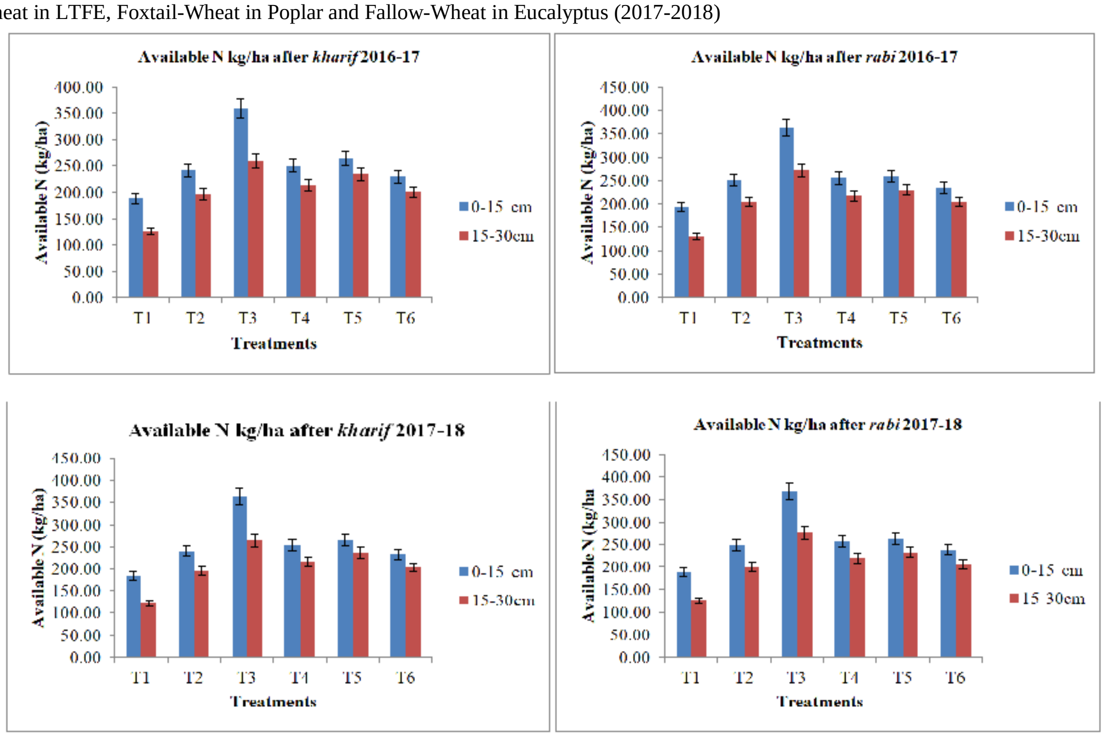

Fig. 2. Effect of long term use of organic manure manures and inorganic fertilizers on available nitrogen (kg ha^{-1}) under different cropping systems after *kharif* and *rabi* seasons during 2016-17 and 2017-18.

C. Soil electrical conductivity

Pooled data for soil electrical conductivity (SEC) was given in Table 3 revealed that significant difference in SEC of both surface and sub-surface soil in *kharif* and *rabi* season at both the experimental sites. After kharif season, SEC of surface soil ranged from 0.29 to 0.41 dSm^{-1}. Highest SEC found in Poplar (Agroforestry) (T5) followed by Eucalyptus (Agroforestry) (T6) and 100% NPK + FYM (LTFE) (T3). SEC was higher in popular (Agroforestry) (T5) 28.13 % and Eucalyptus (Agroforestry) (T6) 18.75% as compared to 100% NPK (T2). In case of sub-surface soil, SEC varied from 0.26 to 0.36 dSm^{-1}. Lowest SEC was reported in control (T1) followed by 100% NPK (T2) and highest for Poplar (Agroforestry) (T5). The SEC was increased 23.33% and 16.67 % in popular (T5) and Agroforestry (T6), respectively as compared to 100% NPK (T2).

Similarly, in *rabi* season SEC was ranged from 0.28-0.39 dS m^{-1} and 0.26-0.36 dS m^{-1} for surface soil and sub soil, respectively. In surface soil, highest SEC was found in popular (T5) followed by eucalyptus (T6), 100% NPK + FYM (T3) and lowest in control (T1) both in surface and sub-surface soil. In different chemical fertilizer treatments EC was slightly increased at both the surfaces except control plot whereas, EC was decreased. This might be due to addition of chemical fertilizer increases accumulation of salt in the soil which contributes increases in EC of soil. Similar findings were observed by Bhatt *et al*. (2018); Uthappa *et al*. (2015). Newaj *et al*. (2007) reported that the EC higher under poplar based system may be due to high secretion of many carbonic acids from degradation of litter fall and the influence of climatic variables *viz*., temperature, solar radiation, precipitation, relative humidity and wind velocity.

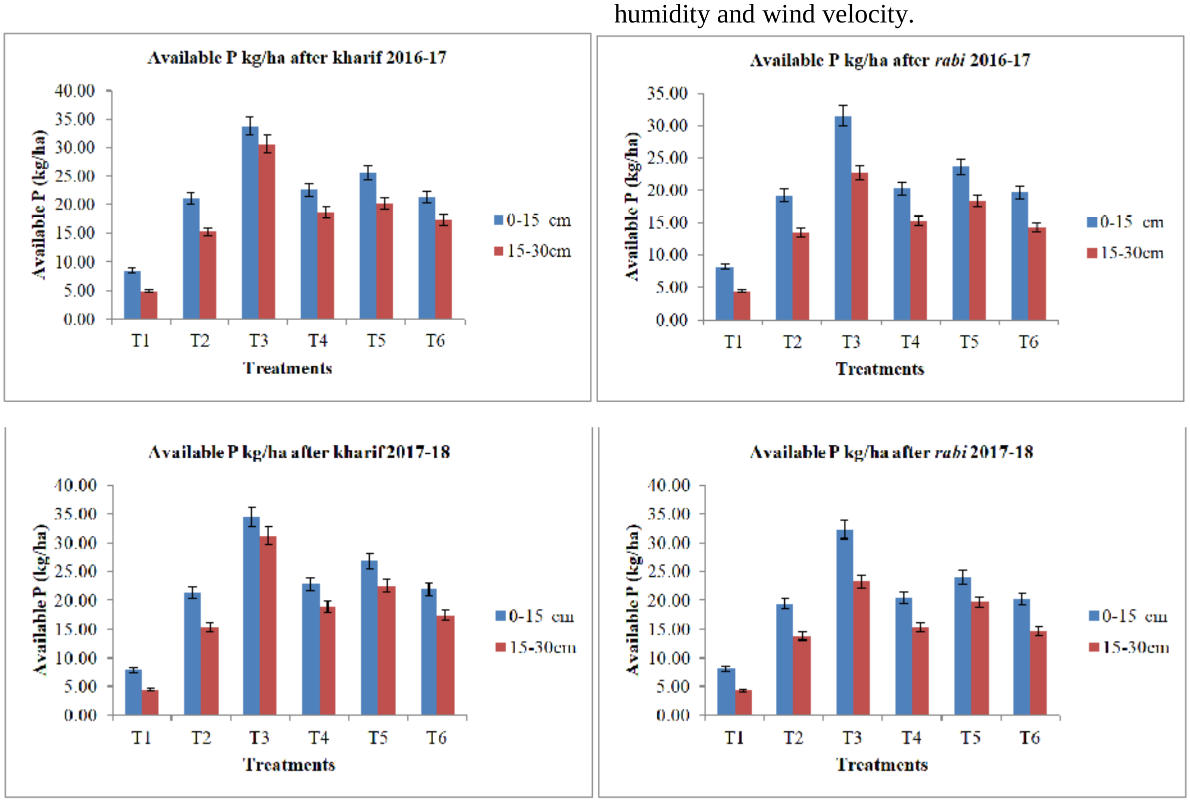

Fig. 3. Effect of long term use of organic manure manures and inorganic fertilizers on available phosphorus (kg ha^{-1}) under different cropping systems after *kharif* and *rabi* seasons during 2016-17 and 2017-18.

D. Available nitrogen (N kg ha^{-1})

Pooled data on available soil nitrogen (ASN) are presented in Fig. 4. Different nutrient management treatments for kharif season gave significantly higher ASN than the control (180.06 and 123.33 kg ha^{-1}) for 0-15 and 15-30 cm soil, respectively. The highest ASN in surface and sub-surface soil were obtained with 100 per cent NPK + FYM (361.68 kg ha^{-1} and 273.87 kg ha^{-1}). Popular based agroforestry system resulted in 14.37 % and 20.40 % increase in ASN than 100% NPK for both surface and sub-surface soil, respectively. Whereas, eucalyptus based agroforestry system gives 4.32 % and 3.27 % higher ASN than the 100% NPK treatment.

In rabi season, pooled data of ASN for surface and sub-surface soil gave significantly higher results than control (190.25 and 127.98 kg ha^{-1}) both for surface and sub-surface soil. Like as kharif season, rabi season has also higher ASN in the 100% NPK +FYM treatment (365.86 and 273.87 kg ha^{-1}) for both surface and sub-surface soil, respectively. In surface soil highest ASN was in 100% NPK + FYM followed by fallow (256.19 kg ha^{-1}) which is statistically at par with popular and eucalyptus and minimum in control (190.25 kg ha^{-1}). Treatment 100% NPK + FYM gives higher results 54.84% followed by popular (10.33%) and eucalyptus (5.62 %), respectively as compared to 100% NPK. In sub-surface soil, ASN was highest in T3 (273.87 kg ha^{-1}) followed by T5 (231.20 kg ha^{-1}), T4 (218.61 kg ha^{-1}), T2 (202.17 kg ha^{-1}) and lowest in control (127.98 kg ha^{-1}). 100% NPK + FYM gives higher ASN as 113.99 %, popular (80.65%) and eucalyptus (61.05 %) in comparison to 100% NPK. The soil available nitrogen was reduced with soil depth which may be entrusted to the high amount of farm yard manure and crop residue addition on the surface soil. It was also surprising to notice that available nitrogen increased in all the treatments except control and 100% NPK treated plots at both the surface and sub surface soil. This might be attributed to the fact that the nitrogen present in N fertilizer and FYM could be release plant available nitrogen by biochemical reaction. These outcome were similar with the findings of Yadav and Kumar (2009); Kumar *et al*. (2008). Trees can also enhance soil chemical, physical, and biological properties of soil by adding organic matter and releasing nutrients in agro-forestry systems (Antonio and Gama-Rodrigues, 2011; Chaudhary *et al*., 2007).

E. Available phosphorus (P kg ha^{-1})

Data on available soil phosphorus (ASP) are given in Table 3 revealed that ASP was significantly higher in both the season of kharif and rabi for surface and sub-surface soil. In kharif season, ASP for surface soil was highest in 100% NPK +FYM (30.90 kg ha^{-1}) followed by agroforestry (21.36 kg ha^{-1}), follow (18.77 kg ha^{-1}), eucalyptus (17.36 kg ha^{-1}) and lowest in untreated plot (4.68 kg ha^{-1}). The ASP content was increased by 60.39 % in T3, 23.31 % in T5 and 1.55 % in T6 in comparison to T2. Similarly, in sub-surface soil highest ASP content was observed in T3 (30.90 kg ha^{-1}), followed by T5 (21.36 kg ha^{-1}), T4 (18.77 kg ha^{-1}), T6 (17.36 kg ha^{-1}) and lowest in T1 (4.68 kg ha^{-1}). Increase in ASP by 39.88 % and 13.69 % observed in popular and eucalyptus based agroforestry system as compared to 100% NPK nutrient management system.

ASP in rabi season was ranged from 8.16 to 31.89 kg ha^{-1} and 4.37 to 22.95 kg ha^{-1} for surface and sub-surface soil, respectively. Highest ASP for surface soil was obtained in T3 (31.89 kg ha^{-1}) followed by T5 (23.86 kg ha^{-1}), T6 (19.95 kg ha^{-1}) whereas, lowest in T1 (8.16 kg ha^{-1}). The ASP content was increased by 65.06 % in T3, 23.50% in T5 and 3.26% in T6 in comparison to T2 nutrient management system. Similarly, sub-surface soil was also following similar trend as highest ASP was observed in T3 (22.95 kg ha^{-1}) followed by T5 (18.99 kg ha^{-1}) and T4 (15.25 kg ha^{-1}) which is at par with T6 (14.45 kg ha^{-1}) and lowest in T1 (4.68 kg ha^{-1}). The ASP as increased by 68.01 % in T3, 39.02 % in T5 and 5.78 % in T6, respectively over 100% NPK nutrient management system. It was also noticed that available phosphorus increased in all the treatments except in control plot at both the surface and sub surface soil. The soil available phosphorus was decreased with increase in soil depth. Application of FYM with 100% NPK enhance the availability of P might be due to release of organic acid that bind aluminum and iron, thereby reducing P fixation and increasing its availability. Similar findings were observed by Manjhi *et al*. (2014). Soil organic matter on the soil surface favored the solubilization of insoluble P releasing much more quantity to the surface (Chaudhary *et al.*, 2006) and also due to the imprisonment cultivation of crop to the rhizosphere and inosculate of the depleted P through external sources *i.e.*, chemical fertilizers (Kumara *et al.*, 2010; Rajeswar and Aariffkhan, 2007).

Table 3: Effect of long term use of organic manure manures and inorganic fertilizers on available phosphorus (kg ha^{-1}) and available potassium (kg ha^{-1}) under different cropping systems after *kharif* and *rabi* seasons during 2016-17 and 2017-18.

Treatments	**Available phosphorus (kg ha^{-1})**				**Available potassium (kg ha^{-1})**			
	After *Kharif* 2016-17	**After *Rabi* 2016-17**	**After *Kharif* 2017-18**	**After *Rabi* 2017-18**	**After *Kharif* 2016-17**	**After *Rabi* 2016-17**	**After *Kharif* 2017-18**	**After *Rabi* 2017-18**
	0-15 cm							
T1- Control	8.48^{d}	8.20^{d}	7.87^{d}	8.13^{d}	108.54^{e}	105.74^{e}	106.42^{e}	103.98^{e}
T2- 100% NPK (LTFE)	21.18^{c}	19.22^{c}	21.38^{c}	19.42^{c}	138.66^{d}	128.25^{d}	139.24^{d}	129.18^{d}
T3-100% NPK+FYM (LTFE)	33.83^{a}	31.51^{a}	34.42^{a}	32.26^{a}	182.42^{a}	178.88^{a}	184.38^{a}	181.04^{a}
T4- Fallow (LTFE)	22.65^{c}	20.34^{c}	22.84^{c}	20.37^{c}	160.22^{c}	155.18^{b}	161.12^{c}	155.86^{b}
T5- Poplar (Agroforestry)	25.64^{b}	23.74^{b}	26.84^{b}	23.98^{b}	170.84^{b}	158.67^{b}	171.80^{b}	160.28^{b}
T6- Eucalyptus (Agroforestry)	21.35^{c}	19.74^{c}	21.88^{c}	20.16^{c}	148.92^{d}	140.44^{c}	149.22^{cd}	141.28^{c}
15-30 cm								
T1- Control	4.88^{e}	4.40^{e}	4.48^{f}	4.35^{e}	95.24^{e}	93.54^{d}	94.72^{d}	92.84^{d}
T2- 100% NPK (LTFE)	15.24^{c}	13.52^{d}	15.30^{e}	13.80^{d}	126.78^{d}	117.11^{c}	127.18^{c}	117.85^{e}
T3-100% NPK+FYM (LTFE)	30.65^{a}	22.72^{a}	31.16^{a}	23.18^{a}	158.20^{a}	154.00^{a}	159.66^{a}	156.81^{a}
T4- Fallow (LTFE)	18.74^{bc}	15.24^{c}	18.80^{c}	15.27^{c}	138.56^{bc}	135.28^{b}	139.20^{b}	135.78^{b}
T5- Poplar (Agroforestry)	20.18^{b}	18.36^{b}	22.54^{b}	19.62^{b}	148.26^{ab}	136.66^{b}	150.82^{a}	137.32^{b}
T6- Eucalyptus (Agroforestry)	17.34^{d}	14.25^{cd}	17.38^{d}	14.65^{cd}	130.88^{cd}	120.42^{c}	131.14^{bc}	121.52^{c}

Rice-Wheat in LTFE, Soybean-Wheat in Poplar and Fallow-Wheat in Eucalyptus (2016-2017).

Rice-Wheat in LTFE, Foxtail-Wheat in Poplar and Fallow-Wheat in Eucalyptus (2017-2018)

F. Available potassium (K kg ha^{-1})

The pool data on available soil potassium (ASK) given in Fig. 4 revealed that both the surface and sub-surface ASK was significantly affected by various treatments after *kharif* and *rabi* seasons at both the experimental sites. After *kharif* season, the highest ASK content in surface soil was recorded under T3(183.40 kg ha^{-1}), followed by T5(171.32 kg ha^{-1}), Fallow T4(160.34 kg ha^{-1}) and T6(149.07 kg ha^{-1}) system whereas, the lowest was observed under the T1(107.48 kg ha^{-1}). The ASK increased by 31.99% in T3, 23.30% in T5 and 7.28% in T6, respectively over 100 % NPK under rice-wheat system (T2). Likewise, the ASK content in sub-surface also follow similar trend. The value of ASK content in sub-surface varied from 94.48 kg ha^{-1} in control to 158.93 kg ha^{-1} in 100 % NPK + 15 t FYM ha^{-1}. ASK content in popular agroforestry (T5) and eucalyptus agroforestry system (T6) increased by 17.77 % and 3.17 %, respectively than ASK in 100% NPK under rice-wheat system.

Similarly, ASK content for surface soil varied from 104.86 kg ha^{-1} in control to 179.96 in 100% NPK + 15 t FYM ha^{-1} after *rabi* seasons (Fig. 4). Application of 100 % NPK under popular (T5) and eucalyptus (T6) agroforestry system increased ASK by 17.22 and 6.80 per cent, respectively than application of 100 % NPK under rice-wheat system (T2). ASK for sub-surface soil ranged from 93.19 kh ha^{-1} in control to 155.40 kg ha^{-1} in 100% NPK + FYM. Like, surface soil, in sub-surface soil application of 100% NPK under agroforestry system of popular and eucalyptus system increased ASK by 16.61 and 2.97 %, respectively over 100% NPK under rice-wheat system (T2).

Surface soil (0-15 cm) had higher plant available K content as compared to sub surface soil. This perhaps due to intense weathering of potassium bearing minerals, release of K from crop residues, use of K fertilizers and upwardly translocation of K from lower depth along with capillary movement of ground water. Similar finding were observed by Basavaraju *et al.*, 2005; Rao *et al.*, (2013). The beneficial effect of 100% NPK RD along with FYM on plant available K perhaps ascribed to the reduce potassium fixation, solubilization and release in view of interaction of organic carbon with clay particle besides the direct K addition to the potassium pools of soil. Ram *et al.* (2016) found that the long term application of FYM and chemical fertilizer, for 41 years significantly enhance plant available K was recorded under the farm yard manure applied plots followed by the super optimal dose of NPK fertilizers. Respectively, the minimum value of available potassium recorded in control. Bora *et al.* (2018) observed that the significantly highest content of available potassium was noticed in the treatments where manure was incorporated along with N and P_2O_5 as compared to the treatments where no organic manure was applied.

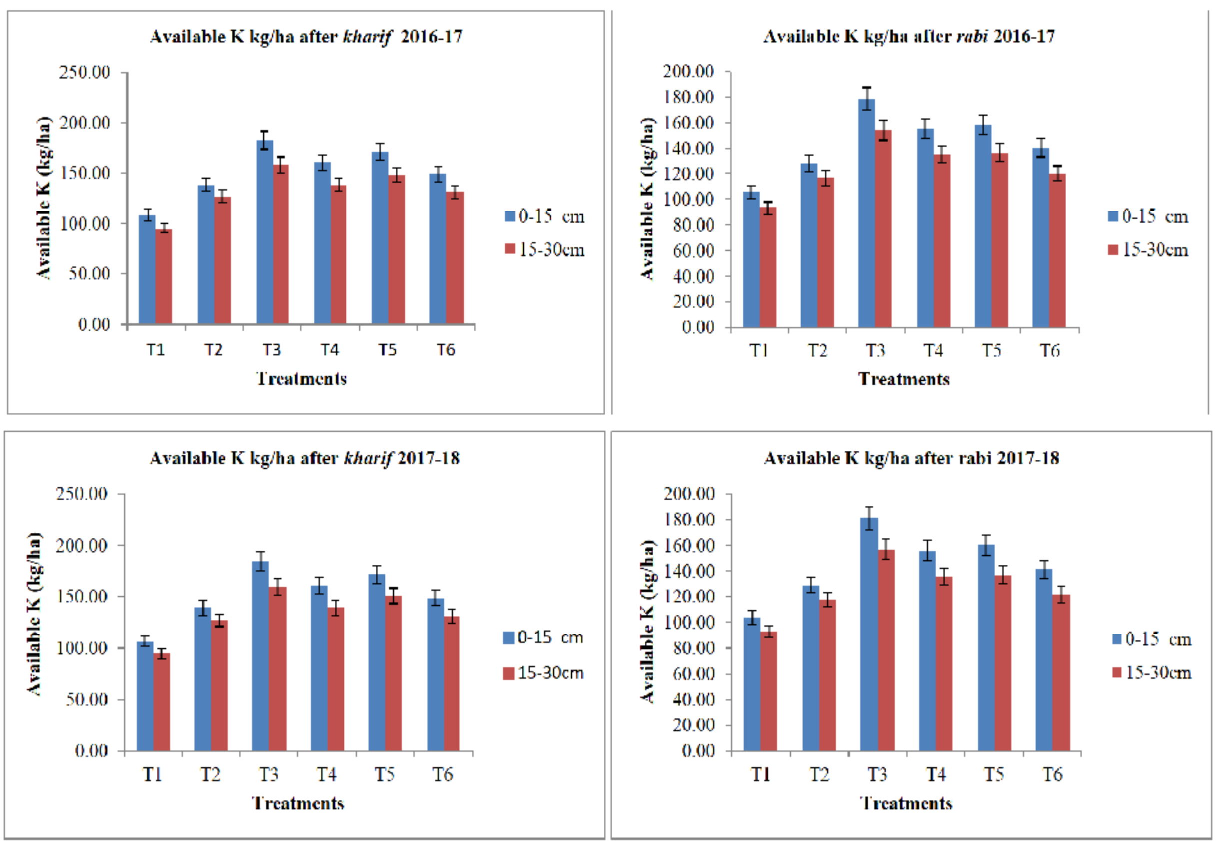

Fig. 4. Effect of long term use of organic manure manures and inorganic fertilizers on available potassium (kg ha^{-1}) under different cropping systems after *kharif* and *rabi* seasons during 2016-17 and 2017-18.

CONCLUSION

Continuous application of inorganic fertilizers alone or integration with any of the organics did not influence soil pH. The inorganic fertilizers with organic manure maintained or improved available N, P, K and soil organic carbon content in comparison to application of NPK fertilizers alone in both the cropping system *i.e.* R-W and agroforestry based cropping system. It is concluded that continuous application of inorganic fertilizers alone could not sustain the soil fertility status and productivity. Thus, integrated nutrient management in continuous cropping system and agroforestry based cropping systems proved effective for sustainability of soil on long term basis.

FUTURE SCOPE

After green revolution era India agriculture encountered the several problems of soil health, slightly stagnation of food grain production, reduce the ecological resilience etc. resulting overall declining in the system productivity. Integrated application of nutrients for rice-wheat (RW) and agro-forestry system is necessary for maintaining soil properties. Continuous application of inorganic fertilizers alone or integration with any of the organics did not influence soil pH. The inorganic fertilizers with organic manure maintained or improved available N, P, K and soil organic carbon contention comparison to application of NPK fertilizers alone in both the cropping system *i.e.* R-W and agro-forestry based cropping system. It is concluded that continuous application of inorganic fertilizers alone could not sustain the soil fertility status and productivity. Thus, integrated nutrient management in continuous cropping system and agro-forestry based cropping systems proved effective for sustainability of soil on long term basis. Thus, AF is much more beneficial for boosting of soils and fertility levels level of soil resulting increase the productivity of the system. We need some more research on the above facts for knowing the accuracy in results.

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