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Chemical and biological properties of the soil influenced by crop geometry and nutrient management practices in winter maize (*Zea mays* L.)+potato (*Solanum tuberosum* L.) intercropping system

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Abstract
A field experiment was carried out during *rabi* season of two consecutive years, 2015-16 and 2016-17 at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University- Varanasi (UP) to study the effect of crop geometry and nutrient management practices on chemical and biological properties of the soil in winter maize (*Zea mays* L.) + potato (*Solanum tuberosum* L.) intercropping system. Results revealed that among the chemical properties of the soil, *viz.*, soil pH and EC were affected non-significantly during both the years of experimentations with crop geometry as well as with nutrient management practices. The changes in organic carbon (%) in the soil were found non-significant with crop geometry but under nutrient management practices, were found significantly superior with the application of 100% RDF + 25% N through poultry manure, on par with the application of 100% RDF+ 25% N through vermicompost, as compared to rest of the treatments. In sole crops, maximum pH and EC was recorded with sole maize than sole potato however sole potato was recorded maximum organic carbon (%) than sole maize. In case of biological properties of the soil, *viz.,* bacteria (cfu), fungi (cfu) and actinomycetes (cfu) were recorded non-significant during both the years of experimentation with crop geometry. Under nutrient management practices the biological properties were affected significantly superior with the application of 100% RDF + 25% N through poultry manure but on par with 100% RDF + 25% N through vermicompost, over rest of the treatments. In case of soil microbial biomass carbon (µg C g^{-1} soil) in the soil, the effect was found not significant during both the years of experimentation with crop geometry as well as nutrient management practices. In sole crops, maximum bacteria (cfu), fungi (cfu) and actinomycetes (cfu) as well as soil microbial biomass carbon (µg C g^{-1} soil) were recorded with sole potato than sole maize during both the years of experimentation. Thus, the results suggest that the 1:2 row ratio (crop geometry) in additive series along with 100% RDF + 25% N trough poultry manure (nutrient management practices) followed by 100% RDF + 25% N through vermicompost was found feasible and viable during both the years of experimentation.

Keywords: Crop geometry, organic carbon (OC), soil microbial biomass carbon (SMBC)

Introduction
Winter maize is assuming the position of being one of the most important and well adopted cereal crops to be grown after rice in irrigated areas, with high productivity. The acreage of winter maize in India is increasing continuously owing to its higher productivity and net profit compared to traditional rainy season (*kharif*) crop. The average productivity of winter maize in India is 4.0 t ha^{-1}, which is double as compared to 2.0 t ha^{-1} productivity of conventional *kharif* maize. It is spreading fast in the states *viz.*, Bihar, U.P., A.P., Tamil Nadu, Karnataka, Maharashtra, Punjab, Haryana, H.P. etc. It can be successfully cultivated in the entire plain of the country where temperature during the growing season ranges between10 to 30^0C. In the Northern states, temperature is generally low during the initial growth period resulting in slow growth of the crop. However, the plants resume growth with gradual rise in temperature (Singh *et al.*, 2000) [14]. The United States of America (USA) is the largest producer of maize contributes nearly 35% of the total production in the world and maize is the driver of the US economy. In India, maize (*Zea mays* L.) is the third most important cereal crop after rice and wheat. It is cultivated over 8.69 m ha area with a production and productivity of 21.81 m t and 2509 kg ha^{-1}, respectively. (DAC & FW, 2015-16). In UP, the present area under maize cultivation is about 0.68 m ha area with the annual production of 1.26 m t. The average productivity of the crop is about 1848.0 kg ha^{-1} (Anonymous, 2016) [1]. Potato (*Solanum tuberosum* L.) is reported to have originated in Andean region of high hills of South America and brought to India first by the Portuguese in the 17th century.

Amongst the major potato growing countries of the world, China ranks first in area followed by the Russian federation, India, Ukarine, USA, Germany and Poland. It is known as 'The King of vegetables' has emerged as forth most important food crop in India after rice, wheat and maize. In world scenario, India became the second largest producer of potato (Scott and Suarez, 2011) [12]. India produced 43.42 m t potato from 2.12 m h area with an average productivity of 20.5 m t ha^{-1} (DAC & FW, 2015-16). In UP, potato is grown in an area of 0.61 m ha, with an annual production of 13.85 m t and average productivity of 22.81 m t ha^{-1} (Anonymous, 2017) [2]. It is the third most important food crop in the world after rice and wheat in respect of human consumption. It is grown in almost all the states in India and under various agro-climatic conditions.

Since, maize is a widely spaced crop, inter- row space could profitably be utilized for other crops particularly in winter season. This approach may increase the possibility to generate the yield recovery of such system. There are many winter crops which may be suitably adjusted in between two rows of winter maize. It increases the productivity of per unit area of land via better utilization of resources, minimizes the risk, reduces the weed competition and stabilizes the yield. There are so many factor which is influence the intercropping such as maturity of crop, selection of compatible crop, planting density time of planting as well as socio economic status of the farmers. (Seran *et al.,* 2010) [13]. Intercropping in intensively cultivated areas is one of the most promising options for crop diversification of sustainable agricultural production system in India. This could be a viable agronomic technology of risk minimizing farmer's income and subsistence oriented, energy efficient and sustainable venture (Faroda *et al*., 2007) [5].

Organic manures particularly vermicompost (VC) and poultry manures (PM) have traditionally been used by maize as well as potato growing farmers of this region. Higher food production needs higher amount of plant nutrients then farmers go to use for chemical fertilizers for supplying the nutrient to present day. Continuous use of inorganic fertilizers creates imbalance in nutrient supply leading to decline in soil fertility, crop productivity and sustainability. Use of organic matter to meet the nutrient requirement of crops would be an inevitable practice to Sustained the yield (Upadhyay *et al.,* 2003) [15].

Supplying of nutrients through the organic source can be opted for avoiding the hazardous effects of fertilizers and maintaining sustainability. Bio-fertilizers like PSB and *Azotobacter*, also play a major role in supplementing the crop nutrients through nitrogen fixation and solubilization of fixed forms of phosphorus in soil. Integration of organics with inorganics fertilizers is an approach that seeks to increase crop production and safeguard the environment for future generation. As no single source is capable of supplying all the nutrients in required quantity, integrated use of inorganic and organic sources of plant nutrients is a must to be supply balanced nutrient to the crop. In this scenario, the diversification of maize and potato intercropping system with efficient nutrient management provides a sustainable solution. It is not only sustaining the system productivity but also improves soil health. Keeping all these facts in view, the present investigation entitled: "to study the effect of crop geometry and nutrient management practices on chemical and biological properties of the soil in winter maize (*Zea mays* L.) + Potato (*Solanum tuberosum* L.) intercropping system".

Methods and materials

A field experiment was conducted during the *Rabi* season of two consecutive years, 2015-2016 and 2016-17 at the Agricultural Reasearch Farm, Institute of Agricultural Sciences, Banaras Hindu University- Varanasi (UP). It is situated in the South-Eastern part of Varanasi. Geographically, experimental site falls under sub-tropical zone of Indo-Gangatic plains and lies on the left bank of river Ganga. It is located on 25°15'19.7"N latitude, 82°59'34.2"E longitude and at an altitude of 76 meters above mean sea level. Varanasi falls in the belt of semi-arid to sub-humid climate receiving a mean assured rainfall of more than 1100 mm and potential evapotranspiration of about 1525 mm. thus causing a moisture deficit of 425 mm. The mean weekly maximum temperature varied from 19 to 39.20 °C with an average of 27.76 °C during 2015-16, and 20.10 to 39.40 °C with an average of 27.05°C during 2016-17 in the crop cycle of maize and the mean weekly maximum temperature varied from 19 to 30.04 °C with an average of 24.97 °C during 2015-16, and 20.10 to 29.0 °C with an average of 23.82°C during 2016-17 in the crop cycle of potato. The weekly mean minimum temperature ranged from 7.2 to 23.10 °C with an average of 14.21°C during 2015-16, and 8.2 to 22.4°C with an average of 13.44°C during 2016-17 in the crop cycle of maize and the weekly mean minimum temperature ranged from 7.20 to 17.20 °C with an average of 12.05°C during 2015-16, and 8.20 to 16.30°C with an average of 11.69°C during 2016-17 in the crop cycle of potato. The experimental soil was sandy clay loam, neutral pH (7.45), EC (0.18) dSm^{-1} organic carbon (0.36%), medium in available N (199.89 kg ha^{-1}), P (20.28 kg ha^{-1}) and K (205.66 kg ha^{-1}). The field experiment carried out in split –plot design with 3 replications. The main plot treatments consisted 4 crop geometry, *viz.,* 1:1 and 1:2 row ratio in replacement series having spacing 60x20 cm, and similarly 1:1 and 1:2 row ratio in additives series having spacing 75x20 cm and the sub plot treatments consisted of 5 nutrient management practices, *viz.,* 100% RDF, 100% RDF + 25% N through vermicompost, 100% RDF + 25% N through poultry manure, 75% RDF + 25% N through vermicompost + *Azotobacter* and 75% RDF + 25% N through poultry manure + *Azotobacter* were taken during both the years for experimental field investigation. Half dose of nitrogen and full dose of phosphorus and potash were applied at the time of sowing/planting and remaining half dose of the nitrogen were applied at knee high stage of maize as well as earthing up of potato. Bulky organic manure (Vermicopost and poultry manure) was applied as per treatments over the plot as a broadcasting. The maize hybrids late maturity variety 'DKC-9081' and medium maturing variety of potato 'Kufri Badshah' was taken for conducting an experiment during both the years of experimentation. Seed/tuber of maize and potato was sown in second fortnight of November. *Azotobacter* were used to inoculate the maize seeds and potato tubers as per the treatment. For maize, A slurry was prepared by boiling 100 g jaggary in one litre of water. After cooling, one packet bio-fertilizer containing 200 gms culture was disovled to the jaggary mixture for seed treatment of maize about 10 kg and for potato tubers, *Azotobacter chroococum* culture solution was prepared by mixing 50 grams bacterial culture and 100 grams jaggery in one litre of water and stirred well. The solution was sprayed over 25 kg well sprouted tubers of potato and mixed with hand so that uniform and even spray of bio-fertilizer over the tubers was achieved. The tubers were planted in the field after drying in shade.

Statistical analysis

The observations recorded during the course of investigation were tabulated and analyzed statistically to draw a valid conclusion. The data were analyzed as per the standard procedure for “Analysis of Variance” (ANOVA) as described by Gomez and Gomez (1984) [6].

Results and discussions

Chemical properties of the soil

The data pertaining to chemical properties of the soil after harvesting of the crop during both the years of experimentations are presented in Table -1 and it clearly indicated that crop geometry and nutrient management practices did not influence the soil pH and EC significantly. The organic carbon content also did not influenced significantly by crop geometry but it was recorded significantly superior with nutrient management practices under 100% RDF+25% N through poultry manure was on par with application of 100% RDF+25% N through vermicompost, over rest of the treatments. Soil pH slightly tends toward neutral with the application of poultry manure and vermicompost. It may be due to the fact that because of application of poultry manure and vermicompost microbial population might have increased and as a result soil aggregation and decomposition have resulted in increased organic carbon content in soil. Organic manure has some solubulizing effect on some mineral compounds present in soil and brings about the conversion of a number of chemical elements in available form. During decomposition of organic manures, various phenolic and aliphatic acids are produced which solubilize phosphatase and phosphate bearing minerals and thereby lowers the phosphate fixation and increase its availability. Bellakki *et al*. (1998) [3] reported that use of organic materials lowered the electronic conductivity of vertisol over chemical fertilizers separately in rice-rice cropping system. The beneficial effect of organic manures on organic carbon content could be attributed to the presence of higher residue and litter, enhanced microbial activity. This results are similar to the reports shown by (Sarwar *et al.*, 2012) [11] who reported that replacement of 25% or 50% N with organic manure increases the organic matter content in the soil after harvest of the maize crop. The integration of organic and inorganic sources of nutrients resulted in maximum organic carbon when poultry litter was applied in maize. These observations are in agreement with the findings of *Saha et al.* (2006) [9] and Patel *et al.* (2008) [8]. In sole crops, maximum pH and EC was found with sole maize and lowered in sole potato however maximum organic carbon was found with sole potato as compared to sole maize because potato added more biomass carbon than maize.

Table 1: Effect of crop geometry and nutrient management on soil pH, electrical conductivity and organic carbon in winter maize + potato intercropping system after harvesting of the crop

Treatments	Soil Ph		EC		OC (%)	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Crop geometry						
1:1 (M+P) 60x20 cm*	7.44	7.43	0.182	0.181	0.37	0.39
1:2 (M+P) 60x20 cm*	7.43	7.42	0.177	0.177	0.39	0.41
1:1 (M+P) 75x20 cm**	7.42	7.40	0.175	0.174	0.38	0.41
1:2 (M+P) 75x20 cm**	7.40	7.38	0.173	0.169	0.40	0.43
SEm±	0.03	0.03	0.033	0.035	0.015	0.019
CD (P= 0.05)	NS	NS	NS	NS	NS	NS
Nutrient management						
100% RDF	7.45	7.44	0.183	0.182	0.34	0.36
100% RDF + 25% N through vermicompost	7.40	7.38	0.179	0.177	0.39	0.42
100% RDF + 25% N through poultry manure	7.39	7.37	0.178	0.176	0.41	0.44
75% RDF + 25% N through vermicompost + *Azotobacter*	7.43	7.41	0.181	0.18	0.35	0.37
75% RDF + 25% N through poultry manure + *Azotobacter*	7.42	7.40	0.181	0.179	0.36	0.39
SEm±	0.02	0.03	0.025	0.027	0.01	0.015
CD (P= 0.05)	NS	NS	NS	NS	0.03	0.041
Sole crops						
Maize (60 x 20 cm)	7.45	7.44	0.189	0.186	0.35	0.36
Potato (60 x 20 cm)	7.44	7.42	0.182	0.179	0.36	0.38

Note: *Replacement series and **Additive series

Biological properties of the soil.

Data pertaining to biological properties of the soil after harvesting of the crop during both the years of experimentation are presented in Table -2 and 3 and it obviously indicated that crop geometry did not influenced significantly the biological properties of the soil, *viz.*, bacteria (cfu), fungi (cfu) and actinomycetes (cfu) whereas nutrient management practices were affected significantly superior the biological properties of the soil. The highest bacteria, fungi and actinomycetes (cfu) population was associated with the application of 100% RDF + 25% N through poultry manure but on par with 100% RDF + 25% N through vermicompost, over rest of the treatments. The increase in microbial population with the application of organic manure might be due to stimulated growth and activities of micro-organism. The crop plants secreted various types of organic acids from roots, which is an easily available source of food for soil micro-organism. The addition of organic inputs enhanced the microbial counts in soil, which might be due to carbon addition and changes the biophysico-chemical properties of the soil (Gunjal and chitodkar, 2017) [7]. In case of soil microbial biomass carbon (µg C g^{-1} soil) in the soil, the effect was found not significant during both the years of experimentation with crop geometry as well as nutrient management practices. Continuous addition of organic manure, microbial inoculants, and liming in conjunction with NPK fertilizers showed the most microbial biomass phosphorus, where it was the lowest in the control (Saha *et al*. 2010) [10]. In sole crops, among the biological properties of the soil, *viz.*, bacteria (cfu), fungi (cfu), actinomycetes (cfu) as well as soil microbial biomass carbon (µg C g^{-1} soil) was recorded maximum with sole potato as compared to sole maize during both the years of experimentation because higher organic matter was added by root and shoot of potato during the course of time.

Table 2: Effect of crop geometry and nutrient management on bacteria, fungi and actinomycetes in maize + potato intercropping system after harvesting of crop

Treatments	Bacteria (cfu)		Fungi (cfu)		Actinomycetes (cfu)	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Crop geometry						
1:1 (M+P) 60x20 cm*	69.25	71.01	29.85	32.07	37.82	41.15
1:2 (M+P) 60x20 cm*	70.44	72.67	30.14	32.98	38.26	42.40
1:1 (M+P) 75x20 cm**	71.43	74.69	31.45	34.42	40.18	43.92
1:2 (M+P) 75x20 cm**	72.80	75.54	32.7	35.90	41.45	44.75
SEm±	1.45	1.33	0.85	1.12	1.06	1.10
CD (P= 0.05)	NS	NS	NS	NS	NS	NS
Nutrient management						
100% RDF	64.9	67.32	27.98	28.88	35.21	37.11
100% RDF + 25% N through vermicompost	69.87	73.96	31.74	35.03	40.02	43.74
100% RDF + 25% N through poultry manure	72.34	75.71	32.59	36.12	41.63	45.29
75% RDF + 25% N through vermicompost + *Azotobacter*	66.81	71.85	29.67	32.81	37.26	40.18
75% RDF + 25% N through poultry manure + *Azotobacter*	67.45	72.09	30.25	33.3	38.15	41.86
SEm±	1.40	1.20	0.70	0.98	0.91	1.05
CD (P= 0.05)	3.98	3.37	2.01	2.81	2.56	3.02
Sole crops						
Maize (60 x 20 cm)	68.75	69.42	28.25	31.12	35.24	38.86
Potato (60 x 20 cm)	69.05	71.39	29.47	32.10	36.58	39.15

Note: *Replacement series and **Additive series

Table 3: Effect of crop geometry and nutrient management on soil microbial biomass carbon (SMBC) in winter maize + potato intercropping system after harvesting of crop

Treatments	SMBC (µg C g^{-1} soil)	
	2015-16	2016-17
Crop geometry		
1:1 (M+P) 60x20 cm*	176.85	177.02
1:2 (M+P) 60x20 cm*	179.21	180.93
1:1 (M+P) 75x20 cm**	178.15	179.77
1:2 (M+P) 75x20 cm**	181.12	182.78
SEm±	1.96	1.83
CD (P= 0.05)	NS	NS
Nutrient management		
100% RDF	177.09	178.29
100% RDF + 25% N through vermicompost	181.17	182.51
100% RDF + 25% N through poultry manure	182.43	183.25
75% RDF + 25% N through vermicompost + *Azotobacter*	178.64	179.37
75% RDF + 25% N through poultry manure + *Azotobacter*	179.55	180.72
SEm±	1.89	1.78
CD (P= 0.05)	NS	NS
Sole crops		
Maize (60 x 20 cm)	175.41	176.12
Potato (60 x 20 cm)	177.36	179.54

Note: *Replacement series and **Additive series

Conclusions

It may concluded that 1:2 row ratio in additive series along with application of 100% RDF + 25% N through poultry manure followed by 100% RDF + 25% N through vermicompost was found feasible and viable as compared to rest of the treatments.

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