Original Research Article

Effect of inorganic fertilizer, farmyard manure and biofertilizer on physical and chemical properties of soil and system yield of maize –wheat rotation in Mollisol

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ABSTRACT

A field experiment was conducted during the *Kharif andRabi* seasons of 2020-21 and 2021-22 at the Norman E. Borlaug Crop Research Centre, G.B.P.U.A &T., Pantnagar. Randomized block design was followed with 11 treatments and 3 replications. The main objective was to assess the influence of fertilizer and farmyard manure application, with or without *Azotobacter*and zinc, on crop yield and soil properties in a maize-wheat crop rotation. The data demonstrated that application of 100% RDF +FYM 5 t ha^{-1}, resulted in a significantly higher system yield of 12,137 kg per hectare. Intercropping of cowpea with maizealong with the application of FYM 10 t ha^{-1} showed the lowest bulk density in both surface (1.38 Mg m^{-3}) and sub-surface (1.49 Mg m^{-3}) soil and also it led to a reduction in the soil pH and EC. Additionally, hydraulic conductivity was higher in organic treatments, specifically in T$_6$. However, the application of 100% RDF + FYM 5 t ha^{-1} resulted in the maximum retention of organic carbon (1.06% and 0.71%) as well as higher content of available nitrogen (185.11 and 175.95 kg ha^{-1}), phosphorus (36.17 and 31.65 kg ha^{-1}), and potassium (147.90 and 120.68kg ha^{-1}) in surface and subsurface soil, respectively. The study suggests that the application of 100% RDF + FYM 5 t ha^{-1} contributes to improved soil fertility and sustainable crop yields.

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Keywords: maize-wheat, inorganic fertilizer, FYM,organic C, bulk density, hydraulic conductivity, system yield

1. INTRODUCTION

Maize–wheat cropping system is one of the major agricultural management systems in India and ranks first among different maize-based cropping systems. It is the 3rd most important cropping system after rice-wheat and rice-rice system having a 1.8 M ha area that contributes about 3% to the food grain production of India **Dass*et al.*, 2020 [1]**. Rice-wheat is the major cropping system for the past several decades in the *Tarai*region. Both crops are heavy nutrient feeders **Panwar *et al*., 2019 [2]**. Moreover, adaptation of high yielding and

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nutrient responsive varieties of these crops, as well as faulty agricultural practices by the farmers are common in this area. Consequently, overexploitation of the natural resources especially fertile land and plenty of available water created an adverse impact on the soil in the form of deterioration of soil health, fragile crop environment and, reduced profitability of crops **Ram *et al*., 2016 [3]**. **Naresh 2013 [4]** reported that under continuous and intensive farming of rice-wheat cropping system, the nutrient supplying power of most of the soils has been found declining, therefore, becoming less profitable consequently farmers are shifting to other profitable cropping systems. Therefore, farmers of this region are showing their interest in maize crop due to its multipurpose use and higher profitability. The production potential of maize-based cropping systems is higher than that of the conventional rice-wheat system. Maize-based cropping systems provide options for farmers to sustainably diversify from rice-wheat production system as later system exert immense pressure over water resources. The irrigation water productivity under the maize–wheat system is generally higher and was reported 126–160% higher as compared to the rice-wheat cropping system. Furthermore, the maize–wheat system also improves the soil health in comparison with the puddled transplanted rice system **Jat *et al*., 2012 [5]**. Despite being beneficial over the traditional rice-wheat system, the maize- wheat system has certain drawbacks as maize and wheat are known for their high nutrient demands. The practice of continuous cropping in intensive cereal-based systems, without proper nutrient management, accelerates the decline in soil fertility. To mitigate these issues, adopting sustainable agricultural practices becomes crucial. Intercropping with nitrogen-fixing legumes, incorporating organic manure, biofertilizer and integrated use of organic and inorganic sources of the nutrients are strategies that can help to restore the soil fertility. Many researches had reported that manure application increases crop yields besides soil organic matter and improves soil quality as well **(Blair *et al*., 2006; Yang *et al*., 2015) [6,7]**. *Azotobacter*, a free-living N_2 fixing bacterium contributes to nitrogen in many non-leguminous crops and also synthesizes and secretes a considerable amount of biologically active substances which enhances root growth and protects the plant from diseases **(Soleimanzadeh and Gooshchi, 2013) [8]**.The use of inorganic fertilizer or organic manure alone has both positive and negative effects on plant growth, nutrient availability, and overall health of the soil. The organic sources of nutrients are the indigenous sources that can help in increasing production and productivity along with improvement in soil properties. However, organic sources do not contain significant quantities of plant nutrients as they are just soil amendments. Hence, the application of organic matter alone to soil is not a complete substitute for inorganic fertilizer and vice-versa and their roles are complementary to each other. The use of inorganic fertilizers in conjunction with organic manures improves the physical, chemical and biological characteristics of the soil as well as soil organic carbon maintained at a significant level. This approach offers a viable solution for preserving both crop productivity and soil health **(Sharma *et al*., 2020) [9]**.

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Therefore, considering the declining soil fertility and productivity, reduced profitability, ecological disturbance, etc. owing to prolonged excessive and indiscriminate use of chemical fertilizer in rice-wheat system, the present investigation was undertaken to investigate the suitability of nutrients application practice based on effect of the use of fertilizers and organic manure alone or in integrated mode in the maize-wheat cropping system.

2. MATERIAL AND METHODS

The present study is a part of an ongoing long-term integrated nutrient management experiment with a maize-wheat cropping system started with *kharif* season maize in 2019. The experiment was conducted at Norman E. Borlaug Crop Research Centre, G.B.P.U.A &T., Pantnagar, Uttarakhand (29° N latitude, 79° 30’ longitude and an altitude of 243.8 m above the mean sea level) during *Kharif* and *Rabi* seasons of 2020-21 and 2021-22.The soil of the experimental field was sandy loam in texture having initial soil OC, EC, pH, available N, P, and K of 0.80%, 0.25 dSm^{-1}, 7.18, 172.15 kg ha^{-1}, 32.20 kg ha^{-1} and 125.0 kg ha^{-1}, respectively. The experiment was conducted with 11 treatments comprised of; T$_1$ = Absolute control, T$_2$ =100% RDF ,T$_3$ = 75% RDF, T$_4$ = 50% RDF, T$_5$ = FYM 10 t/ha + *Azotobactor*, T$_6$ = Maize + cowpea with FYM 10 t/ha + *Azotobacter*, T$_7$ =100% RDF+ FYM 5 t ha^{-1} , T$_8$ = 75% RDF + FYM 5 t ha^{-1}, T$_9$ = 50% RDF + FYM 5 t ha^{-1}, T$_{10}$ = 100% RDF + Zn 5 kg ha^{-1}, T$_{11}$ = FYM 5 t ha^{-1} were tested in randomized block design replicated 3 times. Recommended dose of N, P andwere 120, 60 and 40 kg ha^{-1} and for Maize (P3401) and 150, 60 and 40 kg ha^{-1} for wheat (HD2967), respectively. Fertilizer sources such as NPK (12:32:16), urea, and muriate of potash were used to provide nitrogen, phosphorus, and potassium, respectively, and the source of Zn was zinc sulphate. All plots received the one third of N, entire amount of P, K and Zn as basal at the time of sowing and remaining N was applied in two equal splits as top dressing through urea at knee high (25-35 DAS) and tassel emergence (100-130 DAS) in maize and at 20-25 (CRI stage) and at 40-45 days after sowing. Well decomposed farmyard manure was broadcasted on the soil surface and intermixed immediately just before the sowing of maize and wheat crop. *Azotobacter*was applied through seed inoculation. Soil samples were collected from two depths from 0-15 cm and 15-30 cm within each plot to assess various soil properties. After collection, the soil samples were air-dried, ground to pass through a 2 mm sieve and subjected to analysis. Soil pH and EC were determined in a soil-water suspension ratio of 1:2 as described by **Jackson (1967) [10]** and **Bower** and **Wilcox (1965) [11]**, respectively. Methods for other soil properties used were wet-oxidation for organic carbon **(Walkley** and **Black, 1934) [12]**; available N **(Subbiah and Asija, 1956)[13],** available P **(Olsen *et al.*, 1954) [14]**, available **K (Schollenberger and Simon,1945)[15],** available Zn **(Lindsay** and **Norvell, 1978) [16]**; bulk density and porosity(**Blake, 1965) [17],** saturated hydraulic conductivity **(Klute, 1965) [18]**. Grain yields for both maize and wheat were recorded from each net plot at harvest. To analyse the collected data, an analysis of variance (ANOVA) was conducted using the statistical software STPR. This statistical approach allowed for the examination of variations in the measured soil properties and crop yields among different treatments within the study.The data were analyzed following the techniques of analysis of variance (ANOVA) prescribed for randomized block design using the statistical software STPR developed by department of Mathematics, Statistics and Computer Science, College of Basic Sciences and Humanities, G. B. Pant University of Agriculture and Technology, Pantnagar. The least significant difference values were tested at 5% level of probability.

3. RESULTS AND DISCUSSION

3.1 Soil properties

3.1.1 Soil pH

Use of fertilizer and farmyard manure alone or in combination were found to have significant effect on soil pH at both the depth of soil. The pH levels exhibit a range of 6.85 to 7.22 and 6.99 to 7.27 in surface (0-15 cm) and sub-surface (15-30 cm), respectively **(Table 1)**. Notably, the highest pH at surface (7.22) and subsurface (7.27) were observed with the use of 100% NPK, which exceeded from 0.01-0.37 and 0.06-0.28, respectively, whereas the lowest pH (6.85) in T$_6$ at surface and 6.99 in T$_9$ at sub surface. It is noteworthy that only fertilizer containing treatments (T$_2$, T$_4$ and T$_{10}$) exhibited statistically par and significantly higher pH over FYM retaining treatments at both depths. The decline in pH was more pronounced with the use of organic sources alone and the combined application of organic and inorganic materials, in contrast to the sole application of inorganic fertilizer. This observed decrease in pH can be attributed to the generation of CO$_2$ and organic acids during the microbial decomposition of applied organic manures, complemented by the residual acidity of nitrogen fertilizers **(Kharche*et al.*, 2013; Meena *et al.*,**

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2018)[19,20]. Increment of 25% NPK alone or conjoint with FYM did not produced significant effect on soil pH at both depths. The slight enhancement in soil pH was observed in all treatment. The improvement in soil pH with increase in soil depth was also supported by **Bhatt *et al*. 2019 [21]**. Biofertilizers also lowered the soil pH as compared to non-inoculation treatments and maximum reduction was seen in treatment T_6. Similar findings reported by **(Ramalakshmi*et al*., 2008: Ratanoo*et al*., 2021) [22,23].**

3.1.2 Soil electrical conductivity

The utilization of various organic and inorganic sources, as well as their combinations, exerts a notable impact on the electrical conductivity (EC) of soil (**Table 1)**. It is evident that there is a minimal and more uniform fluctuation in EC values across all the treatments. The soil EC ranged from 0.20 to 0.27 dSm^{-1} in the surface soil and 0.17 to 0.21 dSm^{-1} in the subsurface soil. The highest EC was reported with treatment T_1 (control) **(Meena *et al*., 2018) [20]** interestingly, a decrease in EC values was noted with an increase in depth in the subsurface soil. Furthermore, a noticeable trend emerged, indicating an increase in EC with a rise in the rate of fertilization. This aligns with findings from **Kumar *et al.* (2016) [24],** who also reported an elevation in electrical conductivity when utilizing chemical fertilizer alone. This increase is likely attributed to the accumulation of soluble salts, originating from fertilizer application and the exchange of various cations. Similar observations were documented by **Rao (2003), Pant (2016),** and **Bhatt (2012) [25, 26,27].**

3.1.3 Soil organic carbon

Distinct variations were observed in the content of soil organic carbon (OC) both in the surface and subsurface layers attributed to diverse organic and inorganic nutrient sources. Organic carbon exhibited a range of 0.59 to 1.06% and 0.37 to 0.71% in surface and subsurface soil, respectively. Treatment 100% RDF + FYM 5t ha^{-1} displayed the significantly highest OC content (1.06 and 0.71%) at both depths followed by maize + cowpea + FYM 10t +*Azotobacter*(0.98 and 0.68%). In contrast, the control treatment demonstrated the lowest content. The combined application of FYM 5t ha^{-1} with each 25% increment in inorganic fertilizer from 50% RDF to 100% RDF resulted in higher organic carbon content compared to treatments with sole inorganic fertilizers. Remarkably, the application of 100% RDF + FYM 5t ha^{-1} led to a substantial increase of 79.6% and 92% in surface and subsurface soil OC, respectively, compared to the control treatment. The improvement in OC is also reported by **Saha*et al.* (2010) [28]** across different soil depths through the consistent application of organic manure and lime in conjunction with chemical fertilizers. Similar outcomes were observed by various researchers, including **Brar *et al.* (2015) [29]** and **Patial*et al.* (2022) [30]**. It's noteworthy that organic treatments consistently exhibited higher organic carbon content compared to both the control and inorganic treatments **(Sudhakar *et al.,* 2019) [31].**

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Table 1. Effects of inorganic fertilizer and farmyard manure on soil pH, electrical conductivity and organic carbon in maize –wheat rotation (pooled data of 2 years)

Treatments	**Soil pH**	**Soil EC (dS m^{-1})**	**Organic Carbon (%)**

	0-15 cm	**15-30cm**	**0-15 cm**	**15-30cm**	**0-15 cm**	**15-30cm**
T1	7.12	7.17	0.27	0.21	0.59	0.37
T2	7.22	7.27	0.26	0.21	0.87	0.57
T3	7.19	7.20	0.24	0.19	0.73	0.44
T4	7.18	7.19	0.23	0.18	0.65	0.40
T5	6.94	7.08	0.21	0.17	0.92	0.65
T6	6.85	7.08	0.20	0.17	0.98	0.68
T7	7.11	7.15	0.24	0.19	1.06	0.71
T8	7.11	7.13	0.23	0.17	0.89	0.60
T9	7.10	7.17	0.24	0.17	0.79	0.56
T10	7.21	7.21	0.25	0.21	0.86	0.54
T11	6.89	6.99	0.25	0.20	0.73	0.41
SEm±	0.02	0.03	0.01	0.01	0.01	0.01
C.D.(*P*=.05)	0.05	0.10	0.02	0.01	0.04	0.03

3.1.4 Bulk density

The use of FYM 10 t ha^{-1} along with biofertilizer led to the most notable decrease in soil bulk density compared to other treatments at both depths. Application of FYM 10t ha^{-1} + *Azotobacter* in maize-cowpea intercropping treatment (T$_6$), resulted in the lowest bulk density in both surface and subsurface soil with the values of 1.38 and 1.49 Mg m^{-3},respectively, followed by FYM 10 t + *Azotobacter*(T$_5$). Compared to control,the treatments T$_6$ and T$_5$ showed reduction in bulk density of approximately 11.5 and 10.3% in surface soil, and 12.4 and 10.0% in subsurface soil, respectively. Moreover, all the treatments received sole application of chemical fertilizers were failed to bring significant reduction in bulk density as compared to their respective doses combined with FYM 5 t ha^{-1} at both depths of soil. Subsurface arrested the higher bulkdensities in all treatments compared to subsurface, attributed to compaction **(Kharche*et al*., 2013) [19].**Consistent with these observations, **Kumar *et al.* (2016)[24]** noted a reduction in bulk density when using a combination of 50% nitrogen through organic manure + 25% nitrogen through urea + biofertilizers + Zn. This decline is attributed to the addition of high organic matter, creating more pore spaces and enhancing soil aggregation. The findings were in accordance with **Bamboriya*et al.* (2022) [32]** with the addition of phosphorus-enriched compost in maize and **Ranjan *et al.* (2023) [33]** with 50%RDF + 50% N through FYM in wheat crop.

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3.1.5 Saturated Hydraulic Conductivity

The impact of fertilizer and farmyard manure (FYM), whether applied independently or in combination, significantly influenced soil saturated hydraulic conductivity (K_S) at various soil depths (Table 3). However, the combined application of FYM 10 t ha^{-1} + *Azotobacter* in maize + cowpea (T_6) exhibited the highest K_S, reaching 1.80 cm h^{-1} and 1.19 cm h^{-1} in the surface and sub-surface soil, respectively while control consistently displays the lowest values. Furthermore, the application of FYM in conjunction with RDF notably contributed to an increase in soil K_S. Treatment 100% RDF + FYM 5t ha^{-1} increases $K_S$by 50.0% and 34.8% $K_S$over the control. Similarly**, Gautam *et al.* (2022) [34]** observed an increase in the K_S of approximately 26% for FYM and 46% for FYM+NPK compared to the control in pearl millet-fellow cropping system. However, it's important to note that $K_S$tends to decrease with increasing depth. The observed increases in $K_S$in FYM-treated plots may be attributed to the promotion of better soil structure and porosity through the addition of organic matter. Organic matter functions as a binding agent, fostering stable aggregates that form channels and spaces within the soil, thereby enhancing water movement. Similar findings were also reported by **Singh *et al*. (2016) [35]** and **Pant and Ram (2018) [36].**

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3.1.6 Available nitrogen

The 25% increase in amount of inorganic fertilizer alone or with FYM resulted in a substantial increase in the available nitrogen content at both soil depths. It varied from 143.65-185.11 kg ha^{-1} in the surface and 138.47-175.95 kg ha^{-1} in the sub-surface soil. Application of 100% RDF + FYM 10 t ha^{-1} consistently exhibited the highest nitrogen content at both the depths, which was statistically superior to all other treatments, followed by 100% RDF + 5kg Zn ha^{-1} and 75% RDF + FYM 5t ha^{-1} while the control consistently showed the lowest content. **Bonde and Gawande (2017) [37]** also reported that the application of fertilizers, either alone or in combination with organics, was significantly superior to the control. The sub-surface layer generally demonstrated lower available nitrogen compared to the surface layer. Specifically, Treatments T_7, T_8 and T_9, which received inorganic fertilizer in combination with FYM 5 t ha^{-1} exhibited increase in available nitrogen content of about 4.6, 8.2 and 5.3%, respectively, compared to treatments T_2, $T_3$and T4 where only chemical fertilizer was applied. A similar trend was observed in the sub-surface layer. The highest available nitrogen in the treatment involving 100% RDF+ FYM 5t ha^{-1} could be attributed to the mineralization of nitrogen from native sources during decomposition, along with the direct addition of nitrogen through FYM to the available soil pool and improved microbial activity **(Panwar *et al.,* 2008) [38]**. The organic treatments, specifically T_6, where cowpea was taken as intercrop in maize resulted in significantly higher nitrogen content at surface soil compared to the treatment without cowpea (T_5). Consistent with the findings, **Parewa*et al.* (2014) [39]** also noted higher values of available nitrogen as a result of the combined application of 100% NPK fertilizer, FYM 10 t ha^{-1} and bio inoculants. Similar results were obtained by **Pothare*et al.* (2007) [40]**, **Bhatt (2012) [27],** and **Dhiman *et al.* (2019) [41].**

3.1.7 Available phosphorus

Content of soil available phosphorus significantly influenced by the use of different organic and inorganic sources of nutrient, the values ranged from 23.03 to 36.17 kg ha^{-1} in the surface soil and from 15.48 to 31.65 kg ha^{-1} in the subsurface soil. The highest available phosphorus (36.17 and 31.65kg ha^{-1}) in both the depths was observed with 100% RDF+ FYM 5t ha^{-1} which was statistically at par with T_8 and T_2 and lowest (23.03 and 15.48 kg ha^{-1}) was recorded under control. Treatments that received FYM along with inorganic fertilizer

(T_7, T_8 and T_9) in general maintained statistically at par but higher levels of available phosphorus in both soil depths compared to the treatments received nutrients solely through inorganic fertilizers (T_2, T_3 and T_4). Cowpea intercropping (T_6) significantly enhanced available P by 3.28 kg ha^{-1} over without cowpea (T_5) at surface and treatments T_5 and T_6 exhibited significant increase in available phosphorus compared to treatment $T_{11.}$ However, inorganic fertilizer alone or in combination with FYM maintained higher available P compared to organic mode. The results are in conformity with the findings of **Tilahum*et al.* (2013) [42], Sudhakar *et al.* (2019) [31],** and **Singh *et al.* (2019**) [43]. The application buildup of available phosphorus owing to use of inorganic fertilizers alone or in combination with organics could be attributed to the release of organic acids during decomposition, which in turn may have facilitated the release of phosphorus from the native pool of phosphorus in the soil **(Urkurkar*et al*., 2010) [44]**. Additional use of Zn 5 kg ha^{-1} with 100% NPK significantly reduced available P compared to 100% NPK. This might be due to zinc has an antagonistic effect with phosphorus which might have decreased the phosphorus content in soil at harvest of crop **(Sharma *et al.,* 2023) [45]**. A noticeable decrease in available phosphorus from 3.25-7.55 kg ha^{-1} was observed in 15-30 cm compared to 0-15 cm.

3.1.8 Available potassium

Significant variations in soil available potassium were observed among the different treatments (Table 3). The available potassium varied from 113.06 to 147.90 kg ha^{-1} in the surface soil and from 91.25 to 120.68 kg ha^{-1} in the sub-surface soil. The highest potassium content was obtained with 100% RDF + FYM 5t ha^{-1} which was statistically at par with 75% RDF+ FYM 5t ha^{-1} at surface, and significantly higher than all other treatments at both depths of soil. **Pandey *et al.* (2009) [46]** demonstrated a build-up of available potassium with the combined use of chemical fertilizers, compost, and crop residue incorporation in the soil. In contrast, the control treatment exhibited the lowest potassium content **(Bonde and Gawande, 2017) [37]** which likely due to increased crop demand leading to soil potassium depletion. Application of 100% NPK alone or in combination with FYM or Zn and 75% NPK with FYM 5 t ha^{-1} significantly enhanced available K by 16.45, 34.84, 19.05 and 31.12 kg ha^{-1} over control, respectively in the surface soil. However, all treatments except T_{11} had significantly higher available K over control for sub surface. Moreover, organic mode treatments (T_6, T_5 and T_{11}) in general did show statistically at par for available K at both depths. The higher available potassium levels in RDF + FYM amendment treatments may be attributed to the decomposition of FYM in the soils, leading to the release of organic colloids. This process improves cation exchange capacity, allowing the soil to hold more exchangeable potassium **(Pathariya*et al*., 2022) [47]**.

3.1.9 Available zinc

The available Zn in both the surface and subsurface soil was significantly varied among the treatments **(Table 2**). Treatment 100% RDF + Zn 5 kg ha^{-1} recorded the highest zinc content in both the depths, being significantly higher from 0.13-0.56 and 0.12-0.4 mg kg^{-1} than other treatments in the surface and subsurface soil, respectively. The higher zinc content in treatment 100% RDF + Zn 5 kg ha^{-1} may be attributed to zinc supplementation through chemical fertilizer. The highest DTPA extractable zinc 3.69 and 3.62 ppm at 0-15 and 15-30 cm, respectively, with 100% NPK +Zn applicationwas also reported by**Priyanka *et al*. (2019) [48].** In the treatments with conjunctive use of inorganic fertilizer and FYM (T_7, T_8, and T_9), available zinc content was found to be significantly increased by 12.3%, 27.6%, and 24.5% in surface soil, and by 44.0%, 88.2%, and 50% in subsurface soil, respectively, compared to the treatments with sole application of inorganic fertilizer. However, organic treatments (T_5,

T_6,) showed a lower content of available zinc and were found to be at par with 75% RDF treatment but significantly higher amount over T_1 and T_{11}. The control treatment exhibited the lowest zinc content**(Bonde and Gawande, 2017) [37]**. **Srivastava *et al*. (2014) [49]** also reported significant increase in DTPA extractable zinc by 10.2% over the control with the application of Zn 2.5 kg ha^{-1} in rice-wheat system. Available zinc content was found to be decreased with an increase in depth of soil.

Table 2. Effects of inorganic fertilizer and farmyard manure on available nitrogen, phosphorus, potassium and zinc in maize –wheat rotation (pooled data of 2 years)

Treatments	**Available N (kg ha^{-1})**		**Available P (kg ha^{-1})**		**Available K (kg ha^{-1})**		**DTPA-Zinc (mg kg^{-1})**	
	0-15 cm	**15-30cm**	**0-15 cm**	**15-30cm**	**0-15 cm**	**15-30cm**	**0-15 cm**	**15-30cm**
T1	143.65	138.47	23.03	15.48	113.06	91.25	0.48	0.08
T2	176.92	164.70	35.78	28.95	129.51	107.63	0.81	0.25
T3	166.13	149.62	33.83	26.79	126.41	102.59	0.65	0.17
T4	160.77	143.39	31.23	25.46	118.20	99.10	0.57	0.12
T5	157.94	148.70	28.16	24.91	120.20	100.76	0.62	0.14
T6	165.61	149.73	31.44	27.29	123.33	102.07	0.67	0.15
T7	185.11	175.95	36.17	31.65	147.90	120.68	0.91	0.36
T8	179.91	165.73	35.01	29.37	144.18	111.59	0.83	0.32
T9	169.39	153.85	32.35	27.14	127.06	103.19	0.71	0.18
T10	180.50	168.22	27.40	21.82	132.11	110.04	1.04	0.48
T11	156.37	142.51	25.24	18.07	119.87	94.13	0.53	0.09
SEm±	1.77	1.69	0.78	0.98	4.88	2.57	0.02	0.01
C.D. (*P*=.05)	5.07	4.83	2.23	2.80	13.96	7.34	0.05	0.03

Table 3. Effects of inorganic fertilizer and farmyard manure bulk density, porosity and system yield in maize –wheat rotation (pooled data of 2 years)

Treatments	**Bulk density (Mg m^{-3})**		**Hydraulic conductivity (cm hr^{-1})**		**System yield (kg ha^{-1})**
	0-15 cm	**15-30cm**	**0-15 cm**	**15-30cm**	

T1	1.56	1.70	1.12	0.86	6324
T2	1.47	1.62	1.34	0.97	10913
T3	1.50	1.64	1.24	0.94	10182
T4	1.54	1.67	1.19	0.92	8693
T5	1.40	1.53	1.69	1.10	9093
T6	1.38	1.49	1.80	1.19	10872
T7	1.44	1.57	1.68	1.16	12137
T8	1.47	1.60	1.56	1.10	11495
T9	1.51	1.62	1.46	1.08	10413
T10	1.51	1.65	1.40	1.03	11244
T11	1.54	1.65	1.34	0.89	7586
SEm±	0.01	0.01	0.02	0.02	157.1
C.D. (*P*=.05)	0.04	0.04	0.06	0.05	449.0

3.2 System yield

Significant variation was found in averaged system yield of the maize-wheat due to different combinations of inorganic and organic sources of nutrients (Table 3) which ranged from 6324 to 12137 kg ha^{-1}. Notably, each treatment was found to be varied significantly with other for system yield. Plot received 100% RDF+ FYM 5t ha^{-1} produced significantly higher system yield (12137 kg ha^{-1}) over others followed by 75% RDF + FYM 5 t ha^{-1} (11495 kg ha^{-1}) while the least with control (6324 kg ha^{1}). Conjoint use of different doses of RDF with FYM 5 t ha^{-1} (T_7, T_8 and T_9) attained significantly higher system yield over respective RDF alone (T_2, T_3 and T_4) and highest yield difference (1720 kg ha^{-1}) was obtained between 50% NPK with FYM 5 t ha^{-1} and 50% RDF alone. Among the organic treatments, each varied significantly for system yield however, cowpea intercropping (T_6) produced higher system yield which was at par with 100% RDF.**Manjhi*et al*. (2014) [50]** also reported the highest system productivity (wheat-equivalent yield of 8.2 t ha^{-1}) with the substitution of 50% N through FYM along with 50% RDF in maize and 100% RDF through inorganic fertilizer in wheat. The observed increase in system yield with a balanced application of organic manure and inorganic fertilizers may be attributed to improvements in soil physical properties and the sufficient supply of nutrients from FYM and inorganic fertilizers. **Saha*et al.* (2010)[28]** obtained similar results with 100% RDF along with FYM, bio fertilizer, and lime for maize and mustard. System yields were found to be decreased by 731 and 1489 kg ha^{-1} without FYM and by 642 and 1082 kg ha^{-1} with FYM by reducing NPK from 100% to 75%, and 75% to 50%, respectively. Inclusion of FYM 5 t ha^{-1} was found to be more beneficial for system yield compared to Zn 5 kg ha^{-1} over 100% NPK.

Comment [H14]: try to cite from recent findings.

3.3 Relationship between soil properties and system yield.

A significant and negative correlations were obtained between saturated hydraulic conductivity and EC (-0.604*) and organic carbon with bulk density (-0.836**), while organic carbon was significantly and positively correlated with saturated hydraulic conductivity (0.948***), available N (0.732*) and available $P_2O_{5,}$ (0.614*) and system yield (0.717*). In general, strong relation was observed for available nitrogen with available P_2O_5 (0.683*), available K_2O (0.848***), available zinc (0.873***) and system yield (0.935***). Available P_2O_5,available K_2O and available Zn were also found to be strongly correlated with system yield (0.848***, 0.789*** and 0.824*).

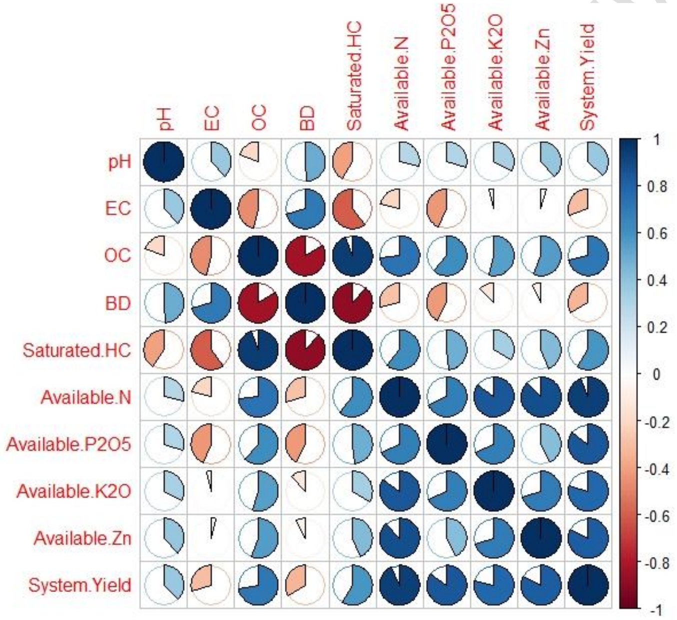

Figure 1: Pearson correlation correlogram for soil properties and system yield

3.4 Principal component analysis (PCA)

Since all measured soil properties tangibly affected the system yield in maize-wheat rotation, therefore, it is obligatory to screen out the corresponding “highly weighted” variables to be retained and include in the minimum data set (MDS) from the eigenvector weight value or factor loadings. So, multivariate analysis i.e., principal component analysis (PCA) was carried out on the maize – wheat system yield and soil properties.

Results of PCA **(Figure 2)** accomplished generated two principal components which explained 5.97 % and 29.82% of the total variance for PC1 and PC2, respectively. The corresponding loadings plot **(Figure 2)** revealed that PC1 had slightly large positive loading on bulk density and electrical conductivity and large negative loading on available N, available P_2O_5 and available K_2O, available Zn, hydraulic conductivity and system yield, while PC2 had small positive loading on organic carbon and large negative loading on pH, electrical conductivity, bulk density and small negative loading on hydraulic conductivity, available N, available P_2O_5, available K_2O and available Zn and system yield.

Table 4: Results of principal components analysis of soil properties and system yield

	PC1	PC2
Standard deviation	2.30	1.7
% of variance	52.97	29.82
Cumulative %	52.97	82.79
Factor loadings		
Parameters	PC1	PC2
pH	-0.038	-0.476
EC	0.214	-0.368
OC	-0.395	0.166
BD	0.279	-0.426
Hydraulic conductivity	-0.346	-0.315
Available N	-0.389	-0.205
Available P_2O_5	-0.358	-0.073
Available K_2O	-0.327	-0.269
Available Zn	-0.307	-0.302
System yield	-0.402	-0.190

***Extraction Method: Principal Component Analysis*

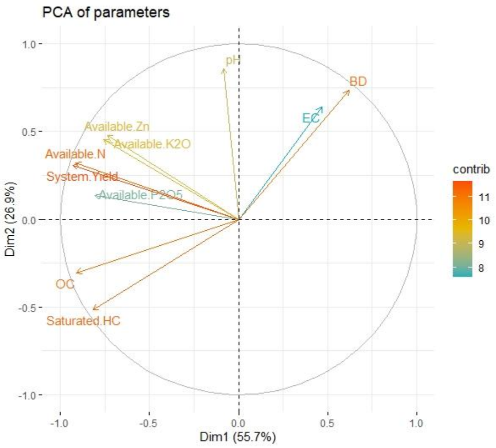

Figure 2: Loading's plot formed by principal components 1 and 2 with different parameters

4. CONCLUSION

On the basis of field study on maize-wheat rotation conducted for two years it may be concluded that the integrated approach of using farmyard manure (FYM) in conjunction with inorganic fertilizer maintained the soil properties, specifically with 100% RDF + FYM 5 t ha^{-1}. However, use of FYM 10 t ha^{-1} along with *Azotobacter*enhanced the organic carbon content to a greater extent. Conjoint use of zinc 5 kg ha^{-1} with 100% RDFfavours the higher availability of zinc in *tarai* soil. Integrated use of 100% RDF along with FYM 5 t ha^{-1} produced the highest system yield of maize-wheat hence could be a better option. However, organic mode of nutrient application especially FYM 10 t ha^{-1} + *Azotobactor* with or without cowpea intercropping in maize failed to achieve the higher system yield. Gradual decrease in RDF level alone or in combination with FYM 5 t ha^{-1} significantly retarded the system yield.The PCA and correlation matrix also confirmed the role of soil properties in the augmentation of system yield.

Comment [H15]: Please follow the same spacing pattern in the entire paper.

Comment [H16]: azotobacter

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