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Comparative study of impact of inorganic and organic fertilizer on maize-wheat cropping system

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Abstract

There are ongoing worries and mounting evidence of accelerating biodiversity loss. A key issue is that loss of biodiversity may result in changes in ecosystem functioning, posing threats to agricultural systems' stability and resilience. In light of this, this study looks into the empirical relationship between the amount of inorganic fertiliser and organic fertilizer used and the danger of loss on the Maize-Wheat cropping system. The statistical estimations show that the amount of inorganic fertiliser used per hectare of arable land is highly associated to growing biodiversity risk, based on cross-country biodiversity risk indices. After correcting for heterogeneity, robust findings across several specifications remain.

Keywords: Biodiversity, inorganic fertilizer, heterogeneity

Introduction

Country's most major farming system is maize-wheat. As a result, improving the viability of this crucial cropping sequence is critical to changing the agricultural landscape in India. The farmers generally rely on traditional farming methods and use pesticides. A large number of fertilisers, especially inorganic fertilisers like urea (which contains 46 percent nitrogen) and to increase paddy rice yield, use diammonium phosphate (DAP; contains 46 percent P and 18 percent N). Inorganic fertilisers pollute groundwater and are not environmentally friendly. Plant tissues absorb and deposit heavy metals more frequently as a result of continuous and consistent use of inorganic fertilisers, lowering crop nutritional and grain quality. As a result, excessive use of inorganic fertilisers has resulted in soil, air, and water pollution as a result of nutrient leaching, soil physical characteristics destruction, toxic chemical accumulation in water bodies, and other factors, as well as severe environmental problems and biodiversity loss. As a result, agrochemicals are one of the most significant and dominant sources of pollution in developing countries, and they endanger human and cattle health. Organic fertilisers, such as animal manure, sawdust, and others, as well as a combination of organic and inorganic fertilisers, can be used as an alternative to using inorganic fertilisers.

Organic fertilisers, as opposed to inorganic fertilisers, preserve soil quality, enhance soil organic matter, and improve soil physical and chemical qualities by allowing things to decompose. Soil nutrients, plant growth regulators, and biodiversity are all improved by organic matter. Consumer acceptance and marketability of grains, on the other hand, are mostly determined by its quality, which has an impact on the growers' economies. The grain physicochemical properties, which include physical characteristics such as chalkiness, shape, size, perfectness, and appearance, as well as chemical composition characteristics such as amylose, protein, and lipid content, have a significant impact on rice production, consumption, and consumer preference. As a result, consumers are increasingly demanding better grain quality.

Furthermore, combining organic and inorganic fertiliser sources can increase root growth, allowing for more efficient use of stored soil moisture and minerals (Bandopadhyay *et al.* 2003) [4]. Through judicious integration of mineral fertilisers, organic and green manures, crop residues, and biofertilizers, sustained efforts are needed to improve and maintain this most important natural resource base – the soil – so that it nourishes intensive cropping without being irreversibly damaged in the process (Swarup 2010) [31].

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With this in mind, the current study was designed to look at the long-term effects of fertilisers and amendments on maize-wheat cropping system.

Methodology

The soil's initial parameters are: silty clay loam texture with clay 24%, silt 47%, and sand 29%, pH 5.8, organic carbon 7.9 g kg-1, available N 736, available P 12, available K 194.2, and available S 13.5 kg ha-1, respectively (Sharma *et al.* 2002) [23]. In a randomised block design, the trial included eleven treatments with four replications. T1: Control; T2: 100% N; T3: 100% NP; T4: 100% NPK; T5: 100% NPK+ FYM; T6: 100% NPK + lime; T7: 100% NPK + Zn; T8: 100% NPK + HW; T9: 100% NPK (-S); T10: 150 percent NPK; T11: 50% NPK In kharif 1981, the 11th treatment (100 percent NPK-S) was introduced. The 100 percent NPK dose is 120 kg/ha N, 26 kg/ha P, and 33 kg/ha K for maize and 120 kg/ha N, 26 kg/ha P, and 25 K kg/ha for wheat, and corresponds to state-level recommendations for the relevant nutrients. Urea, single super phosphate, and muriate of potash were used as N, P, and K sources, respectively. P was applied using di-ammonium phosphate in 100 percent NPK (-S) to evaluate the influence of ‘S' free high analysis P fertiliser in crop productivity. Zn was applied to both crops in T7 as zinc sulphate at a rate of 25 kg/ha every year. Maize (kharif) and wheat (*Rabi*) crops were planted on June 7, 2008, and November 11, 2008, respectively, with harvest dates of September 25, 2008, and May 20, 2009. In both crops, chemical weed control strategies were used, except in T8 (100 percent NPK + hand weeding), where weeds were manually eliminated.

Grain and straw yields were measured separately when the crops were harvested at maturity. Maize grain yield was standardised at 13% moisture content and stover yield was measured on an oven dry basis, whereas wheat grain and straw yields were measured on an air-dry basis. The available N was evaluated by the alkaline permanganate method (Subbiah) and the organic carbon by Walkley and Black (1934) [37].

Following the harvest of the wheat crop, root tests were conducted. The root samples were obtained to a depth of 0.0-0.30 m using the core break method (Bohm 1979) [6] and cleaned with tube well water followed by distilled water to remove any soil particles. The root length (RLD) was calculated using Marsh (1971) [17] and Tennant (1975)'s modified version of Newman's (1966) formula:

Root Length = 11/14 * number of intersections (N) *grid unit Root volume (RVD): displacement method, root mass density (RMD): root mass density (RMD): root mass density (RMD): root mass density (RMD): root mass density (RMD): root mass density (RMD): root mass density (RMD): root mass density (RMD): root mass density (RMD): root mass density (RMD): root mass density (To calculate root mass density and root surface area (RSA), the fresh weight of the roots was divided by the volume of the sampling core: [volume (cm3) x x length (cm)] Area (cm2) = 2 12 was calculated using the displacement method (Mishra and Ahmed 1987) [18], and the root CEC (RCEC) was evaluated using Crooke's method (1964) [11].

Results

Productivity

Continuous treatment of 100% N through urea for the past 36 years has reduced yield in 100% N (T2) to 0.0 t/ha in both crops (Table 1). Control (T1) had the lowest grain and stover/straw yields of maize and wheat (1.78 and 1.46 t/ha, respectively), whereas 100 percent NPK + FYM (T5) had the greatest (13.9 and 9.7 t/ha, respectively). Except for 100% NPK + lime (T6), which was comparable to T5, these two treatments differed dramatically from the rest of the treatments. Yields were found to be comparable to 100 percent NPK alone in plots where Zn was administered together with 100 percent NPK (T7) and in plots where Hand Weeding (T8) was used. The use of P in combination with N resulted in a significant increase in maize yield (365 and 105 percent, respectively). Over N alone and control treatment, productivity increased in maize (377 and 158 percent) and wheat (377 and 158 percent). However, continued deficiency in K and S in crop nutrition resulted in a significant drop in crop yield (133 and 66.8 percent). Maize and wheat yields in NP (T3) and NPK (-S) Treated plots was significantly lower than the number of plots not treated with T9.

Table 1: Long-term effect of chemical fertilizers and amendments on productivity (tonnes/ha) of maize and wheat.

Treatment		Maize		Wheat	
		Grain	Stover	Grain	Straw
T_1	Control	0.49	1.29	0.39	1.07
T_2	100% N	0.00	0.00	0.00	0.00
T_3	100% NP	1.09	2.56	1.10	2.67
T_4	100% NPK	2.73	5.78	1.93	4.36
T_5	100% NPK + FYM	4.34	9.56	3.12	6.58
T_6	100% NPK + lime	4.00	9.24	2.86	6.02
T_7	100% NPK + Zn	2.46	5.82	1.85	4.27
T_8	100% NPK + HW	2.81	6.42	2.05	4.87
T_9	100% NPK(-S)	0.91	2.18	1.33	2.73
T_{10}	150% NPK	2.56	5.67	1.73	4.09
T_{11}	50% NPK	1.60	3.80	1.52	3.38
CD	(p=0.05)	0.35	0.82	0.29	0.80

Source: Shweta Shambhavi *et al.* (2017)

Table 2: Long-term effect of chemical fertilizers and amendments on productivity (tonnes/ha) of maize and wheat.

Treatment	Root length density	Root mass density	Root volume density	Root surface area	Root CEC
	mm^3 x 10^{-4}	kg m^{-3}	m^3 m^{-3} x10^{-3}	m^2 x 10^{-4}	c mol (p^+) kg^{-1}
T_1 Control	0.57	0.46	0.46	19.83	3.63
T_2 100% N	0.00	0.00	0.00	0.00	0.00

T_3 100% NP	0.91	0.85	1.63	46.76	5.87
T_4 100% NPK	1.21	1.83	3.88	83.07	6.83
T_5 100% NPK + FYM	2.60	4.08	10.84	204.12	8.37
T_6 100% NPK + lime	2.42	3.68	9.11	180.50	7.07
T_7 100% NPK + Zn	1.89	1.84	3.03	91.99	4.70
T_8 100% NPK + HW	2.32	3.26	7.20	157.21	5.77
T_9 100% NPK(-S)	1.01	1.07	1.69	50.35	4.07
T_{10} 150% NPK	2.02	2.46	4.00	109.33	5.17
T_{11} 50% NPK	1.14	1.44	1.89	56.46	4.17
CD (p=0.05)	0.064	0.040	0.210	3.190	0.183

Source: Shweta Shambhavi *et al.* (2017)

The low yield levels of both crops in zero fertilised plots over the years are understandable and might be explained by the soils' innate capacity to supply the requirements of crops in terms of vital nutrients. Over time, applying N alone had the most detrimental effect of uneven fertilisation on crop productivity, resulting in zero yields. Several researchers in other parts of the country (Swarup, 2000; Edmeades, 2003; Diacono and Montemurro, 2010; Sharma *et al.* 2014; Brar *et al.* 2015) [30, 13, 12, 8, 26] observed full soil degradation in plots treated with nitrogen alone over time, resulting in negative yields.

As reported by Kaushal (2002) [15] under the same set of management techniques, a fast drop in pH began the process of land degradation by increasing the concentration of Al and Fe ions to lethal levels, rendering the soil wholly unsuitable for crop growth. When P and N were applied together, the yield of both crops was significantly higher than when N was applied alone. A higher phosphorus supply has been linked to proliferous root growth, which results in increased water and nutrient absorption. Second, it is required for the formation of primordia for reproductive organs (Tisdale *et al.* 1985) [34], which has a positive impact on yield. The high P-fixing capacity of these soils, which results in a lower amount of labile P accessible to crop plants, could explain the dramatic responses to additional P. Furthermore, P increases the concentration of exchangeable cations (K+, Ca2+, Mg2+, and so on) while decreasing the concentration of hazardous elements, impacting crop yield.

Brar *et al.* (2015) [8] In later years, both crops' yields decreased as a result of to the depletion of K as a result of continual mining reserves of the natural world crop production reductions in the absence of K have also been recorded. Potassium is essential for enzyme activation and starch digestion, protein synthesis, nitrogen uptake, and synthesis The N, P, and K fertilisers are used to boost agricultural yields. As a result, K in sufficient amounts is intelligible and acceptable.

Increased crop yield over the years in manual weeding treatment may be due to better physico-chemical properties in this treatment and increased microbiological growth, which helps in better root proliferation and thus, increased crop yields (Kaushal 2006) [16]. Application of lime increases the soil pH and decreases the active forms of Al and soil acidity, thereby providing favourable conditions for crop growth (Kaushal 2006) [16].

Further, decline in crop yield due to application of Znover the years might be probably because of the increased level of Zn as well as P (Table 3) in the soils. Besides this, the antagonistic effect of Zn and P might have also played a role in reducing the yield of both the crops.

The causes of the increased sensitivity to farmyard manure are often attributed to farmyard manure's favourable impacts on soil productivity (Brady and Weil, 2002) [7]. Organic manures provide soil with nutrients and complexing agents such as dissolved natural organic carbon, humic acid, fulvic acid, polycyclic aromatic hydrocarbon, and others, ensuring a balanced supply of nutrients. The nutrient supply to plants are insoluble plant nutrients. Due to fulvic acid and humic acid which are generated from organic molecules, they are soluble (between pH 4.5 to 6.5) and make themselves available to plants for growth. Better crop development and yields could have resulted from enhanced availability of micronutrients and primary nutrients, as well as granular soil conditions conducive to higher biological activity (Diacono & Montemurro, 2010) [12].

The treatment of N, P, and K at super-optimal levels (150 percent) reduced productivity, owing to secondary nutrient shortages, particularly Mg, in the current soil (Sharma *et al.* 2002) [23]. In this investigation, the source of P was single super phosphate (SSP), which included gypsum. Although the gypsum provided through SSP met the Ca and S requirements, continual cropping and manuring resulted in Mg insufficiency. While lower yields at sub-optimal NPK levels (50%) may be attributed to less exhausting effects on native soil NPK stores as compared to optimal treatment, resulting in sustained output at low levels (Sharma *et al.* 2002) [25]. The usage of DAP (high analysis fertiliser) has resulted in a significant decrease in crop yields for both crops. In comparison to SSP, the DAP includes 46% P but no S or Ca. As a result of its continued use, sulphur mining of the soil has occurred, resulting in a severe loss in crop yields.

Soil Properties

Available N: Continuous manuring and cropping resulted in a significant decrease in available N content in soils in all treatments. The initial available nitrogen content in soils was 736 kg per hectare which fell to 256.1 kg/ha in plots that received no fertilization. The use of 100 percent nitrogen (T2), 100% NP (T3) and 100% NPK (T4) resulted in soil N depletion of 59.5, 58.1, and 56.7 percent, respectively. The addition of farmyard manure, lime, or zinc, as well as NPK resulted in a 54.5, 58.8, and 61.7 percent depletion of accessible N pools, as compared to its inception.

Available P: In both the control and 100% N treated plots, the available P content decreased. These are the plots that revealed a 61.1 and 33.5 percent drop, respectively. Long term P fertiliser inclusion (treatments incorporating P fertilisers) in usage of NP and NPK) increased the amount of accessible P in the soil as compared to its initial concentration of 12 kg/ha (Table 2).

Available K: When compared to its starting state of 194.2 kg/ha at the start of the trial, exchangeable K decreased in practically all treatments except 100% NPK + FYM (Table

2). The drop in available K content was greatest in plots that received no K. The treatment employing 100% NPK FYM, on the other hand, kept the soils' initial K status. The absence of K in crop nutrition (control, 100% N, 100% NP) has resulted in the maximal mining of its natural pools over time.

Root Dynamics

Root Length Density: The plots getting FYM once in a cropping cycle in combination with the recommended quantity of NPK for 36 years had the maximum root length density of 2.60 mm -3 x 10-4, while the plots receiving control had the lowest RLD of 0.57 m m-3 x 10-4. On the other hand, plots treated with 100% N alone did not demonstrate any root growth. Chemical fertiliser use at greater levels (T10) resulted in a 67% increase in RLD, while lower levels (T11) resulted in a 6% drop in RLD when compared to the recommended level of NPK (T4). When K (T3) and S (T9) were not included in plant nutrition, root length density was lowered when compared to the recommended NPK level. The root length density (RLD) is a significant statistic for modelling water and nutrient flow in the vadose zone, as well as studying interactions between soil, root, shoot, and atmosphere (Roshani *et al.* 2005) [22]. The lack of root growth in 100% N plots could be owing to a severe P deficiency, low organic matter, high soil strength, and inadequate soil aeration, all of which are necessary for root spread.

Root Mass Density: The plots getting farm yard manure once in combination with the recommended level of NPK had the highest root mass density (4.08 kg m-3) (Table 2). In plots treated with 100% N alone for 36 years, there was essentially no growth. Due to long-term fertilisation, graded doses of chemical fertilisers had an almost synergistic effect on root dispersion in wheat. Over the plots receiving ideal NPK doses, the RMD of the FYM, lime, and manually weeded plots grew by 122, 101, and 78%, respectively. The RMD in the Zn-adjusted plots was statistically equivalent to that of the plots treated with 100% NPK. Enhanced nitrogen treatment increased root mass density (RMD) in wheat. This could be due to improved N nutrition and the availability of applied N. The RMD increased dramatically after phosphorus was applied, possibly due to an increase in the number and length of root hairs. Higher RMD in plots receiving FYM and inorganic fertilisers, followed by lime-treated plots, could be attributed to the crop's efficient absorption of nutrients in the presence of OM, resulting in higher root proliferation (Rajput *et al.* 1984; Cadisch *et al.* 1993; Bandopadhyay *et al.* 2003) [21, 9, 4].

Root Volume Density: The root volume of wheat (*Rabi*, 2008-09) at harvest was comparatively higher in the plots getting zero fertiliser than in the plots receiving 100 percent N alone. The plots treated with 100 percent NPK + FYM had the highest root volume density (10.84 m3 m-3 x 10-3). RVD grew as the use of chemical fertilisers increased. Over unmanured plots, the increase in root volume in 50, 100, and 150 percent NPK treatment was 1.43, 3.42, and 3.54 m3 m -3 x 10-3, respectively.

Conclusion

The long-term impact of chemical fertilisers and amendments on various root parameters such as root mass density, root volume density, root length density, root surface area, and root cation exchange capacity was found to be positive in organically amended plots (100 percent NPK + FYM) followed by lime treatment due to the availability of an ideal soil environment for their growth. The use of 100% N resulted in the entire destruction of soil structure, resulting in diminished or non-existent root growth in these plots. According to the findings of this study, improved and more sustainable farming methods are required to ensure agricultural sustainability. Excessive use of chemical fertilisers has long-term negative effects on soil parameters, resulting in deterioration of soil health. As a result, combining fertilisers and amendments will almost surely lower the need of chemical inputs while also ensuring agricultural production's long-term viability.

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