Review Article

Soil chemical properties, distribution of zinc fractions and Zn uptake by rice as influenced by long term application of inorganic fertilizers and organic manures: A review

ABSTRACT

Zinc (Zn) deficiency is one of the important abiotic factors limiting rice productivity worldwide and is also a widespread nutritional disorder affecting human health. Zinc deficiency greatly influences and changes the soil physico-chemical properties over long application of inorganic fertilizers and organic manureson different type of agricultural soils. Given that rice is a staple for populations in many countries, studies of Zn dynamics and management in rice are of great importance in different agroclimatic regions of agricultural soils. In this context, the continuous application of chemical fertilizers and organics has widely affected the zinc dynamics, nutrient content and their uptake by rice crop.

Keywords: Chemical fertilizers, organics, zinc, zincfractions

Introduction

Zinc is one of the eight follow components that are fundamental for ordinary solid development and proliferation of plants. It is required as a basic part of an enormous number of proteins, for example, interpretation factors and metallo-compounds.The adoption of high yielding farming methods and the increasing zinc demands of dense cropping systems have led to widespread shortages of zinc (Zn) throughout the world. Additional factors contributing to the increase in Zn-deficient areas include increased crop production on soil with low Zn levels, high Zn low fertilizer use, reduced use of animal manure, manure, and crop residues, and participation of natural and anthropogenic factors that limit the availability of adequate plant nutrients and lead to nutritional imbalances. This literature pertinent to the present investigation entitled “A review on continuous application of inorganic fertilizers and organic manures on soil chemical properties, zinc dynamics, content and uptake by rice”has been reviewed under the following heads:

1. Effect of the continuous application of inorganic fertilizers and organic manure on soil chemical properties.

2. Effect of long term fertilizer experiment treatments on distribution of zinc fractions.

3. Effect of long term application of inorganic fertilizers and organic manure on total zinc content and their uptake in plant.

1. Effect of the continuous application of inorganic fertilizers and organic manure on soil chemical properties

1.1 Soil pH

Tembhre *et al*.(1998) established that the pH of the soil is a good indicator of soil fertility, and consequently, of soil strength and capacity for productivity. However, it is expected that the variation in soil change will reflect soil characteristics on a broad scale.

Dwivedi and Dixit(2002), Swarup and Yaduvanshi(2000) stated that due to the high $CaCO_3$ composition and great inherent buffering capability of grown Vertisols, their pH remains stable. Fertilizer, however, has a significant long-term impact on the pH of the soil when used in an intensive planting system for continual fertilization.

Dwivedi *et al*. (2007) reported that due to the high pH level in the black soil it remains virtually unchanged even under fertilizer use for more than three decades.

Dwivedi and Dwivedi (2015) and Singh *et al*. (2011) reported that in a long-term fertilizer experiment conducted in the Inceptisol of West Bengal, it was discovered that despite continuous fertilizer application to crops, the pH value of the soil remained unaffected even after more than ten years. It was also discovered that the pH values gradually decreased as the soil profile descended in comparison to the surface soil. Farmyard manure has also been seen to act as a stabilizing factor to counteract fluctuations in soil responses.

El Fouly *et al.* (2015) noted that when chemical fertilizer was used alone as opposed to other fertilizers and organic fertilizers, the risk of pH fluctuation was higher, according to the results of ongoing use of fertilizer and soil fertilizer.

1.2 Electrical conductivity of soil

Bhriguwanshi, (1988) also reported that the use of chemical fertilizers continuously for 14 years in Almora's sandy loam and clay loam soil was attributed to a non-significant change in EC value.

Santhy *et al*. (1999) reported that marginal variations in soil EC when FYM and chemical fertilizers are applied to a rotation of finger miller, maize, and cowpeas on irrigated tropical garden land.

Swarup *et al*. (2000) reported that due to dissolved salts, chemical fertilizers applied to cultivated soil in the form of water soluble may have a negative impact on soil fertility. The amount of salt that accumulates in the soil system depends on whether organic manure is used alone or in combination with inorganic fertilizer.

Dwivedi *et al*. (2002) evaluated that when constantly application of inorganic fertilizers used in soybean-wheat-maize crop rotation for 16 years to Typic *Chromustert* of Jabalpur it caused severe changes in soil EC.

Dwivedi and Dwivedi (2015) reported that there is no marked influence on soil EC due to alone use of inorganic fertilizers continuously but compound use of FYM with fertilizer can be increased the buffering capacity of soil caused by addition of organic manure in the soil.

1.3 Soil Organic Carbon

Tembhare *et al*. (1998) reported thatregular changes in organic compounds over time have been found in long-term fertilizer trials and are directly correlated with the rate of carbon deposition in the soil system.

Vasanthi and Kumaraswamy (2000) observed that due to the continuous use of 100% NPK per 10t ha^{-1} FYM, there is a larger increase in OC content compared to 100% and 50% NPK capacity. The maize pearl millet and sorghum used in this experiment were grown in the red loamy soil of Madurai. The comparable amounts of organic carbon were 10.5, 6.0, and 5.2 g kg^{-1}. This shows that ongoing composting alone or in combination with FYM has boosted soil carbon content over time, which has enhanced the factors that can affect the health of the soil.

Santhan *et al*. (2001) conducted a study on the sequential growth of finger millet, maize, and cowpea in Coimbatore's Vertical Ustopept and found that employing crop leftovers continuously for 20 years increased the OC content compared to fertilizer use.When 100% NPK + FYM @ 10 t ha^{-1} was administered during continuous cultivation, a higher carbon content of 0.34% was studied in comparison to the organic carbon content of the control scheme (0.08%).

Dwivedi and Dixit (2002) found that in addition, it was noted that there was an increase in biomass contribution due to increased yields from the use of organic fertilizer and direct contribution by the use of organic fertilizer over a long period of time. Soil carbon content improved as a result of continuous use of synthetic fertilizer and manure alone or in combination.

Hati *etal*. (2006) conducted a three-year rice-wheat trial and revealed that controls had an OC content of 3.0 to 3.2 g/kg. However, sites receiving 100% NPK + FYM observed an increasing amount of 3.7 gm kg^{-1}.

1.4 Available nitrogen content in Soil

Walia *et al.* (1998) found that more values came from the continuous mineralization of OC in surface soils. There was a positive link between available N and organic carbon, mineral N, and total N, but there was a negative correlation with clay, which may be related to slower N mineralization due to OM's physical protection in small pores and increased $NH4^+$ fixation.

Dixit and Gupta (2000) reported that with the application of blue green algae (10 kg/ha) and FYM (10 t/ha) addition with inorganic fertilizers reported that available N content in Inceptisol increased.

Stalin *et al.*(2006) revealed that the results of a field experiment to evaluate the effects of organics, agrochemicals, and biofertilizers on the production of a rice-rice cropping system in interaction with variations in soil fertility showed that the status of available N content of the soil decreased after 10 years in all fertilized treatments, with a magnitude of decline of about 5-23% in all treatments and 30% in the unfertilized control.

Bajpai *et al.* (2006) conducted a long-term field study of a plot from 1991 to 2003 to ascertain how natural nitrogen sources interacted with synthetic sources to affect rice and their lasting "impact on succeeding wheat in the rice-wheat cropping" pattern at the Raipur Inceptisol.

With in situ integration of Sesbania aculeate and 50% N through fertilizer followed by 50% N through FYM and rice straw, the available nitrogen status of surface soil after the harvest of wheat may be significantly improved.

Yang quanwei *et al.* (2015) results indicated that "N influenced by impact C and N cycling by converting certain fractions of SOM. The most sensitive fraction under N fertilization was Nitrate".

Shanmugasundaram, R. *et al*. (2019) investigated "under the status of the available nitrogen was highest under 100% NPK + FYM, followed by 100% NPK, according to the results of the continuous cropping system of finger millet and maize".

1.5 Available phosphorus content in Soil

Akinrinde *et al.* (2006) studied there are six different types of paddy, and the observed variants vary greatly in terms of growth, generation of dry matter, and efficiency in the use of P. They classify the rice varieties into efficient or non-efficient and responsive or non-responsive types based on their observation.

Garg and Mikha (2010) reported that inorganic phosphorus pool was major sink for fertilizer phosphorus and it was found that the majority of the remaining P fertilizer was gathered as organic P (74-89%) followed by organic P (11-26%) and Olsen P (9-19%).

Elanchezhian *et al.*(2015) concluded that on the one hand, plants without certain root characteristics are unable to access significant amounts of phosphorus in agricultural soils, and on the other hand, the world's P stocks are swiftly depleting. In view of ever-dwindling natural P reserves, it is crucial for future sustainable agricultural production to produce P-efficient cultivars that can survive on low accessible P concentrations in soil solution and with minimal reliance on artificial P fertilizers.

Sanyal*et al*. (2015) reported because just a small portion of the total P in the soil is used by plants, soils vary greatly in their ability to provide P to crops. Consequently, unless the soil has enough plant P available or the soil obtains a (organic) P fertilizer, the growth of plants and their output are likely to suffer negatively.

Shanmugasundaram*et al*. (2019) was investigated "under the results of long-term fertilizer applications and a continuous cropping system of maize and finger millet showed that adding fertilizer P at increasing concentrations50, 100, and 150% NPK levels, for examplehas increased the soil available P over 100 percent NPK (22.62% in the case of finger millet and 26.35% in the case of maize)".

1.6 Available potassium content in Soil.

Dixit and Gupta (2000) found greater available potassium (195 kg ha^{-1}) in post 11 harvest of crop in upper soil of Inceptisol under pooled application of farm yard manure and blue green algae or treatment of highest fertility level (120:60:60) as compared to control can be due to bio-degradation of root biomass missing in soil.

Swarup *et al*. (2006) observed in the potassium fertilizer experiment, the potassium that was applied remained in the top 30 cm of the soil and traveled in progressively less amounts down the soil profile to a depth of 60 cm in the plots. The 150% NPK and 100% NP treatments yielded the highest and lowest results, respectively.

Bhattacharyya *et al*.(2007) experiment concluded that K has been thus acknowledged as deficient element after N and P in Indian soils.

Shanmugasundaram, R. *et al*. (2019) investigated "under the long term fertilizer applications and continuous cropping system of maize - finger millet and the results showed that the addition of different levels of K has improved the soil available K (18.32% in finger millet and 14.41% in maize) when compared to 100% NPK".

1.7 Available zinc content in Soil

Anurag *et al.* (2000) performed a test on the DTPA zinc content released in Raipur, Madhya Pradesh and found that it varies from 0.20-2.04 mg kg^{-1} in Inceptisols, 0.20-1.66 mg kg^{-1} in Alfisols and 0.22-2.04 mg kg^{-1} in Vertisols.

Nayak *et al*. (2000) conducted the experiment in alluvial soil of Arunachal Pradesh and found available zinc content that varied from 0.2-1.12 mg kg^{-1} in surface soils and 0.11-0.97 mg kg^{-1} in sub-surface soils. Available Zn was positively correlated with CEC, clay and OC of soil and negatively correlated with soil pH.

Venkatesh *et al.* (2001) conducted experiment on depth wise distribution of 4 available micronutrient cations (Zn, Cu, Mn and Fe) in soil profiles of North Karnataka under oilseed cropping systems. They concluded that given the large variance in the source material and the level of weathering, the difference in micronutrient status was expected. The amount of organic carbon and the availability of micronutrients were shown to be strongly positively correlated.

Jalali and Sharma (2002) conducted experiment in hill altitude of Jammu region soil was sandy loam to clay loam in texture and pH slightly acidic to alkaline in nature. They found that Zn status ranged 0.32 to 3.32 mg kg^{-1}, significant positive correlation with organic carbon (r=0.81**) and significant negative correlation with pH.

Krishnamurthy and Srinivasamurthy (2005) conducted experiment on various agroclimatic zones in Karnataka to determine the distribution of extractable Fe, Mn, Zn, and Cu from DTPA. They collected 80 surface soil samples from areas with black and red soil, and they discovered that the accessible Zn in those areas ranged from 0.31 to 2.01 mg kg^{-1}. Significant positive correlations with clay (r=0.551*), accessible zinc red soil (r=0.746**), and sesquioxides were found, but negative correlations with organic carbon were also found.

Reyhani *et al.* (2006) corroborated that DTPA extractable Zn was significantly correlated with water soluble plus exchangeable, amorphous Fe oxide and carbonate allied Zn forms in calcareous soils of Tehran province.

Verma *et al*. (2012) conducted a trial in Alfisol in the west of the Himalayas for the 36-year trial of a study conducted since 1972. They discovered that sustained investment causes suitable changes to the environment and to the soil's constituent constituents. Wheat maize was rotated using various amounts of N, P, K, Zn, and FYM. Continuous farming has an impact on pH, OC, N, P, and K. For more than 30 years, the growth in OC, from an initial value of 7.9 to 12.0 g kg^{-1}, was noted in the therapy of 100% NPK + FYM. For enhanced nutrient status or crop yield, use 100% NPK, FYM, or lime.

2. Effect of long term fertilization on distribution of zinc fractions

Murthy, A.S.P. (1982) conducted “experiment of Zn fraction of wetland rice soil. Four zinc fractions were: (1) zinc in soluble organic complexes and exchange positions (2) zinc in amorphous iron and aluminum oxides (3) zinc in crystalline oxides of iron and aluminum and (4) residual zinc fraction mainly in clay structures. $Cu(OAc)_2$, Ammonium oxalatereagents may divide zinc from the soil matrix that is essential for plant growth. This analysis confirmed by Correlation, multiple linear regression and path-coefficient analyses”. “Evidence was noticed by the bar diagram that plant available zinc is controlled by equilibrium involving zinc in soluble organic complexes, exchange position and amorphous iron and aluminum oxides ($r^2 = 0.91$). They concluded Zn determined by Cupric acetate extraction appears to be of major importance and maintaining a zinc level sufficient for rice in wetland soil". [78]

Shuman and Hargrove (1985) investigated the outcome of conservation agriculture on allocation of Zn in soil fractions in a long term conservation agriculture experiment of 8 years duration including wheat and soybean in cropping system at Georgia. Treatments were minimum tillage, no-tillage and conventional tillage. Zn in the soil was determined in following fractions: i.e. exchangeable, organic, Mn oxide, amorphous Fe oxide, crystalline Fe oxide, and residual-Zn. Tillage significantly affected the exchangeable fractions of Zn. Exchangeable Zn was lower for normal cultivation compared to minimum tillage. The mixing of Zn from plant remains into the soil may have had this impact. The organic Zn component did not differ significantly from the sowing treatment, however there was a tendency for no-tillage to be more effective. The organic components may be the source of the high double acid-extractable Zn that is released by zinc after inactive tillage treatment.

Mandal *et al.* (1988) showed that water soluble exchangeable (0.42), organic complexed (0.85), amorphous sesquioxide (1.92) and sesquioxide bound Zn (1.53%) of the total content, leaving the majority (95.3%) in the remaining forms corresponding to the mineral components in the soil.

Chatterjee *et al.* (1992) was conducted an experiment on the alteration of resident and used Zn in 4 laterite soils under submergence and revealed the gradual decrease with increasing period of incubation due to water soluble + exchangeable and the crystalline sesquioxides bound forms of soil zinc. Another result was decrease after showing and increase during initial incubation phase by the organically bound, MnO_2^- bound and amorphous sesquioxides bound forms of Zn. Only 22.5-35.5% of applied Zn might exist reported for by its existence in these 5 concluded Zn forms and remaining 64.7 to 77.5% was originate to be renovated to residual form in the soil system.

Kumar *et al.*(2004) observed some fractions that are supplied directly to the available pool of zinc are water soluble, organic matter occluded, specifically adsorbed and acid soluble fractions but there are exchangeable zinc fractions that do not contribute directly to any of the zinc types. The adverse and negative effect is also obtained due to the residues in the liable zinc pool.

Dhiman (2007) reported that all Zn fractions except Zn-V (Al and Fe oxide bound zinc), which dropped while Zn-VI (residual zinc) remained unaltered, rose with long-term integrated food supply. A higher level of organic carbon content and the addition of organic residues to the soil may be the reason why the amount of the decline in Zn-V was greater under INM treatments than it was under farmers' practices. On the other hand, inorganic fertilizers boosted all other fractions of zinc in the soil system, with the exception of Zn-I (non-specifically adsorbed exchangeable zinc) and Zn-II (specifically adsorbed exchangeable zinc), which saw a reduction.

Falatah *et al.* (2009) investigated "a study to find out the effect of various agricultural systems on the distribution of species in a particular Saudi Arabian micronutrient cation. The evaluation involved three ways of conservation [i.e. (non-tillage (NT), harrowing (HR) and chisel (CH)]) and two standard hacking systems [mouldboard (MB) and disking (DS)]. Soil samples are classified separately to obtain Zn in the following types: exchangeable, organic, occulted (Mn oxide, amorphous Fe oxide, crystalline Fe oxide) and residual forms. Conservation tillage programs (HR, CH, and NT), had a significant impact on the distribution of Zn in exchangeable and organic conditions compared to conventional waste remediation programs (DS and MB). Conservation system increase Zn in an exchangeable and organic way and reduce Zn in an occluded manner (amorphous Fe oxide fraction). Studies have shown that conservation pathways convert Zn from residual and occluded form (amorphous Fe oxide and crystalline Fe oxide) into forms of exchangeable, organic or Mn oxide fractions".

Mishra *et al.* (2009) reported that the highest concentration of Zn-extracted CBD was found in the unfertilized soil, which could be explained by the high concentration of crystalline oxides in undisturbed soils, the combination of 100% NPK + FYM resulted in a higher content of copper acetate-extractable as well as pyrophosphate-extractable Zn.

Nandapure *et al. (*2009) conducted "an experiment to evaluate the long-term effects of fertilizer and FYM on physical properties and plant production following the 19th cycle of sorghum-wheat crop rotation. The combined use of inorganic fertilizers (100% NPK) and FYM

@ 10 t ha^{-1} significantly improved the bulk density, hydraulic conductivity, available water capacity, water stable aggregates and coefficient of linear extensibility of soil and crop yield. Total yield (sorghum + wheat) was found to correlate well with these properties. They concluded that concluded that long term application of FYM @ 10ton ha^{-1} in combination with recommended dose to sorghum (100:50:40 NPK kg ha^{-1}) and wheat (120:60:60 NPK kg ha^{-1}) significantly improved the physical properties of soil and sustained the crop productivity in Vertisol under semiarid conditions".

Narwal *et al*. (2010) accounted that "increasing levels of FYM from 0 to 45 Mg ha^{-1} under the pearl millet-wheat cropping system increased the exchangeable, carbonate bound, oxide bound, organic bound and residual Zn fractions at surface (0-0.15 cm) and subsurface (0.15-0.30 cm) soil. Farmyard manure used during the winter (rabi) season reason a significant increase in all Zn concentrations compared to summer application (kharif). The percentage impact of different fractions of Zn on the surface and ground Zn revealed the following: exchangeable < carbonated bound < oxide bound < organic bound < residual".

Shambhavi (2011) observed the amount of non-specifically adsorbed (Zn-I) and particularly adsorbed (Zn-II) zinc that is present under different sequences of maize culture after the acid Alfisol has been significantly impacted by the frequent application of chemical fertilizers and amendments. Due to the constant use of Zn for the past 36 years, it was discovered that the nonspecifically and specifically adsorbed fractions of the zinc increased up to 82 and 394% and correspondingly in the surface layer under 100% NPK + Zn treatment compared to buffer plots. Compared to the deep soil, the top surface soil contained the most. Zn treated plots and FYM treated sites had the highest levels of organically bound Zn. Due to the continued use of the chemical fertilizer content of MnO_2 (Zn-IV) and the Al and Fe-oxide bind (Zn-V) zinc components were strongly influenced but no significant influence on the residual and total zinc content.

Sahare *et al*.(2014) conducted "an experiment that was going on LTFE with soybean-wheat cropping sequence at Jabalpur, M.P during 2010-11. This experiment was performed to determine the effect of continuous use of spray fertilizer and organic fertilizer on the wise distribution of Zn fractions under the wheat-soybean planting sequence in Vertisol. They found that the treatment receiving 100% NPK + Zn, followed by 100% NPK + FYM had the highest amount of DTPA-Zn and its components (water soluble-Zn, exchangeable-Zn, complexed-Zn, organically bound-Zn, occluded- Zn and residual-Zn and the lowest amount of DTPA-Zn and its fractions was found to be controlled. Soil depths of 0-15cm Zn and various Zn fractions have been found to increase and which has decreased with increasing soil depth throughout treatment. The water soluble <exchangeable-Zn <complexed-Zn <organically bound-Zn <occluded-Zn <residual-Zn was the order of Zn content in the various parts. That confirms the positive water Zn composition relationship observed with the pH, EC, OC and $CaCO_3$ content at 0–15 cm soil depth".

Sharma and Subehia (2014) have learned that the way that nutrients interact changes how zinc (Zn) is converted to different chemical pools. On acidic soils in the Indian Himalayas, the experiment got underway in May 1991 during the kharif season (May–October). Due to continuous chemical fertilizer usage for more than 20 years and integrated use of organic and chemical fertilizers, Zn pools experienced more depletion than buffer plots as compared to chemically treated plots. The most important zinc fraction that contributed to the production of (DTPA)-extractable zinc was absorbed exchangeable zinc (Zn I). The soil's level of DTPA-extractable Zn also increased with the integrated usage of chemical fertilizers. Residual Zn makes up 55% of all Zn, whereas non-specifically adsorbed exchangeable Zn is the major Zn contributor.

Zhang *et al*. (2014) conducted an experiment in Northeast China which examined micro nutrient in surface soil with 30 year filed fertilization and to evaluate the effects of long-term fertilizer application on soil made with available micronutrients on the farm. Treatments are No fertilizer, Nitrogen only; Nitrogen and Phosphorus only; NP and Potassium; NPK plus cornstalk, and NPK with FYM. The test resulted in significantly increased DTPA-Zn in FYM amendment, and the micronutrients did not differ significantly between NPK treatment with cornstalk and No fertilizer. Zn in treatment NPK with FYM were about 3.9 and 6.5 times as much as in no fertilizer soil.DTPA-Zn is increased through increased soil organic carbon and EC.

Dhananjay Kumar (2016) conducted "a study in a long term conservation agriculture experiment at BAC farm, Sabour, Bhagalpur, Bihar in order to determine the effect of conservation agriculture on zinc transformation. The experiment was performed in a split-plot design with comprises 3 main plots of different rice techniques which are zero tillage, permanent bed and conventional tillage and different cropping system was comprised in sub-plot treatment which are Rice-wheat, Rice-maize and Rice-lentil. Among the Zn fractions, Water soluble-Zn increased significantly from 1.04 to 1.51 mg kg^{-1} due to various treatment compounds. Water soluble, exchangeable, organically complexed, crystalline oxide bound and amorphous oxide bound-Zn significantly increased by Zero tillage and permanent bed up to 18, 09, 20, 14 and 15%, respectively as compared to conventional tillage. Zn mostly presents in residual form and small fractions were present in easily soluble form".

Begum *et al.* (2016) conducted "a study evaluating the distribution and concentrations of various Zn forms in soils of Gazipur, Gerua, Kalma and Khilgaon. A series of soils were identified in three types of terrain, referred to as highland, medium high land and medium low land, respectively. Soil samples were collected from each soil series at different depths such as surface (0–15 cm), sub surface (15–40 cm) and substratum (40 cm) to determine soil characteristics and distribution pattern of Zn fractions. The results showed that the amount of total Zn varied greatly, ranging from 14, 99 to 36.11 μg g^{-1} at different concentrations of different soil types. In addition, the purpose of the subsequent extraction or separation was to obtain Zn from the exchangeable organic matter bound, Mn oxide, amorphous Fe oxide, crystalline Fe oxide and the remaining fractions. In Gerua, Kalma and Khilgaon and soils, the concentration of Zn is increased in rate followed by FeO fractions. The results revealed that soil properties have an influence on the distribution of different Zn fraction in the soil".

Dasappagol *et al.* (2017) conducted an experiment at the Agricultural Research Station, Bheemarayanagudi to determine the distribution of zinc fractions after 5 years of agricultural conservation in the area of rainfed pigeon pea. The trial consists of five treatments namely conservation tillage (T_1), zero tillage raised based mulch (T_2), zero tillage raised bed without mulch (T_3), zero tillage with mulch (T_4) and zero tillage except for mulch (T_5). The sequential extraction method is used to estimate the various chemical pool of Zn viz. water soluble plus exchangeable Zn, organically bound Zn, amorphous bound Zn, crystalline bound Zn, manganese oxide bound Zn and residual Zn. the water soluble plus exchangeable Zn was recorded at the highest T_2 (1.04%) while the lowest was recorded at T_1 (0.49%) while the lowest Zn was recorded at T_4 (3.34%) and the lowest was recorded at T_1 (0.80%). Amorphous bound Zn, Crystalline bound Zn, manganese oxide bound Zn were significantly higher at T_2 and lowest recorded at T_1. Residual Zn was the most prominent fraction among the Zn fractions, was 95.44% at T_1 and recorded the highest among treatments with other treatments such as T_3 (93.18%), T_4 (91.16%), T_5 (92.88%) and T_2 (90.86%)), respectively.

Spalbar *et al.* (2017) studied the distributions of different Zn forms in seven blocks of rice-wheat growing soils of Jammu region. Understanding the Zn distribution in soil is important for efficient and effective management of the fertilizers resources and to achieve a higher productivity rate. Sequential extraction scheme was used to fractionate Zn into(WSEX), (OCx), (AMOX), (CRYoX) and (Res Zn). The distribution of Zn in the soils on the basis of average concentrations was in the order 34.32 mg kg^{-1} Res Zn (78%) > 4.82 mg kg^{-1} OCx (11%) >3.39 mg kg^{-1} AMOX (8%)> 0.89 mg kg^{-1} CRYoX (2%)> 0.52 mg kg^{-1} WSEX (1%) Percentage of possibly available Zn fraction was highest in Bishna block (26.57%) and lowest in Hiranagar block (11.48%). Correlation analysis (n=55) showed all the fractions were significantly negatively correlated with pH except for OCx, while as a positive relation with electrical conductivity (EC), organic carbon (OC) and clay content.

Priyanka *et al.* (2017) the objectives were to assess effect of INM on cationic Zinc fractions and to establish relationship among Zn fractions themselves and with nutrient uptake, yield by maize and wheat and soil properties. The experiment consisted of 12 treatment combinations with four replications in a randomized block design. After harvest of Wheat crop under maize-wheat rotation of both years (2014-15 & 2015-16), the pooled analysis reveals that integrated nutrient management practice (100% NPK+ FYM 10 t ha^{-1}) increased zinc fractions except DTPA soluble. However, DTPA– Zn was significantly high with 100% NPK +Zn application followed by 100% NPK +Zn +S. These zinc fractions deceased with depth in all INM treatments. Water soluble zinc fraction highly correlated with reducible (0.926**) and DTPA (0.914**) fractions. DTPA –Zn and reducible Zn also correlated (r =0.920**) significantly. In this investigation, a positive association between Zn percentages and OC and a negative correlation with pH were found. Exchangeable-Zn and DTPA-Zn had strong relationships with grain yield and Zn uptake by grains, respectively. After correlating the values of various Zn fractions, it was discovered that total Zn had a positive and substantial association with other fractions, indicating the possibility of a dynamic equilibrium between the various forms. The levels of the correlation coefficients make it abundantly clear that practically all fractions are interdependent.

Panwar *et al*. (2017) conducted the experiment to find out the effect of the continuous use of inorganic fertilizers and organic manure on the depth wise distribution of Zn fractions under the wheat soybean cultivation series Vertisol at Jabalpur, Madhya Pradesh during 2016–17. The experiment consists of ten treatments i.e. T_1 50% NPK, T_2 100% NPK, T_3 150% NPK, T_4 100% NPK + Hand weeding, T_5 100% NPK + Zn ($ZnSO_4$), T_6 100% NP, T7 100% N, T_8 100% NPK+FYM, T_9 100% NPK–S (Sulphur free) and T_{10} control with four replications in a randomized block design. Results revealed that the highest content of DTPA-Zn and its fractions (water soluble-Zn, exchangeable-Zn, complexed-Zn, organically bound-Zn, occluded-Zn and residual-Zn) were recorded in the treatment receiving 100%NPK + Zn, followed by 100% NPK +FYM; while the lowest content of DTPA-Zn and their fractions were noted in treatment where no fertilizer and organic manure was applied since inception of experiment. The obtained Zn fractions and the various Zn fractions were found to be higher at 0 - 20 soil depths which decreased with increasing soil depth throughout the treatment. Zinc content in various fractions in water soluble is Z- <complexed-Zn <organized bind-Zn <occluded-Zn <residual-Zn.

Jangir *et al.*(2018) studied the distribution of various zinc fractions and their relationship to soil properties in the arid regions of the Panchkula district of Haryana, India. Fifteen surface (0-20 cm) soil samples from the farmer's field were collected from different selected sites of Panchkula district in the year 2017-2018. Fractionation of zinc in soil samples was carried out with standard procedure. The results showed that the distribution of zinc in soils under rice land use in Panchkula district. The exchangeable zinc fractions in these soils were in the range of 0.13 to 0.96 mg kg^{-1}. Organic matter bound (OM-Zn), carbonate bound (CA-Zn), iron and manganese oxides bound (Fe & MnOX-Zn) and residual (RES-Zn) zinc fractions were in the range of 0.81 to 3.17, 0.59 to 3.01, 7.95 to 13.35 and 32.82 to 57.17 mg kg^{-1}, respectively. Exchangeable zinc was the lowest of the different fractions investigated in all the soils when compared to other fractions, but it is still crucial for plant availability. In contrast to exchangeable zinc, organically bound zinc, carbonate-bound zinc, and crystalline iron-manganese oxide bound zinc fractions, residual zinc predominated. However, the predominance of the different zinc fractions maintained in the same order in some samples: exchangeable zinc, organic zinc, carbonate zinc, crystalline iron and manganese oxide bound zinc, and residual zinc.

Kamini kumara *et al.* (2018) investigate that the long-term effect of plant residues and zinc residues on Zn components in the soil and their contribution to Zn uptake in the rice system was studied in calciorthents at Rajendra Agricultural University, Pusa, Samastipur, (Bihar), India, 2010-11 and 2011-12. The order of dominance of the various fractions in the soil was total Zn (164.35 mg kg^{-1})> residues - Zn (156.41 mg kg^{-1})> Zn coated with crystalline oxide (3.06 mg kg^{-1})> Zn (2.27 mg kg^{-1}) complex $^{-1}$)> organized Zn (1.14 mg kg^{-1})> dissolved water and Zn (0.84 mg kg^{-1}) and Zn coated with carbonate and amorphous oxide (0.73 mg kg$^{- 1}$). Strong correlations between all of the Zn soil components show that they are in strong equilibrium with one another. Zinc and agricultural leftovers enhance the uptake of zinc by wheat-rice. The varied grain yields and nutrient intake of wheat and rice are largely explained by differences in the concentrations of Zn bound to crystalline oxide, carbonate, and amorphous oxide, in that order. The usage of 100% plant residues and 10 kg Zn ha^{-1} was found to result in the maximum zinc absorption in rice and wheat.

Rajni *et al.* (2018) investigate the distribution of zinc and zinc fractions in paddy soils of UKP command area. The results revealed the order of availability of zinc fractions in those soils was, water soluble plus exchangeable zinc < organically bound zinc < crystalline bound zinc < amorphous sesquioxide bound zinc < manganese oxide bound zinc < residual zinc. The correlation studies have shown that,soluble plus exchangeable zinc and total zinc ware negatively correlated with pH and $CaCO_3$ and organic carbon and clay content. The correlation studies have shown that,soluble plus exchangeable zinc and total zinc ware negatively correlated with pH and CaCO3 and organic carbon and clay content. Organically bonding Zn shows good correlation with soil carbon content. Manganese oxide bound zinc and amorphous sesquioxide bound zinc and crystalline sesquioxide bound zinc correlated positively with clay content. The residual zinc interacts well with the organic carbon content of the soil. The different forms of zinc present in Surpur taluk at surface and subsurface paddy soils were positively correlated.

Sarangthem *et al*. (2019) An experiment to study the distribution of zinc in some valley soils of Manipur was conducted during rabi season of 2016-17. Twenty soil samples were collected from different paddy fields of Manipur. All the soil samples were acidic in nature with mean value of pH 5.52. The mean electrical conductivity was 0.09 dSm^{-1}. There was wide variation of organic carbon content with a mean value of 10.82 g kg^{-1}. The mean cation exchange capacity, available nitrogen, available phosphorus and available potassium were 18.0 [Cmol (p+) kg^{-1}], 303.98 kg ha^{-1}, 28.68 kg ha^{-1} and 231.06 kg ha^{-1}, respectively. The studied soils were clay in texture. The mean value of available (DTPA extractable) zinc was 0.91 mg kg^{-1}. The DTPA extractable zinc show positive and significant correlation with EC, OC, CEC, available nitrogen, available potassium, silt and clay. A negative and significant correlation was observed with pH, available phosphorus and sand. Sequential extraction scheme was used to fractionate zinc into water soluble + exchangeable (WSEX), organically complexed (OC), amorphous sesquioxide bound (AMOX), crystalline sesquioxide bound (CRYOX), manganese oxide bound (MnOX) and residual zinc (Res-Zn). The distribution of zinc in the soil on the basis of average concentration was in the order: WSEX-Zn (0.40 mg kg^{-1}) < CRYOX-Zn (1.35 mg kg^{-1}) <MnOX-Zn (1.97 mg kg^{-1}) < AMOX-Zn (3.10 mg kg^{-1}) < OC-Zn (3.22 mg kg^{-1}) < Res-Zn (85.90 mg kg^{-1}). All the zinc fractions showed positive correlation with EC, OC, CEC, available nitrogen, available potassium, clay and negative correlation with pH, available phosphorus and silt.

Liu et al. (2020) revealed that Zn uptake by winter wheat and soil concentrations of all Zn components have increased significantly as a result of repeated applications of Zn fertilizer over several years, with the increase being more pronounced at higher rates. The concentration of Zn fractions and total Zn input showed a linear or quadratic growing relationship during the course of the experiment. The percentage of Zn in the Ex-, Car-, MnO-, and FeO-Zn fractions was likewise enhanced by zinc treatment, while the percentages of OM- and Res-Zn were either unchanged or even decreased. Crop Zn uptake rose linearly with DTPA-extractable Zn soil concentrations, peaking at 12 mg kg^{-1}, which may be taken as the upper limit for Zn fertilizer treatment recommendations.FeO-Zn was found to be the most significant variable influencing winter wheat's uptake of zinc through stepwise regression analysis. This suggests that, in the event that zinc fertilizer is applied repeatedly to increase zinc bioavailability in crop grains, the bond between zinc and Fe oxides will dominate zinc availability for the calcareous soil. For the control of zinc fertilizer, the correlations between crop Zn uptake and various types of zinc can be quite useful.

Lakshmiet al. (2021) studied that the six-year study showed that a significant amount of zinc was residual and that the amount of crystalline zinc components in the soil increased with increasing doses and frequency of zinc treatment. The majority of the Zn fraction (78–83%) was made up of the residual Zn (RES-Zn) fraction, which was followed by the water-soluble and exchangeable Zn (0.38–0.87%) fraction, crystalline oxide bound Zn (8.06–9.89%), organically bound Zn (5.48–7.94%), complexed Zn (2.57–4.16%), and carbonate and amorphous oxide bound Zn (1.01-33%). The percentage concentration of zinc in various pools rose in accordance with varying Zn application rates, which were as follows: first year application < alternate year application < annual application. Regarding the yield of wheat grains and the uptake of zinc by the crop under various zinc fertilization techniques, it was observed that the maximum yield of wheat was obtained by applying zinc at a rate of 10 kg ha^{-1} in alternating years. This method of application was found to be comparable to applying zinc at a rate of 7.5 kg ha^{-1} annually. Despite the fact that these two methods of applying zinc were equivalent, the six-year analysis revealed that the application of zinc at a rate of 10 kg ha^{-1} applied on alternate years accounted for a total of 15 kg less zinc application than the application of zinc at a rate of 7.5 kg ha^{-1} applied annually.Therefore, increasing the Zn usage efficiency of the wheat crop cultivated in the rice-wheat system can be achieved by applying the Zn solution every other year. Therefore, after six years of research, it can be concluded that the most effective way to fertilize calcareous soils lacking in zinc is to apply 10 kg ha^{-1} of zinc fertilizer every other year.

Drescheret al. (2022) concluded that under a no-till system, 16 continuous applications of solid and liquid pig dung over an 11-year period resulted in Cu buildup, mostly in the organic and residual fractions. While there were trace amounts of these elements in the soil solution, zinc was primarily deposited in the clay mineral fraction. Under the DL treatment, soil Cu and Zn adsorption was increased. Zn showed a notable adsorption decrease in the competitive adsorption system, where Cu was mostly adsorbed by the functional groups of reactive soil particles. Thus, regular application of pig dung tends to enhance zinc bioavailability significantly and raise the risk of zinc transference and toxicity in aquatic habitats. However, Cu buildup indicates that the use of pig dung needs to be closely watched throughouttime until it reaches amounts that are probably harmful to plants. The application of pig manure rates based just on crop N demand is foolish as it amplifies metal, primarily Zn, transfer and toxicity. Our results also indicate that the kind of residue (i.e., solid or liquid) must also be taken into consideration to monitor possible metal transmission in the environment.

Mouryaet al. (2023) revealed that Zn added to post-harvest soil in combination with organic matter (such as vermicompost or farmyard manure) significantly increased biomass yield and Zn uptake by Indian spinach and DTPA-extractable Zn. The distribution of different zinc components was positively impacted by the simultaneous treatment of zinc and organics (vermicompost or farmyard manure).

3. Effect of longterm application of inorganic fertilizers and organic manures on total zinc content and their uptake in plant

3.1 Growth attributes

Joshi *et al.* (1987) conducted a field study on groundnuts showed that adding zinc to a medium-calcareous soil considerably boosted plant dry weight at various phases of crop growth. In a pot trial with cluster beans, Gupta and Potalia (1988) discovered that the addition of 5 and 10 ppm ZnSO4 raised the dry matter yield from 2.93 to 95 and 111 g pot^{-1}, respectively.

Sunder (2001) conducted an experiment in which resulted that plant height, no. of branches, dry matter production; LAI and total chlorophyll content were considerable enhanced by application of Zn@ 5 kg ha^{-1} over control in cluster bean.

Saini (2003) conducted a trial in mothbean and found that use of Zn@ 5 kg ha^{-1} enhanced plant height, branches/plant, content of chlorophyll, dry matter production, RGR, LAI over control.

Narolia (2004) reported that application of Zn upto 5 kg ha^{-1} significantly increased height of plant, no.of tillers/plant and dry matter accumulation of isabgol crop over control.

Suresh and Salkinkoppa (2016) conducted an experiment in Dharwad, Karnataka on growth and yield of rice with Zn and Fe fertilization. They reported that combined applications of soil ($ZnSO_4$ and $FeSO_4$ each at 25 kg ha^{-1}) and foliar ($ZnSO_4$ and $FeSO_4$ each at 0.5%) $ZnSO_4$ and $FeSO_4$ significantly increased the number of tillers per m of row length, leaf area, LAI, SPAD value, and total dry matter production when compared to other treatments. The combined application of soil ($ZnSO_4$ and $FeSO_4$ each @ 25 kg ha^{-1}) and foliar ($ZnSO_4$ and $FeSO_4$ each @ 0.5%) $ZnSO_4$ and $FeSO_4$ resulted in significantly higher grain yield, straw yield, and yield attributing parameters such as number of productive tillers per row length, number of filled grain per panicle, panicle weight, and test weight.

3.2 Nutrient uptake by plant

Ram *et al.* (1995) performed and experiment on rice at Faizabad in 1992-1993. Soil having 9.2 (0-15cm) and EC 7.8 dSm^{-1} and soil were applied with 40 kg $ZnSO_4$ ha^{-1} basal, top dressed, and also 1-3 sprays of 0.5% $ZnSO_4$ solution with or without 20 kg $ZnSO_4$ ha^{-1}. High yield was attained by treatment 20 kg $ZnSO_4$ + 3 foliar applications which was 3.3-4.0 t ha^{-1} followed by 2.7 t ha^{-1} without Zn application. The highest improvement of applied Zn (7.4%) was given by 2 foliar spray of Zn, whereas basal application to the soil had the greatest effect on available soil Zn.

Khanda and Dixit (1996) reported in the field experiment at Bhubaneshwar, Orissa, in 1991 and 1992. They used 2 Zn resources ($ZnSO_4$ and Zn-EDTA), 2 sources of Zn application soil application and foliar spray and four treatment of N (0, 30, 60, 90 kg ha^{-1}) applied to rice. When zinc and nitrogen were treated together, grain yield rose by 7.2% in comparison to nitrogen alone. The economic return also increased when zinc and nitrogen were applied together.

Khan (2002) reported that implementation of zinc effectively raised the number of tiller/plant, spikelet/panicle, 1000 grain weight, grain and straw yield of rice over control (no Zn application). They additionally revealed that application of Zn has increased the height of plant, productive tillers per hill, number of grains per panicle, 1000-grain weight, increased yield of paddy and straw by upward trend of 9 kg Zn ha^{-1}.

Muthukumararaja *et al.* (2012) was investigated that due to Zn deficiency in soil it is difficult to obtain higher yield in rice. Deficiency was maintained by application of suitable Zn fertilizers. In this experiment result reported that by the graded dose of Zn application rice yield increased. Treatment (5 mg Zn kg^{-1}) was noticed as best for higher grain (37.53 g pot^{-1}) and straw yield (48.54 g pot^{-1}) which was about 100 % and 86% higher than control (no zinc). This effect was also reported on DMP. Higher DTPA-Zn, Zn concentration, grain, straw was found at 7.5 mg Zn kg^{-1} treatment. Grain Zn concentration and grain Zn uptake caused 89.64 and 89.01% variation in rice yield. This result showed by linear regression analysis. Similarly analysis of DTPA-Zn linear regression showed 98.31, 96.34 and 93.12% variation in yield of rice at tillering, panicle initiation and harvest stages respectively.

Saha *et al*. (2013) founded that the extent of increase in grain yield when compared with control was 29% in soil plus foliar of Zn application and 22% in only soil application of Zn. When 20 kg $ZnSO_4$ ha^{-1} of a base dose and two foliar sprays with 0.5% Zn via $ZnSO_4.7H_2O$ were applied, the grain's Zn content increased by two to three times. Zn application at the base of the crop has been shown to increase grain yield, whereas soil plus foliar application of Zn improves the final product's Zn content and quality.

Nawaz *et al.* (2015) studied that the use of $ZnSO_4$ along with different fertilizers enhanced yield and the FUE. Zinc sulphate with a standard dose of NPK was applied alone and after mixing at a different time and was compared with the control treatment. All of the treatments reportedly produced noticeable results in terms of yield and yield components. When administered during puddling time, $ZnSO_4$ + NPK produced the highest yield (6.72 t ha^{-1}), followed by $ZnSO_4$ + NPK applied 20–25 days after transplanting, while the control produced the lowest yield.

Rajendra Prasad *et al*. (2016) studied that the pH is the dominant factor determining the availability of Zn. In alkaline and calcareous soils, Zn gets adsorbed or precipitated on hydroxide- (especially those of iron) and carbonate surfaces. Zinc also gets adsorbed or precipitated on negative charges of phosphates. On the other hand in highly Cu-contaminated soils Zn can get released in the soil solution. The interaction between Zn and other plant nutrients may not be a serious problem in cultivated soils. In plants, however, the interaction between Zn and other plant nutrients does exist and both positive and negative interactions are reported. Nitrogen and potassium interact positively with Zn and increase its absorption and translocation in plants. Phosphorus, calcium, iron and copper react negatively with Zn and reduce its absorption by roots or/and its translocation to shoot in plants. As regards sulphur, both positive and negative interactions are reported. On the other hand Zn application reduces boron uptake by plants and Zn fertilization is recommended for alleviation of B toxicity in boron-rich soils. Mechanisms responsible for positive or negative interactions between Zn and other nutrients in plants are not well understood and call for further research.

Conclusion

From the above studies, it has been concluded that the integrated application of chemical fertilizers with organics recorded significantly greater contents of soil available nutrients and

DTPA-extractable Zn compared to the application of chemical fertilizers alone. The distribution of zinc dynamics in surface soil is greater than in subsurface soil and decreases significantly with respect to the depth of the soil**.**The addition ofFYM and green manure enhances the uptake of zinc and its content in rice crops.

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