



## CONTRIBUTION OF INTEGRATED NUTRIENT MANAGEMENT PRACTICES FOR SUSTAINABLE CROP PRODUCTIVITY, NUTRIENT UPTAKE AND SOIL NUTRIENT STATUS IN MAIZE BASED CROPPING SYSTEMS

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### ABSTRACT

*Over applications of inorganic fertilizers lead nutrient imbalances, inefficiency and environmental contamination while insufficient application of nutrients causes soil fertility depletion. This problem drives the use of organic manures, which supply balanced micro and macro nutrients to the current crop and also leave a substantial residual effect on the succeeding crops in different cropping systems. But it is required in bulk as it contains nutrients in small proportion. Hence its availability is scarce for large farms. Therefore, to eliminate both excessive and inadequate applications, judicious use of integrated nutrient management is best alternative for sustainable crop productivity while maintaining soil fertility status in maize and other cereal based cropping systems. Such integrated applications have complementary and synergistic effects. Various research results have confirmed that INM improves sustainable crop productivity and soil fertility status rather than organic or mineral fertilizers alone. Most of research findings reviewed in this paper indicated that among the alternative integrated nutrient management combinations, application of chemical fertilizers integrated with organic manures in equal proportion significantly improved sustainable crop productivity, nutrient uptake and soil nutrient status in maize based cropping systems. In general, combined application of inorganic fertilizers with different sources of organic manures in different proportions has significant role to boost crop productivity, improve nutrient uptake by plants and maintain soil nutrient status in maize based cropping systems.*

**Keywords:** Integrated nutrient management (INM), Sustainable productivity, Nutrient uptake, Soil nutrient status, Maize, Cropping systems.

## Contribution/ Originality

This study contributes in the existing literature to give recent information on the importance of judicious use of integrated nutrient management that improve sustainable productivity of maize based cropping system using nutrients efficiently and ecologically friendly while keeping the soil healthy in the long run.

## 1. INTRODUCTION

Increasing the inputs of nutrients has played a major role in increasing the supply of food to a continually growing world population. However, over application of inorganic fertilizers causes inefficient use, large losses and imbalances of nutrients. It also leads to environmental contamination in a number of areas in developed world. On the other hand, insufficient application of nutrients and poor soil management, along with harsh climatic conditions and other factors, have contributed to the degradation of soils including soil fertility depletion in developing countries like Sub-Saharan Africa [1].

To replenish the soil nutrient depletion, application of chemical fertilizers is essential. However, high cost of chemical fertilizers coupled with the low affordability of small holder farmers is the biggest obstacle for chemical fertilizer use. Moreover, the current energy crisis prevailing higher prices and lack of proper supply system of inorganic fertilizers calls for more efficient use of organic manure, green manure, crop residues and other organic sources along with the inorganic fertilizers to sustain the yield levels [2]. Organic manures supply nutrients to the current crop and also leave a substantial residual effect on the succeeding crops in different sequential cropping systems. The efficiency of applied chemical fertilizers is also increased when applied along with organic manures. Therefore, better management of soil nutrients is required that delivers sustainable agriculture and maintains the necessary increases in food production while minimizing waste, economic loss and environmental impacts [1]. Various long term research results have shown that neither organic nor mineral fertilizers alone can achieve sustainability in crop production. Rather, integrated use of organic and mineral fertilizers has become more effective in maintaining higher productivity and stability through correction of deficiencies of primary, secondary and micronutrients [3]. Therefore, judicious use of integrated nutrient management is best alternative to supply nutrient to crop needs and improve soil conditions [4]. Integrated plant nutrient management (INM) is the combined use of mineral fertilizers with organic resources such as cattle manures, crop residues, urban/rural wastes, composts, green manures and bio-fertilizers [5]. Its basic concept is sustaining soil and crop productivity through optimization of all possible sources of plant nutrients in an integrated manner. In this system, all aspects of mineral and organic plant nutrient sources are integrated into the crop production system [FAO \(Food and Agriculture Organization of the United Nations\)](#) [6] and are utilized in an efficient and judicious manner for sustainable crop production [7]. It

contributes in attaining agronomically feasible, economically viable, environmentally sound and sustainable high crop yields in cropping systems by enhancing nutrient use efficiency and soil fertility, increasing carbon sequestration, reducing nitrogen losses due to nitrate leaching and emission of greenhouse gases [3, 6].

Since cropping system serves as a component of INM for sustaining the productivity of the system through efficient nutrient cycling, balanced fertilization must be based on the concept of the cropping system to sustain productivity of a system as a whole rather than a single crop [5]. Intensified and multiple cropping systems require judicious application of chemical, organic and bio-fertilizers for yield sustainability and improved soil health [8]. Such integrated applications are not only complementary but also has synergistic effects. Therefore, the nutrient needs of crop production systems can best be met through integrated nutrient management [9]. The main **objective** of this paper is to review the contribution of integrated nutrient management practices on sustainable crop productivity, nutrient uptake and soil nutrient status in maize based cropping systems.

## **2. ROLE OF INM ON CROP PRODUCTIVITY IN MAIZE BASED CROPPING SYSTEM**

Various studies revealed that sustainable yield and yield related parameters of maize are significantly improved by integrated nutrient management (INM) practices. Balanced application of NPK fertilizers with FYM and lime improved sustainable crop productivity and growth of maize [10, 11]. Twenty years of experimental study, at Kathalagere, India, revealed that higher maize yields were observed with application 50% N through FYM and 50% NPK through inorganic fertilizers [2]. Study in Islamabad revealed that substitution of 25 or 50% N with FYM + 4 kg Zn/ha performed better grain and straw yield than 100% N (120kg/ha) from chemical fertilizer alone. Maximum maize grain yield (5.18 t/ha) was obtained with 75% chemical fertilizer (CF) + 25% Farm Yard Manure (FYM) and 4 kg Zn/ha, which was statistically at par with application of 50% CF + 50%FYM or 4 kg Zn/ha or 75% CF + 25% FYM and 8 kg Zn/ha [12].

Another study revealed that application of 50% organic manure (poultry and farm yard manure) along with 50% nitrogen from urea resulted in higher yield and yield components compared to either organic or mineral nitrogen alone. Application of mineral N and 50% poultry manure produced higher ear length, grain per ear, grain and biological yields of maize [13]. The results of Ahmad, et al. [14] showed that combining FYM with 50% of recommended NPK fertilizers produced the highest grain and biological yields of maize over the 50% NPK treatment and were statistically at par with those receiving 100% NPK fertilizers. Moreover, the net return was greatest when organic sources were combined with 50% of recommended NPK fertilizers. According to Mugwe, et al. [15], sole application of cattle manure at 60 kg N ha<sup>-1</sup> and combined

application of cattle manure (30 kg N ha<sup>-1</sup>) with inorganic fertilizer (30 kg N ha<sup>-1</sup>) gave significantly higher yields than the recommended rate of inorganic fertilizer.

The highest grain and Stover yields (8.0 tons ha<sup>-1</sup> and 8.9 tons ha<sup>-1</sup>, respectively) of maize were recorded by the combined applications of 60 kg N ha<sup>-1</sup> from poultry manure and mineral fertilizer at 60-40-40 kg ha<sup>-1</sup> NPK compared to the unfertilized treatment which recorded the lowest grain and Stover yields of 2.10 tons ha<sup>-1</sup> and 4.30 tons ha<sup>-1</sup>, respectively [16]. The research result of Ali, et al. [13] also showed that poultry and farm yard manure along with urea at equal proportion resulted in higher yield and yield components of maize than sole organic or mineral nitrogen (Table 1). In other study, poultry manure alone or combination of 25% NPK from chemical fertilizer + 75% from poultry manure increased yield of maize by 579 %, while 50% NPK+ 50% poultry manure increased yield by 499 %, respectively over the unfertilized one. The author generally ranked the effects of INM on growth and yield of maize as poultry manure alone = 25% NPK+ 75% poultry manure > 50% NPK+ 50% poultry manure >75% NPK+ 25% Poultry manure > 25% NPK+ 75% Compost > Compost alone > 50% NPK+ 50% Compost > 75% NPK + 25% Compost > NPK alone > unfertilized plot [17]. Similarly, Cheema, et al. [18] found that applying 50% N from poultry manure and remaining from urea fertilizer produced maximum grain yield of maize (5.6 t ha<sup>-1</sup>), harvest index (24.91%) and grain weight per cob (68.98 g) compared to unfertilized treatment which gave the lowest harvest index (15.71%), grain yield (2.40 t ha<sup>-1</sup>) and weight per cob (44.53 g).

Agricultural wastes alone or in combination with reduced rates of NPK fertilizer increased seed weight per plant, 100-seed weight, number of seeds per cob and grain yield of maize compared with un-amended treatment [19]. Combination of industrial by-products in 2:1 P ratio produced 14 to 27% more dry matter yield of 40-days old maize plants compared to the chemical fertilizer alone. Its residual effect on wheat following maize was also higher in straw and grain yield [20]. INM including vermicompost showed best results in yield parameters of maize like number of grains per cob, weight of the cob, 100 seed weight and yield [21]. Fanuel and Gifole [22] recommended to apply combination of compost at 5 ton ha<sup>-1</sup> along with inorganic fertilizer (50 kg urea ha<sup>-1</sup> + 100kg DAP ha<sup>-1</sup>) to obtain better yield of maize.

Application of 25% recommended dose of fertilizers (20 kg N+ 60 kg P<sub>2</sub>O<sub>5</sub>+ 60 kg K<sub>2</sub>O/ha) in combination with biofertilizers, green manuring and compost @10 t/ha increased maize grain yield by 252.38% over control (no fertilizer application) and 147.62% over the application of 100% recommended dose of fertilizers alone [23]. A study in Ethiopia also revealed that integrated use of Mucuna green manure as fallow along with chemical NP fertilizers increased grain yield of maize [24]. Biomass transfer technologies involving *Calliandra*, *Leucaena* and *Tithonia* applied solely or in combination with inorganic fertilizer at 60 kg N ha<sup>-1</sup> can be used as nutrient sources to meet N requirement for maize in smallholder farming systems maintaining maize yields at 4 to 6 t ha<sup>-1</sup>. Though herbaceous legumes yielded the lowest maize yields, the

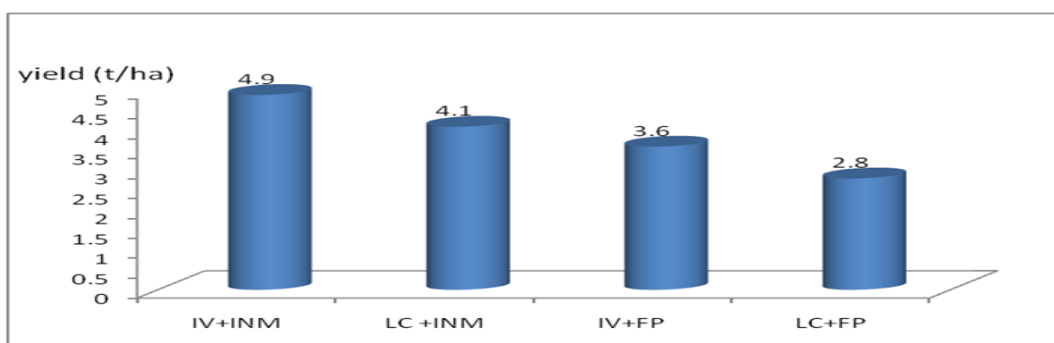
increase in maize yield with application of herbaceous legumes compared with the control demonstrate that legumes make a significant contribution to maize crop production. Farmers can therefore be benefited by incorporating these legumes in the farming systems as an option to subsistence farming where farmers currently crop their farms without any inputs. Use of *Tithonia* combined with chemical fertilizer was most effective in increasing maize yields [15].

**Table-1.** Thousand grain weight (g), grain yield and biological yield (kg ha<sup>-1</sup>) of maize as affected by INM

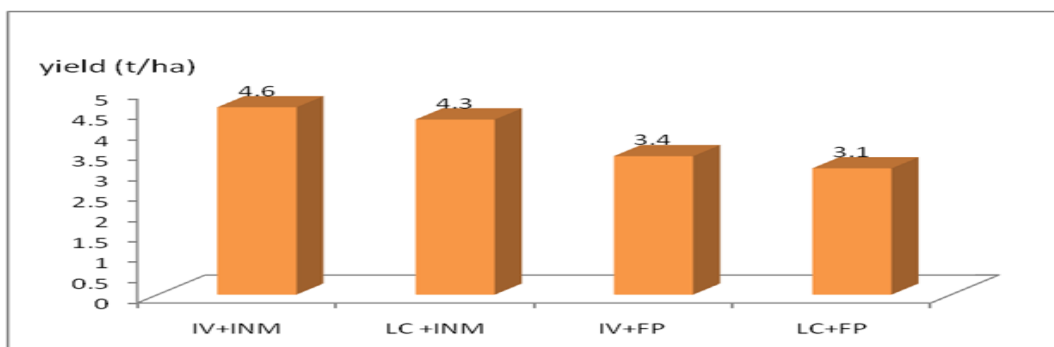
Treatments	1000 seed weight	Grain Yield	Biological yield
Control (unfertilized)	232.91 <sup>d</sup>	2489 <sup>f</sup>	11050 <sup>c</sup>
Nitrogen alone (150 kg/ha)	245.47 <sup>bcd</sup>	3742 <sup>ce</sup>	13646 <sup>b</sup>
FYM Alone (12 t/ha)	234.71 <sup>cd</sup>	2800 <sup>ef</sup>	10735 <sup>c</sup>
PM Alone (5 t/ha)	235.43 <sup>cd</sup>	2664 <sup>cef</sup>	9688 <sup>c</sup>
25 % N +75 % FYM	241.95 <sup>cd</sup>	3140 <sup>d</sup>	10953 <sup>c</sup>
50 % N +50 % FYM	248.61 <sup>abc</sup>	4178 <sup>ab</sup>	16139 <sup>a</sup>
75 % N + 25 % FYM	256.70 <sup>abc</sup>	3866 <sup>c</sup>	13147 <sup>b</sup>
25 % N +75 % PM	248.31 <sup>abc</sup>	2611 <sup>ef</sup>	9572 <sup>c</sup>
50 % N +50 %PM	262.62 <sup>a</sup>	4306 <sup>a</sup>	16502 <sup>a</sup>
75 % N + 25 % PM	258.90 <sup>ab</sup>	3960 <sup>ab</sup>	13900 <sup>b</sup>

Key: FYM= Farm Yard Manure, PM = Poultry Manure

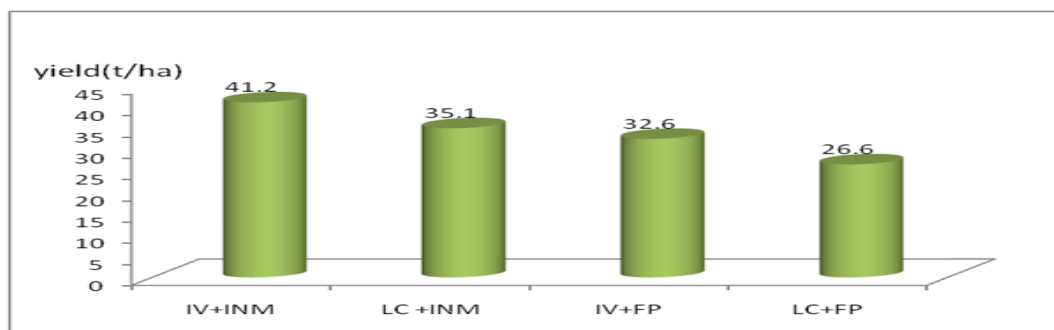
Source: Ali, et al. [13]



(a) Maize yields (t ha<sup>-1</sup>)



(b) Wheat yield after maize harvest

(c) Potato yield after maize harvest ( $t\ ha^{-1}$ )

**Figure-1.** Productivity of maize-wheat and maize-potato cropping system under different nutrient management in North West India (the figure is drawn by the data taken from Naresh, et al. [4].

Key: IV = improved Variety, LC = Local Cultivar, FP = Farmers' practice

### 3. ROLE OF INM ON NUTRIENT UPTAKE OF CROPS IN MAIZE BASED CROPPING SYSTEMS

Study in Islamabad showed that substitution of 25 or 50% N with FYM + 4 kg Zn/ha performed better nutrient uptake than 100% N (120kg/ha) from chemical fertilizer alone. The highest N uptake (98.7 kg/ha) was observed with 50% CF + 50% FYM and 8 kg Zn/ha application, while maximum Zn uptake (250.7 g/ha) was observed with 75% CF + 25 % FYM and 4 kg Zn/ha application [12].

Combined application of NPK mineral fertilizer and poultry manure has significantly higher NPK uptake values of maize than the sole organic and inorganic fertilizers. Integrated applications of 60 kg  $ha^{-1}$  N as poultry manure and mineral fertilizer at 60-40-40 kg  $ha^{-1}$  NPK resulted in higher NPK uptake values than either organic or inorganic fertilizers alone [16]. Integrated use of P sources not only increased crop yield but also increased nutrient uptake, protein content and P recovery efficiency in maize. The P recovery efficiency and NP uptake by maize following the application of poultry manure with inorganic P source showed higher values than those recorded by applying inorganic P sources alone indicating that integrated use of poultry manure with chemical P sources can save 30 to 40 kg mineral P fertilizer [25].

Integration of poultry waste and di-calcium phosphate in 2:1 P ratio significantly increased total P-uptake and P fertilizer use efficiency of maize by 30 to 66% over single super phosphate alone. Its residual effect showed that P-uptake of wheat was higher by straw and was lower by grain in single super phosphate alone but it was higher in grain and lower in straw with application of integrated use of industry byproducts which indicates that transportation of assimilates from source to sink was relatively higher and better utilized for grain production by integrated management. It was also observed that integrated use of nutrients increased P-fertilizer use efficiency from 2.8 to 59.7% over chemical fertilizer alone [20]. The results of

Wakene Negassa, et al. [24] showed that the uptake of N and P was significantly increased from Mucuna as improved fallow and supplemented with low dose of NP fertilizers and FYM. The uptake of K was significantly low only in treatment received the recommended NP fertilizers (Table 2).

**Table-2.** Effect of integrated nutrient management on uptake of N, P, and K of maize

Treatment	N	P	K
Control (unfertilized)	0.48 <sup>b</sup>	0.16 <sup>c</sup>	1.71 <sup>a</sup>
Mocuna fallow	1.92 <sup>a</sup>	0.19 <sup>b</sup>	1.59 <sup>ab</sup>
Mocuna + 55/10 kg ha <sup>-1</sup> N/P	1.90 <sup>a</sup>	0.18 <sup>b</sup>	1.61 <sup>a</sup>
Mocuna + 37/7 kg ha <sup>-1</sup> N/P	1.88 <sup>a</sup>	0.18 <sup>b</sup>	1.71 <sup>a</sup>
Mocuna +4 t ha <sup>-1</sup> FYM	2.12 <sup>a</sup>	0.22 <sup>a</sup>	1.75 <sup>a</sup>
Mocuna +2.7 t ha <sup>-1</sup> FYM	2.15 <sup>a</sup>	0.22 <sup>a</sup>	1.75 <sup>a</sup>
110/20 kg ha <sup>-1</sup> N/P	2.07 <sup>a</sup>	0.17 <sup>bc</sup>	1.42 <sup>a</sup>
LSD (5%)	0.33	0.02	0.21

Source: Wakene Negassa, et al. [24]

#### 4. ROLE OF INM ON SOIL NUTRIENT STATUS IN MAIZE BASED CROPPING SYSTEMS

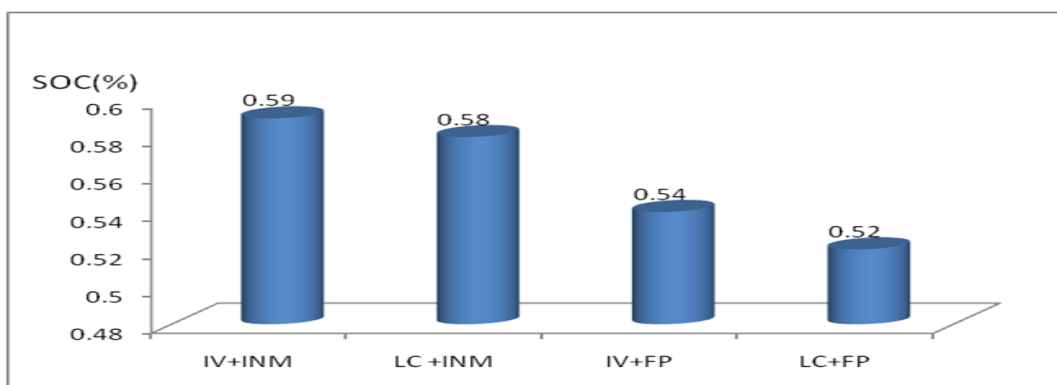
Different results reported that integrated nutrient management practices significantly improved macro and micronutrient status of soils in maize cropping system. Balanced application of NPK fertilizers with FYM or agricultural wastes improved the soil fertility status in addition to increase in maize yield [11, 19]. As depicted in figure 3, organic matter content in INM superior than farmers' practice and initial soil organic matter content in maize-wheat and maize-potato cropping system [4]. Substitution of 25 or 50% N with FYM + 4 kg Zn ha<sup>-1</sup> increased soil organic matter content [12]. Application of compost at 5 ton ha<sup>-1</sup> along with inorganic fertilizers (50 kg urea ha<sup>-1</sup> + 100 kg DAP ha<sup>-1</sup>) improved physico-chemical properties of the soil on sustainable basis rather than using inorganic fertilizer alone [22]. Similarly, twenty years of experimental study showed that application of 50% N through FYM and 50% NPK through inorganic fertilizers improved soil fertility status [2]. The soil analysis after maize crop harvest revealed that soil organic matter, total N, extractable P and K, were greatest from plots receiving organic sources with 50% of recommended NPK fertilizers, suggesting integrating organic sources with 50% of recommended NPK fertilizers are appropriate for sustainable crop production on a low fertility soil [14].

The availability of nutrients in soil were significantly high in organic and integrated nutrient management practices compared to chemical nutrient management practices at harvest of both *kharif* and *rabi* crops in maize based cropping system. At the end of the fourth year in the study, there was increase in available N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O and S by 19.0, 46.3, 9.6 and 54.1%, respectively due to integrated nutrient management over its initial values. There was also significant build up of the micronutrient at the end of fourth year due to integrated nutrient management practices as

compared to chemical nutrient management practices. Micronutrients such as Zn, Fe, Mn and Cu in the soil were increased by 18.5, 30.6, 36.5 and 30.0 % respectively due to integrated nutrient management practice over their initial values. On the other hand, in chemical nutrient management practices, there was depletion of micronutrient compared to its initial value [10].

Application of 25% chemical fertilizers (20 kg N + 60 kg P<sub>2</sub>O<sub>5</sub>+ 60 kg K<sub>2</sub>O ha<sup>-1</sup>) in combination with biofertilizers, green manuring and compost @10 t/ha increased organic carbon, available N and available P<sub>2</sub>O<sub>5</sub> by 0.14%, 4.4 kg/ha and 11.7 kg/ha, respectively compared to the initial nutrient status of the soil [23]. Similarly, Wakene Negassa, et al. [24] reported that integrated use of mucuna green manure as fallow along with low dose of NP fertilizers increased soil nutrients status and related soil properties in addition to increasing maize yield, indicating INM improves both crop yield and soil fertility in sustainable way.

Application of recommended dose of inorganic fertilizer along with vermicompost at 6t ha<sup>-1</sup> to maize not only enhanced productivity of maize but also improved soil fertility in terms of higher available N, P, K and organic carbon content over the control and recommended N, P and K [21].



**Figure-2.** Soil OM content under different nutrient management of maize-wheat and maize-potatocropping system in North West India (adapted from Naresh, et al. [4])

**Key:** IV = improved Variety, LC = Local Cultivar, FP = Farmers' practice

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