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Review Article

Role of Integrated Nutrient Management on Soil Fertility Improvement and Selected Crop Production in Ethiopia: Review Study

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Abstract: Ethiopia's most significant industry, accounting for 46% of the country's GDP and 90% of its export revenues, is agriculture. A decline in soil fertility is the major constraint to agricultural production and food security in Ethiopian farming systems. The ability of farmers to invest in soil conservation techniques or fertilizers is quite limited. Because of low yields, many farmers must use fallow and marginal areas for crops to fulfill their food demands. The first stage in preserving soil fertility should focus on preserving the soil's organic matter level. This may be achieved by adding organic compost or manure in addition to mineral fertilizers while employing the proper crop husbandry techniques. This review was focused on production of five selected crops namely barley, maize, teff, wheat, and onion through application of organic and inorganic fertilizers. Accordingly, different Authors stated that the application of (integrated nutrient management) INM with various components increases plant nutrient uptake by improving the availability of nutrients for them. Under acidic soil conditions incorporating liming materials also played a dominant role to raise the Power of Hydrogen (pH) and other cations like potassium, calcium, magnesium, and others of the soil from the initial point. On the other hand, application of INM play a great role in increasing the yields and yield components of crops and is economically more beneficial compared to using sole use of either organic or inorganic fertilizers.

Keywords: Crop Production, Integrated Nutrient Management, Soil Fertility

1. Introduction

Resources such as land, soil, water, biodiversity, and plant nutrients are necessary for the production of food on a global scale. Ineffective exploitation of these priceless resources is bad for both the environment and society. Due to the growing global population and predicted changes in food consumption habits, the requirement for plant nutrients in agriculture is substantial and is likely to rise in the ensuing decades [15]. Because of this, the majority of global challenges focused on ways to improve nutrient utilization and resource usage efficiency. This is particularly important for nitrogen since, on the one hand, it is vital for life and needed in huge amounts, and, on the other hand, it is extremely prone to loss from soil-plant systems, leading to severe environmental contamination.

Agriculture is the most important sector in Ethiopia, and it is the backbone of the Ethiopian economy. It accounts for 46% of its gross domestic product (GDP) and 90% of its export earnings [27, 45]. However, in Sub-Saharan African agriculture, particularly in Ethiopia, the decline in soil fertility is frequently the main issue. In Ethiopia, the populace is not particularly happy with consistent output; instead, a decrease in agricultural yield is making them suffer from their dire economic situation and malnutrition [14, 61]. According to studies, farmers in some regions of Ethiopia have food shortages, particularly between June and September [3, 14, 61]. In seasons of the year when the rain is favorable for their farming, farmers in the majority of the country labor nonstop; nonetheless, despite their efforts [14, 61] They obtained little, which does not aid them to escape their existing system of living.

The main obstacle to agricultural output and food security in Ethiopian farming systems is the decline in soil fertility. Farmers' ability to invest in soil conservation practices or fertilizers is quite limited. According to the study as a result of low yields, many farmers are compelled to convert fallow and marginal areas into productive lands to fulfill their food demands [63]. The greatest method for enhancing soil fertility and raising crop production is seen to be the application of locally accessible organic inputs such as compost, manures, and crop residues along with mineral fertilizers [5, 12]. However, the research region has a poor adoption rate for using compost with mineral fertilizers to increase soil fertility and maize output.

In Ethiopia, maintaining soil fertility often involves applying mineral fertilizers like urea and diammonium phosphate [23]. However, due to the high cost of fertilizer and lack of recommendations relevant to the soil and crop, resource-poor farmers have been using low rates of mineral fertilizer [60]. The recommended extension rates of 150 kg DAP and 100 kg urea ha-1 are substantially below the national average application rates of maize, which are 45 kg ha-1 DAP and 33 kg ha-1 urea [22]. Additionally, the continued use of fertilizers containing only N and P would primarily enhance the absorption and depletion of micronutrients like zinc and boron as well as secondary nutrients like sulfur [21]. In addition to Nitrogen and Phosphorus fertilizers, blended fertilizers have recently been created that also contain sulfur (S), zinc (Zn), and boron (B) [23]. However, continuing to use chemical fertilizers might result in the degradation of soil quality, including an increase in soil acidity, loss of organic matter, and depletion of nutrients not included in the formulation of the fertilizer [40].

The information that is currently available indicates that adding compost can significantly improve soil attributes, including soil porosity, water availability, organic matter, nitrogen status, crop yields, and soil bulk density [5, 43]. Small-scale farmers are unable to add the necessary amounts of compost because of a lack of organic resources, competing uses for the compost, such as animal feed and fuel, and a labor shortage due to the bulky nature of the compost needed for an adequate supply of plant nutrients [4, 48]. To fulfill the nutritional requirements of crops and to maximize crop yields, using sole compost as a replacement for inorganic fertilizers is not a maintainable strategy [25].

As a result, combining various agricultural techniques and agronomic practices will help to address the issues associated with soil fertility depletion. Instead of focusing solely on mineral fertilizers, consider a variety of appropriate approaches that will reduce costs for these struggling farmers, such as agroforestry or the use of green manures like Erythrina bruice. Similarly, to this, Belay [14] demonstrated the value of crop rotation, intercropping, and conservation techniques, as well as the use of better crop types and the use of mineral fertilizers. Therefore, the major objectives of this study are to evaluate Ethiopia's soil fertility status, identify the root causes of fertility loss, and look for more effective solutions. Therefore, the primary goal of this research is to examine how ISFM has improved agricultural output in Ethiopia.

2. Role of Integrated Nutrient Management on Selected Crop Production

2.1. Integrated Nutrient Management

The term "Integrated Nutrient Management" (INM) refers to the process of maximizing the advantages from all potential sources of organic, inorganic, and biological components in an integrated manner to maintain the soil fertility and plant nutrient supply at an optimal level for maintaining the desired productivity. It can safeguard the environment and resource quality while simultaneously enhancing plant performance and resource efficiency [68]. The benefits of INM include enhancing nutrient usage efficiency, restoring soil fertility, maintaining crop production, preventing secondary- and micronutrient deficiencies, and having a positive impact on the biophysicochemical health of soils [57].

2.2. Components of INM

Organic manures, green manures, compost, soil fertility restoring crops like legumes, crop residues, industrial wastes and byproducts, sewage, sludge, biochar, chemical fertilizers, genetically modified crops, proper crop rotation, and intercropping are the main components of INM [13].

2.2.1. Organic Manures and Their Use

The use of organic manure, including farmyard manure, green manure, composted poultry manure, biochar, Sulage silage, and other organic waste, has been recognized by many researchers as having positive effects on soil health, crop productivity, and the environment [8, 44, 31]. Farmyard manure, which is made from bovine dung, urine, and bedding material, increased soil biological activity and controlled the process by which components necessary for plant growth were transformed [52]. In addition to excreta, bedding material, waste feed, and feathers, poultry manure also includes significant amounts of minerals that are crucial for plant growth, such as calcium, sulfur, magnesium, calcium, chlorine, salt, manganese iron, copper, zinc, molybdenum, and arsenic [33].

Due to their status as plants that improve soil, green manures are a practical and sustainable option [8]. The green manure crop is a legume produced for biological N fixation to provide N to succeeding crops and organic matter for soil property improvement [50]. It demonstrated higher soil covering and nutrient cycling for sub-squint crops. When maximum production of a comparatively higher C: N biomass is sought, such as for ground cover or to increase soil organic carbon (OC), green manure is frequently stopped before maturity, however, it may be allowed to develop to maturity [47]. Although it is frequently mixed into the soil, it may also be used as mulch on top of the soil.

Biochar is a C-rich byproduct of the low-temperature, oxygen-starved burning of carbonaceous biomass, such as agricultural leftovers, stall bedding, cull lumber, and sawmill wastes [39]. Recent studies have shown that applying biochar can significantly improve soil organic carbon [16], soil cation exchange capacity [41], water holding capacity [2] soil microbe activity [62], soil porosity and nutrient availability [69], soil quality [64].

2.2.2. Inorganic Fertilizers

It is a chemical that contains one or more necessary plant components that, when given to soil or plant systems, promotes plant growth and/or boosts productivity by adding more vital components for usage by plants. The main purpose of synthetic N-fertilizer is to give the crop an instant amount of nitrogen, which is frequently the nutrient that limits plant development the most. Good fertilizer usage procedures include using the proper source of fertilizer and applying it at the appropriate rate, timing, and location.

The proper source or kind of fertilizer must offer one or more nutrients that are insufficiently present in the soil to fulfill the demands of the crop. Controlling the loss of nitrogen is aided by considering fertilizer type. Nitrate-containing fertilizers are more prone to leaching than amide and ammonium-containing fertilizers, while in contrast, ammonium and amide-containing fertilizers are more vulnerable to volatilization loss than nitrate-containing nitrogen fertilizers [24]. Positively charged NH4+ is shielded from leaching because it is absorbed by negatively charged soil colloids, whereas negatively charged NH3- is prone to leaching.

2.2.3. Bio-Fertilizer

Bio-fertilizer is a substance that contains one or more beneficial living microorganisms that, when applied to soil, seed, or plant surfaces, colonize the rhizosphere or the interior of the plant and promote growth. These biofertilizers work by fixing N2, boosting nutrient availability in the rhizosphere, favorably affecting root development and shape, and encouraging other advantageous plant-microbe interactions [7].

2.3. Effect of ISFM on Soil Fertility Improvement

Soil fertility is the ability of the soil to meet the biophysicochemical requirements for plant development for productivity, reproduction, and quality, related to plant and soil type, land use, and climatic circumstances. It is becoming clear that equal care must be given to the biophysicochemical components of soil to utilize soil resources for agriculture. Increasing soil fertility will help you create a sustainable agricultural system [1].

The first stage in preserving soil fertility should focus on preserving the soil's organic matter level. This may be achieved by adding organic manure or compost together with mineral fertilizer while employing the proper crop husbandry techniques. While organic fertilizers can gradually offer nutrients to the soil, chemical fertilizers can swiftly restore the soil's fertility [38].

The use of fertilizers increases agricultural production and yield, as is widely recognized. Given that they affect distinct aspects of soil qualities, the mixture of both organic and mineral fertilizers is essential. A high concentration of nutrients that are readily available to plants characterizes mineral fertilizers. Numerous researches revealed that the use of mineral fertilizer significantly increased grain output. According to Dunjana [19], small-holder population pressure is growing together with fertilizer application rates. Farmyard manure (FYM), which is frequently the source of OM, is used as organic material at the smallholder level [20]. Lowest bulk density, highest bulk density, TN, OC, AP, AS, CEC and exchangeable bases were observed during use 10t/ha of compost and 100/100kg/ha of NPSB (Table 1).

Table 1. *Interaction effects of mineral fertilizers and compost on selected soil properties [66].*

Compost t/ha	Urea or NPSBkg/ha	BD	pH	TN	OC	AP	AS	Exchangeable bases (Cmol (+) kg^{-1})				
								Ca	Mg	K	Na	CEC
0	0/0	1.37a	5.52e	0.10f	1.45e	3.92g	10.82g	14.10e	5.4	0.45	0.07	30.02cd
	50/50	1.35b	5.48f	1.43ef	0.12e	5.08f	11.32f	13.90f	5.4	0.4	0.06	29.62de
	100/100	1.34b	5.45g	1.41f	0.13e	5.79de	12.13e	13.85f	5.3	0.36	0.05	28.96e
5	0/0	1.26c	5.58c	1.65d	0.15d	4.35g	11.95e	14.58d	5.6	0.49	0.09	30.64bc
	50/50	1.27c	5.56cd	1.67cd	0.16cd	6.15d	13.15d	14.61bc	5.6	0.52	0.08	30.71bc
	100/100	1.25cd	5.55d	1.71c	0.18c	7.48c	13.40cd	14.64bcd	5.7	0.55	0.09	31.09b
10	0/0	1.22f	5.55d	1.89b	0.17c	5.65e	13.68bc	14.71abc	5.7	0.64	0.1	32.68a
	50/50	1.23ef	5.66ab	1.92ab	0.19b	9.04b	13.76b	14.75ab	5.8	0.63	0.11	32.72a
	100/100	1.24de	5.65b	1.96a	0.22a	10.90a	14.15a	14.80a	5.8	0.65	0.1	33.07a
LSD		0.013	0.18	0.044	0.013	0.453	0.245	0.116	0.1	0.066	0.014	0.715
CV		0.62	0.19	1.43	4.9	4.04	1.35	0.46	0.8	7.39	9.82	1.33

LSD = least significance difference, CV = coefficient of variation, ns = not significant, AP= available phosphorus, AS= available sulphur

2.4. Nutrient Concentrations and Uptake

The content of TN, P, K+, and S in barley grain was dramatically raised by combining the application of lime with organic and inorganic fertilizers. Total nitrogen, phosphorus, potassium, and sulfur nutrient concentrations increased significantly when applied lime was combined with organic and inorganic plant nutrient sources, going from 1.16%, 0.18 ppm, 0.19 meq 100g soil-1, and 0.17% to 1.37%, 0.36 ppm, 0.28 meq 100g soil-1, and 0.27%, respectively, when associated to the control plot. In comparison to the control, more N (74 kg ha-1), P (19.65 kg ha-1), K (16.05 kg ha-1), and S (15 kg ha-1) were achieved using 0.611 t lime + 5 t compost + 150 kg NPSB + 100 kg KCl + 72 kg N ha-1 (Table 2). The soil's microbial activity and nutrient availability are both greatly increased by the Integrated Nutrient Management system. Continuous cropping was found to be efficient for preserving soil fertility status, boosting nutrient absorption, and enhancing the grain yield of crops when organic manure and chemical fertilizer were applied together [58]. Comparatively, using both organic and inorganic fertilizers enhance the concentration of nutrients in the soil (Table 3 and 4).

Table 2. *Integrated use of lime, blended fertilizer, and compost on TN, P, K, and S concentrations and uptake (Kg/ha) of barley [67].*

Treatments	Nutrient concentration				Nutrient uptake (kg/ha)			
	TN%	P%	K (meq/100g)	S%	TN	P	K	S
T1	1.16f	0.18d	0.19c	0.17d	15.29b	2.46c	2.59b	2.25c
T2	1.21e	0.22c	0.21bc	0.18cd	19.67b	3.55c	3.52b	2.95c
T3	1.22e	0.22c	0.22bc	0.18cd	20.53b	3.69c	3.70b	3.01c
T4	1.25d	0.23c	0.24b	0.19cd	21.91b	4.04c	4.18b	3.36c
T5	1.28cd	0.32b	0.27a	0.20c	60.91a	15.34b	12.95a	9.82b
T6	1.22e	0.23c	0.23b	0.18cd	20.37b	3.83c	3.84b	3.12c
T7	1.32b	0.33b	0.28a	0.26ab	58.56a	14.56b	12.70a	11.47b
T8	1.37a	0.36a	0.28a	0.27a	74.15a	19.65a	16.05a	15.13a
T9	1.31bc	0.32b	0.27a	0.25b	63.19a	15.51b	13.27a	12.00ab
LSD (5%)	0.034	0.03	0.03	0.02	15.994	3.39	4.25	3.62
CV (%)	0.95	4.38	4.44	4.53	14.18	12.9	18.38	18.06
Grand mean	1.26	0.27	0.24	0.21	39.4	9.18	8.09	7.01

T1- control; T2 - compost (5 t /ha); T3-lime (611 kg /ha); T4 - lime (611 kg /ha) + compost (5 t /ha); T5 – DAP (150 kg /ha) +KCl (100 kg /ha)+ Urea (72 kg /ha); T6-NPSB (150 kg /ha)+ KCl (100 kg /ha)+ Urea (72 kg /ha); T7 Lime (611 kg /ha)+ NPSB (150 kg /ha)+ KCl (100 kg /ha) +Urea (72 kg /ha); T8 Lime (611 kg /ha)+ compost (5 t/ha)+NPSB (150 kg /ha)+ KCl (100 kg /ha) +Urea (72 kg /ha); T9 Lime (611 kg ha- 1)+ compost (2.5 t /ha)+NPSB (75 kg /ha)+ KCl (50 kg /ha) +Urea (36 kg /ha)

Table 3. *Effect of different soil fertility management treatments on soil chemical properties after harvesting wheat in the central highlands of Ethiopia [6].*

Treatments (kg ha^{-1})	pH (H_2O)	OC (%)	N (%)	P (ppm)	NO_3- N (ppm)	NH_4-N (ppm)
Control	5.57	1.36	0.14	9.40	6.00	8.55b
Farmers NP rate (23/10/0)	5.36	1.61	0.16	11.00	6.33b	9.25
Recommended NP (60/20/0)	5.26	1.83	0.17	15.55	7.20	9.78
50% of recommended NP + 50% manure +50% compost as N equivalence	5.76	2.06	0.18	15.57	10.60	13.60
50% Manure +50% compost as N equivalence	6.15	1.98	0.17	15.52	9.78	10.70
F-probability (treatment)	*	**	*	**	**	*
LSD0.05	0.39	0.21	0.02	3.40	1.82	2.97
CV (%)	4.55	13.20	2.69	16.40	14.81	18.61

Table 4. *Effect of different soil fertility management treatments on soil chemical properties after harvesting teff in central Ethiopian Highlands [6].*

Treatments-N/PK/organic (Kg ha^{-1})	pH (H_2O)	OC (%)	N (%	P (ppm)	NO_3-N (ppm)	NH_4-N (ppm)
Control	5.19	1.29	0.17	7.75	6.23	5.93
Farmers NPK rate (23/10/0)	5.05	1.56	0.17	8.40	6.98	7.00
Recommended NPK (60/20/0)	5.33	1.79	0.18	11.85	9.43	8.38
50% of recommended NPK +50% manure+ 50% compost N equivalence	5.55	2.30	0.19	11.20	10.70	12.90
50% Manure +50% compost as N equivalence	5.48	2.22	0.18	10.25	10.13	8.40
F-probability	NS	**	*	*	*	**
LSD0.05	0.31	0.27	0.01	2.73	3.53	3.03
CV (%)	5.76	14.32	3.40	17.93	26.35	23.06

2.4.1. Nitrogen Uptake

According to the results of this study, adding leaf litter to the agroforestry system enhanced the amount of nitrogen that was easily available. Utilizing organic manure helps the soil become more nutrient-rich while also increasing the crop's access to nitrogen. The findings of the current research are in agreement with those of [37]. The plot treated by vermicompost or FYM in addition to chemical fertilizers exhibited higher nitrogen absorption levels than the control [56, 54]. The intercropping patterns had a significant influence on the N absorption by maize and soybean, and they were positively correlated with soil mineral Nitrogen at both sites during the survey [42].

2.4.2. Phosphorous Uptake

Das [53] reported that the treatment combination of (75 percent) RDF + (25 percent) RDF using Vermicompost resulted in the maximum phosphorus absorption, which was 49.2 kg/ha. The addition of organic sources of nutrients improved soil microbial activity, causing maximal leaf litter breakdown and raising the quantity of available phosphorus under poplar trees [32, 11]. More organic anions are produced and microbial activity is stimulated by the administration of an integrated supply of nutrients.

2.4.3. Potassium Uptake

According to Sharma [59], vermicompost prepared from Teff straw has an Available K (mgK_2O/kg) of 7327 or 0.73%. Similarly, [17, 10, 18] reported that vermicompost contains a lot of potassium. The application of 10 tons of compost per hectare along with 100 kg each of urea and NPSB increases K from 0.48 to 0.65 $Cmol_+$/kg (Table 5). On the other hand, [67] suggested that applying 0.611 t of lime, 2.5 t of compost, 75 kg of NPSB, 50 kg of KCl, and 36 kg of nitrogen per hectare resulted in a high potassium absorption of 13.27 kg/ha (Table 2).

2.5. Role of INM in Increasing Crop Production

Numerous studies have demonstrated that neither organic nor inorganic sources by themselves can increase property production [61]. Additionally, the cost of inorganic fertilizers is rising and becoming prohibitively expensive for smallholder farmers who lack access to resources. Therefore, the most straightforward method for managing soil fertility is a blend of both inorganic and organic fertilizers, where the inorganic fertilizer supplies nutrients and the fertilizer, primarily, will boost organic matter and improve soil structure and buffering capability (Table 6) [66, 27]. It is well-recognized that combining the application of inorganic and organic fertilizers, also known as INM, is a sustainable way to increase soil productivity and/or production [27, 65].

Table 5. *Interaction effects of soil amendments on yield components and yield of maize [66].*

Compost t/ha	Urea or NPSB kg/ha	TGW (g)	SY (t /ha)	AGDB (t /ha)	GY (t /ha)	HI (%)
0	0/0	216.91f	4.53f	5.7g	1.17h	19.36
	50/50	311.29c	9.10cd	12.14e	3.03f	24.98
	100/100	326.64bc	11.07b	15.90c	4.83c	30.45
5	0/0	248.58e	5.97e	7.53f	1.56g	20.36
	50/50	318.29bc	8.85d	12.42e	3.57e	28.72
	100/100	338.15ab	11.36b	16.81b	5.45b	32.43
10	0/0	278.41d	6.09e	7.82f	1.73g	25.58
	50/50	323.28bc	9.77c	14.17d	4.40d	31.06
	100/100	358.60a	12.55a	18.62a	6.07a	32.57
LSD		20.7	0.78	0.86	0.25	2.72
CV		3.96	5.13	4.02	4.1	5.76

LSD = least significance difference, CV = coefficient of variation, TGW = thousand grain weight, SY = straw yield, AGDB = above-ground dry biomass, GY = grain yield

The combination of 100% RDF + BF + GM (one row of Sunnhemp (leguminous) between two rows of maize) produced a noticeably greater grain production than the other treatments [28]. Applying chemical fertilizer and chicken manure together increased the accessibility of nutrients and maize performance more effectively than applying any fertilizer alone [49]. However, the yield from combining organic and inorganic fertilizers was not substantially different from the yield from only using inorganic fertilizers. They found greater yields in the combined usage of chicken manure and chemical fertilizer than in the individual application of poultry dung and control. Similar to this, Khan [34] discovered that combining 20 tons ha-1 FYM with 60 kg ha-1 inorganic fertilizer resulted in greater plant height, 1000 grain weight, LAI, and yield of maize than applying each fertilizer alone. For sustainable crop development, the same authors suggested using organic manure together with less inorganic fertilizer.

Table 6. *Effects of ISFM on wheat grain yield and selected parameters [27].*

Treatments	GY (kg/ha)	TBM (kg/ha)	SY (kg/ha)	HI (%)	TGW (g)
Control	1258e	3644d	2387d	34.5bc	35.2
Farmer NP rate (23/10)	1713d	4864c	2932c	35.2b	34
Recommended NP rate (60/20	3164a	7678a	4514a	41.2ab	32.2
50% RNP+50% compost/manure (3.25 t/ha	2882b	7073b	4192a	40.8ab	32.9
50% manure +50% compost (6.5)	2646c	6219c	3574b	42.5a	34.9
$LSD_{0.05}$	228.58	679.14	556.6	2.97	2.5
CV (%)	9.35	11.94	15.41	7.18	7.22

According to Joy [30], both organic and inorganic sources played a substantial effect on growth metrics. At 90 days after showing, wheat treated with 120 kg/ha of nitrogen, 60 kg/ha of phosphorous, 40 kg/ha of potassium, 10 kg/ha of farmyard manure, and 25 kg/ha of zinc had the most plants (86.43 cm) and tillers per plant (7.33) than other wheat treatments [55]. Study conducted on integrated soil fertility management for sustainable teff production also indicated that the maximum numbers of tiller, straw yield, biomass and grain yield recorded under application of 67% for RDF 33% organic fertilizer (Table 7).

Table 7. *Yield and yield components of teff in ISFM trials at Halaba [46].*

Treatments	PH	No of tiller	Straw yield t/ha	Biomass (t/ha)	Grain yield (t/ha)
T1- 100% RDF	67ab	4.7	3	3.8a	800a
T2- 50% for each RDF and Organic Fertilizer	61b	4.9	2.3	3.2b	700b
T3- 67% for each RDF 33% Organic Fertilizer	68a	5	2.9	3.8a	900a
T4- 33 % for each RDF 67 % Organic Fertilizer	68a	5	2.8	3.6ab	800ab
LSD (%)	6.2	NS	NS	0.56	170

The quantity of suggested inorganic fertilizer to be used in the research area was 69 kg/ha Nitrogen + 30 kg/ha Phosphorus, and the amount of recommended organic fertilizer was divided depending on the amount of recommended inorganic fertilizer. Accordingly, based on Nitrogen equivalency, 50, 33, and 67% recommended Nitrogen and Phosphorus in organic fertilizer were 3.52t/ha, 2.32t/ha, and 4.72t/ha, respectively, whereas 50, 67, and 33% suggested Nitrogen and Phosphorus in inorganic fertilizer were (34.5kg/ha N, 15 kg/ha P), (46kg/ha N, 20 kg/ha P), and (23 kg/ha N, 10 kg/ha P), respectively.

Table 8. *Grain yield (tons ha^{-1}) of teff as affected by the interaction of compost and Nitrogen Phosphorus fertilizer rates [9].*

compost	Fertilizer (N/P_2O_5) rates kg/ha			
	0/0	16/11.5	32/23	64/46
0.0	0.447h	0.899ef	1.172bc	1.293ab
2.5	0.563h	0.932def	1.154bc	1.382a
5.0	0.713g	0.915ef	1.038cde	1.391a
7.5	0.149	0.886f	1.078cd	1.395a
LSD (0.05)	0.149			
CV (%)	8.9			

The maximum yield of teff was produced using 7.5 tons of compost per hectare together with 64 kg of nitrogen and 46 kg of phosphorus (Table 8). When compared to applying only mineral fertilizers, compost treatment enhanced soil pH, OC, TN, accessible P, S, and exchangeable bases (Ca2+, Mg2+, Na+, and K+) however did not increase maize yields. Comparatively to plots modified with just compost and the control treatments, adding mineral fertilizers alone increased soil acidity, decreased SOC, and depleted soil nutrients while boosting maize yields.

The combination of compost and mineral fertilizers significantly increased soil pH, OC, TN, and the quantity of P and S that was readily available while reducing the bulk density of the soil as compared to their applications and the control. Additionally, it was shown that INM was economically viable and delivered maize with the greatest grain production and dry biomass. The application of 10 t/ha compost along with 100/100 kg Urea/NPS Boron ha-1 may be recommended to improve soil fertility and maize production in the research region [66]. But more research is required to understand the long-term consequences and how mineral fertilizer and compost work together.

Table 9. *Seed yield (kg) per hectare of onion as affected by NP fertilizer and vermicompost [35].*

VC (t/ha)	Inorganic NP fertilizer (RDF)				
	0	25% RDF	50% RDF	75% RDF	100% RDF
0	402.8h	454.7h	527.8gh	597.2gh	743.1fg
2.5	553.5gh	865.2ef	1192.3bcd	1462.5a	1189.7bcd
5	948.1def	869.3ef	1448.6a	1356.9abc	1145.8bcd
7.5	1050de	958.8def	1300.8abc	1385.2ab	1128.5cd
LSD (0.05)	217.4				
CV (%)	13.4				

For the best onion production, 50% (50 kg) of the prescribed nitrogen (N) dosage using FYM and 50% (50 kg) of the suggested N dose with chemical fertilizer were applied [51]. According to Gebremichael [26], research, the highest plant height, leaf number, leaf length, neck thickness, bulb length, bulb diameter, mean bulb weight, biological yield, harvest index, and marketable yield were achieved with the mixed treatment of 5 tons per ha vermicompost + 50% inorganic N fertilizers. The use of a mixture of 5 t per ha FYM + 2.5 t per ha vermicompost + biofertilizers (Azospirillum + PSB) resulted in the maximum bulb production and net returns [36]. The maximum yield of onion recorded under 75%RDF and 2.5t/ha of VC (Table 9).

Table 10. *Integrated use of lime, organic, and inorganic fertilizer effects on partial budget and MRR analysis for barley production [67].*

Trt. No	Grain yield (kg/ha)	Adjusted yield-10%	Gross return (ETB/ha)	TVC (ETB)	Net return (ETB/ha)	MRR (%)
T1	1317.77	1185.99	10080.9	260.92	9820.02	
T3	1682.69	1514.42	12872.6	1280.22	11592.4	173.92
T2	1616.99	1455.29	12370	3320.16	9049.79D	-
T4	1744.82	1570.34	13347.9	4292.52	9055.3 6D	-
T5	3810.67	3429.61	29151.7	4662.86	24488.8	381.25
T6	1670.2	1503.18	12777.1	4704.5	8072.55D	-
T9	4799.64	4319.67	36717.2	5584.28	30633.00	666.81

Trt. No	Grain yield (kg/ha)	Adjusted yield-10%	Gross return (ETB/ha)	TVC (ETB)	Net return (ETB/ha)	MRR (%)
T7	4414.24	3972.81	33768.9	6194.87	27574.00D	-
T8	5385.59	4847.03	41199.8	9387.2	31812.6	31.01

T1- control; T2 - compost (5 t /ha); T3-lime (611 kg /ha); T4 - lime (611 kg /ha) + compost (5 t /ha); T5 – DAP (150 kg /ha) +KCl (100 kg /ha)+ Urea (72 kg /ha); T6-NPSB (150 kg /ha)+ KCl (100 kg /ha)+ Urea (72 kg /ha); T7 Lime (611 kg /ha)+ NPSB (150 kg /ha)+ KCl (100 kg /ha) +Urea (72 kg /ha); T8 Lime (611 kg /ha)+ compost (5 t/ha)+NPSB (150 kg /ha)+ KCl (100 kg /ha) +Urea (72 kg /ha); T9 Lime (611 kg ha- 1)+ compost (2.5 t /ha)+NPSB (75 kg /ha)+ KCl (50 kg /ha) +Urea (36 kg /ha) D: Stands for dominated treatment

By using (23 kg/ha N, 10 kg/ha DAPP, and 46 kg/ha organic fertilizer N equivalent), the optimal method for maximizing the advantages of teff production was suggested [46]. The maximum net benefit from teff production was obtained with 7.5 tons/ha of compost plus 64kg of N and 46 kg [9]. Similar to this finding the highest net return and MRR was recorded from treatment Lime (611 kg /ha) + compost (5 t/ha) +NPSB (150 kg /ha) + KCl (100 kg /ha) +Urea (72 kg /ha) as mentioned in Table 10. To achieve the highest benefit-to-cost ratio, [51] employed 50% (50 kg) of the required dosage of nitrogen using FYM and 50% (50 kg) of the suggested dose of nitrogen with chemical fertilizer. The maximum net income (47,565 ETB ha-1) was obtained from a single row of sorghum and a pair of rows of haricot beans in sequence (1S: 2H) planting patterns, while the lowest net income (31,130 ETB ha-1) was obtained from single row of sorghum and single row of cowpea in sequence (1S: 1C) planting patterns [29].

3. Summary and Conclusion

In different regions of Ethiopia, FYM, vermicompost, manure, liming materials, and composts were employed as sources of organic fertilizer alongside the advised dose of inorganic fertilizer for a variety of crop yields as well as to improve soil fertility. The impact of ISFM on yield and the yield components of maize, teff, onion, wheat, and barley production were taken into consideration in this review. Crop yields and biomass were seen to be higher when integrated nutrient management was used, which has a greater impact on improving crop yields and yield-related components than using only organic or inorganic fertilizer. The implementation of different nutrient management techniques, according to various authors, improves the availability of nutrients for plants by increasing their absorption of N, P, and K. Adding liming materials also had a significant part in raising the pH and other cations of the soil, such as K+, Ca2+, Mg2+, and others, from the beginning point under acidic soil conditions.

Various authors conducted economic assessments contrasting integrated nutrient management with various components of just organic and inorganic fertilizers. Their study's findings suggest that INM is more advantageous than the other kind of fertilizer utilized alone. The only an alternative for enhancing the biophysicochemical properties of the soil and enhancing farming sustainability is integrated soil fertility management. In general, this evaluation recommended INM based on studies done on the combined usage of different organic and inorganic fertilizers with proper rates at the right or appropriate times to raise crop yields and improve soil fertility.

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