Effect of Integrated Nutrient Management on Wheat: A Review

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Abstract
Ethiopia is the second largest wheat producer, after South Africa, in Sub-Saharan Africa. Wheat is one of the major staple crops in the country in terms of both production and consumption. In terms of caloric intake, it is the second--most important food in the country behind maize. Research on nutritional aspects relating to wheat cultivation is abundant and is documented comprehensively. Studies being carried out at different locations in Ethiopia indicated that application of all the needy nutrients through chemical fertilizers have deterious effect on soil health leading to unsustainable yields. Therefore; there is a need to improve nutrient supply system in terms of integrated nutrient management involving the use of chemical fertilizers in conjunction with organic manures coupled with input through biological processes. However, the role of major nutrients on crop physiology and the effect of these nutrients on growth, quality, yield and yield components of cereal crops in general and wheat in particular are unsatisfactory. Above all, the role of balanced fertilizer is the application of essential plant nutrients in light proportion and in optimum quantity for a specific soil crop condition in alleviating the yield, quality and its attributes of wheat production is important. In association with this, research on integrated nutrient management in wheat and its effect on growth, yield, yield components and quality parameters are significance. The literature pertaining to these lines of research in wheat is presented in an elaborative way and is reviewed in this paper.
Keywords: Integrated nutrient management, FYM, Chemical fertilizer

2. INFLUENCE OF FERTILIZERS ON CEREAL PRODUCTION

Agriculture is Ethiopia's most important sector, crucial for the country's food security and the livelihoods of nearly 85% of its people, but also the engine for the country's Agriculture Development Led Industrialization (ADLI) strategy (ATA annual report, 2013/14). Ethiopia is the second largest wheat producer, after South Africa, in Sub-Saharan Africa (CSA, 2010). In terms of caloric intake, it is the second--most important food in the country behind maize (FAO, 2014). Fertilizer use has progressed from about 3,500 tons consumption level during 1967-1972 seasons (NFSAP, 2007) to more than 450,000 tons in 2007/08 cropping season (World Bank, 2008). About 44% of smallholder farmers (out of the total estimated number of 10.23 million) applied fertilizer on their farms in 2005.About 60% of total Fertilizer consumption is used largely on production of three cereal crops (Teff, Maize and Wheat) in the country. The national recommended application rate for Ethiopia is 100 kg of diammonium-phosphate (DAP) and 50 kg Urea ha^{-1} for wheat (Elias, 2002).

3. INFLUENCE OF CHEMICAL FERTILIZERS ON WHEAT

3.1. Influences of Nitrogen on Wheat

3.1.1 Role of nitrogen in crop growth

Nitrogen is the principal raw material required for the growth of a plant and in increasing the yield of the crop. Application of proper amount of nitrogen is considered key to obtain bumper crop of wheat. Brady and Weil (2002) stated supply of high N favors the conversion of carbohydrates into proteins, which in turn promotes the formation of protoplasm .Since it is a necessary component of all proteins, N is involved in all plant growth processes.

3.1.2. Influences of fertilizer nitrogen on yield

It is quite normal that increasing levels of applied N increased grain yield of wheat (Behera, 1998). Increasing N levels increased grain yield by increasing the magnitude of yield attributes. Similarly, Tayebih (2011), indicated that the different N rates (120, 240 and 360 kg ha^{-1}) have a significant effect on grain yield increment (46% at N120, 72% at N240, and 78% at N360) compared to control. The increase in grain yield was due to increase in the yield attribute as the level of nitrogen was increased. Channabasavanna and Setty, 1994 stated that the increase in yield attributing characters, however, was the result of better nutrition or N uptake, leading to greater dry matter production and its translocation to the sink (Dalal and Dixit, 1987). Increased productivity of wheat can be achieved by adopting improved agronomic practices and varieties (Sadat *et al.*, 2008). Increasing nitrogen rates had a significant effect on the grain yield with maximum grain yield was obtained in the case of 150 kg N ha-1 (3.91 t ha- 1) while nitrogen application beyond the level of 100 kg N ha-1 did not increase the grain yield ha-1 to a significant extent (Maqsood et al, 2000) . Similar results were reported by Singh and Uttam (1992) who reported that grain yield increased significantly up to 120 kg N ha-1. Ayub (1994) also reported that grain yield increased significantly with the application of nitrogen fertilizer.

Several studies on N rate and time of application on different soil types in our country, Ethiopia, also indicated that wheat yields, N uptake and efficiency were significantly affected. Amsal *et al*., (2000) also reported that nutrient deficiency is one of the major constraints to wheat *(Triticum spp*) production in Ethiopia and application of nitrogen and phosphorus significantly increased all crop parameters studied. The same authors noted that the mean grain yield and biomass response to fertilizer application was 163% and 149% on the vertisols compared with the mean of the unfertilized treatments, respectively. Aleminew *etal.,* (2015) revealed that the highest grain yield (3992 kg/ha) at Kone and (2685 kg/ha) at Geregera was obtained with the application time of urea fertilizer 1/2 at planting and 1/2 at tillering stage of bread wheat in Eastern Amhara Region. The proper use of fertilizers becoming vital to boost crop yield and nitrogen fertilizer being determinant in wheat production in Ethiopia, numerous N fertilizer trials have been undertaken to determine the optimum levels for economically profitable yields (DZARC, 1989). Results indicated that nitrogen rates had significant positive effect on yield up to 230 kg ha^{-1}. (SARC, 2006), conducted experiments on Vertisols of Bale Zone (drained soil) showed that increasing the applied levels of N increased grain yield of wheat. Similarly, Woldeyesus *et al.,* 2012 carried out a series of on-farm and on-station experiments on bread wheat in four zones of the SNNPRs and reported that the current national recommendation for seed rate is increased from 150kg/ha to about 250kg/ha for broadcasted wheat, N fertilizer is increased to about 110kg/ha and sowing is completed around the second week of July which needs further works to give conclusive recommendations. According to Birhanu (2010), grain yields of ten wheat varieties were increased as fertilizer nitrogen increased from 0 to 125 kg N/ha. Hence, nitrogen is a key factor in achieving optimum cereal grain yield. Nitrogen nutrition affects crop performance through its effects on photosynthetic capacity. Several researchers in Ethiopia have reported the role of N in wheat production in the highlands as substantial changes in yield and yield components have been affected with the application of N fertilizer (Tilahun *et al*., 2000).

3.1.3. Effect of fertilizer nitrogen on Yield components

Studies conducted in the Nitosol zones of the central highlands of Ethiopia, a positive and linear response of wheat to applied N fertilizer was evident in selected agronomic parameters such as plant height, number of spikes m^{-2}, thousand kernel weight (TKW), grains m^{-2} and grain yield (Amsal et al., 2000). Liu Dandan and Yan Shi (2013), observed the amount of nitrogen fertilizer increased from 0 to 225 kg/hm^2, the number of kernel per spike and kernel yield increased significantly with nitrogen fertilizer increasing, while that of N300 declined, but still higher than that of N150; the number of kernel per spike in treatment N150, N225 and N300 were all significantly higher than N0, but the differences between treatment N150 and N300 were not significant (Table 1).

Table 1: Effects of different treatments on yield components and yield of wheat

Treatment (kg/ha)	No of spikes ($\times10^4$/hm^2)	No of kernel per spike	Weight per 1000 kernels (g)	Kernel yield (kg/hm^2)	Biology yield (kg/hm^2)	Harvest index
N0	654.00d	35.80c	35.50b	7263.0d	16890.5d	0.43
N150	697.35c	38.15b	36.75a	8356.4c	19105.4c	0.44
N225	725.85b	39.40a	36.70a	9135.6a	20302.8b	0.45
N300	756.90a	38.40b	35.31b	8745.7b	20936.5a	0.42

Source: - Liu Dandan and Yan Shi.2013 **Note**: N0, N150, N225 and N300: 0, 150, 225 and 300 kg/hm^2 of nitrogen fertilizer respectively; Lower case letters represented significant differences at p<0.05 level

Nitrogen at the rate of 125 kg ha-1 produced significantly taller plants (97.65 cm) than 100 and 75 kg N ha-1, yet it did not differ significantly from treatment 150 kg N ha-1 (97.05cm).

Maximum number of fertile tillers was recorded in the treatment of 150 kg N ha-1 (290.5) followed by 125 kg N ha-1 (255.3) whereas the minimum number of fertile tillers m-2 was recorded in control treatment (191.8) (Maqsood et al. 2000). Similarly, Hussain *et al.* (1984) who reported that increasing nitrogen rate increased number of fertile tillers m-2 and the increase in the number of spikelets per spike. Kirrilov and Pavlov (1989) who reported that application of nitrogen markedly increased 1000-grain weight. According to (Tayebih ,2011) spikes number/m^2, seeds number spike^{-1} and 1000 grain weight significantly enhanced with increasing nitrogen levels from (46% at N120, 72% at N240), but there was no significant increase for two parameters from 240 to 360 kg N ha $^{-1}$ except seed number spike $^{-1}$. Thus, the yield of wheat is a function of many factors, among them efficient fertilizer management which must combine rate, time, placement and source of application in a manner that optimizes crop yield and quality, while minimizing nutrient losses to the environment (Grant, 2000). Therefore, various studies cited above indicated that N rate, application timing and method of application significantly affected yield, N uptake, efficiency and grain quality depending on soil type and locations.

3.1.4. Effect of fertilizer nitrogen on Quality

N is the crucial factor of yield and quality in the cereals. Grain quality is a complex trait resulting from the interactions between numerous protein components (Daniel and Triboi, 2000). Study elsewhere indicates that wheat grains contain 8–20% proteins, which are divided into two major categories: prolamins including gliadins and glutenins and non-prolamins consisting of water-soluble albumins and salt-soluble globulins. The protein composition of wheat seeds is important in determining bread-making quality (Johansson *et al*., 2001). According to Torbica *et al.*, 2007,gluten proteins, a large complex composed mainly of glutenins and gliadins, play a key role in baking quality because of their impact on water absorption capacity of the dough, dough elasticity and extensibility that can affect wheat flour quality. Studies on time of N application on Nitisols at Holleta and Vertisols at Ginchi showed that application of 50 % of the total nitrogen at sowing and the rest at full tillering stage significantly increased grain yield as well as the protein content of wheat (Asnakew *et al*., 1991). Liu Dandan and Yan Shi (2013) stated that taking yield and the quality of nitrogen fertilizer into account, we thought that the best nitrogen application level was 225 kg/hm.[2]

Maqsood et al, 2000 also reported crop fertilized with 150 kg N ha-1 gave the maximum grain protein content (11.72%) while the minimum protein content was found in control (9.02%) (Table2). Similarly, Ayub *et.al.* (1995), and Kirrilov and Pavlov (1989) also reported that applied nitrogen increased wheat grain protein content by 20.29%.

Table 2. Effect of different nitrogen rates on agronomic traits and grain protein content of wheat

NP (kg ha-1)	Plant height (cm)	Fertile tillers m-2	Spikeletsspike-1	Grain per spike	1000-grain weight	Grain yield (t ha-1)	Protein content (%)
F0 = 0 - 100	76.5d	191.8d	14.7c	33.7d	40.5c	2.2c	9.0c
F1 = 75 - 100	90.3c	223.5c	16.6b	46.5c	40.5c	3.5d	9.8b
F2 = 100 - 100	94.2b	231.0c	17.2b	50.4b	42.4bc	3.6ab	9.8b
F3 = 125 - 100	97.6a	255.3b	18.1a	55.1a	46.5a	3.7a	11.2a
F4 = 150 - 100	97.1a	290.5a	18.5a	54.9a	44.4ab	3.9a	11.7a

Source: Maqsood et al. 2000

Variability in grain protein is attributed to environments that differ across locations and years with respect to seasonal temperatures, moisture, and soil type (Gooding and Davis ,1997); differences to cultivar genetic potential and to management decisions (Smith and Gooding, 1996) especially through the grain filling period (Daniel*,* 2000). These factors influence the rate and duration of wheat grain development, protein accumulation and starch deposition (Dupont and Altenbach, 2003). Among them N fertilizer application rate and timing is the most important management practices influencing grain protein content. The greatest influence of N fertilizer on grain quality is achieved through its effect on grain protein concentration (Gooding and Davies, 1997). Increasing N fertilizer rates can result in higher grain protein content (Kelley, 1995). Split-application of N resulted in superior quality attributes than when the entire N was applied at once (Ooro *et al*., 2011).

Report of (Johansson *et al*., 2004) shows that nitrogen fertilization could increase the total quantity of flour proteins, resulting in an increase in both gliadins and glutenins. However, the albumins-globulins content is scarcely influenced by N nutrition (Fuertes-Mendizábal *et al*., 2010). Some other researches shown that applications of N later in the season (spring) and near anthesis is more effective in enhancing grain protein content in wheat than earlier applications (Bly and Woodard, 2003). In contrast, others revealed no significant effects of N rates and its time of application on leaf protein content in different growth stages. However, seed protein content was significantly affected. According Majid (2010), found the highest protein values with the highest N rate. Halverson *et al.* (2004) also indicated that grain protein content generally increased with rate of increased N level. Several studies indicate that N fertilization can increase both wheat grain yield and grain protein content (Subedi *et al.,* 2007; Gorjanovic and Kraljevic-balalic, 2008).

3.2 Role of Phosphorus in Plant Nutrition

Although phosphorus is required in lower amounts than other major nutrients, it is critical in the early developmental stages of growth, and in energy transfer within the plant throughout the growing season. Typical phosphorus contents of plants range between 0.1 to 0.46 percent P on a dry weight basis, approximately ten times less than for nitrogen or potassium. Phosphorus apparently stimulates young root development and earlier fruiting (earliness). It is essential in several biochemicals that control photosynthesis, respiration, cell division, and many other plant growth and development processes. The uptake of some nutrients and their transport within the plant as well as the synthesis of new molecules, are energy using processes that adenosine triphosphate (ATP) helps to implement (Brady and Weil, 2002). Phosphorus has very useful effect on cell division and albumen formation, flowering and fruiting including seed formation and crop maturation. Phosphorus storage occurs in seeds to prepare them for germination and early growth prior to extensive root development. Early tillering under P fertilization was significantly higher when plants developed both root systems than only primary or adventitious (Annioux, 1996).

Kaleem etal.2009 who recorded maximum yield of 3557 kg ha-1 by the application of 128- 128 kg ha-1 (NP) ratio 1:1 which was indicating importance of phosphorus at its highest dose in achieving maximum wheat productivity.

Table 3. Mean yield and yield components of wheat variety Inqlab-91 as affected by different levels of phosphorus

Treatments	NP Kg ha-1	Germination Count m-2	Fertile Tillers m-	Grains per spike	1000 grains wt. (g)	Yield (kg ha-1)
T1	128-32	148.5	292.50	24	40.03	3142c
T2	128-42	156.00	304.00	25.50	40.78	3286b
T3	128-84	176.50	328.00	22.5	42.49	3251b
T4	128-96	155.00	302.50	25.5	40.31	3204b
T5	128-128	162.50	319.50	26.00	44.01	3558a
		NS	NS	NS	NS	

Source**:-** Kaleem *etal.*2009

Maximum dose of phosphorus combined with fix N, yielded maximum number of grains spike-1 i.e. 26 in plots treated with 128-128 kg NP ha-1(Table 3). Similarly, maximum germination count and fertile tillers m-2 were obtained in plots treated with NP 128-84 kg ha-1 indicates that at germination stage seed uses its internal resources and does not depend largely upon external material. Highest phosphorus dose contributed in achieving highest 1000 grain weight and finally resulted in statistically significant grain yield ha-1. These findings indicate that application of the highest dose of phosphorus in combination with fix nitrogen, i.e. in 1:1 ratio contributed maximum to translocate dry matter and physiological attributes towards the yield attributes in wheat variety, Inqlab-91 and therefore maximum phosphorus dose helped in achieving highest number of grains spike-1, 1000 grain weight and ultimately wheat yield (Kaleem *etal.*2009). Despite its essentiality for a plant, P is deficient in most soils. Phosphorus deficiency cause purple discoloration, delay in maturity and stunted plant growth. Besides, reduction in leaf expansion and leaf surface area is most striking effects in plants suffering from P deficiency (Brady and Weil, 2002). According to Marschner (1995), in contrast to shoot growth, root growth is much less inhibited under P deficiency, leading to reduction in shoot-root dry weight ratio.

3.3. Interaction of nitrogen with phosphorus

Low soil fertility is one of their major production constraints of Ethiopian farmers. On farm Fertilizer trials conducted on bread wheat from 1988-1990 in the country showed that fertilizer N and P have significant effects on soil and crop parameters, weed density, and diseases incidence (Tanner *et al*., 1992). Increasing levels of N and P application and their interaction significantly and positively affected grain yield of wheat and concentration of N and P in the plant (Eylachew, 1996; Schulthess *et al*., 1997).

Brady and Weil (2002) reported that plant roots take up N from the soil solution principally as nitrate (NO_3^-) and ammonium (NH_4^+) and the effects of these two ions on the pH of the root rhizosphere is known to influence the uptake of other companion ions, such as phosphate. According to Tanner *et al.* (1992), research conducted at several locations in Ethiopia indicated that post-harvest soil N was increased by the application of fertilizer N. In many crops, N and P interact closely in affecting maturity. Excess N may delay plant maturity and cause the plant to be more susceptible to diseases and insect pests. It also makes high shoot-to-root ratios while abundant P hastens maturity and in contrast to excess N, it increased root growth relative to shoot growth (Brady and Weil, 2002). Numerous authors conducted research on influence of environment on variety , timing, doses and types of fertilizer applications have been reported to have effects on durum wheat grain yield as well as grain quality (Leta G., Belay G., and Worku W., 2007; Woyema A, Bultosa G. and A Taa.,2012 and Haile D.*et al*.,2012). Adamu Molla, 2013 noticed the application of N101P10 (200/50 of Urea/DAP) and N130.5P30 (225/150 of Urea/DAP) kg ha is recommended for bread wheat production on relatively fertile and infertile black soils, respectively, in the central highlands of Ethiopia.

4. Influence of Farm Yard Manure and Compost

Addition of organic matter in the soil is a well-known practice to increase crop yields. Organic matter like FYM has supplied available nutrients to the plants provided favourable soil environment and increase water holding capacity of soil for longer time. In addition to commercial fertilizer application organic amendments in the form of farm/home yard manure and green manure or these processed in the form of compost have always been used by Ethiopian smallholder farmers to enhance fertility and soil physical properties (Edward, 2005). Study at Holleta red soil applying 12 to 18 ton ha $^{-1}$ of farm yard manure was found to be as effective as 100 kg ha^{-1} DAP ($N_{18}\,P_{20}$), and 200 kg of bone meal was 85% effective as compared with 100 kg ha^{-1} DAP. In another experiment at Ginchi, mustard meal as a source of nitrogen for wheat showed better effect than urea (Taye Bekele, 1993).

Singh and Tomer, 1991 reported that application of Farm yard Manure helps to increase the DMP, yield and nutrient uptake by wheat. The soil incorporation of mustard/taramira + FYM and FYM at 10 t ha-1significantly increased grain yield of wheat across the years (Regar *et al*.,2005). Application of FYM @ 10 and 20 tonnes / ha increased the grain yield and the total N P and K uptake in wheat crop (Singh and Agrawal, 2005). FYM application (10tha-1) resulted in a 2004 and 21.5 % increase in grain and straw yield over control respectively. Response of FYM measured as kg grain tonne-1 was highest in wheat (Mahapatra *et al.,* 2007).

Application of organic amendments improves soil physical fertility (Biswas and Khosla, 1971) and using them in conjunction with organic fertilizers augments the beneficial effects. Soil organic matter imparts desirable physical environments to soils by favourably affected soil structure expressed through soil porosity, aggregation, bulk density and soil water storage (Benbi *et al.,* 1998; Benbi and Nieder, 2003). FYM is applied to the soil mainly as a source of plant nutrients. Animal manure supplies all the macronutrients as well as micronutrients necessary for plant growth, hence it acts as a diverse fertilizer. Its fertilizing effect on crops can be compared to that of mineral fertilizers. Application of manure in a certain year influences crops grown in that growing season but also to crops in later years because its decomposition is not completed in one season. Therefore, application of farmyard manure is synergistic to mineral fertilizers for various nutrients. This illustrates that nutrients from farmyard manure can be substituted for mineral fertilizers and this also improves soil environment.

Field experiments revealed that N availability was 40 % for manure and 15 % for compost in the first year and was 18 % for manure and 8 % for compost in the second year after application. Similar results showed that the combination of compost with chemical fertilizer further enhanced the biomass and grain yield of crops (Sarwar *et al*., 2007; Sarwar *et al*., 2008). Singh, *et al., (*2007) have shown that use of inorganic fertilizers in combination with FYM / green manure (GM) /crop residue (CR) plays an important role in improving the damaged soil structure by reducing bulk density and increasing infiltration rate and the mean weight diameter of the aggregates. Organic carbon content registered an increase varying from 28.6 to 35.7 % over control due to continuous application of FYM, rice straw, or green karanj leaf over the year. Besides, there is plenty evidence that application of organic fertilizer also enhances the effectiveness of commercial fertilizer through favorable soil microbial activity and augmentation of organic soil colloids (humus) that possess large nutrient retaining surface area (Manna *et al*., 2005). An average rate of application of organic amendments is still a very small fraction (about 100 kg per each small farmer per year) as compared to the total requirement of the product. As a result of land degradation problems (soil erosion, removal of crop residue for animal feed and fuel and burning of animal dung), soil with organic matter content below 2% (even below 1% in many areas) is wide spread in the country. The country in general is rich in live stock and lot of biomass that can be used as compost these integrated fertility management would help to change the existing situation. Bajpai *et al.,* 2006 addition of organic nutrient source might have created environment conducive for formation of humic acid, stimulated the activity of soil microorganism resulted in an increase in the organic carbon content of the soil

5. Combined effect of FYM, Compost and chemical fertilizers on wheat

According to (Fassil *et al.,* 2009) soil erosion causes several damages to the physicochemical characteristics of soil such as loss of organic matter, loss of soil fertility, decreased infiltration rate and water holding capacity, and exposure of subsoil with higher clay content and poor soil fertility. This indicates that valuable nutrients are lost every year resulting in low soil fertility. Imbalanced fertilization practiced over a long period of time and replacement of recycling of organic materials and application of organic manures in this part of the country raised concerns about the potential long-term adverse impacts on soil productivity and environmental quality (Edward, 2005). Addition of FYM with inorganic fertilizers to soil has been reported to increase the efficiency of applied fertilizers moreover; addition of FYM with inorganic fertilizers improves organic matter content of soil and consequently water holding capacity of soil (Hati *et al*., 2006). Nutrient replenishment by merely adding chemical fertilizers is often not economically feasible and even in the technically, it may not be in balance with the supply of organic matter.

Study in Nitisols of South Ethiopia by the Hawassa Agricultural Research centre indicate that using *Erythrina bruice* as a green manure crop either its biomass alone or in combination with mineral fertilizer is found to increase the yield and yield components of bread wheat (Haile, 2012). *E. bruice* is a nitrogen fixing plant, which fix's the nitrogen through its leaves; this tree is endemic to Ethiopia and is a fast growing nutrient rich plant particularly high with nutrient contents on NPK (Haile, 2012). An integrated use of chemical and organic fertilizer has proved to be highly beneficial for sustainable crop production. Several researchers have demonstrated the beneficial effect of combined use of chemical and organic fertilizers to mitigate the deficiency of many secondary and micronutrients in fields that continuously received only N, P and K fertilizers (Chand *et al.,* 2006). Integrated nutrient-management program in which both organic manure and inorganic fertilizer are used has been emphasized as a rational strategy in improving yield (Wakena *et al*., 2002; Abay and Tesfaye, 2012; Dejene K.*et al*, 2012). It is commonly believed that the combination of organic and inorganic fertilizer will increase synchrony, enhancing the efficiency of the fertilizers, and reduce losses by converting inorganic nitrogen (N) into organic forms but also reducing environmental problems that may arise from their use.

Thus, the study reflects those integrated use of chemical fertilizers, organic manures including green manure and recycling of crop residues, assume greater significance of improving efficiency of chemical fertilizers in soil.

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