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Role of Combined Fertilizer Application on Soil Fertility, Growth and Yield of Potato (*Solanum tuberosum* L.): A Review

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ABSTRACT

The combined fertilizer application is a strategy that combines both organic and inorganic plant nutrients to achieve higher crop productivity, prevent soil degradation and thereby aid encounter future food supply needs. The main objective of this paper is to review the role of combined fertilizer application on soil fertility, growth and yield of potato. This paper is done by assessing various kinds of published and unpublished materials and relevant information from different literature sources like libraries, research report, journals, books and Internet center. It has integrated use of organic and inorganic fertilizer affects the tuber yield and its attributing characters like an average number of tuber/hills, average tuber weight/hill, marketable tuber number and total dry matter yield. The use of farmyard manure and vermicompost along with inorganic fertilizers is superior to the application of either farmyard manure or vermicompost alone. Application of organic manure along with inorganic fertilizer increased organic carbon, available P and K. But the application of inorganic fertilizer alone had no significant effect on the fertility status of the soil. The reports revealed that integrated use of organic manure and reduced rates of inorganic fertilizer significantly improved potato productivity and improved the fertility status of the soil and could save inorganic fertilizer for sustainable potato production in potato growing areas.

Key words: Fertilizer, Growth, Nutrient, Potato, Soil fertility, Yield.

Potato (*Solonaum tuberosum* L.) is a leading vegetable crop in Ethiopia. It is a crop with high potential to contribute to poverty reduction and becoming an important food crop in Ethiopia. Potato crop can contribute to refining food and nutritional security. Due to its ability to provide a high yield per unit input with a short crop cycle than major cereal crops, it is considered as a high potential food security crop for densely populated highland regions (Adane *et al.*, 2010). Hence, the Ethiopian government has identified it as one of the priority crops for agricultural growth programme (Tesfaye *et al.*, 2012). Especially in rain fed systems, this is often of essence, because it makes potato one among the primary crops which will be harvested after the onset of the rainy season. In conditions of food shortage, potato act as an essential hunger breaking crop to assure staple food before grains can be harvested.

Potato provides more energy and protein per unit area and unit time than most other major food crops; it is fat free and contains substantial amount of vitamin and minerals. Potato is a major source of high level carbohydrate and significant amount of vitamin b, c and minerals. It has the highest protein content (around 2.1% on a fresh weight basis) in the family of root and tuber crop and protein of a fairly high quality with an amino acid pattern that is well harmonized to human requirements. The balance of protein and calories, among the more important amino acid in protein and the composition of mineral make potato second to eggs in nutritional value as a single source (Scott *et al.*, 2000).

According to Muriithi and Irungu (2004), low soil fertility is one of the most important constraints limiting potato production in Eastern Africa. Farmers should challenge this problem through the integrated nutrient management, which modify the soil environment. In development and extension programs in SSA integrated nutrient and soil fertility management, among smallholder farmers are more accepted and highly benefited (Place *et al.*, 2003).

The strategy combines both organic and inorganic plant nutrients to achieve higher crop productivity, prevent soil degradation and thereby aid encounter future food supply needs. It has been acknowledged that organic and inorganic mineral inputs cannot be substituted entirely by one another and are both required for sustainable crop production (Vanlauwe *et al.*, 2002; Place *et al.*, 2003). As Sanchez and Jama (2000) reported fertilizer or organic resources alone may not offer adequate amounts or may be inappropriate for lessening specific restraints to crop production.

Excessive use of mineral fertilizers alone resulted in adverse effect on soil nutrient balances leading to reduce plant growth performance. This justifies the requirement to add organic manure. Animal manure is normally used in higher value commodities like potato, coffee and vegetables

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(Freeman and Coe, 2002). Ethiopia is gifted with conducive climatic and edaphic conditions for potato production. However, the national average yield is estimated at 10.5 t/ha, which is very low by any standards compared to the world average of 16.4 tons/ha (FAO, 2004). One of the causal reasons to this low yield is improper agronomic management practices particularly in fertilizer and mineral use by potato growers. Potatoes are heavy feeders, requiring large quantities of fertilizers, account of their limited and shallow root system and partly because they have to bulk up yield. However, intensive use of lone chemical fertilizers without organic has formed a number of problems which have significantly affected soil fertility and potato productivity (Shalini *et al.*, 2002).

A potato crop of average yield may uptake 50 to 80 kg N, 20 to 30 kg P_2O_5 and 80 to 100 K_2O per ha from the soil (Leukema and Van der Zaag,1990). Organic manure plays a significant role for removal of these nutrients. The authors also confirmed that potato benefits from the application of organic manure not only from the amounts of nitrogen, phosphate and potash it obtains but also from its positive effects on the tilth and the moisture retaining properties of the soil. The objective is to review the role of combined fertilizer application on soil fertility, growth and yield of potato.

Review of litratures

Nutrient requirement of potato

Potato requires optimal level of essential nutrients throughout the season. Nutrient uptake rates often slow early in the season, increase rapidly during the tuber bulking phase. The increased uptake of nutrient relates to NPKS fertilization and organic manure application resulted to proliferous root development. Balanced nutrient application which helps in better absorption of water and nutrients and improved physical environment (Pathak *et al.*, 2005; Laxminarayana, 2006). Phosphorus is important for early root and shoot development, providing energy for plant process such as ion uptake and transport. Roots absorb phosphate ions only where they are dissolved in the soil water. Potato plants take up large quantities of potassium throughout growing season and require large amount of soil potassium since this nutrient is crucial to metabolic functions such as the movement of sugars from the leaves to the tubers. Calcium enriched cell walls are more resistance to bacterial and fungal attack and magnesium take a crucial role in photosynthesis.

Concepts of combined fertilizer application

Combined fertilizer application is an approach that seeks both increase agricultural production and safeguard the environment for future generation. The strategy combines both organic and inorganic plant nutrients to achieve higher crop productivity, prevent soil degradation and thereby encounter future food supply needs. The residual effect was more pronounced with integrated use fertilizers and organic manures. Moreover, integrated nutrient management is needed for proper plant growth and sufficient use of water, soil and land management, will be critical for sustaining agriculture over the long term. Modern nutrient management strategy has shifted its focus toward the concept of sustainability and eco-friendliness. Integrated use of varied soil fertility amendment inputs aims at alleviating the limiting nutrients problem and improving their availability through interactions with the mineral soil and reducing the P capacity of the soil (Palm *et al.,* 1997). The same authors, however, reported that crop yields still short of their potential because of inadequate nutrient inputs, inappropriate quality of the organic materials and inefficient combination. Due to the continual decrease in organic matter and nutrient content of the soil, the importance of integrated nutrient management for efficient utilization of nutrient resources and for long-term maintenance of soil fertility has been indicated (Misra and Maheshwari, 1998).

Combined use of organic and inorganic fertilizer

Combined use of farm yard manure and inorganic fertilizer

Various researchers reported that supplementing the inorganic fertilizers with Farmyard manure substantially increased both quantity and quality of potato (Teklu *et al.,* 2004; Tolessa *et al.*, 2002). The authors also reported that the decision whether to apply the full dose of recommended rate of the N and P or the reduced rates depends on various socio-economics factors like the efficiency, profitability, affordability and availability of the fertilizers. The experiment conducted at Kenya showed that well decomposed farmyard manure could be used in combination with inorganic fertilizers to consider soil fertility and potato tuber yield in smallholding farms. Many authors also reported that seeing cost of inorganic fertilizer and its adverse effects on the environment, reduced usage at half the recommended rates combined with half rates of farmyard manure is feasible option friendly to the farmers, soil and environment (Muriithi and Irungu, 2004).

According to Melkamu *et al.* (2020) report the combined application of NPS fertilizer and FYM increased tuber weight of potato. In addition, many research findings indicated tuber weights of potatoes may be increased due to the application of phosphorus containing fertilizer which boost the availability of soil phosphorous up to certain level. The combined application of NPS fertilizer and FYM increase the plant height (Melkamu *et al.*, 2020) and the combined application of organic manure and inorganic fertilizer increased growth and vigor of the plants (Shalini *et al.*, 2002) over application of inorganic fertilizers alone. The combined application of different rates of inorganic fertilizer (NP) and various rates of organic manures (FYM) fasten days to maturity, increase marketable and total tuber yield (Hegde and Dwivedi, 1993; Mohammed *et al.*, 2018).

Combined use of vermicompost and inorganic fertilizer

The use of vermicompost in improving the soil conditions and increasing the crop yield and crop quality is now fairly

accepted as a general practice in India. Vermi-compost not only helps in improving the soil fertility on a sustainable basis, but it also helps in minimizing the use of chemical fertilizers to the extent of 25 to 50 per cent and increases the crop yield by 15 to 20 per cent due to increased supply of all essential elements (Zende *et al.,* 1998). The author further stated that the application of vermicompost at 5 to 10 tons per hectare, increased the juice quality and magnitude. Several authors (Kachapur *et al.*, 2001; Shanward *et al.*, 2001) have reported the utilization of vermicompost as an organic manure.

According to Kachapur *et al.* (2001), vermicompost use in crop production is gaining importance due to yield benefits and it improves the soil physical and chemical properties. The author also observed that variations in plant height of kharif sorghum due to levels of vermin compost were mostly non-significant though there was higher plant height with higher levels of Vermicompost. At the same time, they also observed that variation in days to 50 per cent flowering due to levels of vermicompost indicated that no specific trend and the variations were mostly non-significant. According to Ramadass and Palaniyandi (2007), increased ability to production and soil fertility resulted in the compost supplemented with chemical fertilizers in the field the ability to access the elements of high consumption caused by the products.

Combined use of animal manure and inorganic fertilizer

Inorganic fertilizers are considered as an important source of major elements in crop production. The deficiency of micro nutrients, imbalance in soil physicochemical properties and unsustainable crop production were caused by continuous use of inorganic fertilizer (Jeyathilake *et al.*, 2006). To ensure soil productivity, plants must have an adequate and balanced supply of nutrients which will be realized through integrated nutrient management where both natural and man-made sources of plant nutrients are used (Gruhn *et al.,* 2000). Combining inorganic and organic fertilizers result in greater benefits than either one input alone through positive interactions on soil biological, chemical and physical properties (Bekunda *et al.,* 2010). Drechsel *et al.* (2001) reported that the application of recommended mineral fertilizers does not improve the negative nutrient balance relates to the upper nutrient removal from the soils. Many researches recommend is that integrated soil amendment practices are crucial to notice greater crop productivity induced by the utilization of mineral fertilizers and it does not translate into better soil fertility in the future when large amounts of carbon and nutrients are loosed every season from the fields with the crop harvests residue (Bekunda *et al.,* 2010). Therefore, the use of integrated nutrient management is very significant and best approach to uphold and advance soil fertility thereby to increase crop productivity in an effectual and environmentally friendly manner without sacrificing soil productivity of future generations.

Integration of inorganic NPS and cattle manure depicted an increase in tuber yield of potato. This could be due to balanced C/N ratio, more organic matter builds up, enhanced microbial activity, improvement in soil properties, better root proliferation, sustainable availability and accelerated transport and higher concentration of plant nutrients. All these may need accelerated metabolic activities, resulting in better photosynthesis and efficient translocation of photosynthesis from source to sink (Ouda and Mohadeen, 2008). Under Ethiopian condition particularly within the highlands, integrated soil fertility management will give better yields as high as balanced application of fertilizer and significantly higher yields than the normal cultivation method. To recover the soil to its productive state it was not enough to apply mineral fertilizer alone, therefore integrated nutrient management was considered for the area (Zelalem, 2014). The combined use of organic manure and inorganic fertilizers helps to maintain soil health and sustain productivity especially in heavy feeder crop like potato (Dayegamiye, 2009).

Isreal *et al.* (2018) stated that increasing the application of cattle manure increased total nitrogen in the soil, also averted loss of mineral nitrogen into the environment. The total nitrogen content of soil improved by 48% when the application of 55kg ha^{-1} and 20 t ha^{-1} mineral NP fertilizers combines with 14 t ha^{-1} cattle manure (Girma *et al.*, 2017); the total nitrogen content in the soil improved by 67 % when the application of cattle manure at 30 t ha^{-1} + Nitrogen at 120 kg ha^{-1} + 92 kg P_2O_5 ha^{-1} as compared to zero application of mineral and cattle manure (Biruk *et al.*, 2015).

The availability of phosphorus in the soil increased due to increased application cattle manure (Balemi, 2012; Isreal *et al.*, 2018). Likewise, the application of 5 t ha^{-1} cattle manure with 120:60:40 NPK kg ha^{-1} boosted P availability as compared to sole application of mineral fertilizer (Kesarwani, 2017). Increase the addition of cattle manures in the soil can minimize the soluble exchangeable Al which, in turn, reduces exchangeable acidity (Narambuye and Haynes, 2006; Isreal *et al.*, 2018). The application of increase organic manure with inorganic fertilizer is a means for improving soil aggregation, structure and fertility causes the improvement in cation exchange capacity of soil (Tolanur, 2002).

Combined use of biofertilizer and inorganic fertilizer

Inorganic fertilizer is the main source of nutrients use for potato cropping. However, continuous application of Inorganic fertilizer causes nutritional imbalance and adverse effects on physico-chemical and biological properties of soil. On the other hand, the price of inorganic fertilizers has increased to an extent that those are out of reach of the small and marginal farmers. So, it has become difficult for farmers to apply such expensive inputs for a crop of marginal returns. Integrated application of half of the recommended dose of fertilizer + biofertilizer could produce more or less the same economic yields, besides a saving of half of the recommended dose of N and P (Kumar *et al.*, 2010). Thus, the integrated nutrient management could be a key factor for producing and maintain high level of tuber yield in sustain

manner. A combined application of biofertilizer and inorganic sources of nutrients is important to maintain soil health and improve nutrient efficiency and organic manure application with chemical fertilizer could maintain soil nutrient balance, enhance nutrient availability, improve soil chemical and physical properties, increase soil organic matter, reducing fertilizer both enhanced C storage in soils and decrease emissions from N fertilizer.

Soil fertility management

Declining soil fertility in Sub Saharan Africa is seen as an important factor in the international debate about African food security, poverty and environmental degradation (Lay *et al*., 2002). One of the most difficult problems facing the horticultural crop production is how to maintain the fertility of the soil. It is mostly associated with decline in soil organic matter, with loss of soil structure, lower water infiltration, soil compaction and increasing erodibility and leaching, leading to a decrease in nutrient holding capacities and a poorer environment for faunal activities. Inorganic fertilizers on the other hand, supply only nutrients and exert no beneficial effects on the soil's physical condition (Mathew and Karikari, 1990).

Moreover, the continuous and unbalanced use of inorganic nutrients from the chemical fertilizers under intensive cropping system has been considered the main cause for stagnating or declining crop productivity. Under such situation, it has been assumed by many that the integrated plant nutrition system would be a reliable approach to manage the soil fertility and to supply plant nutrients in a sustainable basis. Integrated use of various soil fertility amendment inputs aims at alleviating the limiting nutrients problems and improving their availability from soil reserves (Muriithi and Irungu, 2004).

There are several options for restoring and maintaining soil fertility. The option includes application of inorganic fertilizers to offset the nutrients removed by the crops, recycling part of the nutrients through use of manures or leave the crop residues in the field to decompose and offset soil organic matter losses, as the amounts applied are insufficient to meet crop demands. Crop residues and animal manures cannot meet crop nutrients demand over large areas because of the limited quantities available, the low nutrients content and the high labour demands for processing and application (Palm *et al*., 1997). Several literature evidences indicate that organic and inorganic fertilizers work best when they are used together. In western Oromia, nutrient input sources depend not only on yield gains but also on market conditions as underscored. Sustainable cropping system and yield increment can be achieved by the level of soil organic matter and quantity of fertilizer that used.

CONCLUSION

Potato belongs to the family Solanaceae and is a major source of high level of carbohydrate and significant amount of vitamin b, c and minerals and protein content. However, low soil fertility is the major constraints or limiting factor that lack potato production and productivity. The excessive use of mineral fertilizers has also caused adverse effect on soil nutrient balances and, thus reduced potato growth performance. This further justifies the need to use organic fertilizers. Animal manure is commonly used on high value commodities such as potato and other commodities. Application of integrated use of farmyard manure along with recommended dose of fertilizer is superior in yield and performance of potato than the application of only recommended rate of inorganic fertilizer. Hence, it would be reasonable to point out that integrating farm yard manure or vermicompost along with little inorganic fertilizer, not only obtained significantly higher tuber yield but also, improved the fertility status of the soil and could save 25 to 50 percent chemical fertilizer. The effects of combined fertilizer application on growth yield and its attributing characters and, nutrient status of soil and content in potato with various combinations of vermin compost, farm yard manure and inorganic fertilizer increases its productivity. The growth attributes of potato are influenced by the application of organic manure and inorganic fertilizer.

FUTURE PROSPECTIVE

Potato is a major source of high level of carbohydrate and significant amount of vitamin B, C and minerals. It has the highest protein content (around 2.1% on a fresh weight basis) in the family of root and tuber crop and protein of a fairly high quality with an amino acid pattern that is well harmonized to human requirements. However, low soil fertility is one of the most important constraints limiting potato production. The excessive use of mineral fertilizers only has also caused adverse effect on soil nutrient balances and, thus reduced potato growth performance. To solve this problem-integrated nutrient management is highly preferable to improve yield and environment pollution. Therefore, scaling up of combined fertilizer application practices on farmers field and further research in the amount applied per unit of land that have different soil properties is very important.

Conflict of interest: None.

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