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SOIL & CROP SCIENCES | REVIEW ARTICLE

Effects of nitrogen and phosphorus on potatoes production in Ethiopia: A review

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Abstract: Nitrogen and phosphorus are essential nutrients for all living organisms. They are critical determinants of plant growth and productivity. Hence, plants require these elements relatively in large amount. Despite the fact that, due to serious land degradation problem availability of those nutrients are depleted and the problem is common in the highland areas of Ethiopia. This paper is a review on application of inorganic fertilizer (nitrogen and phosphorus) for maximization of potato yield. Different researches conducted in the country shows that potato yield is declined due to an inadequate application of nutrient especially nitrogen and phosphorus fertilizers are the most limiting factors. Increasing application of nitrogen and phosphorus can maximize the yield and yield component of potato throughout the country. However, most farmers of the country have understood the importance of fertilizers, but due to different reasons they are not applying the fertilizers as recommendation. Lack of credit availability, high cost of fertilizer and lack of awareness on the use of organic fertilizer are the most limiting factors that affect the use of fertilizer. To feed the ever-increasing population of the country use of fertilizer is not an unsparing concern. Therefore, the application of fertilizer is one of the only means to maximize the production of potato for smallholder farmers to make their food security sustainable.

Subjects: Agriculture & Environmental Sciences; Soil Sciences; Earth Sciences

Keywords: nitrogen; phosphorus; potatoes; tuber yield; growth

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PUBLIC INTEREST STATEMENT

Potato is one of the most important vegetable cash crops grown in highland areas of Ethiopia. It is grown by irrigation season and main rainy season. It plays a great role in improving food security of small-holder farmers. It is rich in vitamin C, a good source of vitamins B1, B2 and B6 and minerals such as potassium, phosphorous and magnesium, and a good source of high-quality protein. Despite the abovementioned importance of the crop, the production and productivity of potato is around 8–10 t ha^{-1}. Lack of appropriate agronomic practices and degradation of natural resource are the major problems that influence the production and productivity of potato. Hence, the use of appropriate agronomic practices and management of natural resource are inevitable to boost the production and productivity of the specific commodity.

1. Introduction

Potato (*Solanum tuberosum* L.) is a crop of the world's major economic importance and number one non-grain food commodity (Rykaczewska, 2013). It contains practically all essential dietary constituents like carbohydrates, essential nutrients, protein, vitamins, and minerals (Sriom et al., 2017). Even though the productivity of potato could reach up to 30 t ha^{-1} attainable yield (Haverkort et al., 2012), its productivity in Ethiopia is very low which is below 11.88 t/ha (CSA, 2016). There are many complicated reasons for this low actual yield of potato in the country. Soil fertility, lack of good quality seed, unbalanced mineral nutrition, inadequate application of fertilizers, pests and disease, irregularity of water supply and traditional irrigation schemes and schedules are the main reason which accounts for the low productivity of potato (Bezabih & Mengistu, 2011). Plants require a variety of elements for the growth and development of which N and P are the most important of the essential nutrients to plants because they are required in large quantities. Potato is a high yielding and exhaustive crop, thus requiring a variety of balanced plant nutrients for growth and development. Nitrogen (N), Phosphorus (P) and Potassium (K) are among the most important elements that are essential for potato productivity (Pervez, Ayyub, Shaheen, & Noor, 2013). A good supply of nitrogen stimulates root growth and development as well as the uptake of other nutrients (Brady. & Weil, 2008). Adequate phosphorus nutrition enhances many aspects of plant physiology, including the fundamental processes of photosynthesis, root growth particularly the development of lateral roots and fibrous rootlets (Brady. & Weil, 2008).

2. Effect of nitrogen and phosphorus on the growth and yield of potato

2.1. Role of nitrogen on growth of plants

Nitrogen (N) is the motor of plant growth. It makes up 1–4% of dry matter of the plant. It is taken up from the soil in the form of nitrate (NO_3^-) or ammonium (NH_4^+). In the plant, it combines with compounds produced by carbohydrate metabolism to form amino acids and proteins. Being the essential constituent of proteins, it is involved in all the major processes of plant development and yield formation. A good supply of nitrogen for the plant is also important for the uptake of the other nutrients (Bell, 2016).

2.2. Effects of nitrogen on growth of potato

There are many investigations with respect to the effects of nitrogen and phosphorus fertilization on the productivity of different crops. However, the scope of this review is focused on the effects of nitrogen and phosphorus fertilizer on potato production.

Firew, Nigussie, and Wassu (2016) conduct an experiment to know the effects of nitrogen and phosphorus on growth and yield of potato using Babu Potato variety. The authors applied four rates of nitrogen (0, 56, 112 and 168 Kg N ha^{-1}) and four rates of phosphorus (0, 46, 92 and 138 Kg P_2O_5 ha^{-1}) and observed that plant height increase with increasing of nitrogen level up to 168 kg ha^{-1}. Maximum (88.67 cm) plant height was recorded at a rate of 168 kg ha^{-1}. Likewise, Alemayehu, Nigussie, and Tamado (2015) conducted an experiment during the rainy season of 2012 to ascertain the effect of nitrogen and plant density on yield and yield components of potato using Babu variety and confirmed that application of 110 kg ha^{-1} increases the plant height by 12 cm over the control treatment. Here, the experiments are conducted in the eastern part of the country and the result of experiments indicates that there is a difference in nitrogen and phosphorus response. Hence, Firew et al. (2016) had conducted under irrigation condition whereas, Alemayehu et al. (2015) had conducted the experiment in the rainy season. This different response in the same variety of Babu is might be that of nitrogen availability is influenced by soil moisture, soil texture, soil aeration, soil temperature and salt content of the soil. Similarly, Israel, Ali, and Solomon (2016) conducted an experiment in Acrisols with potato variety of Jalene in Southwestern Ethiopia with four nitrogen rates of 0, 55, 110 and 165 kg ha^{-1} and four phosphorus rates of 0, 20, 40 and 60 kg ha^{-1}. The authors confirmed that increasing rate of nitrogen increases the plant height by around 16 cm over control treatment. Similarly, Fayera (2017) also conducted an experiment in west Oromiya Region of Ethiopia to determine the influence of N-fertilizer application rate and plant density on the yield and yield

components of Potato. He reported that the obtained result as the application of nitrogen fertilizer has a significant effect on plant height. They also found that increasing the N-fertilizer application at a rate from 0 to 150 kg ha^{-1} increases by 38.58 cm over control treatment. Similarly, an experiment conducted by Zelalem, And, and Nigussie (2009) in vertisol of central highland areas of Debre-birhan with Gorebella potato variety, confirms that nitrogen at a rate of 207 kg ha^{-1} increases plant height by 24 cm. This is due to the fact that increased concentration of nitrogen fertilizer can increases the nitrogen uptake. This increment has a positive effect on the chlorophyll concentration the photosynthetic rates the leaf expansion the total number of leave and the dry matter accumulation. Consequently, nitrogen fertilizer plays an important role in canopy development especially on the shoots` dry matter, the LAI and the plant height (Najm, Hadi, Fazeli, Darzi, & Shamorady, 2010).

2.3. Effects of nitrogen on the yield of potato

Different experiments have shown that yield and yield component of potato tubers has increased with increasing nitrogen application. Fayera (2017) confirmed that increasing rate of nitrogen increase average tuber weight $plant^{-1}$, marketable tuber weight, unmarketable tuber weight, total tuber yield $plot^{-1}$, yield, tuber number $plant^{-1}$ and small tuber size. The effects of different rate of nitrogen and phosphorus fertilizer on yield and yield component of potato trial had conducted at Masha district in southwestern Ethiopia, during 2010/2011 main cropping season. The results obtained showed that nitrogen rate increases the total tuber number, marketable total number, total tuber yield, marketable tuber yield and average tuber weight with increasing nitrogen up to 165 kg ha^{-1}. Alemayehu et al. (2015) reported that total marketable and unmarketable tuber yields were increased by an application of nitrogen at a rate of 110 kg ha^{-1} but, increasing the rate of nitrogen beyond 110 kg ha^{-1} has not statistically significant increment on the tuber yields. Research conducted by Birtukan (2016) in southwestern Ethiopia shows that nitrogen application at a rate of 110 kg ha^{-1} and 165 kg ha^{-1} gave the highest marketable total yield with statistically nonsignificant manner. In contrary, Desalegn, Wakene, Dawit, and Tolessa (2016) conduct an experiment to know the effects of nitrogen and phosphorus fertilizer levels on yield and yield components of potato in Bule Hora district of southern Ethiopia. They reported that increasing rate of nitrogen application decreases the tuber yield of potato.

2.4. Role of phosphorus on the growth of plants

Phosphorus is claimed to be the second most often limiting plant nutrient. It is an essential component of deoxyribonucleic acid (DNA), the seat of genetic inheritance, and of ribonucleic acid (RNA), which directs protein synthesis in both plants and animals. Phospholipids, which play critical roles in cellular membranes, are another class of universally important phosphorus-containing compounds. Thus, phosphorus is essential for the general health and vigor of all plants. Some specific growth factors that have been associated with phosphorus are: Stimulated root development, Increased stalk and stem strength, Improved flower formation and seed production, More uniform and earlier crop maturity, Increased N-fixing capacity of legumes, Improvements in crop quality, Increased resistance to plant diseases and Supports development throughout entire life cycle of the plants (Mosaic, 2016).

2.5. Effects of phosphorus on the growth of potato

Many authors reported that phosphorous had a significant effect on the yield of potato. An experiment conducted by Firew et al. (2016) in eastern Ethiopia confirms that the application of phosphorus from 0 to 138 kg ha^{-1} increased the height of potato plants from 34.00 to 64.00 cm. Similarly, Girma, Abebe, and Zeleke (2017) conducted an experiment to know the effect of phosphorus and plant spacing for potato production using Belete variety in Nitosol of central highlands of Ethiopia, shows that an increasing the application of phosphorus fertilizer at rate from 0 to 115 kg ha^{-1} increases the plant height of Potato by 32.78 cm over control treatment. In a similar way experiment conducted at Assosa, in Nitosol of western Ethiopia by Habtam (2012) also indicated as phosphorus fertilizer application rate affects the height of potato. Among the phosphorus treatment rates 138 kg, ha^{-1} increases the height of Potato by 27% over control

treatment. There is a different phosphorus response in the same soil type of Nitosol, in a different location of the country. Habtam (2012) was conducted in Nitosol of western Ethiopia with the potato variety of Gudene whereas Girma et al. (2017) have conducted an experiment in Nitosol of central highlands of Ethiopia with variety Belete. This is due to the fact that nutrient availability depends on internal or genetic and external factors. The morphological characteristics of plants, the ratios of their shoots and roots and also the characteristics of their root development affect the nutrient availability of the crop. In contrary, research done in Gudene potato variety by Niguse (2016) in Tigray, Ethiopia shows that application of phosphorus has no significant effect on plant growth of potato.

2.6. Effects of phosphorus on the yield of potato

An experiment conducted in Nitosol of Assosa western Ethiopia to ascertain the response of nitrogen and potassium on the yield of potato shows that application of nitrogen with increasing rate increases the marketable and total tuber yield of potato. The highest yield was recorded with an application of nitrogen at a rate of 230 kg ha^{-1}. The marketable yield has increased by 34% on the control treatment. Birtukan (2016) confirmed that Phosphorus fertilization significantly increased the marketable tuber yield. Increasing application of phosphorus has increased marketable tuber yield per hectare. Maximum tuber yield was recorded at a rate of 135 kg ha^{-1} with 98% yield advantage over control treatment. Similarly, Niguse (2016) has conducted an experiment in Tigray, Ethiopia shows that application of phosphorus at a rate of 89.50 kg ha^{-1} had highest marketable and total tuber yield. Girma et al. (2017) indicated that as phosphorus rate increases the total tuber numbers, marketable tuber numbers and average tuber weight were highly increased mainly due to high responsive of potato as compared to other tuber crops. An experiment conducted by Desalegn et al. (2016) showed that the increasing rate of phosphorus increases the marketable and total tuber yield of potato. The highest marketable tuber yield was recorded at a rate of 90 kg ha^{-1} and 135 kg ha^{-1}. Application of phosphorus has positive effect on potato yield. This might be phosphorus performs functions in plants, such as a structural element forming part of the macromolecular structures such as nucleic acids (RNA and DNA) and in the phospholipids of cell membranes (Marschner, 2002).

2.7. Effects of nitrogen and phosphorus on the growth of potato

Different researchers have reported that nitrogen and phosphorus had positive effects on the growth parameter of potato. The research was done by Israel et al. (2016) in South Western Ethiopia confirmed that the highest plant height was recorded at the combined application of N and P_2O_5 which was significantly increased by 51% over the control treatment. The similar result reported by Birtukan (2016) which were done in southwest Ethiopia shows that the combined effect of nitrogen and phosphorus had a significant effect on the growth of potato. The author indicates that application of nitrogen and phosphorus at a rate of 165 kg ha^{-1} of nitrogen and 110 kg ha^{-1} of phosphorus, respectively increases the plant height significantly by 63% over control treatment. Firew et al. (2016) confirmed that the highest plant height was recorded from combined application of nitrogen and phosphorus at a rate of 168 kg ha^{-1} of N and 138 kg ha^{-} of P_2O_5.

2.8. Effects of nitrogen and phosphorus on the yield of potato

Different investigators have been reported that combined application of nitrogen and phosphorus had a significant effect on the yield of potato. Effects of nitrogen and phosphorus on yield and yield component of potato conducted in southeastern Ethiopia by Israel, Ali, and Solomon (2012) shows that highest marketable yield (35 t ha^{-1}) was recorded with the application of 165 kg ha^{-1} of nitrogen is combined with phosphorus at rate 60 kg ha^{-1}. Similarly, Birtukan (2016) reported that the interaction of nitrogen and phosphorus was significantly affected the marketable tuber yield per hectare. The author observed that the highest marketable yield (36.13 t ha^{-1}) was recorded with combined application of nitrogen at a rate of 165 kg ha^{-1} and phosphorous at a rate of 135 kg ha^{-1}. The marketable yield has increased by 88% with an increasing rate of nitrogen and phosphorus. Firew et al. (2016) and his colleague undertaken an experiment in eastern Ethiopia to

determine the effect of nitrogen and phosphorus on yield and yield components of potato under irrigation condition. The result confirmed that an application of nitrogen and phosphorus influences the yield of potato. However, the authors observed that application of nitrogen beyond 56 kg ha^{-1} reduces the yield of potato. The highest tuber yield was recorded at a rate of 56 kg ha^{-1} of nitrogen and 138 kg ha^{-1} of phosphorus. Similarly, Wubengeda, Kassu, Tilahun, Yonase, and Dawit (2016) and his colleagues also conducted an experiment in Oromiya Region of Arsi zone to determine optimal irrigation regime and NP fertilizer rate for potato. They reported that the obtained results as the application of nitrogen and phosphorus increase the yield of potato. According to them, the highest tuber yield (31.80 t ha^{-1}) was recorded from application of nitrogen and phosphorus at a rate of 244 kg ha^{-1} of DAP and 206 kg ha^{-1} of urea. Desalegn et al. (2016) studied the effects of nitrogen and phosphorus fertilizer levels on yield and yield components of potato at Bule Hora district, southern Ethiopia and reported that application of nitrogen and phosphorus had significantly influenced the yield of potato. The highest yield was recorded from the combined rate of nitrogen and phosphorus 50/135 kg ha^{-1} in a respective manner which maximizes the yield of potato by 361% over the control treatment.

Nitrogen supply plays a major role in the growth and development of plants as well as yield because it is an essential constituent of protein and chlorophyll. Among fertilizers, nitrogen is first the most important nutrient. Nitrogen is essential for maintaining higher haulm growth, increased bulking rate, quality of tuber and more dry matter production (Sandhu, Sharma, Bhutani, & Khurana, 2014).

3. Conclusion

Potato is one of the most widely cultivated vegetable crops in the highlands of Ethiopia. Yield and productivity of potato are far below the world national average yield. Among different factors, soil fertility and nutrient management are the key factors affecting crop productivity and soil nutrient depletion. To enhance the productivity of potato soil fertility management has to be the primary role of the producers. Different experiments conducted in Ethiopia show that application of nutrient has a positive relation to producing a higher yield of potato. The experiments confirmed that adequate application of nitrogen and phosphorus increases the production of potato. Therefore, application of adequate nutrient is the only option to maximize production and productivity of potato.

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Competing interests
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