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A review on influence of nitrogen and phosphorus on growth and yield of potato

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Abstract
Nitrogen (N) and phosphorus (P) are playing a vital role in several growth attributes of plants, hence they are essentially required in large quantities. However, N and P are present in the soil in limited amounts. Therefore, extraneous application of N and P usually boost potato yield, considering their application dose because higher or lower application rate may exert a negative impact on different growth parameters of potato and hence on overall potato tuber yield. It has been observed that although most of the farmers in the country recognize the application of chemical fertilizers in potato cultivation, they do not use them at their recommended doses due to limited credit supply, high fertilizer cost, lack of knowledge about the use of organic fertilizer etc. Besides, excessive use of fertilizers, mono-cropping, continuous cropping, and abandoning the following system, reduced use of manure and crop rotation may lead to land degradation, poor growth, tuber yield, and quality potato. However, the use of fertilizer is an inevitable concern to meet the present-day food crisis of the ever-increasing population in the world. Therefore fertilizers at their recommended dose areas essential to increase potato yield and ensure long-term food security. In this review an attempt has been made to describe and analyze the trends in current research on nutrient management practices, especially considering N and P, to improve and sustain potato tuber yield.

Keywords: Nitrogen, phosphorus, potatoes, monocropping, tuber yield

1. Introduction
Potato (*Solanum tuberosum* L.) is the world's most important and the number one non-grain food crop (Rykaczewska, 2013) [45], grown in over 164 countries. It is a vital source of nutrients for human populations and is taken almost daily by over a billion people fresh or refined (FAOSTAT, 2017) [15]. To keep pace with the ever-increasing human population, potato yield must be increased. However, it should be kept in mind that soil, variety, environmental factors, and agronomic practices including nutrient management influence potato yield and quality. Among all factors influencing potato yield, fertilizer application is considered a major one (Westermann 2005) [56]. Potato yield and fertiliser application are significantly associated, and the use of the required fertilisers can significantly improve the quality and yield of potatoes (Srek *et al.* 2010) [50]. In general, potatoes require several elements for their growth and development, the most important of which are N and P which are needed in large quantities. N fertilization plays a crucial role in the vegetative and reproductive development phase in potatoes, while P involves in various biochemical and physiological processes, enhances tuber production and improves potato quality (Brady and Weil, 2008) [6].

2. The effects of nitrogen and phosphorus on potato growth and yield
2.1 Nitrogen's importance in plant growth
Nitrogen (N) is a growth stimulant for plants. It makes up around 1–4% of the plant's dry matter. Plants will absorb nitrogen in the form of nitrate (NO_3^{-1}) or ammonium (NH_4^+). Amino acids and proteins are generated when it reacts with compounds produced by carbohydrate metabolism in plants. As an integral component of proteins, it participates in all of the main biochemical and physiological processes for crop growth and yield. (Bell,2016) Nitrogen is also needed for the plant's absorption of other nutrients.

2.2 Nitrogen's effect on the growth of potatoes
Nitrogen is an essential component of protein and chlorophyll, so its availability is critical to plant growth and yield. The most important nutrient in fertilizer is nitrogen. Nitrogen is

required to maintain higher dry matter production, tuber quality,b ulking rate, and haulm growth. (Sandhu *et al*., 2014) [48]. Zewide *et al*. (2012) [58] experimented that applying 165 kg N/ha increased the dry weight of the shoots from nearly 52-72 g/hill. When compared to the control treatment, they found that N increased shoot dry weight to about 37%. This is due to the positive impact of N on photosynthetic rate, leaf expansion, total number of leaves, and dry matter production are all variables to consider. N triggers vegetative growth development. As a result, N fertilizer is crucial in canopy growth, especially in terms of shoot dry matter (Najm *et al.*, 2012). The higher nitrogen content can be attributed to increased root proliferation due to nitrogen's effect on cellular activities and the translocation of some growth-stimulating compounds to roots, resulting in improved tuber growth and nutrient absorption (Sharma and Sood, 2002) [49].

2.3 Influence of nitrogen on yield of potato

Zewide *et al*. (2012) [58] performed experiments on N application at various levels and reported that increasing nitrogen application rates resulted in an increase in tuber yield from 23.75 to 38 tons/ha. At a dosage of 165 kg/ha, the maximum yield was achieved. Increased nitrogen application increased the total tuber number per hill from about 10-12, which might be attributed to the potato plant's increased vegetative growth. This result confirmed other researcher's findings (Reddy and Rao, 1968 [46]; (Hanley *et al*., 1965; Zabihi-e-Mahmoodabad *et al*., 2010) [22], Herlihy and Carroll, 1969; and Knutson, 1965; Hanley *et al*., 1965; Zabihi-e-Mahmoodabad *et al*., 2010) [23, 22]. With an increase in added nitrogen, the number of marketable tubers increased, but the number of small tubers decreased. This finding was consistent with Hanley *et al.*, (1965) [22], who reported from their 3-years study that N application increased the number of tubers per hill. Several experiments have shown that nitrogen application significantly impacts potato tuber yield and yield attributing characters (Fayera, 2017). The effects of nitrogen fertiliser on canopy growth, particularly shoot dry matter, Leaf area index, and plant height, are important. (Shamorady, Hadi, Fazeli, Darzi, & Najm, 2010) [34]. Zamil *et al*. (2010) [57] and Guler (2009) [18] also reported that nitrogen dosage 300 and 254 kg nitrogen per ha applied respectively, the maximum tuber yield was obtained. When nitrogen fertilizer was applied at a rate of 200 kg ha-1, Nizamuddin *et al*. (2003) [35] observed the highest tuber yield. They also found a drop in tuber yield when N was applied at higher rates than recommended. When nitrogen was applied at a rate of 110 kg/ha, overall tuber yields increased; however, no statistically significant increase in tuber yields was observed with further increase in N application (Getie *et al.*, 2015) [16]. Under potato-based intercropping systems, nitrogen application increased the number of shoots and tubers per hill by up to 75 kg ha-1, while plant height, LAI, the yield of A and B grade tubers, and seed yield increased by up to 150 kg N ha-1, the tuber yield (15.5-26.9 t ha-1) and tuber equivalent yield (20.8-35.8 t ha-1) showed a perceptible increase with successive increases in N level up to 150 kg N ha-1 at Newdelhi Rana *et al*2019. Among the nitrogen levels, 150 kg N ha-1 produced substantially more potato tuber yield (15.2 t ha-1) than the other treatments. The lowest tuber yield (11.0 t ha-1) was observed with a N application of 50 kg ha-1. For 150 Kg N ha-1 and 100 Kg N ha-1, respectively, yields increased by 38.5 percent and 18.5 percent over 50 Kg ha-1.. When enough irrigation water was applied, a higher rate of N nutrition was needed to increase yields (Thompson *et al*., 2000 and Rajasekaran, 2007) [53, 42]. Increases in nitrogen levels from 50 to 150 kg ha-1 resulted in a substantial rise in starch content. The highest starch content (64.6%) was reported when 150 kg N ha-1 was applied, and it was found to be superior to the other nitrogen levels. The rate of photosynthesis, the translocation of photosynthates from leaves to tubers, and eventual conversion to starch both influence the amount of starch accumulated (Praveen *et al*., 2008) [39]. (Uday bhaskar 2010) conducted trail at the nitrogen levels, applying 150 kg N ha-1 resulted in a substantially higher potato tuber yield (15.2 t ha-1) than the other treatments. The lowest tuber yield (11.0 t ha-1) was achieved when N was applied at a rate of 50 kg ha-1. Over 50 Kg ha-1, yield increased by 38.5 percent and 18.5 percent with 150 Kg N ha-1 and 100 Kg N ha-1, respectively. When sufficient quantities of irrigation water were applied, a higher rate of N nutrition was required to maximise yields (Thompson *et al*., 2000 and Rajasekaran, 2007) [53, 42].

2.4 Importance of phosphorus on growth of plants

P is also essential to crop and vegetable physiology. It is a part of nucleic acids, nucleotides, phospholipids, phosphoproteins, coenzymes and phosphorylated sugars and plays a role in cellular energy transfer, photosynthesis, and respiration (Marschner, 1996; Plaxton and Carswell,1999; Havlin *et al*., 2016) [20]; Hopkins *et al*., 2018;) [29, 38]. The most crucial functions of P in plants are energy storage and its transport (Hopkins *et al.*, 2018; Bruulsema *et al.*, 2019) [2]. The abundant P concentration in the plant can form and produce sufficient quantities of adenosine triphosphate (ATP) and adenosine diphosphate (ADP), which are involved in energy-converting processes (Rosen *et al*., 2014 [44]; (Havlin *et al.*, 2016) [20]; Hopkins *et al.*, 2018). Phosphorus is also essential for all plants' overall health and vigour. Root growth is stimulated, stalk and stem strength is increased, flower formation and seed production is improved, crop maturity is more uniform and earlier, legume N-fixing ability is increased, crop quality is improved, plant disease tolerance is increased, and development is promoted over the entire life cycle of the plant are some of the specific growth factors that have been associated with phosphorus (Mosaic, 2016) [33]. In most soils, P is the second most essential macronutrient that limits plant growth after nitrogen.

2.5 Influence of phosphorus on growth of potato

P is strongly associated with increased root development. It was evidenced that a significantly widespread of roots occurred with an increase in $H_2PO_4^{-1}$ levels in the soil (Balemi 2009, Hailu, *et al*., 2017) [4, 24]. As a result of roots proliferation, more soil is accessible to plants for their water and nutrient requirements. Thus, with adequate P supply, yield efficiency and disease tolerance to plants are improved (Rosen *et al.*, 2014, Fernandes *et al.*, 2017) [44, 12]. A decline in photosynthesis in phosphorus-deficient plants was demonstrated in several reports (Brooks 1986; Fredeen *et al*., 1989; Passarinho *et al*., 2000; Fujita *et al*., 2004) [5, 13, 37, 14]. This is affected by the decrease in The reduced photosynthesis rate per unit leaf area exerted an adverse effect on the Net Assimilation Rate (NAR) and in turn, the rate of plant growth. According to several studies, the most important factor influencing biomass accumulation is light interception which is usually associated with varying P supply (Lynch *et al*., 1991; Colomb *et al*., 2000; Rodriguez *et al*., 1998; Plenet *et al*., 2000) [28, 8, 47].

2.6 Influence of phosphorus on yield of potato

Increased P application aided the development of roots, especially lateral and fibrous rootlets. In the young cells of root tips, large amounts of P are also needed. where there is a high rate of cell division and root growth, according to Brady and Weil (2002). P application increased the number of potato tubers set per unit (Knutson, 1965; Sparrow *et al*., 1993) [52]. They found an 8.19% increase in the total tuber number in comparison to the control, when P was applied at a rate of 60 kg/ha P fertilisation increased the marketable tuber yield, Birtukan (2016) [1]. Increased phosphorus use resulted in a higher per-hectare marketable tuber yield. At a 98 percent return benefit over control treatment, maximum tuber yield was estimated to be 135 kg/ha. Previously, it was shown that soaking seed tubers in P solutions before planting increased tuber yield and P uptake (Grewal and Trehan, 1993). Soaking seed tubers were very successful in meeting part or even all of the crop's P needs, depending on the soil's availability. There is increase in tuber/m2 in the small grade and decreases in broad grade but won't affect the medium grade tubers with increase in phosphorus application. Sharma U.C.*et al* (l987) [51]. Rosen *et al*. (2008) [43] conducted experiments on various P concentrations (25-33 mg/kg soil) and suggested that increased P fertilizer application increased overall tuber yield; however, decreased the yield of big tubers, indicating an important role of P nutrition in tuber set regulation. Hahlin 1992 conducted a trial at three application rates of P fertilizer that were measured for potatoes on loamy soils at 0, 45, and 90 kg P/ha. The yield increased from 29.05 to 30.00 tonnes per hectare as application rates were increased from 45 to 90 kg P/ha. The author came to the conclusion that the optimal potato application rate was more likely higher than 90 kg P/ha than lower, and that the current recommendations were appropriate.

2.7 influence of phosphorus and nitrogen on yield and growth of potato

The combined application of N and P fertilizer showed good yield responses across different locations of low N and P status of the soils (Webb. P *et.al*, 1994) [55]. In a study conducted on the response of potatoes to different fertilizer levels in a rain-fed highland situation at Deber Berhan, According to Zelalem *et al*. (2009) [60], the highest tuber yield was achieved by applying 207 kg N/ha and 90 kg P/ha.They also found that higher levels of N and P fertilization had a substantial impact on potato root dry weight. Besides the total tuber number, the effect of N and P on other yield parameters including marketable tuber number and total tuber yield was found to be highly significant. The addition of phosphorus to the soil improves potato production. This may be because phosphorus serves a multifunctional role in plants, being a component of macromolecular structures like nucleic acids (RNA and DNA) and phospholipids membranes of cells (Marschner, 2002) [31]. Zewide 2020 [59] demonstrated that different N and P concentrations, as well as their interactions, exhibited a positive and promising effect on potato growth and marketable tuber yield. A combination of (165 kg N ha) and (60 kg P/ha) produced the highest marketable tuber yield. In the Bule Hora district of southern Ethiopia, Desalegn *et al*. (2016) [9] studied the effects of nitrogen and phosphorus fertiliser levels on potato production and yield components, finding that nitrogen and phosphorus fertiliser application had a significant influence on potato yield. In a proportional way, the total nitrogen and phosphorus rates are 50/135 kg ha1produced the maximum yield, which increased the yield of potato by 361%over the control treatment. Zelalem *et al*. (2009) [60] discovered that adding 207 kg N/ha and 60 kg p/ha increased marketable tuber volume by 95.6 percent and 43.5 percent, respectively, as compared to the control. Mulubrhan (2004) [32] also found that adding nitrogen and phosphorus to the soil increased the number of potato tubers per unit area. The relationship between nitrogen and phosphorus was extremely important (*P*< 0.0001) in terms of total tuber yield per hectare. As nitrogen and phosphorus concentrations were steadily raised, total tuber yield increased from 12.91 to 42.27 t ha-1. With a combined application of 165 kg N and 135 kg P ha-1, the maximum overall tuber yield (42.27 t ha1) was achieved, while the lowest value (12.91 t ha1) was obtained with the control (Birtukan 2016) [1]. The starch content in potato significantly increased with different levels of NPK and biofertilizers over control and the maximum starch content (18.66%) was recorded with 100% recommended dose of NPK as basal coupled with Azospirillum and Phosphobacteria inoculation (Mahendran and Chandramani, 1998) [7, 30]. (Ghosh *et al*., 2000)concluded that tuber yield of a potato crop fertilised at the recommended rate (240-89-167 kg NPK ha-1) was substantially higher (67.8%) than that of a potato crop fertilised at a lower rate (120-44.5- 83.5 kg NPK ha-1) and the increase in tuber yield was primarily due to large and medium tubers.

3. Conclusion

Potatoes are one of the staple food in many countries, but productivity and yield are par below the demand of consumption. Major constraints in potato cultivation are soil fertility and nutrient management. Nitrogen and phosphorus are the major key nutrients required for potato cultivation. However, to date, the production of potatoes is not up to the mark due to improper and ineffective use of fertilizer. It should also be

kept in mind that excessive use of inorganic N and P fertilizers may cause ecological contamination such as eutrophication, soil erosion, and land deterioration. Hence, it is necessary to apply N and P to the soil judiciously at a recommended dose to obtain sustainable potato production.

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