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EFFECT OF NUTRIENT OMISSION ON GROWTH AND YIELD OF POTATO (*SOLANUM TUBEROSUM* L.) UNDER RAINFED ECOSYSTEMS OF NORTH EASTERN HILLY REGION, MEGHALAYA

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ABSTRACT: A field experiment was conducted to identify the most limiting nutrients for potato (*Solanum tuberosum* L.) production in Shillong, NEH Region, Meghalaya, India, during 2019-20. The experiment was replicated three times using a factorial randomized complete block design. The study included five nutrient treatments *viz*., control (-NPK), omission of nitrogen (-N), phosphorus (-P), and potassium (-K), recommended NPK (+NPK) and two potato varieties *viz*., K. Girdhari and K. Megha. Results showed that the average potato yield for the nutrient omission treatments were -K (12.67 t ha^{-1}), -P (10.81 t ha^{-1}), -N (7.85 t ha^{-1}), and -NPK (3.53 t ha^{-1}). The recommended NPK treatment resulted in the highest production (16.46 t ha^{-1}) with a net return of ₹160559 ha^{-1} and a B:C ratio of 1.95, indicating its superiority in terms of profitability and sustainability. The agronomic efficiency of nitrogen (AEN), phosphorus (AEP) and potassium (AEK) ranged from 52.17~92.32, 35.97~107.71 and 71.94~215.41 kg yield increase per kg of nutrient applied, respectively. Similarly, the partial factor productivity for nitrogen (PFPN), phosphorus (PFPP), and potassium (PFPK) under the fully fertilized treatment was 117.54, 137.14, and 274.27 kg yield per kg of nutrient input, respectively.

KEYWORDS: Nutrient response, nutrient omission, potato, varieties

INTRODUCTION

Potato (*Solanum tuberosum* L.) is an important food and cash crop in hilly regions of Meghalaya and is widely grown under rainfed conditions. However, Meghalaya's potato production is 1.87 lakh tons from 19,000 hectares with an average productivity of 10 t ha^{-1}, which is lower than the national average of about 23 t ha^{-1} (Kharumnuid *et al*., 2022). In Meghalaya, traditional potato farming often involves using less than the recommended dose of fertilizer, resulting in insufficient nutrients for potato growth and development. Several studies have demonstrated that imbalanced fertilizer use during crop cultivation contributes to low yield and quality, especially when most farmers of Meghalaya ignore nitrogen and potassium (Kadian *et al.,* 2010; Chulet *et al.*, 2017).

Potato a heavy feeder that requires a higher quantity of nitrogen (N), phosphorous (P) and potassium (K) and fertilizers are important sources of these nutrients for potato (Koch *et al*., 2020). Nitrogen supply affects the plant growth (Ahmed *et al.,* 2015), tuber bulking rate and weight (Zebarth and Rosen 2007); phosphorous promotes root

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development, tuber initiation and maturity (Hopkins *et al*., 2014), while potassium affects tuber size, yield and quality of Potato (Trehan *et al*., 2009). Balanced fertilization significantly enhanced potato productivity (Gupta *et al.,* 2004). Numerous field trials have been conducted to estimate the amount of fertilizer required by potatoes in different parts of India (Kumar *et al.*, 2005; Kumar *et al.*, 2011; Kumar *et al.*, 2012) as crop productivity depends on the interaction of nutrients (N × P × K and micronutrients). Estimating the role of each nutrient is one of the biggest challenges for site-specific nutrient management. Nutrient omission can be a simple approach to determining the influence of each nutrient on crop growth and development (Yadav *et al*., 2020).

Furthermore, the omission of nutrients (N/P/K) shows the response of the crop and reduces the growth, yield and quality of potatoes (Singh *et al*., 2020; Yadav *et al*., 2020; Mugo *et al*., 2021). Crop yields in nutrient omission and non-omission areas are related to the soil's inherent nutrient supply and crop response to specific nutrients (Singh *et al*., 2020 and Nagar *et al*., 2023). Fertilizer application recommendations based on local climate, soil, and management approaches can significantly boost potato productivity. However, constant dependence on chemical fertilizers can lead to a nutritional imbalance that affects the soil's physical, chemical and biological properties and increases the cost of potato cultivation (Yadav *et al*., 2020). Therefore, to increase potato productivity, it is necessary to improve the nutrient supply capacity of the soil (N, P, K) and the response of the crop to nutrients. The omission trials have shown that potato production can be improved by developing location-specific nutrient recommendations based on soil nutrient-supplying capacity and crop response (Nagar *et al*., 2023). However, the indigenous nutrient supply capacity of soil in this region and the response of potatoes to nutrient omission were unclear. Based on the above facts, a field trial was conducted to identify the main limiting nutrient of potato.

MATERIALS AND METHODS

Experimental site description

The nutrient omission trials were conducted during the summer season of 2019-2020 (February– July) at the research farm of ICAR-Central Potato Research Institute, Regional Station, Shillong, Meghalaya. Shillong is situated in North Eastern India, at 25°54′ N latitudes and 91°84′ E longitudes, at 1738 m above mean sea level. It has a sub-tropical climate, with an annual rainfall of 2647 mm, of which 63% is from February to July. The maximum temperature ranges from 16 to 25°C and the minimum temperature ranges from 7 to 17°C during both cropping seasons (Fig. 1). Two potato cultivars, K. Girdhari and K. Megha, which are late maturing, good yield potential and resistant to late blight, were used in this experiment.

Nutrient omission trials

The soil is a well-drained sandy loam with pH of 5.12, electrical conductivity of 0.21 dS m^{-1}, organic carbon 1.5%, and soil

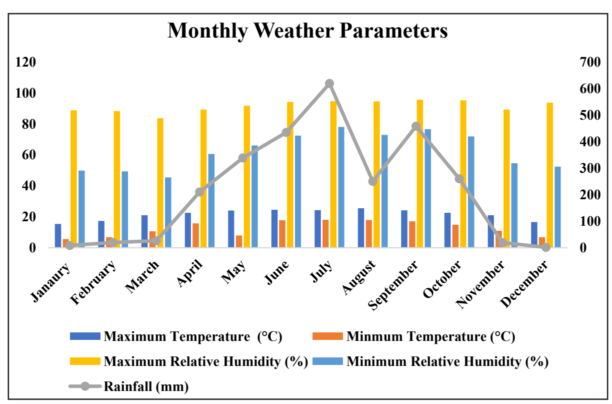

Fig. 1. Average monthly weather parameters (pooled mean of 2019-2020) of experimental site, Upper Shillong, Meghalaya

available N, P, and K at a depth of 0 to 15 cm are 260, 25, 217 kg/ha respectively. The study was laid out in a factorial randomized block of two varieties, five treatments, and three replications. The fertilizer treatments included (T_1) PK (N0PK), (T_2) NK (NP0K), (T_3) NP (NPK0) compared with (T_4) recommended RDF (+NPK) and (T_5) Unfertilized control (-NPK). The recommended dose of fertilizer (RDF) rate for potato in this region is 140:120:60 kg ha^{-1} along with 15 t ha^{-1} farmyard manure (0.90% N, 0.22% P, and 0.93 % K) was applied. All plots were fertilized according to the treatments. Nitrogen, phosphorus, and potassium were applied in the form of urea (46% N), single superphosphate (16% P_2O_5), and muriate of potash (60% K_2O), respectively. All nutrients were applied at the planting time except nitrogen, which was applied in two split applications (i.e., 50% base, 50% at 45 DAP). Uniform cultural practices and plant protection measures were used in all treatments.

Growth and yield determination

Seven plants from each plot were randomly selected for various biometric observations. Leaf chlorophyll content was measured at 35 days after planting (DAP) using an at LEAF+ chlorophyll meter (FT Green LCC, Wilmington, DE, USA). All plants were harvested manually and graded according to their weight and number, categorizing them as large (>75 g), medium (50-75 g), small (25-50 g) and very small (< 25 g) tubers. The tuber yield per plot was calculated and converted into tonnes per hectare.

Estimating yield response (YR), yield loss (%) agronomic efficiency (AE) and partial factor productivity (PFP)

The following formulas were used to compute yield response, yield loss, partial factor productivity and agronomic efficiency.

(i) $YR = Y_{NPK} - Y_0$- expressed in t ha^{-1}

(ii) Yield Loss = $((Y_{NPK} - Y_0)/ Y_{NPK}) \times 100$ -expressed in percentage (%)

(iii) $AE = (Y - Y_0)/F$- expressed in kg yield per kg nutrient applied

(iv) $PFP = Y/F$-expressed in kg yield per kg of nutrient applied

Where Y_{NPK} stands for tuber yield of nutrient management practices (+NPK t ha^{-1}); Y_0 is the tuber yield of nutrient omission (N/P/K- t ha^{-1}). Where Y represents the yield of nutrient management practices (+NPK kg ha^{-1}), Y_0 represents the yield in the control plot (kg ha^{-1}), and F represents the quantity of nutrients applied (kg ha^{-1}). The agronomic efficiency (AE) of N, P, and K is represented by the variables AEN, AEP, and AEK, and the partial factor productivity (PFP) of N, P, and K is represented by the variables PFPN, PFPP, and PFPK. For the economics calculation of the 2019-2020 season, the prevailing market prices for inputs and outputs were used (sale of potato @ 20,000/tonne).

Data analysis

Analysis of variance was done for the information generated in FRBD using TNAUSTAT statistical software (Manivannan, 2014). The significance of treatment differences was compared through critical difference at a 5 % level of significance (P = 0.05) and interpretation of treatment results was made according to Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Plant growth characteristics

Potato plant growth parameters, including plant height (cm), number of stems per plant, and number of compound leaves per plant of the potato were significantly affected by nutrient omissions (Table 1) and potato varieties, except for the number of stems per plant. These results were significant for

Table 1. Effect of nutrient omissions on growth attributes of potato.

Treatments	Plant height (cm)	Number of haulms plant^{-1}	Number of compound leaves plant^{-1}	Chlorophyll reading
Fertilizer application rate (N)				
Without N (100% PK)	35.49^{c}	2.68^{bc}	33.43^{c}	40.65^{c}
Without P (100% NK)	41.77^{b}	2.95^{b}	39.00^{b}	46.39^{b}
Without K (100% NP)	42.43^{b}	2.93^{b}	42.19^{b}	49.62^{b}
100% RDF of NPK	49.12^{a}	3.69^{a}	48.48^{a}	55.78^{a}
Unfertilized control (-NPK)	23.02^{d}	2.44^{c}	26.81^{d}	41.56^{c}
Potato variety (V)				
K.Girdhari	41.55^{a}	2.88	39.77^{a}	45.23^{b}
K. Megha	35.19^{b}	3.00	36.19^{b}	48.35^{a}
Analysis of variance				
Nutrients	6.04	0.40	5.11	4.34
Varieties	3.82	NS	3.23	2.75
N × V	NS	NS	NS	NS

Within columns means followed by the same superscripts are not significantly different at p 0.05, NS- non-significant.

both varieties in both seasons ($p < 0.005$). The interaction effect of potato variety and nutrient omission was not significant. The results showed that -NPK omission produced the shortest plants (23.02 cm) with the fewest numbers of stems (2.44) and compound leaves per plant (26.81 number). Conversely, recommended NPK (T_4) recorded the tallest plant (49.12 cm), more stems (3.69 number) and compound leaves per plant (48.48 number). This could be due to the availability of all the essential nutrients that enhance the growth of potato (Jatav *et al*., 2017). The omission of N significantly reduced plant height (35.49 cm) compared to the omission of P and K (41.77 cm and 42.43 cm, respectively). Therefore, the results suggested that nitrogens plays a critical role in cell division and vegetaive growth. This findings are in line with Singh *et al*. (2020) and Yadav *et al*. (2020). Similarly, the number of stems per plant (2.95 and 2.93) and compound leaves per plant (39 and 42.19) un affected by omissions of P and K suggesting these nutrients have less influence on growth parameters.

Further, growth parameters such as plant height, number of stems and number of leaves were significantly lower in treatments where N was omitted (- NPK and -N) compared to those of treatments receiving nitrogen (-P, -K, +NPK). In acidic, erosion-prone soils of Meghalaya’s hilly terrains, Nitrogen is the most limiting nutrient for potato cultivation. Continuous farming in these area has led to nitrogen losses due to leaching, denitrification, and ammonia volatilization (Bharti and Ram, 2023). Several authors have found the impact of nutrient omission on potato growth (Singh *et al*., 2020; Yadav *et al*., 2020; and Mugo *et al*., 2021), and these studies explained the importance of N/P/K on potato growth and development. The taller plant (41.55 cm) and maximum number of leaves (39.77) were recorded in K. Girdhari and the shorter (35.19) and minimum number of leaves (36.19) were found in K. Megha. Both varieties had statistically similar numbers of stems per plant production. Since the environmental conditions during the growing period were similar, the different responses of the cultivars reflect the genetic differences between the cultivars (Singh *et al*., 2019).

Soil Plant Analysis Development (SPAD) value

The SPAD readings indicated that chlorophyll content was highest in the fully fertilized treatment (+NPK), followed by -K omission (49.62) and -P omission (46.39) (Table 1). In contrast, -N omission recorded the lowest chlorophyll content (40.65), which was on par with unfertilized control (41.56). These results reflect the nitrogen role in chlorophyll synthesis and photosynthesis efficiency (Jongschaap and Booij, 2004).

SPAD or chlorophyll meter values increased with increasing nitrogen levels (Singh *et al.*, 2019). Interestingly, the variety K. Megha exhibited higher SPAD valus (48.35) than K. Girdhari (45.23) suggesting varital differences in nitrogen use efficiency.

Potato yield and yield components respond to applied nutrients.

Potato tuber yield and its components were significantly influenced by nutrient omissions and different varieties used. There was no significant interaction between these factors, indicating that the response to nutrients was consistent across the varieties. The omission of N, P, and K had a significant reduction in potato tuber yield (Fig. 2). The ranking of total tuber yield and marketable tuber yield under different nutrient treatments was as follows: + NPK> -K >-P >-N > -NPK. This indicates nitrogen is the most yield-limiting nutrient for yield, followed by phosphorus and potassium. Soil incorporation of recommended NPK combined with farm yard manure recorded the highest total tuber yield (16.46 t ha^{-1}) and marketable tuber yield (12.32 t ha^{-1}), highlighting the benefits of integrated nutrient management in this region. Conversely,the lowest total and marketable tuber yield was found in -NPK (3.53 and 1.76 t ha^{-1}) and -N (7.85 and 5.44 t ha^{-1}) treatments, highlighting nitrogen deficiency, consistent with earlier studies (Singh *et al.*, 2020; Yadav *et al.*, 2020).

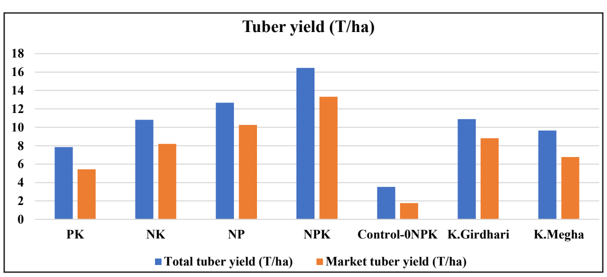

Fig. 2. Effects of nutrient omission on total and marketable tuber yield(t ha^{-1}) of potato

K. Girdhari produced a higher total and marketable potato tuber yield(10.89 and 8.43) compared to K. Megha (9.64 and 6.37 t ha^{-1}). However, K. Girdhari recorded a lowest non-marketable tuber yield (2.46 t ha-1) than K. Megha (3.27 t ha^{-1}). These varietal differences in yield and their components emphasize the importance of selecting varieties that are well adapted to local conditions. Overall, K. Girdhari consistently outperforms K. Megha.

Both the total and marketable tuber numbers showed the same pattern and their characteristics were significantly lower in -NPK omission and higher in no omission (+NPK) treatment (Fig. 3). The recommended NPK (T_4) had the highest total number of tubers (560.48 thousand ha^{-1}) and marketable tubers (339.68 thousand ha^{-1}) than -K (479.18 thousand ha^{-1} and 218.01 thousand ha^{-1}), -P (199.99 thousand ha^{-1} and 209.22 thousand ha^{-1}), -N (128.36 thousand ha^{-1} and 230.07 thousand ha^{-1}), and -NPK (231.02 thousand ha^{-1} and 50.46 thousand ha^{-1}) omission. The appropriate and timely use of nutrients and their combinations can improve plant growth and yield (Kumar *et al.*, 2023).

Yield response (t/ha) and yield loss (%) of nutrients

The omission of nutrients significantly influenced the tuber yield. Fig. 4 shows the

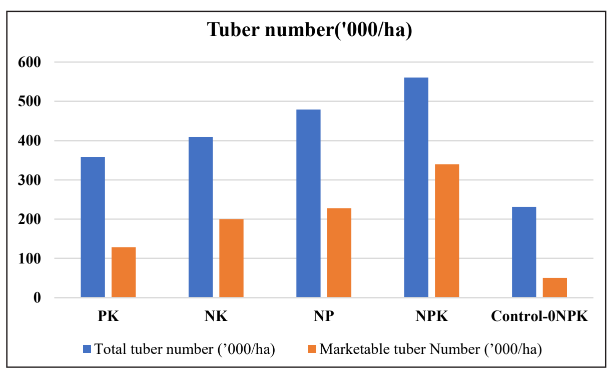

Fig. 3. Effects of nutrient omission on total and marketable tuber number ('000 ha^{-1}) of potato

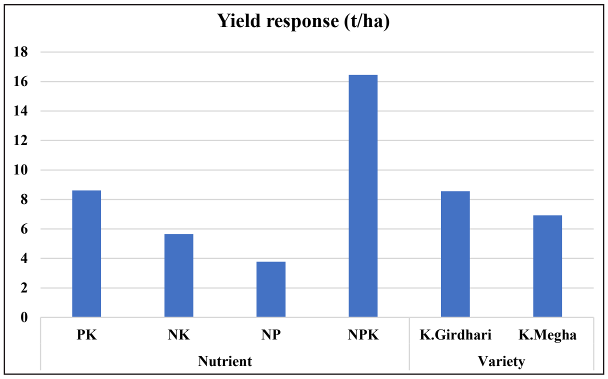

Fig. 4. Potato yield response (t ha^{-1}) as influenced by nutrient omission and potato varieties.

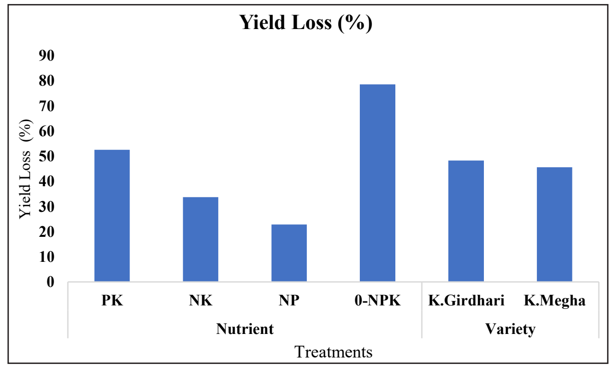

Fig. 5. Potato yield loss (%) as influenced by nutrient omission and potato varieties.

differences in yield responses to different nutrients across the seasons and varieties. The total tuber yield of recommended NPK was used as the target yield (16.46 t ha^{-1}). The highest yield response (yield reduction in nutrients omission) was recorded as -N omission (8.61 t ha^{-1}), followed by -P omission (5.65 t ha^{-1}) and -K omission (3.78 t ha^{-1}). The nutrient response of K. Girdhari (8.56 t/ha) was higher than K. Megha (6.92 t ha^{-1}) in the unfertilized control compared to the optimum fertilized treatment. This may be due to K. Girdhari cultivar produces higher yields than K. Megha with recommended fertilization

The substanical yield loss observed in -NPK (%) and -N (53%) omission indication crital role of nitrogen in potato (Fig. 5). Phosphorous and potassium omissions caused moderate yield reductions (34 and 23%) reflecting their secondary but still important roles. In Meghalaya, 81% of the total cultivated area is acidic and phosphorus (P) is the yield-limiting nutrient as it tends to fix P in the form of iron and aluminium phosphate (Sharma *et al.*, 2006). Available potassium status was low to medium in soils of the northeastern region of India (Mandal *et al.*, 2013). These findings suggested that site specific nutrient management is important for optimizing yiled.

Agronomic efficiency (AE) and Partial factor productivity (PFP) of nutrients

Indigenous soil productivity can be estimated by using tuber yield from nutrient omission treatments, highlighting nutrient use efficiency and partial factor productivity (PFP). The mean agronomic efficiency of N (AEN) ranges from 52.17 to 92.32 kg tuber kg^{-1} N applied (Fig. 6). The AEN of -K omission (NP) was higher than -P omission (NK). Phosphorus plays a crucial role for enhancing AEN, as confirmed by Dua *et al.* (2007), who found the optimal potato AEN to be between 48-135 kg tuber kg^{-1} nitrogen. The mean agronomic efficiency for phosphorus (AEP) ranged from 35.97 to 107.17 kg tuber kg^{-1} P_2O_5, while potassium (AEK) ranged from 71.94 to 215.41 kg tuber kg^{-1} K_2O and the lowest AEP and AEK were recorded in

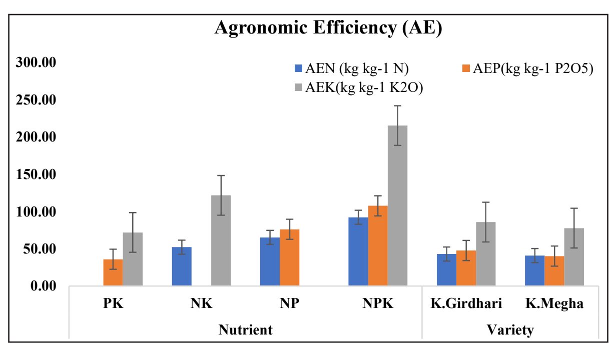

Fig. 6. Agronomic Efficiency (AE) as influenced by nutrient omission and potato varieties.

–N omissions. Fully fertilization (+NPK) led to the highest AEN, AEP, and AEK values of 92.32, 107.71, and 217.41 kg kg^{-1}, respectively. Similar results on the agronomic efficiency of potato by Singh *et al.* (2020) confirmed the highest reduction of AEP and AEK in nitrogen-omitted soils in Gwalior, India.

Partial factor productivity (PFP) measures crop productivity per unit of nutrient applied. Balanced fertilization (+NPK) increased PFP of N, P, and K (117.54, 137.14,274.27 kg kg^{-1}) (Fig. 7). The PFP of nitrogen was higher when potassium was omitted (90.53 kg kg^{-1} N) compared to phosphorus omission (77.39 kg kg^{-1}). When K was omitted, the PFP of P showed improvement compared to the omission of N (105.61 and 65.40 kg kg^{-1} P_2O_5,). On the other hand, when P was omitted, the PFP of K increased compared to the omission of N (180.59 and 130.80 kg kg^{-1} K_2O, respectively). Singh *et al.* (2020) found that phosphorus positively affected nitrogen uptake. Additionally, K. Girdhari outperformed K. Megha in AEN, AEP, AEK, and PFP. According to Dua *et al.* (2007), the cultivar showed differential responses to AE and PFP for N application.

Economics

Table 2 presents the economics of potato cultivation under different nutrient omission treatments. Cultivation and seed costs remained the same for all treatments except fertilizer. The results showed that nitrogen omission had the highest economic loss compared to P and K nutrient omission, indicating that nitrogen is more crucial for potato yield. Recommended NPK fertilization (T_4) recorded the highest cost of cultivation (₹168566 ha^{-1}), net returns (₹160559 ha^{-1}) and (B:C) ratio (1.95) compared to nutrient omissions and unfertilized control. Unfertilized (-NPK) and N omission (PK) treatments are unprofitable due to lower tuber yield, resulting in losses in net income and Benefit-Cost ratio (0.52 and 0.93 values). The next best profits were obtained by omission of K followed by P. Therefore, nutrient application (NPK) can maximize the economic returns, particularly in nutrient-exhaustive crops like potato.

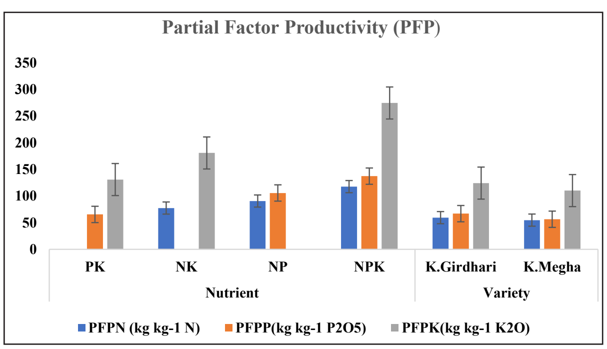

Fig. 7. Partial Factor Productivity (PFP) as influenced by nutrient omission and potato varieties.

Table 2. Effect of nutrient omission on the economics of potato cultivation.

Treatments	Economic parameters (Rs/ha)			B:C ratio
	Cost of cultivation	Gross returns	Net returns	
Without N (100% PK)	166722	156960	9761	0.93
Without P (100% NK)	161353	216200	54847	1.34
Without K (100% NP)	166558	253400	86842	1.52
100% RDF of NPK	168566	329125	160559	1.95
Unfertilized control	135000	70600	64400	0.52

CONCLUSION

The current study has adopted an omission technique to determine the importance of nitrogen (N),phosphorous (P) and potassium (K) in potato production in the acidic soil of the Shillong, NEH region, Meghalaya. The results revealed that nitrogen is the most critical nutrient for growth and yield of potato, followed by phosphorus and potassium with average yield reductions of 53%, 34% and 23%, respectively, when these nutrients were omitted. Application of 140 kg N, 120 kg P_2O_5 and 60 kg K_2O ha^{-1} along with farm yard manure significantly improved potato productivity (16.46 t ha^{-1}), higher yield response (12.92 t ha^{-1}) profitability (₹160559 ha^{-1}). This study highlights the importance of integrated nutrient management with organic manures, especially this region was prone to nutrient losses. Farmers should be encouraged to adopt soil test-based fertilizer application to sustain soil health and improving productivity, profitability and nutrient use efficiency of potato. Future research should focus on long-term nutrient studies, the use of precision technologies to optimize fertilizer application and development of location specific nutrient management protocols for hill agriculture. Integrating these approaches can improve the sustainability and profitability of the potato farming system in the North East hilly region and similar agroecological zones.

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