NUSANTARA BIOSCIENCE
Vol. 17, No. 2, pp. 313-321
November 2025

ISSN: 2087-3948
E-ISSN: 2087-3956
DOI: 10.13057/nusbiosci/n170213

Effect of phosphorus and potassium on growth and yield parameters and disease incidence of potato

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Manuscript received: 26 October 2025. Revision accepted: 9 November 2025.

Abstract. *Islam MS, Khan AA, Rubayet MT, Haque MM, Karim MA, Mian IH. 2025. Effect of phosphorus and potassium on growth and yield parameters and disease incidence of potato. Nusantara Bioscience 17: 313-321.* A study was undertaken to find out the effects of two macronutrient elements on plant growth, tuber, and tuber disease incidence of potato (*Solanum tuberosum*). The major nutrient elements were phosphorus (P) and potassium (K). The doses of nutrients were P @ 0, 20, 35, 50 kgha^{-1}, and K @ 0, 90, 140, 190 kgha^{-1}. Data were recorded on vine number/ten hills, plant height, canopy coverage, tuber number per ten plants, and tuber weight per plot. Disease incidence and physiological disorders such as common scab (*Streptomyces scabies*), dry rot (*Fusarium* sp.) and soft rot (*Erwinia carotovora*) of potato were also assessed. The highest tuber yield of 24.05 (44.53 tha^{-1}) and 24.12 kg plot^{-1} (44.66 tha^{-1}) was obtained with 35 kgha $^{-1}$ P and 140 kgha^{-1} applied individually. When both the elements were applied together, the highest yield of 30.68 kg plot^{-1} (56.82 tha^{-1}) was obtained at 35 kg P and 140 kg K per hectare. Tuber diseases and disorders were minimal when 35 kgha^{-1} P and 140 kgha^{-1} K were applied together during the potato cultivation under field conditions. Based on findings of the present study, it may be concluded that application of P and K at the rates of 37.67 and 136.69 kgha^{-1} along with a standard dose of N is optimum for maximum plant growth, tuber yield and minimizing the incidence of disease and disorders of potato tuber.

Keywords: Diseases, Phosphorus (P), Potassium (K), potato, yield

INTRODUCTION

Potato (*Solanum tuberosum*) is a high nitrogen (N), phosphorus (P), and potassium (K)-demanding crop. Deficiency of any or combinations of these nutrients can result in retarded growth or complete crop failure in severe cases. Phosphorus and potassium are the major nutrients after nitrogen, which play an important role in the growth, yield and quality of any crop (Malik and Ghosh 2002). Phosphorus is the element that is most often limited in soils. It is absorbed primarily as the monovalent phosphate anion ($H_2PO_4^-$) and less rapidly as the divalent anion ($H_2PO_4^{2-}$). Soil pH controls the relative abundance of these two forms ($H_2PO_4^-$ is favored at a pH below 7 and $H_2PO_4^{2-}$ above 7). Much of the phosphate is converted into organic forms as it enters the root or after it is transported through the xylem to the vine or leaves. Phosphorus is never reduced in plants, where it remains as phosphate, either free or bound in organic forms such as esters.

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. It also has an important function in energy transfer, such as in the esters of energy-rich phosphate present in the metabolic mechanisms of the cells, within which ATP participates in the main metabolic processes, such as photosynthesis and respiration. Optimum plant growth is accompanied by a demand for P to meet the demands for the functions and so depends on the availability of P in the soil, and the ability of the plant to absorb P from the soil. Many factors influence the supply of P to plants. Among the most important are the availability of P in the soil, temperature, root density and root efficiency in P uptake.

Potato fertilization usually requires high amounts of phosphate fertilizer (60 to 80 kgha^{-1} P) to achieve economically acceptable yields. Young plants with a P deficiency are bluish green in color in the early stages of growth. Older leaves with deficiency symptoms usually appear dark green. Phosphorus deficiency in the potato slows apical growth, resulting in small, rigid plants; reduces the formation of starch in the tubers causing necrotic spots distributed in the tuber; decreases CO_2 absorption capacity of leaf photosynthesis; results in an inadequate supply of phosphates which prevents the export of triose phosphate from the chloroplast, and therefore, affects the synthesis of sucrose, and causes delayed development of the tubers. Phosphorus has a direct impact on shoot growth, root development and tuber formation in potato. Rosen and Bierman (2008) found that the numbers and yield of small tubers increased as the dose of P was increased. It indicates that P may play an important role in regulating the number of tubers per plant.

Potato has a relatively high potassium requirement (K), which has led to the suggestion that high doses of the element are needed for potato production. Potassium is a monovalent cation, and its capture is highly selective, coupled with metabolic activity. It is characterized by high mobility in plants at all levels; it is the most abundant cation in the cytoplasm and, along with its accompanying anions, makes a high contribution to the osmotic potential of cells and tissues. This element has an important role in water relations of the plant; furthermore, K is not metabolized and forms easily interchangeable weak complexes. It stimulates the activity of the enzyme associated with starch synthesis (Mengel and Kirkby 1987). In addition, it facilitates the translocation of assimilates to the tubers, which ultimately increases the bulking capacity of the tuber and its biomass. Potassium deficiency can result in a decrease in yield, tuber size and quality (Maiti et al. 2004). Some quality factors, such as dry tuber, specific gravity, sugar content, flesh color and hollow heart, are affected by K fertilization. Potassium probably exerts its greatest effects on disease through specific metabolic functions that alter compatibility relationships of the host-parasite environment. Potassium in plants increases the production of disease-inhibitory compounds, such as phenols, phytoalexins and auxins around infection sites of resistant plants. K deficiency leads to thinner walls and slower growth of meristematic tissue, making it easier for the parasites to penetrate the epidermis (Bergmann 1992). Adequate potassium fertilizer application can be useful because it makes potato plants adapted to environmental stresses and may lead to increased resistance of potato to some pests (AL-Moshileh et al. 2005).

Growth parameters, yield and yield components of potato responded positively to P and K fertilizers, either applied as sole or in combination. The average tuber weight, marketable and total tuber yield were significantly affected by P and K fertilizer levels and their interaction. The highest tuber yield, average tuber weight, number of tubers per plant and number of vines per hill were obtained from application of a combined P, K fertilizer at the rate of 89.7 Kg $P_2O_5ha^{-1}$ and 100 Kg K_2O ha^{-1}.

In the past, fertilizer recommendations for major food crops were based solely on agronomic evaluations. Little or no consideration has been given to the direct and indirect effects of fertilizer rate on pest epidemics and their effects on yield. But some experiments demonstrated that fertilizer could be used to manage some diseases of the potato. Sharma and Sood (2002) showed that the application of potassium significantly reduced the incidence of late blight of potato. The role of potassium in increasing crop resistance to diseases caused by bacteria and fungi was widely reviewed by Perrenoud (1990). In general, potassium application improves plant health and vigour, making infection less likely or enabling a quick recovery (Perrenoud 1993). Potassium fertilization was found to decrease the incidence of several diseases, such as late blight (*Phytophthora infestans*), dry rot (*Fusarium* spp.), powdery scab (*Spongospora subterranea*) and early blight (*Alternaria solani*) (Perrenoud 1993; Marschner 1995).

Therefore, the study was initiated with the major objective of investigating the effects of applying different levels of phosphorus and potassium on tuber yield and quality of seed potato.

MATERIALS AND METHODS

The experiment was conducted at the Research Farm of the Department of Plant Pathology, Gazipur Agricultural University, Bangladesh. The soil of the experimental field belongs to the Salna series under the Agro Ecological Zone (AEZ)-28: Madhupur Tract (24.05^0 N latitude and 90.16^0 E longitude) at an elevation of 8.4 m above sea level. The texture of the soil was silty clay in the surface layer and silty clay loam in the subsurface layer (Rahman et al. 1998). The soil contains less than 1% organic matter and has a pH range of 6.0-6.5. The experimental site is situated in the subtropical climate zone characterized by heavy precipitation during the months of April-September or scanty or no rainfall during October to March.

Materials

Potato seed tubers of variety Diamant (seed class foundation) collected from Bangladesh Agricultural Development Corporation (BADC) were used in this experiment.

Land preparation, experimental design and fertilizer application

The land was prepared using a harrow and disk plough with laddering to obtain a good tilth. The land was leveled, and large clods were broken into small pieces. Weeds and other stubble were removed. After final land preparation, experimental unit plot of size was 2.25 m × 2.40 m were prepared. The experiment was laid out in a factorial Randomized Complete Block Design (factorial RCBD) with three replications. Blocks were spaced 1 m apart, and an equal 1 m spacing was maintained between plots. The soil of the experimental plot was fertilized at the rate of Urea 300 kg, Gypsum 100 kg, Magnesium sulphate 60 kg, Zinc sulphate 10 kg as recommended by BADC (Anonymous 2008). Cow dung was added with the soil at the rate of 10 tha^{-1} during land preparation. Half of the urea and full dose of all other fertilizers were used at the time of planting of seed potato. The rest of the urea was added to the soil of growing potato plant as top dressing after 35 days of planting of seed potato.

Treatment

Phosphorus (P) was applied at the rate of 0, 20, 35 and 50 $kgha^{-1}$ and potassium (K) was applied 0, 90, 140 and 190 $kgha^{-1}$ with 3 replications. Number of treatments was 16, viz. P_0K_0 = 0 kg P ha^{-1} + 0 kg K ha^{-1}, P_0K_{90} = 0 kg P ha^{-1} + 90 kg K ha^{-1}, P_0K_{140} = 0 kg P ha^{-1} + 140 kg K ha^{-1}, P_0K_{190} = 0 kg P ha^{-1} + 190 kg K ha^{-1}, $P_{20}K_0$ = 20 kg P ha^{-1} + 0 kg K ha^{-1}, $P_{20}K_{90}$ = 20 kg P ha^{-1} + 90 kg K ha^{-1}, $P_{20}K_{140}$ = 20 kg P ha^{-1} + 140 kg K ha^{-1}, $P_{20}K_{190}$ = 20 kg P ha^{-1} + 190 kg K ha^{-1}, $P_{35}K_0$ = 35 kg P ha^{-1} + 0 kg K ha^{-1}, $P_{35}K_{90}$ = 35 kg P ha^{-1} + 90 kg K ha^{-1}, $P_{35}K_{140}$ = 35 kg P ha^{-1} + 140 kg K ha^{-1}, $P_{35}K_{190}$ = 35 kg P ha^{-1} + 190 kg K ha^{-1}, $P_{50}K_0$ = 50 kg P ha^{-1} + 0 kg K ha^{-1}, $P_{50}K_{90}$ = 50 kg P ha^{-1} + 90 kg K ha^{-1}, $P_{50}K_{140}$ = 50 kg P ha^{-1} + 140 kg K ha^{-1}, $P_{50}K_{190}$ = 50 kg P ha^{-1} + 190 kg K ha^{-1}. The P was used as TSP (Triple super phosphate) and K as MP (Muriate of Potash). The whole amount of phosphorus and half of the potassium were used at the time of planting of seed potato. The rest of the potassium was added to the soil of growing potato plant as top dressing after 35 days of planting of seed potato.

Seed sowing and intercultural operations

Seed tubers were kept under defused light for sprouting. Sprouted tubers were planted in 5-7 cm depth furrows. The plant spacing was maintained as row to row 60 cm and tuber to tuber 15 cm distance. Four lines were accommodated in each unit plot. Each plot contained 60 seed tubers at the rate of 15 tubers per line. First irrigation was done one week after planting which was continued several times as required. After 20 days of planting weeding was done. To control the fungal disease especially late blight, Dithane M-45 at the rate of 2.5 kgha^{-1} and to control aphid Admire at the rate of 1000 mlha^{-1} were applied as foliar spray in the potato field with 10 days interval after 20 days of planting until haulm killing.

Crop harvesting, data collection and recording data

Haulm killing was done in 80 days after planting. It was done with a view to avoid spreading viruses and for hardening of tuber skin. After ten days of haulm killing potato tubers were harvested manually and care was taken to avoid injuries to potato during harvest. Ten plants were selected randomly from each plot and following data on plant growth characters and yield such as number of vines/hill, plant height (cm), canopy coverage, number of tuber/plant, yield/plot (kg) were taken. Total yield (tha^{-1}) was calculated based on yield/plot.

Number of vines per hill

Number of vines per hill was recorded 60 days after planting.

Plant height

Plant height was recorded 60 days after planting. It was measured from soil surface to tip of the plant.

Canopy coverage

Canopy coverage was recorded in 45 days after of planting. It was measured by a wooden frame with 60 cm × 15 cm sized.

Grading of potato tubers

Seven days after harvesting, all healthy potato tubers per plot were counted and measured. And then graded by four standard grading size followed by BADC (2015): The grades were A (> 28-41 mm), B (> >41-56 mm), under size (20-28 mm) and over size (>56-60 mm).

Data on disease and physiological disorders

Disease and physiological disorders data of harvested potato tubers were taken after seven days of harvest based on total number of potato and their weight of a plot. The disease was identified by visual symptoms; if necessary, it was confirmed pathologically. Data on different diseases and disorders such as common scab, soft rot, dry rot, heat injury, secondary growth, and greening were recorded based on number and weight of infected tubers and expressed in percentage of incidence following formula given below:

$$\%\ \text{disease incidence} = \frac{\text{number / weight of infected tuber}}{\text{number / weight of total tuber}} \times 100$$

Statistical analysis

Data were analyzed using Statistix 10. All recorded parameters were subjected to ANOVA, and treatment means were separated using Fisher's LSD at the 5% significance level. Graphs were prepared as needed, and SE (5%) was included when required.

RESULTS AND DISCUSSION

Main effect of phosphorus (P) on plant growth and yield attributes

The main effect of phosphorus (P) on vine number per 10 hills, plant height, canopy coverage, tuber number per 10 plants and tuber yield/plot was significant (P=0.05). Application of phosphorus gave a significant increase in those parameters compared to control (P_0). The maximum increase was obtained with 35 kgha^{-1} (P_{35}) followed by 50 kgha^{-1} (P_{50}) (Figure 1).

Like P, main effect of K on vine number per ten hills, plant height, canopy coverage, tuber number/10 plants and tuber yield/plot were significant (P=0.05). Application of K at 90, 140 and 190 kgha^{-1} (K_{90}, K_{150} and K_{190})) caused a significant increase in all the parameters over 0 kgha^{-1} of K (K_0) with few exceptions (Figure 2).

Vine number per 10 hills

Main effect of P: The main effect of phosphorus fertilization was statistically significant on vine number per 10 hills. The significantly highest 60 vines per 10 hills was obtained at 35 kg P ha^{-1} (P_{35}) which was statistically similar with P_{20}. The lowest vine number per 10 hills was observed at the control (45) which was significantly different from other treatments (Figure 1).

Main effect of potassium: The highest 58.30 vines per 10 hills was obtained at 140 kg K ha^{-1} (K_{140}) which was statistically similar with K_{190}. The lowest was observed at the control (K_0) (47.50), which was statistically similar with K_{90} (Figure 2).

Interaction effect: The statistically highest 70 vines per 10 hills was obtained from interaction effect of phosphorus and potassium at the rates of 20 kg P ha^{-1} and 190 kg K ha^{-1} ($P_{20}K_{190}$) which was statistically similar with $P_{35}K_{140}$, $P_{35}K_{90}$, $P_{20}K_{140}$, $P_{35}K_{190}$ and $P_{50}K_{140}$. The lowest vine number per 10 hills was observed at the control (P_0K_0) which was statistically similar with P_0K_{90}, $P_{50}K_0$, $P_{50}K_{90}$, $P_{20}K_{90}$, $P_{20}K_0$, P_0K_{190} and P_0K_{140} (Table 1).

Plant height

Main effect of phosphorus: The tallest plant was recorded 66.8 cm at 35 kg P ha^{-1} (P_{35}) and the shortest plant was found 49.30 cm in control plot which were statistically different from other treatments (Figure 1).

Main effect of potassium: The tallest plant was recorded 64.80 cm at 190 kg K ha^{-1} (K_{190}) and the shortest plant was found 50.0 cm in control plot which was statistically different from other treatments (Figure 2).

Interaction effect: In the interaction effect of P & K, the tallest plant (77.0 cm) was observed at 35 kg P ha^{-1} and 140 kg K ha^{-1} ($P_{35}K_{140}$) which was significantly different from other treatments. The shortest plant (43.33 cm) was found in control (P_0K_0) which was significantly different from others treatment combinations (Table 1).

Canopy coverage (%)

Main effect of phosphorus: The maximum canopy coverage was recorded 88.4% at 35 kg P ha^{-1} (P_{35}) and the minimum canopy coverage was found 68.6% in control plot which was statistically different from other treatments (Figure 1).

Main effect of potassium: The maximum canopy coverage was observed 82.3% at 140 kg K ha^{-1} (K_{140}) and the minimum canopy coverage was found 71.0% in control plot which was statistically different from other treatments (Figure 2).

Interaction effect: Significantly, the highest canopy coverage of 95.3% was observed under the treatment combination $P_{35}K_{140}$. The minimum canopy coverage of 65.0% was found under control (P_0K_0), which was significantly different from other treatments (Table 1).

Tuber number per 10 plants

Main effect of phosphorus: The maximum tuber number per ten plants was recorded 78.80 at 35 kg P ha^{-1} (P_{35}) and the minimum tuber number per ten plants was found 61.5 in control plot which was statistically different from other treatments (Figure 1).

Main effect of potassium: The maximum tuber number per ten plants was recorded 73.2 at 190 kg K ha^{-1} (K_{190}) and the minimum tuber number per ten plants was found 67.5 in control plot which was statistically different from other treatments (Figure 2).

Table 1. Interaction effect of phosphorus (P) and potassium (K) on growth and yield attributes of potato

Dose of K	Level of P			
	P_0*	P_{20}	P_{35}	P_{50}
Vine number /10 plants				
K_0*	40.0 e[1]	50.0 cde	53.3 bcd	46.7 de
K_{90}	40.0 e	50.0 cde	63.3 ab	50.0 cde
K_{140}	50.0 cde	60.0 abc	63.3 ab	60.0 abc
K_{190}	50.0 cde	70.0 a	60.0 abc	53.3 bcd
Plant height (cm)				
K_0	43.3 k[1]	47.0 j	55.3 gh	54.3 h
K_{90}	47.0 j	49.7 i	64.7 d	58.0 f
K_{140}	50.0 i	62.0 e	77.0 a	61.0 e
K_{190}	57.0 fg	67.7 c	70.3 b	64.3 d
Canopy coverage (%)				
K_0	65.0 j[1]	67.0 i	82.0 de	70.0 h
K_{90}	66.7 ij	73.0 g	87.0 c	74.7 g
K_{140}	69.7 h	81.0 e	95.3 a	83.0 d
K_{190}	73.0 g	76.7 f	89.3 b	77.3 f
Tuber number/10 plants				
K_0	60.7 i[1]	64.4 h	76.9 c	67.8 fg
K_{90}	61.4 i	67.0 g	79.3 ab	71.0 de
K_{140}	61.3 i	69.4 ef	81.0 a	77.7 bc
K_{190}	62.6 hi	73.2 d	78.1 bc	79.2 abc
Yield/Plot[χ] (Kg)				
K_0	11.94 k[1]	13.95 j	17.92 g	16.53 h
K_{90}	13.14 j	19.93 f	23.09 de	22.76 e
K_{140}	15.34 i	23.76 cd	30.68 a	26.70 b
K_{190}	13.89 j	20.21 f	24.50 c	23.11 de

Note: *P0: No phosphorus, P20: 20 kg P ha^{-1}, P35: 35 kg P ha^{-1}, P50: 50 kg P ha^{-1}, *K0: No potassium, K90: 90 kg K ha^{-1}, K140: 140 kg K ha^{-1}, K190: 190 kg K ha^{-1}, χ: Plot size 2.25 m × 2.40 m: 5.4 m^2, 1: Figures under the same parameter within same row and column are averages of three replications and having a common letter(s) do not differ significantly (P= 0.05) by LSD test

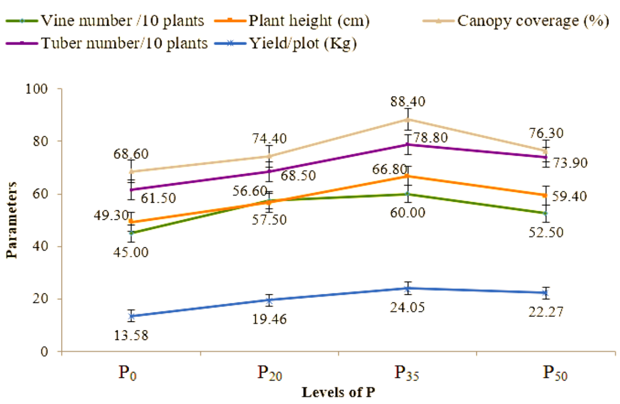

Figure 1. Effect of phosphorus (P) on growth and yield attributes of potato at different levels (P_0: No phosphorus, P_{20}: 20kg P ha^{-1}, P_{35}: 35 kg P ha^{-1}, P_{50}: 50 kg P ha^{-1})

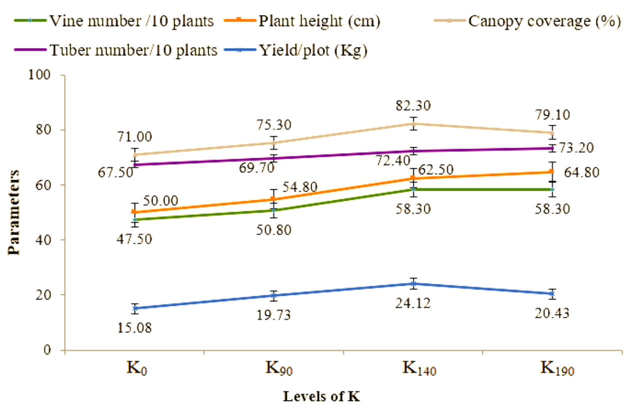

Figure 2. Effect of potassium (K) on growth and yield attributes of potato at different levels (K_0: No potassium, K_{90}: 90 kg K ha^{-1}, K_{140}: 140 kg K ha^{-1}, K_{190}: 190 kg K ha^{-1})

Interaction effect: Among the treatment combinations $P_{35}K_{140}$ gave the maximum tuber number of 81.0 followed by 79.3 obtained from $P_{35}K_{90}$. The lowest number of 60.7 tubers per ten plants was observed under control (P_0K_0), which was statistically like P_0K_{90}, P_0K_{140} and P_0K_{190} (Table 1).

Yield per plot

Main effect of phosphorus: The highest yield per plot was recorded 24.05 kg in main effect of P at 35 kgha^{-1} and the lowest yield per plot was found 13.58 kg in control plot which was statistically different from other treatments (Figure 1).

Main effect of potassium: The average highest yield per plot was recorded 24.12 kg in main effect of K at 140 kgha^{-1} and the lowest yield per plot was found 15.08 kg in control plot which was statistically different from other treatments (Figure 2).

Interaction effect: The average highest yield per plot 30.68 kg was observed in P 35 K 140 kgha^{-1} applied plot. The lowest yield per plot 11.94 kg was recorded in control P 0 K 0 kgha^{-1} which was statistically different from other treatments (Table 1).

Grading of healthy seed tuber

Occurrence of grade-B tuber was maximal followed by grade-A, undersized and oversized potato. Main effect of P as well as K on tuber grade was significant. Interaction effect of two elements was also significant (P=0.05).

Grade A (diameter >28-41 mm)

Main effect of phosphorus: Occurrence of grade-A tuber ranged 23.45-30.08%. Significantly the highest 30.08% grade-A seed tuber was harvested from treatment P_{20}. The lowest 23.45% tuber was found under control plot, which was statistically like P_{35} and P_{50} (Figure 3).

Main effect of potassium: Significantly the highest 27.82% grade-A tuber was recorded at 190 kg K ha^{-1}. The lowest 23.63% grade-A seed tuber was found at K_{140}. The occurrence of grade-A tuber at K_{90} and K_0 were 23.67 and 26.13%, respectively (Figure 4).

Interaction effect: Among 16 treatment combinations with P and K, significantly the highest 33.97% grade-A seed tuber was recorded from treatment combination $P_{20}K_{190}$. The second highest 30.31% occurrence of grade-A tuber was recorded from treatment combination $P_{20}K_0$, which was statistically like P_0K_{190}, $P_{20}K_{90}$, $P_{20}K_{140}$ and $P_{50}K_0$. The lowest grade-A seed tuber of 19.13% was recorded in control plot (P_0K_0), which was statistically similar to $P_{50}K_{140}$ and $P_{35}K_{90}$ (Table 2).

Grade B (diameter >41-55 mm)

Main effect of phosphorus: Occurrence of grade-B tubers ranged 44.02-58.12% under P alone. The highest grade-B seed tuber was recorded at P_{35} followed by P_{50} and P_{20}. Their differences were significant (Figure 3).

Main effect of potassium: Occurrence of grade-B tubers ranged 43.98-57.69% under different levels of K alone. The highest grade-B seed tuber was recorded at K_{190} followed by K_{90}, K_{140}. Significantly the lowest percentage of grade-B tuber was found in control plot compared to other three treatments (Figure 4).

Interaction effect: Under sixteen different treatment combinations of P and K, occurrence of grade-B tuber ranged 39.74-66.32%. Significantly the highest occurrence of grade-B tuber was found under treatment $P_{20}K_{190}$. The second highest occurrence of 61.60% was recorded from $P_{50}K_{140}$, which was statistically similar to $P_{35}K_{90}$, $P_{35}K_{140}$, and $P_{35}K_{190}$. The lowest occurrence of grade-B seed tuber was recorded at P_0K_{140}, which was statistically similar to $P_{20}K_0$, $P_{50}K_0$ and P_0K_0 (Table 2).

Undersize (diameter 20-28 mm)

Main effect of phosphorus: The highest percentage of 9.62% undersize seed tuber was produced at 20 kg P ha^{-1}, which was statistically like 35 kg P ha^{-1}. The lowest was found at 50 kgha^{-1} (Figure 3).

Main effect of potassium: Significantly the highest occurrence of 10.50% undersize seed tuber was found in control plot (K_0). The lowest of 6.68% undersize seed tuber was recorded at 140 kgha^{-1}, which was significantly different from other treatments (Figure 4).

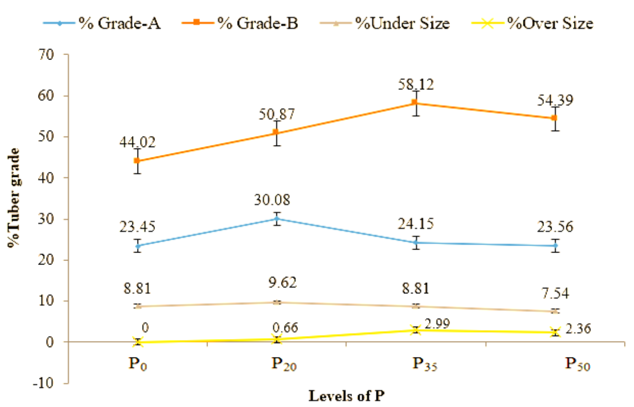

Figure 3. Main effect of P on occurrence of different grades of tubers (P_0: No phosphorus, P_{20}: 20 kg P ha^{-1}, P_{35}: 35 kg P ha^{-1}, P_{50}: 50 kg P ha^{-1})

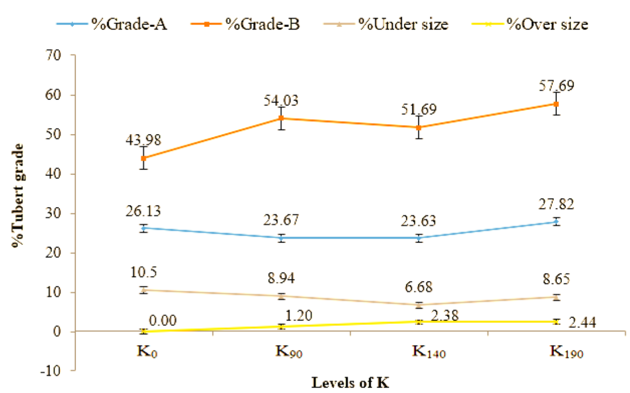

Figure 4. Main effect of K on occurrence of different grades of tubers (K_0: No potassium, K_{90}: 90 kg K ha^{-1}, K_{140}: 140 kg K ha^{-1}, K_{190}: 190 kg K ha^{-1})

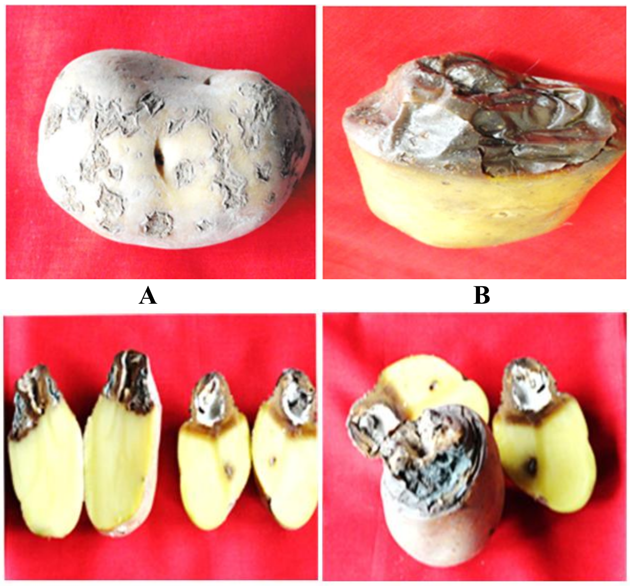

Figure 5. Pathogenic diseases of potato: A. Common scab lesion on potato tuber surface, B. Soft rot disease in potato tuber, C. Dry rot symptoms on the potato tuber

Table 2. Effect of treatment combinations of P and K on occurrence of different grades of tubers

Dose of K	Level of P			
	P_0*	P_{20}	P_{35}	P_{50}
% Grade-A (>28-41mm)				
K_0*	19.13 f[1]	30.31 b	26.85 cd	28.22 bc
K_{90}	22.55 e	28.13 bc	21.48 ef	22.51 e
K_{140}	22.54 e	27.93 bcd	22.8 e	21.24 ef
K_{190}	29.6 b	33.97 a	25.45 d	22.26 e
% Grade-B (>41-55 mm)				
K_0	42.41 ij[1]	40.68 ij	50.84 ef	42.01 ij
K_{90}	46.24 gh	52.62 e	60.55 bc	56.71 d
K_{140}	39.74 j	43.87 hi	61.57 b	61.6 b
K_{190}	47.68 fg	66.32 a	59.51 bcd	57.23 cd
% Under size (20-28mm)				
K_0	7.21 def[1]	13.09 a	12.93 a	8.76 bcd
K_{90}	8.35 bcd	9.91 b	9.72 b	7.8 cde
K_{140}	7.82 cde	6.53 ef	6.01 f	6.37 ef
K_{190}	11.85 a	8.93 bc	6.59 ef	7.23 def
% Over size (>55-60mm)				
K_0	0 f[1]	0 f	0 f	0 f
K_{90}	0 f	0 f	3.27 cd	1.52 e
K_{140}	0 f	0 f	5.84 a	3.69 bc
K_{190}	0 f	2.65 d	2.84 cd	4.25 b

Note: *P0: No phosphorus, P20: 20 kg P ha^{-1}, P35: 35 kg P ha^{-1}, P50: 50 kg P ha^{-1}, K0: No potassium, K90: 90 kg K ha^{-1}, K140: 140 kg K ha^{-1}, K190: 190 kg K ha^{-1}, 1: Figures under the same parameter within row and column are averages of three replications and having a common letter(s) do not differ significantly (P= 0.05) by LSD test

Interaction effect: The highest occurrence of 13.09% undersize seed tuber was found in treatment combination $P_{20}K_0$, which was statistically like $P_{35}K_0$ and P_0K_{190}. The lowest undersize seed was recorded at $P_{35}K_{140}$, which was statistically like $P_{50}K_{140}$, $P_{20}K_{140}$, $P_{35}K_{190}$, P_0K_0 and $P_{50}K_{190}$ (Table 2).

Oversize (diameter >55-60 mm)

Main effect of phosphorus: No oversize seed tuber was recorded under control (0 kg Kha^{-1}). Occurrence of oversize tuber was only 0.66-2.99%. The largest seed tuber was harvest from plot, which received 35 kg Pha^{-1} followed by P_{50} (Figure 3).

Main effect of potassium: Production of oversize potato tuber was found at K_{90}, K_{140} and K_{190}. The highest of 2.44% oversize seed tuber was found at 190 kg K ha^{-1} which was statistically like K_{140} (Figure 4).

Interaction effect: The highest occurrence of 5.84% oversize seed tuber was observed at $P_{35}K_{140}$ which was statistically different from other treatment combinations. On the other hand, no oversize seed was recorded in $P_{50}K_0$, $P_{35}K_0$, $P_{20}K_{140}$, $P_{20}K_{90}$, $P_{20}K_0$, P_0K_{190}, P_0K_{140}, P_0K_{90} and control (P_0K_0) (Table 2).

Incidence of diseases and disorders

After harvesting, various pathogenic diseases and disorders were recorded in tubers harvested from the experimental field under different treatments. The diseases were Common scab (*Streptomyces scabies*), Soft rot (*Pectobacterium carotovorum* subsp. *carotovorum* formerly *Erwinia carotovora* ssp. *carotovora*) and dry rot (*Fusarium* sp.). Common scab attacks vines, stolons and roots of potato plants. Initially, young and rapidly growing tubers were attacked by the bacteria, stimulating the growth forming corky tissue. Potato scab symptoms included dark brown, pithy patches which were raised and "warty" on tubers. Soft rot was characterized by water-soaked, rotted tuber areas with softened tissues, often accompanied by leakage and a foul odor. Healthy tissue was initially distinct from the macerated, creamy infected portion, but the infection eventually spread to the entire tuber. Dry rot is a devastating post-harvest disease for seed potatoes. It appeared on the harvested tuber and the skin of the affected tuber became wrinkled. The rotted areas were brown, grey or black and the rot created depressions in the surface of the tuber (Figure 5).

Common scab incidence was highest in the control (P0) and decreased significantly with P application, with the lowest incidence at P35 followed by P20 and P50 (Figure 6). Similarly, incidence was highest at K0 and was significantly reduced by K application; the lowest incidence occurred at K140, which differed significantly from all other treatments (Figure 7).

Soft rot and dry rot incidence was low, ranging 0.22–0.82% and 0.77–2.72% under the main effect of P, and 0.19–0.86% and 1.32–2.16% under K, respectively. Therefore, detailed results are not presented, but both were included in total diseased tubers (Figures 5 and 6).

Interaction effect of P and K on total disease incidence

Significantly the highest disease incidence was found under control (P_0K_0). Application of P and K together at different treatment combinations caused significant reduction in total disease incidence compared control. The lowest disease incidence was found at $P_{35}K_{140}$. The minimum disease incidence was observed at P_{35} with all levels of K. Similarly, minimum total disease incidence was recorded at K140 with different levels of P (Figure 8).

Incidence of different disorders

Different disorders such as heat injury, secondary growth and greening were recorded in harvested potato tubers (Figure 10). Incidence of disorders was very low (Figure 9). So, the details are not given.

Estimation of optimum level of phosphorus and potassium

Regression analysis was done, and optimum and economic dose of fertilizer were calculated using the formula Y = -b/2c from the response curve (Gomez and Gomez 1984). Dobermann and Fairhurst (2000) stated that the optimum rate of fertilizer application to a crop is that rate which produces the maximum economic returns at the minimum cost, and this can be derived from a nutrient response curve. The large and significant R^2 value in case of P and K of regression indicates that the quadratic response fitted the data. Response curve shows that yield increased with the increasing of nutrients at certain level and thereafter yield decreased.

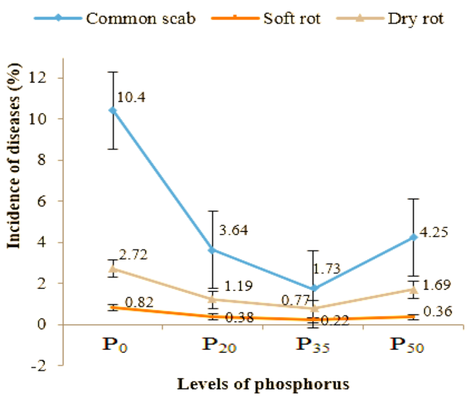

Figure 6. Incidence of common scab, soft rot and dry rot diseases at different levels of irrigation

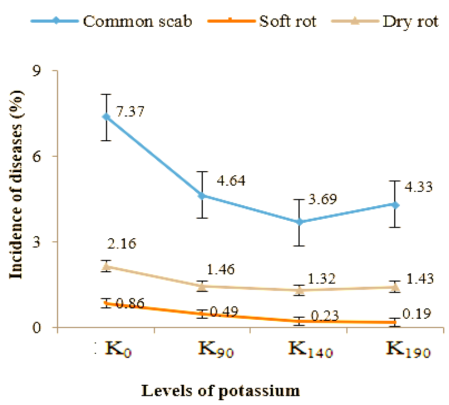

Figure 7. Incidence of common scab, soft rot and dry rot diseases at different levels of fertilization

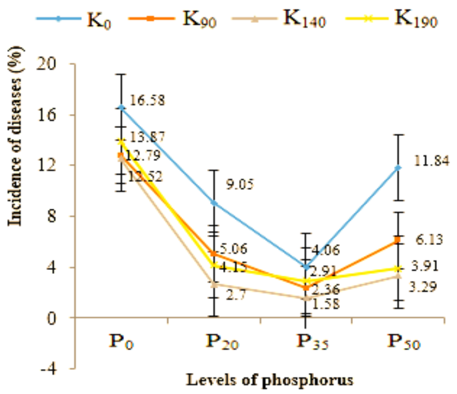

Figure 8. Interaction effect of P and K on incidence of total diseases

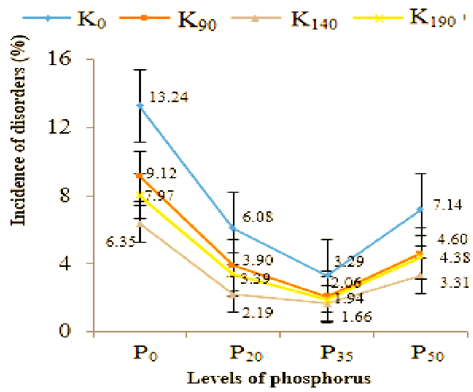

Figure 9. Interaction effect of P and K on incidence of total disorders

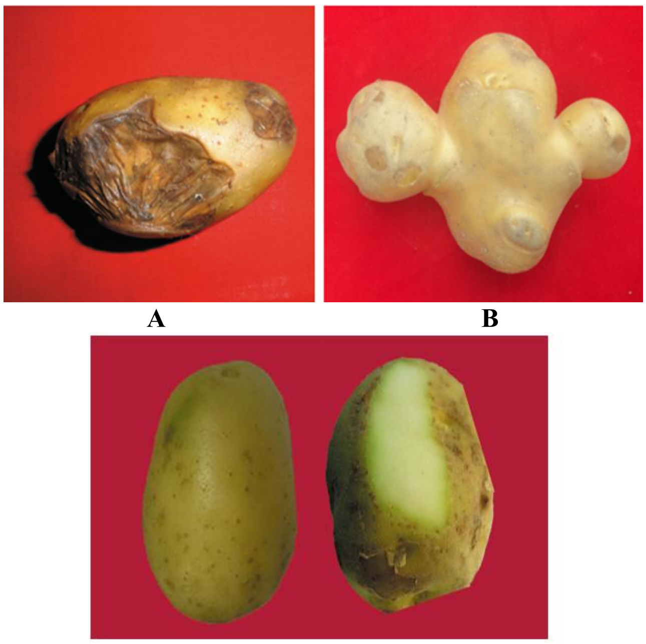

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Figure 10. Different physiological disorders of potato: A. Heat injury symptom on potato tuber, B. Secondary growth symptom on potato tuber, C. Greening symptom on potato tuber

Findings of present study show that potato tuber yield increased with increasing level of phosphorus to a certain limit and then decreased by further increase of nutrients level (Figure 11). But the increment of yield was prominent in case of P and the highest yield (42.05 tha^{-1}) was obtained from 35 kg P ha^{-1}. P has distinct effect on the yield. However, further application of P yield began to decrease. It was indicating the detrimental effect of over fertilization. The reason might be medium P status in soil. From the regression equations optimum dose of phosphorus fertilizer is 37.67 $kgha^{-1}$ for better yield (Table 3).

In case of potassium, yield of potato tuber increased by increasing level of potassium fertilizer to a certain limit and then decreased with further increase of potassium level (Figure 12). But the increment of yield was prominent in case of K and the highest yield (41.34 tha^{-1}) was obtained from 140 kg K ha^{-1}. K levels have positive effect on the yield. Further application of K yield began to decrease. The reason might be medium K status in soil. From the regression equations optimum dose of potassium fertilizer is 136.69 $kgha^{-1}$ for better seed tuber yield (Table 3).

Discussion

The main effects of P and K, as well as their interaction, significantly influenced growth and tuber yield attributes, including vine number (per 10 hills), plant height, canopy coverage, tuber number (per 10 plants), and yield per plot. Total tuber yield increased with higher P and K rates up to 35 kg P ha^{-1} and 140 kg K ha^{-1}, producing the highest main-effect yields (44.53 t ha^{-1} at P35 and 44.66 t ha^{-1} at K140). The maximum yield (56.82 t ha^{-1}) occurred under the interaction P35 × K140, indicating that yield responded more strongly to combined P and K than to individual applications. Increased P and K, alone or combined, may also improve soil chemical properties (CEC, EC, pH, Ca^{2+}, Mg^{2+}, and K^{+}). These results agree with previous studies showing positive effects of P and K on vine number, tuber number, tuber weight, and final yield (Zelalem et al. 2009; Ayalew and Beyen 2012; Aarakit et al. 2021).

Fleisher et al. (2012) reported that effects of P on canopy branching were associated with plant N status. N uptake correlated with P and K fertilizer. Application of NPK significantly increased the dry weight of potato (Zelalem et al. 2009; Eleiwa et al. 2012).

Total tuber number per plant increased with the P × K interaction. Previous studies also show that higher P can increase the number and yield of small tubers, indicating its role in tuber set (Rosen and Bierman 2008). Similarly, NPK application significantly increases tuber number and yield, with higher nutrient supply improving average tuber weight and harvest yield parameters (Jenkins and Mahmood 2003; Adhikari and Sharma 2004; Zelalem et al. 2009; Eleiwa et al. 2012).

Table 3. Regression equation and optimum dose of phosphorus and potassium fertilizer

Nutrients levels ($kgha^{-1}$)	Seed tuber yield (tha^{-1})	Yield increased over control	Regression equation and R^2 value	Optimum dose of fertilizer ($kgha^{-1}$)
Phosphorus levels				
P_0	19.20	-	$y = -0.0148x^2 + 1.1154x + 18.646$ $R^2 = 0.9583$	37.67
P_{20}	32.87	71.19%		
P_{35}	42.05	118.96%		
P_{50}	36.59	90.52%		
Potassium levels				
K_0	22.79	-	$y = -0.0008x^2 + 0.2187x + 22.227$ $R^2 = 0.8486$	136.69
K_{90}	32.54	42.77%		
K_{140}	41.34	81.38%		
K_{190}	34.03	49.31%		

Note: P_0: No phosphorus, P_{20}: 20 kg P ha^{-1}, P_{35}: 35 kg P ha^{-1}, P_{50}: 50 kg P ha^{-1}, K_0: No potassium, K_{90}: 90 kg K ha^{-1}, K_{140}: 140 kg K ha^{-1}, K_{190}: 190 kg K ha^{-1}

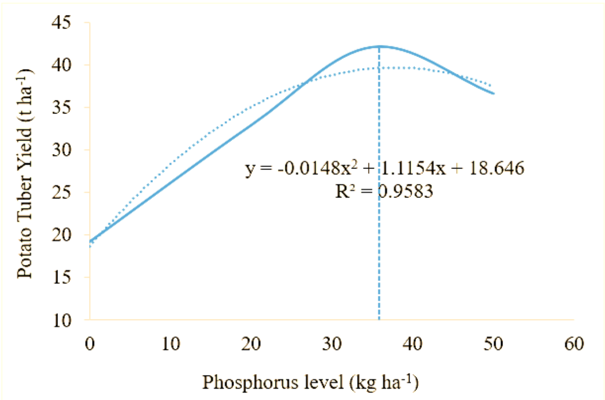

Figure 11. Relationship between phosphorus levels with potato tuber yield

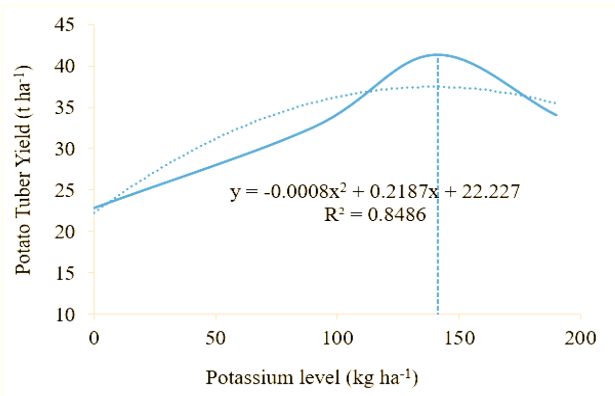

Figure 12. Relationship between potassium levels with potato tuber yield

Significant increase in tuber yield of potato because of K application is well documented (Moinuddin et al. 2005; Zameer et al. 2010). In fact, potato has a higher potassium requirement for optimum production as it produces much more dry matter in short growth duration. Similar root-yield responses to K application have also been reported by Liu et al. (2024). It produces large amounts of starch due to K-mediated carbohydrate metabolism (Singh and Trehan 1998). Thus, K helps the potato tubers to attain large size and heavier weight. This is an evident of the current study, as results observed a progressive increase in aggregate tuber yield. These results are consistent with the findings of Moinuddin and Shahid (2004), Moinuddin et al. (2005) and Abd-El-Latif et al. (2011) who showed an increase in tuber yield with a progressive application of K fertilizer from 0 to 225 kg K_2O ha^{-1} and from 72 to 120 kg K_2O ha^{-1}.

Some authors reported that proper application of fertilizer, especially K, helps in minimizing the diseases of potato (Imas and Bansal 2012). The results of the present experiment also suggest that application of P and K in combination positively influences diseases and physiological disorders of potato tubers.

Conclusions, the present study revealed that the maximum yield and minimum disease incidence such as common scab, soft rot and dry rot were obtained from the combined application of P, K at the rate of 35 and 140 $kgha^{-1}$. However, the regression analysis suggested that application of P and K at the rates of 37.67 and 136.69 $kgha^{-1}$, respectively provide maximum healthy seed tuber yield. Therefore, it is recommended to apply 37.67 and 136.69 $kgha^{-1}$ along with standard dose of N for production of good quantity as well as quality potato seed tubers.

REFERENCES

Aarakit P, Ouma JP, Lelei JJ. 2021. Growth, yield and phosphorus use efficiency of potato varieties propagated from apical rooted cuttings under variable phosphorus rates. Afr J Plant Sci 15: 173-184. DOI: 10.5897/AJPS2020.2113.

Abd-El-Latif KM, Osman EAM, Abdullah R, Abd El-Kader N. 2011. Response of potato plants to potassium fertilizer rates and soil moisture deficit. Adv Appl Sci Res 2: 388-397.

Adhikari CR, Sharma DM. 2004. Use of chemical fertilizers on potatoes in sandy loam soil under humid sub-tropical condition of Chitwan. Nepal Agric Res J 5: 23-26.

Al-Moshileh AM, Errebhi MA, Motawei MI. 2005. Effect of various potassium and nitrogen rates and splitting methods on potato under sandy soil and arid environmental conditions. Emir J Agric Sci 17 (1): 1-9. DOI: 10.9755/ejfa.v12i1.5043.

Anonymous. 2008. A booklet of Production Technology of Quality Seed Potato. Tuber Crops Division, Bangladesh Agricultural Development Corporation (BADC), Dhaka.

Ayalew A, Beyene S. 2012. Characterization of soils and response of potato (*Solanum tuberosum* L.) to application of potassium at Angacha in southern Ethiopia. Intl Res J Biol Bioinfo 2: 46-57.

Bergmann W. 1992. Nutritional Disorders of Plants. Gustav Fischer Verlag, New York.

Dobermann A, Fairhurst T. 2000. Rice Nutrient Disorders and Nutrient Management. Potash and Phosphate Institute, Canada and International Rice Research Institute, Philippines.

Eleiwa EM, Ibrahim SA, Mohamed FM. 2012. Combined effect of NPK levels and foliar nutritional compounds on growth and yield parameters of potato plants (*Solanum tuberosum* L.). Afr J Microbiol Res 6 (24): 5100-5109.

Fleisher DH, Wang Q, Timlin D, Chun JJA, Reddy VR. 2012. Effects of carbon dioxide and phosphorus supply on potato dry matter allocation and canopy morphology. J Plant Nutr 11: 566-586. DOI: 10.1080/01904167.2012.751998.

Gomez KA, Gomez AA. 1984. Statistical Procedures for Agricultural Research (2nd Edn.). International Rice Research Institute, Los Baños, Philippines. John Wiley and Sons, New York.

Imas P, Bansal SK. 2012. Potassium and Integrated Nutrient Management in Potato. Available at: http://www.ipipotash.org/presentn/kinmp.html (Accessed 15 August 2012).

Jenkins PD, Mahmood S. 2003. Dry matter production and partitioning in potato plants subjected to combined deficiencies of nitrogen, phosphorus and potassium. Ann Appl Biol 143: 215-219. DOI: 10.1111/j.1744-7348.2003.tb00288.x.

Liu B, Xv B, Si C, Shi W, Ding G, Tang L, Xv M, Shi C, Liu H. 2024. Effect of potassium fertilization on storage root number, yield, and appearance quality of sweet potato (*Ipomoea batatas* L.). Front Plant Sci 14: 1298739. DOI: 10.3389/fpls.2023.1298739.

Maiti S, Banerjee H, Patra T, Pal S. 2004. Effect of nitrogen and phosphorus on the growth and tuber yield of potato in Gangetic plains of West Bengal. J Interacademicia 8 (4): 555-558.

Malik GC, Ghosh DC. 2002. Effect of fertility level, plant density and variety on growth and productivity of potato. Potato Global Research and Development. Proceedings of the Global Conference on Potato, New Delhi, India, 6-11 December 1999.

Marschner H. 1995. Mineral Nutrition of Higher Plants (2nd Ed.). Academic Press, London.

Mengel K, Kirkby EA. 1987. Principles of Plant Nutrition (4th Ed.). International Potash Institute, Bern, Switzerland.

Moinuddin, Shahid U. 2004. Influence of combined application of potassium and sulfur on yield, quality, and storage behavior of potato. Commun Soil Sci Plant Anal 35 (7-8): 1047-1060. DOI: 10.1081/CSS-120030584.

Moinuddin, Singh K, Bansal SK, Pasricha NS. 2005. Influence of graded levels of potassium fertilizer on growth, yield and economic parameters of potato. J Plant Nutr 27: 239-259. DOI: 10.1081/PLN-120027652.

Perrenoud S. 1990. Potassium and Plant Health. IPI Research Topics No. 3 (2nd Ed.). International Potash Institute, Bern, Switzerland.

Perrenoud S. 1993. Fertilizing for High Yield Potato. IPI Bulletin 8 (2nd Ed.). International Potash Institute, Basel, Switzerland.

Rahman MA, Haider J, Sinha UK, Chowdhury AR, Chowdhury MMU. 1998. Economically viable rates of fertilizers and manures for maximizing growth and yield of year-round tomato. Bangladesh J Agric Res 23 (3): 551-559.

Rosen C, Bierman P. 2008. Potato yield and tuber set as affected by phosphorus fertilization. Am J Potato Res 85 (2): 110-120. DOI: 10.1007/s12230-008-9001-y.

Sharma RC, Sood MC. 2002. Nitrogen and potassium interaction on the tuber yield, quality and organic carbon status of Shimla soils. In: Khurana SMP, Shekhawat GS, Pandey SK, Singh BP (eds). Potato: Global Research and Development. Proceedings of Global Conference on Potato, Indian Potato Association, Shimla 2: 843-851.

Singh JP, Trehan SP. 1998. Balanced fertilization to increase the yield of potato. Proceedings of the IPI-PRII-PAU Workshop on Balanced Fertilization in Punjab Agriculture, Punjab Agricultural University, Ludhiana, India, 15-16 December 1997.

Zameer MK, Ehsan MA, Naeem MS, Masud MM, Sagheer A, Ahmed N. 2010. Effect of source and level of potash on yield and quality of potato tubers. Pak J Bot 42 (5): 3137-3145.

Zelalem A, Tekalign T, Nigussie D. 2009. Response of potato (*Solanum tuberosum* L.) to different rates of nitrogen and phosphorus fertilization on vertisols at Debre Berhan, in the central highlands of Ethiopia. Afr J Plant Sci 2: 16-24.