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STRENGTHENING SEED POTATO AGRONOMY THROUGH ORGANIC AND PHOSPHORUS NUTRITION BASED INTERVENTIONS

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ABSTRACT: Punjab contributes significantly to India's seed potato supply, yet its potato productivity remains below expectations. Poor nutrient management, particularly phosphorus, is a key factor in this underperformance. This study, conducted over two years in Ludhiana and Jalandhar, utilized a split-plot design to test three organic treatments (farmyard manure, biofertilizer, control) and five phosphorus fertilizer levels (46.9, 62.5, 93.8, 125, 0 kg ha^{-1} P_2O_5). Farmyard manure (FYM) significantly increased plant height, LAI, and tuber and haulm weights at 45 and 75 days after sowing (DAS) compared to other organic treatments. FYM consistently outperformed tuber yield compared to other treatments in both locations and years. Phosphorus application at 125 kg ha^{-1} P_2O_5 enhanced tuber yield by up to 24% compared to unfertilized plots, with improvements in plant growth attributes. The highest tuber yields were achieved with FYM (50 t ha^{-1}) and phosphorus levels up to 125 kg ha^{-1} P_2O_5)., underscoring the effectiveness of these strategies in optimizing seed potato production.

KEYWORDS: Seed potato, Farmyard manure, Biofertilizer, Phosphorus and Fertilizer

INTRODUCTION

In Punjab, a staggering 85 percent of the country's seed potato demand is met, with seed potato farming occupying about 60 percent of the state's potato cultivation area (Singh *et al.*, 2024). Yet, despite this massive contribution, the region's potato productivity lags far behind, this is notably lower compared to the national average of 241.2 q ha^{-1} (Anonymous, 2022). The weak performance of Punjab's seed potato cultivation is largely due to poor nutrient management strategies, with phosphorus nutrient being a key factor. Phosphorus is the second most limiting nutrient after nitrogen, and its effective management is crucial not just for increasing yield but also for improving tuber quality, disease resistance, and overall agricultural efficiency (Rosen and Bierman, 2008). Research has shown that phosphorus significantly boosts tuber numbers and size, which in turn maximizes productivity (Kelling *et al.*, 2020). On the flip side, poor phosphorus management can result in fewer tubers per plant and disrupt key physiological processes like tuber emergence and tuber initiation (Cui *et al.*, 2020). Soratto and Fernandes (2016) reported that higher phosphorus levels increased dry matter accumulation, nutrient uptake, and overall tuber yield. Moreover, efficient phosphorus use is vital to avoid long-term degradation of soil health and to maintain the quality of seed potato production (Hopkins *et al.*, 2008).

For Punjab to truly harness its potential, an integrated approach combining organic, inorganic, and biofertilizer sources is essential. This study is focused on exploring

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the effects of various nutrient sources on seed potato crops. The goal is to revolutionize potato farming practices in subtropical regions, providing solutions that could push productivity beyond current limitations. The future of Punjab's potato farming depends on smarter nutrient management and a commitment to sustainable agricultural practices.

MATERIAL AND METHODS

Experimental Area and Climate Overview

The field experiment took place in Autumn 2019 and 2020 at two Punjab locations (School of Organic Farming, Punjab Agricultural University, and Farmer Field, Jalandhar) in subtropical northwest India. Ludhiana [Ldh] (30°56′ N, 75°52′ E, 247 m) lies in the 'Trans-Gangetic' agro-climatic zone, with temperatures ranging from over 46°C in June to below 5°C in December, and 75% of the 759 mm annual rainfall occurring from July to September. Jalandhar [Jal] (31°32′ N, 75°57′ E, 228 m) experiences similar conditions, with summer highs exceeding 39.4°C and winter lows below 6°C, averaging 703 mm of rainfall annually. Ludhiana's soil (0-15 cm depth) is loamy sand with a pH of 7.20, 0.50 percent organic carbon, and higher nitrogen (288 kg ha^{-1}), phosphorus (26 kg ha^{-1}), and potassium (335 kg ha^{-1}). Jalandhar's soil, sandy loam with a pH of 6.85, has slightly lower organic carbon (0.43 percent), nitrogen (263 kg ha^{-1}), phosphorus (21.6 kg ha^{-1}), and potassium (305 kg ha^{-1}).

Treatments and Experimental Design

The experiment employed a split-plot design with three replications. Main plot treatments comprised three organic sources: farmyard manure (FYM) at 50 t ha^{-1}, biofertilizer [Biof] consortium at 10 kg ha^{-1}, and a control. Subplots included five phosphorus levels: 46.9 (P_{75}), 62.5 (P_{100}), 93.8 (P_{150}), 125 (P_{200}), and 0 (P_0) kg ha^{-1} P_2O_5. FYM was applied during seedbed preparation, while phosphorus and biofertilizer were administered at sowing time. Statistical analyses followed Cochran and Cox's guidelines, assessing normality, variance homogeneity, and treatment interactions. Significant effects ($P < 0.05$) were analyzed using Fisher's protected LSD test. Data analysis was conducted using the "Doebioresearch" package in R Studio.

Crop Raising and Data Collection

The experimental field underwent two disc harrow cultivations, followed by two rounds of plowing with a tractor-drawn cultivator, producing a finely prepared seedbed, finalized by planking. The short-duration potato cultivar '*Kufri Pukhraj*' was selected for experimental trials at both locations. Medium-sized tubers (35-45 cm) were planted mid-autumn (Ludhiana: October 9, 2019, and October 16, 2020; Jalandhar: October 28, 2019, and November 13, 2020) in 3.25 m x 4.05 m plots, with 65 cm row spacing and 15 cm plant spacing, at a seed rate of 4.5 t ha^{-1}. Irrigation was immediately applied after sowing, with five total irrigations until harvest. Standard seed potato production practices recommended by Punjab Agricultural University, Ludhiana, were followed. Nitrogen (187.5 kg ha^{-1}) and potassium (62.5 kg ha^{-1}) were supplied through urea and muriate of potash, with half the nitrogen and all potassium applied at sowing and the remaining nitrogen top-dressed 30 days after sowing (DAS). Dehaulming of tubers occurred on January 3, 2019, and January 11, 2020, in Ludhiana, and on February 1, 2019, and February 15, 2020, in Jalandhar. Plant height and leaf area index (LAI) were measured at haulm cutting from five randomly selected plants in each treatment. Plant height was recorded using a measuring tape, and LAI was calculated as the ratio of leaf area to ground area, reflecting the canopy structure. Tuber and haulm weights were recorded by uprooting two randomly selected plants per treatment. The fresh weights of both tubers and haulms were measured separately using an electronic balance to ensure accuracy. The total yield of tubers was measured from a net plot size of 7.89 m^2. All tubers and haulms within the experimental area were harvested and weighed to assess the overall yield under each treatment plot.

RESULT AND DISCUSSION

Plant height

At both Ludhiana and Jalandhar, plant height increased significantly with the application of FYM at 45 and 75 DAS during both years of the study (Table 1). In Ludhiana, FYM treatment recorded plant heights of 35.3 cm and 56.2 cm at 45 and 75 DAS in 2019-20, and 36.8 cm and 59.6 cm in 2020-21. Similarly, in Jalandhar, FYM consistently resulted in higher plant heights than other treatments at the same crop stages. Biof also performed better than the unfertilized control at both locations, while the lowest plant heights were observed in the control plots without fertilization. Among phosphorus treatments, P_{200} resulted in the higher height of seed crop, with P_{150} statistically at par with P_{100} and P_{200}, while P_0 recorded the lowest heights at Ldh and Jal locations. The enhanced plant height with FYM treatment aligns with the findings of Jaipaul et al. (2011), who reported increased height due to the improved nutrient availability from FYM. The phosphorus response is consistent with Kumar *et al*. (2007) and Manorama *et al*. (2017), who noted higher potato plant heights with increased phosphorus rates, which may be attributed to better carbohydrate accumulation and cell growth, as highlighted by Abbasian *et al*. (2018).

Leaf area index

At both Ludhiana and Jalandhar, FYM significantly increased the leaf area index (LAI) at 45 and 75 DAS during both years of the study (Table 2). In Ludhiana, FYM

Table 1. Effect of organic sources and phosphorus nutrition on plant height of seed potato

Treatment	Plant height (cm)							
	Ldh				Jal			
	45 DAS		75 DAS		45 DAS		75 DAS	
	2019	2020	2019	2020	2019	2020	2019	2020
Organic source								
Control	28.2	29.5	43.7	46.2	32.6	25.2	49.3	41.1
Biof	30.2	31.5	48.4	51.5	35.1	26.9	55.8	45.1
FYM	35.3	36.8	56.2	59.6	40.9	31.1	64.4	51.9
LSD (p=0.05)	1.6	1.7	3.2	3.3	1.9	1.3	3.4	2.6
Fertilizer phosphorus								
P_0	28.2	29.4	43.8	46.3	32.6	25.1	50.0	41.4
P_{75}	30.3	31.7	48.2	51.4	35.1	26.7	55.0	44.6
P_{100}	31.2	32.6	49.6	52.7	36.1	27.7	56.6	46.1
P_{150}	32.6	34.0	51.8	54.9	37.9	29.0	59.3	48.3
P_{200}	33.9	35.2	53.7	57.0	39.3	30.0	61.6	49.9
LSD (p=0.05)	1.6	1.8	3.3	3.4	2.1	1.4	3.8	2.7

Table 2. Effect of organic sources and phosphorus nutrition on LAI of seed potato

Treatment	LAI							
	Ldh				Jal			
	45 DAS		75 DAS		45 DAS		75 DAS	
	2019	2020	2019	2020	2019	2020	2019	2020
Organic source								
Control	1.43	1.51	2.51	2.62	1.65	1.25	2.75	2.24
Biof	1.63	1.75	2.85	3.02	1.94	1.43	3.24	2.56
FYM	2.02	2.16	3.54	3.76	2.38	1.78	4.00	3.19
LSD (p=0.05)	0.14	0.11	0.20	0.18	0.15	0.12	0.22	0.21
Fertilizer phosphorus								
P_0	1.46	1.56	2.57	2.70	1.70	1.28	2.84	2.31
P_{75}	1.61	1.72	2.81	2.96	1.89	1.40	3.15	2.52
P_{100}	1.68	1.80	2.94	3.12	1.98	1.48	3.31	2.66
P_{150}	1.80	1.92	3.15	3.33	2.12	1.57	3.55	2.82
P_{200}	1.91	2.05	3.35	3.56	2.26	1.68	3.79	3.00
LSD (p=0.05)	0.14	0.15	0.22	0.24	0.18	0.11	0.28	0.20

recorded the highest LAI at 45 DAS and 75 DAS compared to all other organic treatments, with biof also performing better than the unfertilized control, which had the lowest LAI. Similarly, in Jalandhar, FYM consistently resulted in significantly higher LAI at 45 and 75 DAS, with biof outperforming the control. Among phosphorus treatments, P_{200} achieved the highest LAI at these stages at Ldh and Jal, with P_{150} statistically at par with P_{100} and P_{200}. The lowest LAI was recorded with P_0 at 45 and 75 DAS across both years. These findings are consistent with Koireng *et al*. (2018), who reported increased LAI with FYM, and Kumar et al. (2007), who observed a positive correlation between phosphorus levels and LAI due to enhanced cell elongation and division.

Tuber and haulm weight

The application of FYM resulted in markedly higher tuber and haulm weights compared to other organic treatments (Table 3 and 4), with bio significantly surpassing the unfertilized control, which exhibited the lowest tuber and haulm weights. The increased tuber and haulm weights with FYM can be attributed to the enhanced plant height and leaf area index (Table 4). Similar findings were reported by Asghari et al. (2016) and Alemayehu *et al*. (2020), who observed greater tuber and haulm weights under FYM application compared to control other organic manures. Statistical analysis revealed that P_{200} phosphorus application yielded the highest tuber and haulm weights among the phosphorus treatments in both Ludhiana and Jalandhar, except for the P_{150} phosphorus level, which showed comparable results for tuber weight and haulm. The lowest tuber and haulm weights were recorded with unfertilized phosphorus. The superior tuber and haulm weight with P_{200} could be attributed to enhanced cell elongation and division in the root zone, which led to increased biomass accumulation per plant. These results are consistent with Teshome *et al*. (2018) and Fernandes *et al*. (2016), who also reported higher tuber and

Table 3. Effect of organic sources and phosphorus nutrition on tuber weight per plant of seed potato

Treatment	Tuber weight (g $plant^{-1}$)							
	Ldh				Jal			
	45 DAS		75 DAS		45 DAS		75 DAS	
	2019	2020	2019	2020	2019	2020	2019	2020
Organic source								
Control	43.1	45.3	232.6	238.8	48.5	38.6	246.2	218.9
Biof	47.1	50.4	254.9	267.1	54.9	43.1	280.9	246.1
FYM	54.4	58.3	296.8	311.9	62.9	50.1	324.6	283.7
LSD (p=0.05)	2.7	3.3	16.2	16.5	3.4	2.5	19.3	14.7
Fertilizer phosphorus								
P_0	43.2	45.4	233.9	239.3	48.8	39.0	248.8	222.1
P_{75}	46.8	50.0	253.6	265.8	53.8	42.7	276.3	242.9
P_{100}	48.1	51.4	261.1	273.2	55.4	44.0	284.5	249.9
P_{150}	50.4	53.9	273.4	286.5	58.3	46.1	299.1	261.7
P_{200}	52.6	56.1	285.1	298.3	60.6	47.9	310.9	271.4
LSD (p=0.05)	3.3	3.5	18.3	19.9	4.4	3.0	22.6	17.4

Table 4. Effect of organic sources and phosphorus nutrition on haulm weight per plant of seed potato

Treatment	Haulm weight (g $plant^{-1}$)							
	Ldh				Jal			
	45 DAS		75 DAS		45 DAS		75 DAS	
	2019	2020	2019	2020	2019	2020	2019	2020
Organic source								
Control	48.8	52.2	87.2	94.8	53.4	44.5	96.1	79.4
Biof	55.8	61.4	104.4	114.1	64.1	51.4	120.1	94.3
FYM	68.1	73.7	126.8	137.8	76.2	62.4	142.1	113.9
LSD (p=0.05)	4.1	4.4	9.1	8.5	4.3	3.3	8.2	7.2
Fertilizer phosphorus								
P_0	50.1	54.4	90.4	98.6	55.3	45.8	100.1	81.9
P_{75}	54.1	59.3	100.0	109.8	61.4	49.8	114.4	91.0
P_{100}	57.4	62.2	105.8	115.3	64.2	52.3	119.5	95.5
P_{150}	61.3	66.2	114.0	123.7	68.9	56.2	127.8	102.4
P_{200}	65.0	70.3	120.5	130.5	73.0	59.7	135.2	108.6
LSD (p=0.05)	3.9	4.6	8.3	8.9	5.5	3.9	9.8	7.8

haulm weights with increased phosphorus application in potatoes.

Total tuber yield

Tuber yield is a critical metric for evaluating the effectiveness of various treatments and selecting the best strategy for enhancing seed potato production. The pooled data presented in Table 5 reveal that farmyard manure (FYM) significantly increased tuber yields, with up to a 30 percent increase compared to the control at Ludhiana and Jalandhar. This

Table 5. Effect of organic sources and phosphorus nutrition on total tuber yield

Treatment	Total tuber yield (q ha^{-1})			
	Ldh		Jal	
	2019-20	2020-21	2019-20	2020-21
Organic source				
Control	265.0	269.2	277.6	251.6
Biof	290.5	299.5	315.1	281.0
FYM	339.8	349.7	363.3	322.6
LSD (p=0.05)	17.9	18.8	22.0	17.7
Fertilizer phosphorus				
P_0	266.9	269.2	280.1	255.3
P_{75}	289.6	298.0	309.6	277.1
P_{100}	298.1	306.4	318.9	285.0
P_{150}	312.2	321.5	335.6	298.5
P_{200}	325.5	334.9	349.0	309.5
LSD (p=0.05)	21.2	22.4	25.8	20.2

improvement is attributed to better nutrient availability and soil conditions provided by FYM, which aligns with findings by Moore *et al*. (2011) and Koroto (2017), who also reported enhanced tuber yields with FYM. In addition to organic sources, phosphorus application also played a significant role in increasing tuber yields. Phosphorus levels up to P_{200} resulted in up to a 24 percent higher tuber yield compared to unfertilized plots (P_0). The P_{150} phosphorus level showed similar results to P_{100} and P_{150}. Increased tuber yield with higher phosphorus levels is attributed to enhanced cell division, elongation, and photosynthesis, leading to greater starch synthesis and tuber development. This observation is consistent with Kumar *et al*. (2007) and Nyiraneza *et al*. (2017), who noted that phosphorus promotes above-ground biomass growth and starch accumulation, thereby boosting tuber productivity. Overall, the results underscore the effectiveness of both FYM and phosphorus nutrition in increasing tuber productivity, highlighting their importance in optimizing seed potato production strategies.

CONCLUSION

The study confirms that farmyard manure (FYM) and phosphorus nutrition substantially improved plant growth and tuber yield in seed potatoes. FYM increased plant height, leaf area index (LAI), tuber and haulm weights significantly at 45 and 75 days after sowing (DAS) at both Ludhiana and Jalandhar. The application of FYM resulted in up to 30 percent higher tuber yields compared to the control, supported by better nutrient availability and soil conditions. Phosphorus application further enhanced tuber yield, with 125 kg/ha showing up to a 24 percent increase compared to unfertilized plots. The observed improvements in tuber yield with higher phosphorus levels are linked to enhanced cell division, elongation, and photosynthesis. The study also highlights that while FYM and phosphorus fertilization are effective individually, their interaction did not significantly affect growth attributes. These findings emphasize the importance of both FYM and phosphorus in optimizing seed potato production.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest

ETHICAL STATEMENT

This article does not contain any studies with human participants or animals performed by any of the authors

LITERATURE CITED

Abbasian A, Ahmadi A, Abbasi A and Darvishi B (2018) Effect of various phosphorus and calcium concentrations on potato seed tuber production. J Plant Nutr 41:1765-1777.

Alemayehu M, Jemberie M, Yeshiwas T and Aklile M (2020) Integrated application of compound NPS fertilizer and farmyard manure for economical production of irrigated potato (*Solanum tuberosum*) in highlands of Ethiopia. Cogent Food Agric 6:1-13.

Anonymous (2022) Horticultural Statistics at a Glance. www.agricoop.nic.in. Accessed 15 April 2023.

Asghari MT and Fard RMA (2016) Effect of farmyard manure and nitrogen treatments upon the quality and quantity of potato (Solanum tuberosum). Biharean Biol 10:24-27.

Cui S, Qin Y, Yu J, Shi X, Jia L and Fan M (2020) Improving tuber yield and phosphrous use-efficiency using split phosphorus application to potatoes in Inner Mongolia. American J Potato Res 97:318-324.

Fernandes A M and Soratto R P (2016) Response of potato cultivars to phosphate fertilization in tropical soils with different phosphorus availabilities. Potato Res 59: 259-78.

Hopkins BG, Horneck DA and Macguidwin AE (2014) Improving phosphorus use efficiency through potato rhizosphere modification and extension. American J Potato Res 91:161-174.

Jaipaul, Sharma S and Sharma AK (2011) Effect of organic fertilizers on growth, yield and quality of potato under rainfed conditions of Central Himalayan region of Uttarakhand. Potato J 38:176-181.

Kelling KA, Wolkowski RP, Speth PE and Andraski TW (2020) Interaction of fertilizer phosphorus rate and placement or timing on potatoes. American J Potato Res 97:420-431.

Koireng R J, Singh L N and Devi K P (2018) Integration of different sources of organic manure and micro-nutrients on growth, yield and quality of potato (Solanum tuberosum) grown under new alluvial soil condition. Indian J Agric Res 52: 172-76.

Koroto (2019) Effect of farmyard manure and mineral NP fertilizers on yield related traits and yield of potato (Solanum tuberosum) at Areka, Southern Ethiopia. Int J Hortic Sci Ornam Plant 5:74-85.

Kumar P, Pandey SK, Singh BP, Singh SV and Kumar D (2007) Optimizing phosphorus requirement of chipsona varieties for west-central plains of India. Potato J 34:199-202.

Kumar P, Pandey SK, Singh BP, Singh SV and Kumar D (2007) Optimizing phosphorus requirement of chipsona varieties for west-central plains of India. Potato J 34:199-202.

Manorama K, Govindakrishnan P and Lal S S (2017) Evaluation of potato cultivars for phosphorus efficiency under Nilgiris conditions. Indian J Hort 74: 448-52.

Moore AD, Olsen NL, Carey AM and Leytem AB (2011) Residual effects of fresh and composted dairy manure applications on potato production. American J Potato Res 88:324-332.

Nyiraneza J, Fuller KD, Messiga AJ, Bizimungu B, Fillmore S and Jiang Y (2017) Potato response to phosphorus fertilization at two sites in Nova Scotia, Canada. American J Potato Res 94:357-366.

Soratto R P and Fernandes A M (2016) Phosphorus effects on biomass accumulation and nutrient uptake and removal in two potato cultivars. Agron J 108: 1225-36.

Singh A, Aulakh CS, Sidhu AS and Chawla N (2024) Assessing the impact of organic resources and phosphorus on nutrient uptake, soil traits and seed potato productivity. Crop Forage Turfgrass Manage 10:20298.

Teshome S, Bobo T and Wako B (2018) Response of application time and method of inorganic phosphorus fertilizer on Irish potato production at Bore and Anasora Area, Southern Oromia Ethiopia. Int J Anim Sci Tech 2: 45-54.

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