Fertilization Impacts on Productivity and Profitability of Potato

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Economically viable potato production in West Bengal, India relies on balanced fertilizer management to build high yields of quality product, and return a strong economic response.

This study supported recommended NPK application rates as a means of increasing the proportion of superior grade potato and optimizing economic returns to farmers.

N was the most limiting nutrient, followed by P and then K. Over (150%) or under (50%) application of NPK showed no advantage to potato quality or economic returns.

Potato is one of the major staple crops produced throughout the world. The average potato yield in countries such as U.S., Germany, Netherlands, and France range between 38 to 44 t/ha, while in India it is only 23 t/ha (FAOSTAT, 2015). Three states, Uttar Pradesh, West Bengal, and Bihar, jointly contribute about 78% of the total potato production in India. West Bengal is the second largest potato growing state in India, producing 13,400 t from 409,000 ha—an average productivity of 24 t/ha (Govt. of West Bengal, 2012).

The major constraints for higher yield of potato in the state are inadequate and unbalanced nutrient use (Mozumder et al., 2014). Along with temperature variation, nutrient management plays a major role in potato yield improvement in West Bengal. Nitrogen, P, and K requirements of potato are high (Zewide et al., 2012), and optimum supply of these nutrients improves yield and quality of potato tubers where native soil supplies are limited (Westermann, 2005). These nutrients are key to optimum plant growth and are also essential for regulating plant water status and osmotic pressure, increasing nitrate reductase activity, and raising photosynthesis and transpiration (Li et al., 2011). Nitrogen influences yield by increasing the size and the number of tubers. Phosphorus is the second most limiting nutrient and influences root and shoot growth, as well as the rate of tuberization. Potassium plays an important role in increasing tuber size, yield, and quality. Potassium uptake by potato is high, and it plays a significant role in translocation and accumulation of photosynthates (carbohydrates) from the leaves to the tubers. Deficiencies of the major nutrients limit potato plant canopy growth and its duration, resulting in reduced carbohydrate production and tuber growth.

This potato field trial was carried out in 2012–13 and 2013–14 on alluvial soils in the Hooghly District of West Bengal (**Figure 1**). The objective of the study was to generate information on phenological and productivity changes with varied NPK levels. The experimental soil was clayey in texture, with 0.1 dS/m EC, 0.78% organic matter, pH of 6.2, and 180 kg/ha available N, 24 kg/ha available P_2O_5, and 210 kg/ha available K_2O. The available N was analyzed through the hot alkaline permanganate method. Available P was extracted with 0.5 M $NaHCO_3$ (pH 8.5) and measured through a UV-VIS spectrophotometer. The available fraction of K was extracted with neutral normal ammonium acetate (pH 7.0; 1:10 w/v) solution and estimated through a flame photometer. Maximum and minimum air temperature fluctuated between 36°C and 7°C in 2012–13; 34°C and 9°C in 2013–14. Total rainfall during the experiment (November to March) was 46 mm (5 rainy days) and 55 mm (2 rainy days) in 2012–13 and 2013–14, respectively. The experiment included seven treatments: T_1 (50% NPK), T_2 (100% NPK), T_3 (150% NPK), T_4 (100% PK), T_5 (100% NK), T_6 (100% NP), and T_7 (control without NPK). The 100% NPK treatment provided 200-150-150 kg N-P_2O_5-K_2O/ha, which was the state recommendation (SR). Potato seed pieces (cv. Kufri Jyoti) were planted at a spacing of 60 × 20 cm at a depth of 15 cm. All P and K fertilizers were applied prior to sowing, while N fertilizer was applied in two splits—50% before sowing and 50% at 30 days after planting (DAP). Treatment means were

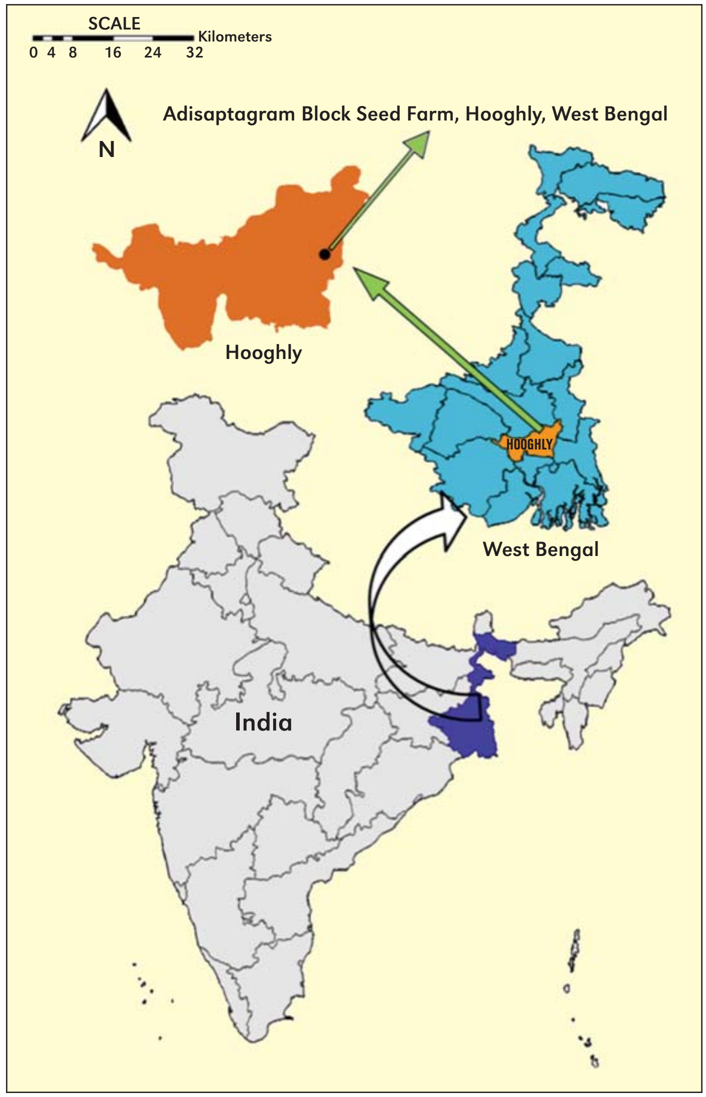

Figure 1. Location of the experimental site (23°26° N and 88°22° E with an elevation of 12 m above mean sea level).

Abbreviations and Notes: N = nitrogen; P = phosphorus; K = potassium.

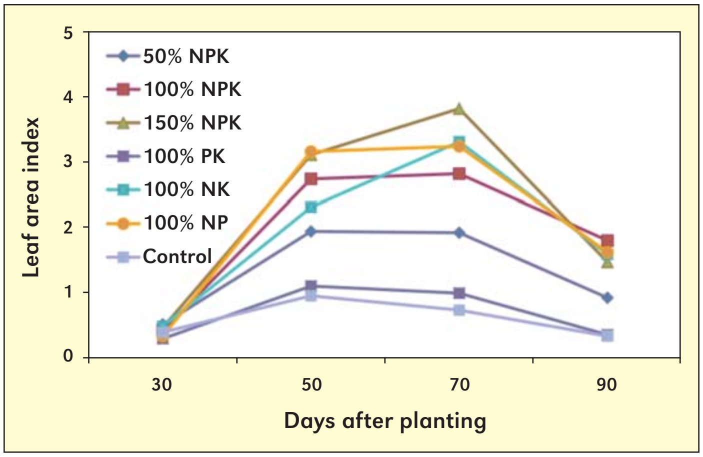

Figure 2. Leaf area index of potato plant over the crop season with varied NPK levels, West Bengal.

separated using a least significant difference (LSD) at the 0.05 probability level.

Impact on Growth, Yield, and Nutrient Uptake

Leaf area index (LAI) and dry weight per plant are considered the two major growth indicators of potato. These characteristics were measured at 30, 50, 70, and 90 DAP. LAI is calculated as the ratio of the measured leaf area of the plant to the ground area. NPK application significantly affected LAI at 30 DAP (**Figure 2**). Omission of N (100% PK) and control plots resulted in a significant reduction in LAI. The LAI of plants receiving 150% NPK declined sharply at 90 DAP, which indicates that NPK application at this rate produced more leaves but also led to early leaf senescence.

Dry weight per plant was determined by drying the entire sample plant to a constant weight at 70°C for 72 hours. Dry weight increased with crop age, and NPK rates significantly influenced the dry weight per plant (**Figure 3**). Factors such

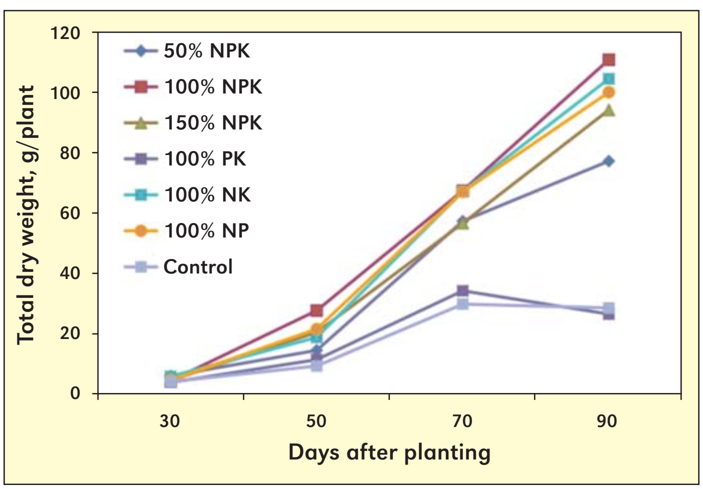

Figure 3. Total dry weight of potato plant (plant + tuber) over the crop season with varied NPK levels, West Bengal.

as maturity of tubers, and nutrient and water uptake by plants regulate dry matter production, while NPK fertilizer promote plant growth by extending the growing period. Under N omission and control treatments, total dry matter production was consistently low, reflecting the role of N in plant nutrient acquisition. Dry matter accumulation in potato was negatively

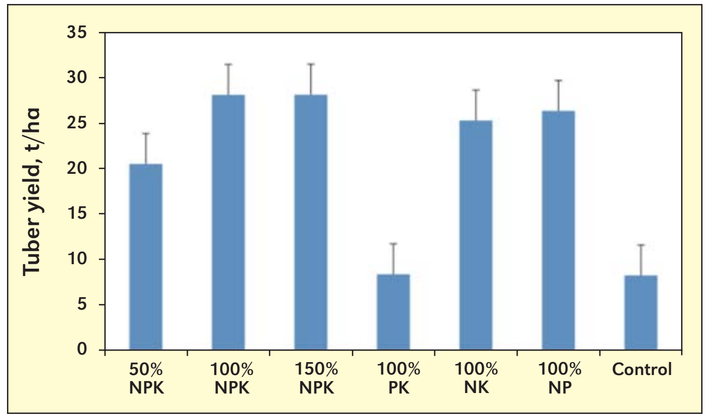

Figure 4. Tuber yield of potato with varied NPK levels, West Bengal.

influenced by N deficiency, but also in conditions when N supply was high.

NPK fertilization showed a positive influence on total tuber yield (**Figure 4**). Tuber yield increased with increasing levels of NPK. Application of 150% NPK produced the highest total tuber yield, although that was statistically at par with 100% NPK. The observed higher fertilizer response may be linked to the increase in total leaf area, that in turn increased the amount of intercepted solar radiation and supported more photoassimilates to produce more tubers (Banerjee et al., 2016). This increase in yield may also be attributed to better availability of nutrients, improved vegetative growth, and greater synthesis of carbohydrates and their translocation.

Potato yield was significantly reduced by nutrient omission. Respectively, omission of N, P, and K reduced tuber yield by 70, 10, and 6% when compared to the 100% NPK treatment. The significant yield reduction due to N omission might be partly attributed to greater reduction in plant growth and yield components, and highlights the importance of N in potato cultivation. Yield loss was higher for P omission than for K omission. The yield reduction due to K omission was rather small, which might be due to the medium K availability of the experimental soil, a reflection of the high K-supplying capacity of these alluvial soil types rich in illitic clays (Sarkar et al., 2013) as well as a history of K application. However, it should also be remembered that high yielding potato removes a significant amount of K from the soil and reduced or omission of K based on an over-reliance on soil K reserves leads to a loss in long term soil fertility.

Plant nutrient uptake was highest for K followed by N then P (**Figure 5**). Potato takes up considerable quantities

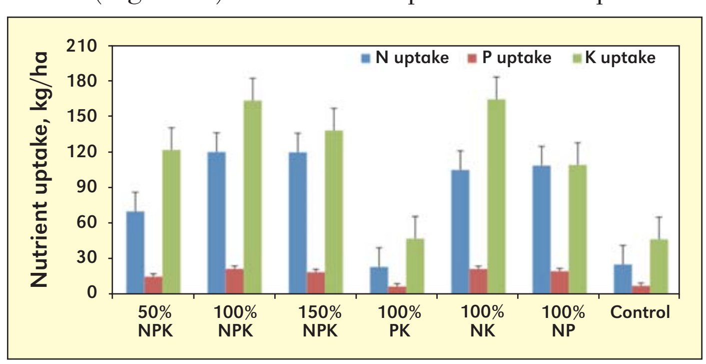

Figure 5. Nutrient (NPK) uptake by potato with varied NPK levels, West Bengal.

of K during the tuber bulking stage to generate yield with bigger tubers. The recommended fertilizer treatment (100% NPK) had significantly higher N uptake over the control and 50% NPK treatment, and was statistically at par with 150% NPK. Lowest N uptake in potato plant was observed under N omission and the control (80% and 79% less than with 100% NPK, respectively). Similar to N uptake, P uptake was higher with 100% NPK, and it did not differ significantly with 150% NPK. Significantly lower P uptake was observed in plants with 100% PK and control plots. Interestingly, the P uptake in N omission treatment was lower than with the P omission treatment. Nitrogen uptake in the 100% NPK treatment was significantly higher than the P and K omission plots that received 100% N. This highlights the importance of balanced P and K application in potato for optimum utilization of applied N. Potassium uptake varied significantly across treatments, but showed higher K uptake with 100% NPK (247% more than the control). Interestingly, N omission had a far greater impact on K uptake than K omission itself, corroborating the synergistic effect of balanced fertilization.

Table 1. Economics of potato production (Mean data of 2 years), West Bengal.

Treatments	Common cost, US$/ha/yr	Treatment cost, US$/ha/yr	Total cost, US$/ha/yr	Gross return, US$/ha/yr			Net return[1], US$/ha/yr	Benefit: Cost ratio
				< 50g	> 50g	Total		
50% NPK	1,259	130	1,389	330	1,402	1,732	343	1.25
100% NPK[2]	1,259	216	1,475	285	2,252	2,537	1,062	1.72
150% NPK	1,259	374	1,633	292	2,241	2,533	900	1.55
100% PK (-N)	1,259	208	1,468	232	382	613	-855	0.42
100% NK (-P)	1,259	177	1,436	325	1,890	2,214	778	1.54
100% NP (-K)	1,259	127	1,386	326	1,994	2,320	934	1.67
Control (-NPK)	1,259	0	1,259	228	377	604	-655	0.48

[1] Net return = Gross return – Total cost; 1 US$ = INR 60 (Indian rupees); Market price for potato 100 US$/t
[2] State recommendation; Selling price of < 50g tubers is INR 150/bag and > 50g tubers is INR 300/bag (1 bag = 50 kg).

Potato field at Adisaptagram Block Seed Farm, Hooghly, West Bengal, India.

Economics

Net income and Benefit to Cost (B:C) ratio continued to increase up to 100% NPK, and further addition (150% NPK) resulted in a decrease of both (**Table 1**). These higher economic returns at 100% NPK are attributed to increased total tuber yield. Cost of cultivation only differed marginally on account of nutrient omissions but resulted in a significant reduction in the yield and net profit, especially for N and P omissions. Negative net returns were recorded in the control plots and N omission treatments. Omission of N reduced the net returns drastically, while P was the second most limiting nutrient. It is to be noted that although the omission of K did not significantly impact the B:C ratio because of the high K-supplying capacity at the site, the application of K fertilizer at the recommended rate helps maintain soil health by avoiding the depletion of the nutrient, which has long term implications on soil fertility and sustainable productivity (Majumdar et al., 2016).

Summary

In summary, potato responded positively to NPK fertilization. Total tuber yield increased with up to 150% of the state recommendation for NPK fertilizer application, and omission of nutrients led to reduced tuber yield. The study highlights that N is the most limiting nutrient for potato production in West Bengal, followed by P and K.

Acknowledgement

This article is an excerpt from a research paper published by Banerjee et al. 2016 in Indian Journal of Plant Physiology. DOI 10.1007/s40502-016-0211-x. BC

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