4R Nutrient Stewardship of Potato: A Major Cash Crop in Eastern India

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4R guidelines are needed to enhance potato growth stages and increase yields.

Potato is one of the major staple crops produced throughout the world. Average potato yields in countries such as the U.S.A., Germany, Netherlands, and France range between 38 to 44 t/ha, while yields average 23 t/ha in India (FAOSTAT, 2015). One of the major constraints to a higher yield of potato in India is inadequate and unbalanced nutrient use (Banerjee et al., 2016). Along with temperature variation, nutrient management plays a major role in potato yield improvement. Nitrogen, P, and K requirements of potato are high and the optimum supply of these nutrients improves yield and quality of potato tubers in areas where native soil supplies are limited. These nutrients are key to optimum plant growth, essential for regulating plant water status and osmotic pressure, increasing nitrate reductase activity, and raising photosynthesis and transpiration. Therefore, all these nutrients are to be applied in the right amount, at the right rate, at the right time, and at the right place for better nutrient uptake, nutrient use efficiency, and increased economic return. This study provides guidelines for the 4R management of the three major nutrients for potato, under an Indian context.

Dr. Banerjee inspecting potato plots in West Bengal.

Nitrogen

Nitrogen is the major limiting nutrient in most Indian soils. It is responsible for increasing vegetative growth, tuber size, tuber number, and the tuber bulking rate (TBR) in the potato plant. Among the different sources of nitrogenous fertilizer, urea is the most easily available and cheapest accounting for 78% of total N fertilizers produced in India (Trehan et al., 2008). However, its efficiency is less than other sources such as calcium ammonium nitrate (CAN) and ammonium sulphate. Ammonium sulphate has been found to be the best source for potato production because of its S supplementation along with N (Dua, 2014), producing 1.2, 9.2, 11, 41, and 63% higher tuber yields than ammonium nitrate, ammonium chloride, CAN, urea, and sodium nitrate respectively at the same N rate (Grewal and Trehan, 1984). However, it is comparatively expensive amongst all the other N sources and unaffordable for small and marginal potato growers. Swaminathan (1972) observed that performance of CAN and ammonium chloride, as N sources, closely follows ammonium sulphate; whereas, urea and sodium nitrate were poor sources of N. Urea has an adverse effect on plant emergence and sodium nitrate reduces the final plant stand. Due to its low cost, attempts have been made to increase the efficiency of urea through optimized rate, time, and placement of application. Higher number of split applications can increase N use efficiency from urea and moisture management during pre-emergence stage counteracts the detrimental effects of urea on crop emergence.

The N rate varies across different potato growing regions depending upon the soil type, variety, and yield target. In the Indo-Gangetic alluvial plains of West Bengal, Banerjee et al. (2016) reported 70% tuber yield reduction in potato with N omission when compared to an application rate of 200:150:150 of N, P_2O_5 and K_2O/ha, respectively. On the contrary, the excess application of N delays the tuber initiation which leads to excessive vegetative growth resulting in poor yield. The N requirement is as high as 240 kg/ha in the alluvial soils of Punjab, Uttar Pradesh, Bihar, and Jharkhand (Dua, 2014), 203 kg/ha in West Bengal (**Figure 1**), 120 to 155 kg/ha in the acidic soils of Himachal Pradesh, Jammu and Kashmir, and north eastern hills, and 600 kg/ha under riverbed cultivation in Gujarat (Sud and Sharma, 2003). Banerjee et al. (2016) recorded significantly higher tuber yield for long duration

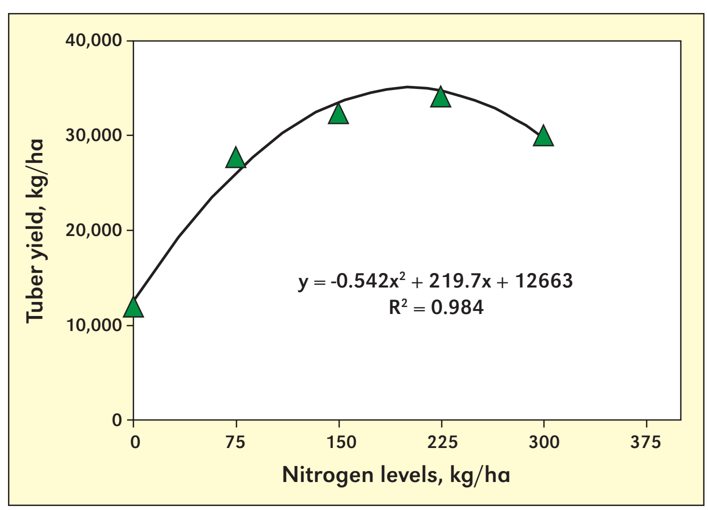

Figure 1. Potato response to nitrogen application in Indo-Gangetic plains of West Bengal (Mozumder et al., 2014).

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; S = sulphur.

cultivar (cv. Kufri Himalini) with 225 kg N/ha, suggesting N requirement increases with increase in crop duration. These findings suggest that location specific N rate estimation needs to be taken into account for growing conditions, yield target and soil nutrient supplying capacity.

The efficiency of nitrogenous fertilizer in potato is greatly influenced by the time and method (place) of its application. Tuber development, commercially the most important phase in potato production, could be extended (65 to 85 days in hills and 40 to 60 days in plains) by providing sufficient N at early growth stages to prolong the growth stages. The efficiency of N can be increased by applying fertilizer 5 to 10 days before planting and mixed with soil properly (Mondal and Chatterjee, 1993). Split application of N, half at planting and half at 30 days after planting, is generally recommended in potato for better efficiency, higher tuber yield, and reduction in leaching loss of N (Mozumder et al., 2014; Banerjee et al., 2016). In hilly areas, where the duration of crop is 4 to 5 months, three split applications of N is better than two. The foliar application of urea at 50 to 60 DAP (1 to 1.5% solution) can improve or correct the N-deficiency at mid-crop growth stages. The N use efficiency (NUE) of potato also depends on the method of application because there is a strong relationship between sources of N and method of application (Trehan et al., 2008). Broadcasting of CAN and ammonium sulphate is better than hand placement in furrows below the tubers, as it helps the quick emergence of crops; whereas, in case of urea, side banding 5 cm away and 10 cm deep was found to be the best (Sharma and Upadhayaya, 1991). Row placement of nitrogenous fertilizer has been found to be a better choice in silt loam soil rather than sandy loam soil (Sud and Sharma, 2003).

Earthing up of soil after top dressing of N at 30 days after seeding.

Phosphorus

Phosphorus is the second limiting nutrient responsible for potato production in different agro-climatic zones of India. Application of P improves tuber yield of potato by increasing the tuber number, as well as the size. It counteracts excessive crop growth due to application of heavy doses of N and accelerates maturity. There are different sources of phosphatic fertilizers that have varying efficacy in different soil types for potato. In the alluvial soils, readily available phosphatic fertilizers such as single super phosphate (SSP) and diammonium phosphate (DAP), are suitable for potato production. The recovery of P by the first crop of potato from SSP is about 20% (Rana, 2014). In general, superphosphate, mono-ammonium phosphate, di-ammonium phosphate and pyrophosphate are considered better sources of P than rock phosphate and bone meal. The Mussorie rock phosphate is less effective when applied alone compared to when it is applied in combination with superphosphate, particularly in the hilly regions (Sahota and Sharma, 1986) where phosphate fixation is a major problem due to the acidic nature of the soils. The SSP was found to be more effective in sulphur deficient soils, whereas DAP at lower rate was found to be more effective in producing higher tuber yield in soils containing sufficient sulphur.

Rate of P application in potato varied from 80 to 100 kg/ha in acidic hill soils of Himachal Pradesh, North-Eastern States of India, and Kashmir (Dua, 2014). The requirement of P_2O_5 varied from 50 to 150 kg/ha in the alluvial soils of Punjab, Uttar Pradesh, and Bihar. Potato responded well up to 150 kg P_2O_5/ha (Mozumder et al., 2014) in the alluvial soils of West Bengal. Banerjee et al. (2016) reported 10% tuber yield reduction in potato with P omission, when compared to full NPK application (200:150:150 N, P_2O_5, and K_2O/ha). However, Grewal et al. (1992) reported that potato grown in heavy textured black soils hardly requires any P application.

Similar to N, the efficiency of phosphatic fertilizer in potato also depends on the time and place of application. Owing to shallow root system, proper placement of phosphatic fertilizer is very important as it affects its use efficiency. Potato needs most of the P at early growth stages. Thus, the entire amount of P fertilizer should be applied in furrows at 5 to 6 cm below the seed tubers at the time of planting (Mozumder et al., 2014). Furrow placement near the active root zone or near the tuber is recommended mainly in the acidic soils and has been found to be more successful than broadcasting for higher tuber yield (**Table 1**). Sahota et al. (1988) reported that the point place-

Table 1. Effect of various method of phosphatic fertilization (48 kg/ha) in a responsive sandy soils at Jalandhar.

Method of fertilizer placement	Average yield increment over control (no P), t/ha	% increase over control
Broadcast before planting and incorporation in the soils in the final ploughing	1.37	12.7
Placed in furrows, in two rows, each about 15 cm from the seed piece in row	1.74	16.4
Placed in furrow on each side of the seed piece but about 3 cm from the seed piece in a row	3.80	36.5

Source: Das, P. C. 2000

ment of SSP had better results than application in furrows of acidic soils in Shillong. In the highly acidic soils of Shillong, P application at 2 to 3 cm above seed tubers was better than its application below seed tubers (Sharma and Grewal, 1989). Compared to soil application foliar application of phosphatic fertilizer resulted in higher tuber yield, provided the crop did not suffer due to P deficiency at early growth stages (Trehan et al., 2008). Before planting, soaking of tubers in 30% SSP + 0.5% urea + 0.2% mancozeb for four hours and basal application of P_2O_5 at 50 kg/ha, could partially meet the phosphate requirement of the crop and economize the phosphate requirement of the crop.

Potassium

Potassium plays an important role in the translocation and accumulation of photosynthates (carbohydrates) from the leaves to the tubers and increasing the size, yield, and quality of tuber. It is essential for starch formation, which accounts for the major portion of dry matter of potato and increases resistance against water stress, frost, and diseases. Potato responds well to K fertilizers and also removes large amounts of K, N, and P from the soil (Banerjee et al., 2016).

Muriate of potash (MOP), or potassium chloride (KCl), and potassium sulphate (K_2SO_4) are the two sources of K largely used by potato farmers for basal application. Tuber yield and quality of potato improved with the application of potassium sulphate (Dua, 2014) compared to MOP. However, MOP is the commonly used K source in potato due to its comparatively lower cost and accounts for 97% of K fertilizer consumption in the potato growing areas of the country (Dua, 2014). In addition, KCl showed better frost resistance in potato over K_2SO_4 (Tiwari et al., 1980). Beside these sources, another source of K, potassium scheonite (having salts of potassium sulphate and magnesium sulphate), has also been found to be equally effective in producing higher tuber yield in the acid and alluvial soils of different growing zones of the country (Trehan et al., 2008). Potassium nitrate (KNO_3) application at a rate of 2 g/L (2% solution) has also proven its effectiveness as source of K when applied through foliar application (Brar and Kaur, 2007).

Although Indian soils are considered high in K, several studies have shown K responses for potato in omission plot trials. This might be due to the fact that the high uptake requirement of K for potato is not matched by the slow rate of K release from the strongly held K pools in the soil (Majumdar et al., 2016). Potato requires K from early growth stages to the tuber development stage. Potato grown in the hills and plains of India requires 80 to 100 kg K_2O/ha. In the hills of Shillong, K_2O application at 60 kg/ha produced higher tuber yield over control (zero K). Studies also demonstrated maximum tuber yield with 60 kg K_2O/ha in Garhwa district of Jharkhand, producing 63% more yields over the control. In the Indo-Gangetic plains of West Bengal, tuber yield of potato is significantly increased with the application of K up to 150 kg/ha. Banerjee et al. (2016) demonstrated about a 6% tuber yield reduction in potato with K omission when compared to a dose of 150 K_2O/ha.

Potassium fertilizer should be applied at the right time and place so it can be fully utilized by the potato plant, further increasing the efficiency of K fertilizer. Generally, the entire dose of K is applied at the time of planting (Mozumder et al., 2014), although there is some evidence showing the positive effect on tuber yield when applied in split application (half at planting and half at the time of top dressing) of N in combination with urea (Trehan et al., 2008). Studies also support foliar application of K_2O in potato. Two foliar sprays of K at 2% solution of KNO_3 at 50 and 70 DAP was effective in long duration varieties, like Kufri Badshah. For short duration varieties, spraying of K through KNO_3 should be done at 45 and 60 DAP in order to get effective results (Trehan et al., 2008). However, foliar spray cannot be comparable to soil application. Furrow method of application for K is considered the better option over broadcasting in rainfed and irrigated conditions. Use of K through broadcasting is as effective as furrow method when potato is grown under light-textured soil (Sharma and Upadhayaya, 1991).

Conclusion

The present study provides a general guideline of 4R Nutrient Stewardship of potato under varied agro-climatic situations. Site specific nutrient management strategies with the support of 4R Nutrient Stewardship concept needs to be adapted for different growing conditions for higher productivity and better economics while maintaining environmental sustenance. BC-SA

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