Indian Journal of Agronomy **59** (3): 451–454 (September 2014)

Research Paper

Effect of balanced fertilization on yield, nutrients uptake and economics of potato (*Solanum tuberosum*) in alluvial soil

SANDEEP SINGH[1], DEEPENDRA KUMAR[2], BANDANA SINGH CHANDEL[3] AND VINAY SINGH[4]

Raja Balwant Singh College, Dr Bhim Rao Ambedkar University, Bichpuri, Agra, Uttar Pradesh 283 105

Received : January 2014; Revised accepted : July 2014

ABSTRACT

A field experiment was conducted at Bichpuri (Agra), Uttar Pradesh, during winter seasons of 2008–10, to study of effect of balanced fertilization on yield, uptake of nutrients and economics of potato (*Solanum tuberosum* L.). The experiment had 12 treatments which were laid out in randomized block design with 3 replications. Significant increases in tuber and protein yields were recorded with balanced use of nutrients over fertilizer state recommendation (SR) and farmer fertilizer practice (FFP) treatments. Use of application of 225 kg N + 150 kg P_2O_5 + 225 kg K_2O + 40 kg S + 2 kg B + 6 kg Zn/ha (T_1) not only enhanced potato tuber yield but also had pronounced effect on tuber dry matter yield. Tuber yield (31.01 t/ha) resulting from T_1 treatment was 40.6 and 35.0% higher than State fertilizer recommendation and farmer fertilizer practice respectively. Omission of nutrients caused tuber yield reductions by 10.5 (–P), 19.1 (–K), 7.5 (–S), 7.0 (–Zn) and 6.4% (–B) compared to T_1 treatment. Balanced use of nutrients (T_1) earned markedly higher net returns (₹105.5 × 10^3/ha) and return/₹ invested (3.13) over SR (₹47.6 × 10^3/ha) and 2.06) and FFP (₹54.9 × 10^3/ha and 2.19). The highest uptake of N (142 kg/ha), P (17.2 kg/ha), K (137.2 kg/ha) S (17.9 kg/ha), Zn (214.5 g/ha) and boron (258 g/ha) was recorded with T_1 (225 kg N, 150 kg P_2O_5, 225 kg K_2O, 40 kg S + 2 kg B + 6 kg Zn) and minimum under SR (150 kg N, 100 kg P_2O_5, 100 kg K_2O/ha). The uptake of P, K, S, Zn and B was significantly reduced in the respective nutrient omission treatments.

Key words : Alluvial soil, Balanced fertilization, Crop management, Economics, Nutrient uptake, Potato, Yield

Potato is well known for its large demand of nutrients and optimum nutrients levels vary with yield goal, weather condition and management factors. However, the productivity of potato in the soils is low due to multi nutrient deficiencies and other allied problems. These deficiencies adversely affect the crop vigour and result in poor yield, low quality of tubers and low profits. The major constraints for high yield of potato are inadequate and imbalanced nutrients use which can be corrected and crop productivity be substantially increased. The farmers of the area, by and large, use N, P and K in potato and as a consequence, deficiencies of S, Fe, Mn, Zn and B are increasing (Shukla, 2011). Zinc is considered as the most important nutrient for potato crop in India. Low recovery of applied Zn is an important limitation in enhancing the yield of potato crop. Of late, an increased frequency of S deficiency has been observed in crops and S may become a factor limiting yield and quality of crops. Boron is an essential micronutrient required for normal growth and development of crop plants. Boron in plants is reported to function at membrane level (Shelp *et al.*, 1995) and is credited with maintaining membrane integrity (Cadmak *et al*. 1995) and enhanced ability of membrane to transport vital nutrients. Due to imbalanced use, mining of nutrients is considered as the main cause for decline in crop yield. Crop removal is much higher than the addition of plant nutrient through fertilizers. Balanced fertilization is the key to increase use efficiency of applied nutrients. A balanced fertilization programme does more than simply replacing the amounts of nutrients removed by the crop. It ensures that fertilizers are applied in adequate amounts for optimum plant growth, sustenance of soil and crop productivity. Thus, balanced fertilizer application increases crop production and maintains soil fertility that is the primary requirement of sustainable crop production (Singh *et al*., 2010). Therefore an experiment was carried out to study the effect of major nutrients (NPK) in combination with secondary (S) and micro-nutrients (B and Zn) on potato yield and economic returns.

[1]Corresponding author Email: chaudharys1973@gmail.com
[1]SMS (Soils) KVK, Department of Agricultural Chemistry and Soil Science; [2]H.A.,A.S.I, New Delhi; [3]Research Associate; [4]Ex-Dean, Faculty of Agriculture, Raja Balwant Singh College, Dr B.R. Ambedkar University, Bichpuri, Agra, Uttar Pradesh 283 105

MATERIALS AND METHODS

The field experiment was conducted during the winter (*rabi*) seasons of 2008–10 at farmer field in village Panwari, Agra (Uttar Pradesh). The soil was sandy loam, alkaline (pH 7.8), low in organic carbon (0.3%) and deficient in available N (145 kg/ha), P (8 kg/ha), K (110 kg/ha), S (17.5 kg/ha), B (0.18 mg/kg) and Zn (0.54 mg/kg). Twelve treatments, viz. T_1, 225 kg N + 150 kg P_2O_5 + 225 kg K_2O + 40 kg S + 2 kg B + 6 kg Zn/ha; T_2, 225 kg N + 75kg P_2O_5 + 225 kg K_2O + 40 kg S + 2 kg B + 6 kg Zn/ha; T_3, 225 kg N + 0 kg P_2O_5 + 225 kg K_2O + 40 kg S + 2 kg B + 6 kg Zn/ha; T_4, 225 kg N + 150 kg P_2O_5 + 150 kg K_2O + 40 kg S + 2 kg B + 6 kg Zn/ha; T_5, 225 kg N + 150 kg P_2O_5 + 75 kg K_2O + 40 kg S + 2 kg B + 6 kg Zn/ha; T_6, 225 kg N + 150 kg P_2O_5 + 0 kg K_2O + 40 kg S + 2 kg B + 6 kg Zn/ha; T_7, 225 kg N + 150 kg P_2O_5 + 225 kg K_2O + 0 kg S + 2 kg B + 6 kg Zn/ha; T_8, 225 kg N + 150 kg P_2O_5 + 225 kg K_2O + 40 kg S + 2 kg B + 0 kg Zn/ha; T_9, 225 kg N + 150 kg P_2O_5 + 225 kg K_2O + 40 kg S + 0 kg B + 6 kg Zn/ha; T_{10}, 225 kg N + 150 kg P_2O_5 + 225 kg K_2O/ha; T_{11}, 150 kg N + 100 kg P_2O_5 + 100 kg K_2O/ha (SR); and T_{12}, 201 kg N + 144 kg P_2O_5 + 100 kg K_2O/ha (FFP), were applied in a randomized block design with 3 replications. All the nutrients except N were applied basal as per treatment. Nitrogen was applied in 2 splits between sowing and first and second irrigation. Sulphur, zinc and boron were applied as elemental sulphur (85% S), zinc chloride (45% Zn) and borax (11% B) respectively. Potato variety, 'Kufri Bahar' was sown at spacing of 60 cm × 20 cm in the first week of October in both the years. The crop was irrigated as required and weed growth was controlled by hand-weeding. All the other recommended package of practices were adopted during the crop-growth periods in both the years. The crop was harvested in the first week of February during both the years, and tuber yield was recorded. Potato tubers were collected, dried in oven and analysed for N by Kjeldahl method. The tubers were digested in di-acid mixture (HNO_3 : $HClO_4$) and P in the digest was determined by vanadomolybdate yellow colour method (Jackson, 1973). Sulphur content in the digest was determined by turbidimetric method (Chesnin and Yien, 1951), K by flame photometer, Zn by atomic absorption spectrophotometer and B by carmine method (Hatcher and Wilcox, 1950). The uptake of nutrients was calculated from the data on concentration of the given nutrient multiplied by dry matter yield. Economics of potato crop was worked out by taking account the prevailing cost of inputs and price of produces during crop season.

RESULTS AND DISCUSSION

Yield

The tuber yield of potato and dry-matter yield of tubers ranged with nutrient-management options, but the highest mean tuber yield and dry-matter yield was registered under complete treatment supplying 225 kg N + 150 kg P_2O_5 + 225 kg K_2O + 40 kg S + 2 kg B + 6 kg Zn/ha (T_1) in adequate and balanced amounts. The higher yield under this treatment may be ascribed to either direct or cumulative effect of supplied macro-and micro-nutrients on metabolic processes of potato. Availability of nutrients, especially the micro-nutrients, at optimum level has direct impact on accelerated cell-division and enlargement, root growth and plant vigour. Singh *et al*. (2010) reported similar results. The SR (150 kg N + 100 kg P_2O_5 + 100 Kg K_2O/ha) resulted in lower tuber yield than FFP but the difference in yield was statistically non-significant. The corresponding dry-matter yields under SR and FFP treatments were 3.60 and 4.07 t/ha respectively. The tuber yield obtained under these 2 treatments (SR and FFP) was inferior to balanced use of nutrients, indicating the effects of inadequate supply of nutrients to the crop. The beneficial effects of nutrients may be attributed to increased availability of these nutrients for the actively growing plants thereby increased translocation of photosynthesis from source to sink (tubers). These results corroborate with those of Pandey *et al*. (2011). Application of P, K, S, B and Zn in potato crop had significant effect on tuber production. Optimum fertilization was also compared against treatments omitting P, K, S, B and Zn in order to isolate the individual response of nutrients. The tuber yield decreased by 10.5, 19.1, 7.5, 7.0 and 6.4% with omission of P, K, S, Zn and B respectively. The corresponding reductions in dry-matter yield were 10.9, 21.7, 10.5, 12.2 and 11.6%. The yield data revealed that K, S and Zn are the main limiting factors under the present experimental set up. The omission of B did not reduce the tuber yield significantly over ample supply of nutrients (T_1). The soil in this study was low in available N, P and K. Therefore, potato responded significantly to their addition. Singh *et al*. (2010) also reported similar results in potato grown on reclaimed sodic soil.

As a tuber crop, potato removes large amounts of soil K, hence there was marked increase (10.6%) in the yield due to K addition (225 kg N + 0 kg P_2O_5 + 225 kg K_2O + 40 kg S + 2 kg B + 6 kg Zn/ha) over no K (225 kg N + 150 kg P_2O_5 + 0 kg K_2O + 40 kg S + 2 kg B + 6 kg Zn/ha). Sud and Sharma (2002) reported a significant effect of K application on yield of potato tubers. Zinc application significantly increased the tuber yield of potato which may be attributed to the beneficial effect on tuberization after zinc treatment under conditions of zinc deficiency in soil. Sharma and Grewal (1988) and Singh *et al.* (2010) reported similar observations due to zinc application in Zn deficient soil. These findings clearly indicate that highest

crop response can be assigned to potassium followed by sulphur, zinc, phosphorus and boron (Singh *et al*. 1990). Application of 225 kg N, 150 kg P_2O_5 and 225 kg K_2O/ha (T_{10}) also produced significantly higher yield over farmer fertilizer practice and State recommendation. The beneficial influence of N, P and K application may be owing to increased availability and absorption of these nutrients for the actively growing plants. Our results confirm the findings of Singh *et al*. (2009) and Singh *et al.* (2010).

Quality

There was a significant increase in protein content in potato tubers with different treatments over State recommendation of NPK fertilizers (Table 1). Protein content ranged from 11.7 to 12.3% and maximum (12.3%) value was recorded in treatment having 225 kg N + 150 kg P_2O_5 + 225 kg K_2O + 40 kg S + 2 kg B + 6 kg Zn/ha, and minimum (11.7%) in State recommendation. Farmer fertilizer practice proved superior to state recommendation for protein percentage in potato tubers. The difference in protein content due to these 2 treatments (SR and FFP) was statistically non-significant. Protein yield in potato tubers (Table 1) ranged between 421.2 and 815.5 kg/ha where maximum protein yield (815.5 kg/ha) was recorded in 225 kg N +150 kg P_2O_5 + 225 kg K_2O + 40 kg S + 2 kg B + 6 kg Zn/ha and minimum (421.2 kg/ha) in State recommendation treatment. This increase in protein yield may be attributed to increased tuber yield and protein content in tuber with ample supply of nutrients. Farmer fertilizer practice proved superior to SR treatment for protein yield. Most of the treatments proved significantly superior to state recommendation in respect of protein yield which may be attributed to higher tuber yield. Omission of P, S, K and Zn reduced the protein yield compared to application of 225 kg N +150 kg P_2O_5 + 225 kg K_2O + 40 kg S + 2 kg B + 6 kg Zn/ha owing to reduction in tuber yield of potato.

Economics

The complete treatment supplying 225-150-225 kg N-P_2O_5-K_2O/ha as well as S (40 kg S/ha) and micronutrients (2 kg B and 6 kg Zn/ha) package gave the best results by showing the highest net profit of ₹105.5 × 10^3/ha with a tuber yield of 31.01 t/ha (Table 1). Treatment based on the State recommendation and farmer fertilizer practice returned significantly less net profit due to lower tuber yields, i.e. 18.42 t/ha (40.6%) and 20.16 t/ha (35.0%), respectively. Corresponding net returns were ₹ 47.6×10^3/ha (54.8%) for SR and ₹54.9 × 10^3/ha (48%) for FFP. A marked change in tuber yield resulted with 150 kg P_2O_5/ha over 75 kg P_2O_5/ha, but the inclusion of all nutrients with 75 kg P_2O_5/ha (T_2) did not return the net profit (₹98.3 × 10^3/ha) level equivalent to, yet less profitable than, the best complete treatment. Therefore, the balanced use of nutrients could be the most accepted treatment to obtain maximum benefit from the potato (Singh *et al.,* 2010).

Nutrients uptake

The average uptake of nutrients by potato tubers ranged from 73.2 to 142.0 kg/ha for N, 7.2 to 17.2 kg/ha for P, 72.2 to 137.2 kg/ha for K, 7.1 to 17.9 kg/ha for S, 86.1 to 214.5 g/ha for Zn and 105.5 to 258.0 g/ha for B. These results showed that the complete treatment maintained the higher uptake values of all the nutrients most probably owing to the higher yield recorded under this treatment (T_1). However, the State recommendation recorded the lowest uptake values, which is again the reflection of the lowest yield recorded under this treatment. In the absence

Table 1. Effect of fertilizer treatments on yield, quality and economics of potato (mean data of 2 years)

Treatment	Tuber yield (t/ha)	Dry-matter yield (t/ha)	Net profit (10^3 ×₹/ha)	Benefit: costratio	Protein (%)	Protein yield (kg/ha)
T_1, N_{225} P_{150}, K_{225} S_{40} B_2 Zn_6	31.01	6.63	105.5	3.13	12.3	815.5
T_2, N_{225} P_{75}, K_{225} S_{40} B_2 Zn_6	29.27	6.23	98.3	3.05	12.3	766.3
T_3, N_{225} P_0, K_{225} S_{40} B_2 Zn_6	27.76	5.91	92.3	2.98	12.1	715.1
T_4, N_{225} P_{150}, K_{150} S_{40} B_2 Zn_6	27.18	5.79	86.9	2.77	12.2	706.4
T_5, N_{225} P_{150}, K_{75} S_{40} B_2 Zn_6	26.83	5.55	85.7	2.76	12.1	671.5
T_6, N_{225} P_{150}, K_0 S_{40} B_2Zn_6	25.09	5.19	77.5	2.62	12.1	628.0
T_7, N_{225} P_{150}, K_{225} S_0 B_2 Zn_6	28.70	5.93	94.6	2.94	12.3	729.4
T_8, N_{225} P_{150}, K_{225} S_{40} B_2 Z_0	28.84	5.82	95.3	2.95	12.3	716.0
T_9, N_{225} P_{150}, K_{225} S_{40} B_0 Z_6	29.01	5.86	96.3	2.97	12.1	709.0
T_{10}, N_{225} P_{150}, K_{225}	27.61	5.30	90.7	2.92	12.0	624.0
T_{11}, N_{150} P_{100}, K_{100} (SR)	18.42	3.60	47.6	2.06	11.7	421.2
T_{12}, N_{201} P_{144}, K_{100} (FFP)	20.16	4.07	54.9	2.19	11.9	484.3
SEm±	1.74	0.21			0.11	41.4
CD (P=0.05)	3.62	0.43			0.23	85.0

SR, State fertilizer recommendations; FFP, farmer fertilizer recommendation

Table 2. Effect of fertilizer treatments on uptake of N, P, K, zinc and boron in potato tuber (mean data of 2 years)

Treatment	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (kg/ha)	Zn (g/ha)	B (g/ha)
T_1, N_{225} P_{150}, K_{225} S_{40} B_2 Zn_6	142.0	17.2	137.2	17.9	214.5	258.0
T_2, N_{225} P_{75}, K_{225} S_{40} B_2 Zn_6	132.7	14.3	128.3	16.2	198.0	237.9
T_3, N_{225} P_0, K_{225} S_{40} B_2 Zn_6	124.7	11.8	121.7	14.8	187.9	226.9
T_4, N_{225} P_{150}, K_{150} S_{40} B_2 Zn_6	122.7	14.5	116.9	15.1	179.6	218.5
T_5, N_{225} P_{150}, K_{75} S_{40} B_2 Zn_6	117.1	14.9	111.0	13.9	172.5	211.0
T_6, N_{225} P_{150}, K_0 S_{40} B_2Zn_6	109.0	11.9	102.3	12.8	160.9	197.5
T_7, N_{225} P_{150}, K_{225} S_0 B_2 Zn_6	126.4	14.2	121.8	13.7	183.6	220.3
T_8, N_{225} P_{150}, K_{225} S_{40} B_2 Z_0	124.1	14.6	118.4	15.1	155.0	223.3
T_9, N_{225} P_{150}, K_{225} S_{40} B_0 Z_6	128.8	14.6	119.5	15.2	181.5	179.3
T_{10}, N_{225} P_{150}, K_{225}	110.8	12.2	108.1	13.2	126.9	163.1
T_{11}, N_{150} P_{100}, K_{100} (SR)	73.2	7.2	72.2	7.1	86.1	105.5
T_{12}, N_{201} P_{144}, K_{100} (FFP)	84.3	8.9	82.2	8.5	94.1	121.9
SEm±	4.6	1.1	4.2	1.0	9.6	13.8
CD (P=0.05)	9.6	2.3	8.7	2.1	19.9	28.7

SR, State fertilizer recommendations; FFP, farmer fertilizer recommendation

of P application, a considerable reduction in P uptake was noticed due to low availability of P and consequently lower crop yield. Phosphorus uptake was significantly reduced with the application of zinc which may be due to antagonistic effect of Zn on P availability and its uptake by the crop. The treatment without K (T_6) not only adversely affected the K uptake but also uptake of N and P because of lower yield and reduced concentration of nitrogen and phosphorus (Singh *et al*., 2009). Omission of S and B had a non-significant effect on the utilization of P and S by the crop. But the application of both (S and B) had significantly beneficial effect on the utilization of N, P, K, S and B by the crop. Application of zinc significantly increased its uptake by potato tubers (Table 2). This may be attributed to increased dry-matter yield and Zn content in tubers (Sharma and Grewal, 1988; Singh *et al.,* 2009; Singh *et al*., 2010).

These results show the significance of balanced use of fertilizers in augmenting the potato tuber yield and net returns. The omission of nutrients reduced the tuber yield significantly compared to balanced use of fertilizers. The uptake of P, K, S, Zn and B was also significantly reduced in the respective nutrient omission treatments. Generalized recommendations proved to be sub-optimal and insufficient for high yielding varieties of potato. Such recommendations require an upward revision of N,P and K levels and inclusion of secondary (S) and micronutrients (B and Zn) which are deficient in soils. In addition, field specific nutrient recommendations should be provided to individual farmer for improved yield of potato and farm profits.

REFERENCES

Cadmak, I., Kurtz, H. and Marschner, H. 1995. Short- term effects of boron, germanium and high light intensity on membrane permeability in boron deficient leaves of sunflower. *Physiologia plantarum* **95**: 11–18.

Chesnin, L. and Yien, C.H. 1951. Turbidimetric determination of available sulphate *Soil Science Society of America Proceedings* **15**: 149–51.

Hatcher, J.A. and Wilcox, L.V. 1950. Colorimetric determination of boron using carmine. *Analytical Chemistry* **22**: 567–69.

Jackson, K.L. 1973. *Soil Chemical Analysis*. Prentice Hall of India Pvt. Ltd, New Delhi.

Pandey, G., Pandey, R., Ahirwar, K. and Namdco, K.N. 2011. Effect of organic and inorganic sources of nutrients on yield, quality and economics of turmeric. *Annals of Plant and Soil Research* **13**(2): 109–11.

Paul Khurana, S.M and Naik, P.S. 2003. The Potato Production and Utilization in Sub-topics. *The Potato,* Mehta Publications, New Delhi, India, pp. 1–14.

Sharma, U.C. and Grewal, J.S. 1988. Relative effectiveness of method of micronutrients application in potato. *Journal of Indian Society of Soil Science* **36**(1): 128–32.

Shelp, B.J., Marentes, E., Kitheka, A.M. and Vivekanandan, P. 1995. Boron mobility in plants. *Physiologia Plantarum* **94**: 356–61.

Shukla, A.K. 2011. Micronutrient research in India: Current status and future strategies. *Journal of Indian Society of Soil Science* **59**(supplement): 88–98.

Singh, A.R., Singh, B. and Singh, A. 1990. Efficacy of nitrogen and boron on the growth, yield and quality of potato (*Solanum tuberosum* L) var. Kufri Chamatkar. *Progressive Horticulture* **22**: 104–07.

Singh, H., Singh, S.P. and Singh, M.P. 2009. Effect of potassium and zinc on tuber yield, quality and nutrient uptake in potato. *Annals of Plant and Soil Research* **11**(2): 140–42.

Singh, V., Singh, S. and Singh, H. 2010. Effect of balanced fertilization on nutrient uptake, yield and profits with potato in partially reclaimed sodic soil. *Annals of Plant and Soil Research* **12**(2): 83–85.

Sud, K.C. and Sharma, R.C. 2002. Role of potassium in potato nutrition under rainfed agriculture in state of Himachal Pradesh. *Journal of Potassium Research* **18**: 79–83.