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Validation of QUEFTS model for nutrient management of potato (*Solanum tuberosum*) in humid south-eastern plains of Rajasthan

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ABSTRACT

The crop/cultivar and location-specific management of nutrients, considering soil supply and plant demand of nutrients according to spatial and temporal variations are possible through the use of models such as Quantitative Evaluation of Fertility on Tropical Soils (QUEFTS) model. The experiment was conducted to validate QUEFTS model for fertilizer management to achieve higher productivity of potato (*Solanum tuberosum* L.) cv. Kufri Bahar in the humid south-eastern plain of Rajasthan during winter (*rabi*) season 2020–21 and 2021–22. The results revealed that the tuber yield with application of 100% NPK as per QUEFTS model (T_5) was 5.64% higher than fertilizer application as per soil test based 100% NPK recommendation for potato, whereas fertilizer application @125% NPK as per QUEFTS model (T_6) was 16.5% higher than the T_3 (125% NPK of RDF) treatment. However, use of 125% NPK as per QUEFTS model gave significantly higher emergence per cent, grade-wise tuber yield, and grade-wise numbers of potato tuber. On the pooled basis, higher values of gross income, net gain, and cost-benefit (B:C) ratio were observed with use of 125% NPK as per QUEFTS model. The results revealed that QUEFTS model may improve the nutritional quality and sustainability of potato production through site specific nutrient management by building improved fertilizer recommendations.

Keywords: B:C ratio, Kufri Bahar, Potato, QUEFTS, Tuber yield, Yield response

Potato (*Solanum tuberosum* L.) cultivation contributes significantly in ensuring world food security for the ever-increasing global population (Thiele *et al.* 2010, Scott and Suarez 2012). India is the second largest potato producer, after China, where potato is grown as an important crop (food as well as industrial crop) in the states such as Uttar Pradesh, Punjab, Bihar, Madhya Pradesh, Haryana, Jharkhand, West Bengal, Gujarat, Rajasthan, Assam and Chhattisgarh. Potato is grown over an area of 13819 ha with average productivity of 201.6 q/ha in Rajasthan (Anonymous 2022).

The blanket fertilizer recommendation based on regional soil tests has a favourable yield response (Li *et al.* 2015), but it has led to high production costs and more nutrient losses resulting in environmental concerns, especially in high fertility soil and lower yield in the case of low fertility soils (Liu *et al.* 2014, Nagar *et al.* 2020). Potato requires high amounts of potassium fertilizer in addition to nitrogen and phosphorus for optimum growth, yield and quality of tubers (Birtukan 2016). Site-specific nutrient management strategies incorporating crop stage, location, soil type and weather specific information may increase production, productivity, nutrient recovery efficiencies and environmental protection as well (Goulding *et al.* 2008).

The QUEFTS model (Janssen *et al.* 1990) quantifies the crop nutrient requirement by estimating the nitrogen, phosphorus and potassium interactions in the soil-plant system, indigenous soil nutrient supply, nutrient utilization and recovery based on different yield potentials through examining the relationship between crop yield and nutrient uptake (Smaling and Janssen 1993, Setiyono *et al.* 2010). The improved crop management interventions such as the supply of nutrients, nutrient uptake and fertilizer application may help in reducing the gap between actual and potential yields (Koch *et al.* 2020), which may efficiently be achieved by using QUEFTS model. The present study aims to examine/validate the QUEFTS model simulated nutrient requirement of potato for growth and yield through field experimentation.

MATERIALS AND METHODS

The present study was carried out at Agricultural Research Station, Ummed Ganj, Kota, Rajasthan on clay loam soil during winter (*rabi*) season in 2020–21 and 2021–22 to study the effect of site-specific nutrients management on the productivity of potato (*Solanum tuberosum* L.) in humid south-eastern plain of Rajasthan using QUEFTS (Quantitative Evaluation of Fertility of

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Tropical Soils) model. The mean annual rainfall of the district is 732.4 mm.

The soil was characterised as slightly alkali in soil reaction (*p*H 7.67–7.86), low in available N (197.8–213.0 kg/ha) and organic carbon (0.43–0.48), and high in available phosphorus (26.16–29.43 kg/ha) and potassium (349.1–375.5 kg/ha). The 10 treatments comprising T_1, 75% NPK of recommended; T_2, 100% NPK of recommended (187.5:125:125 kg NPK per ha); T_3, 125% NPK of recommended; T_4, 75% NPK as per QUEFTS model; T_5, 100% NPK as per QUEFTS model (290:25:60 kg NPK per ha); T_6, 125% NPK as per QUEFTS model; T_7, without N fertilizer (PK); T_8, without P (NK); T_9, without K (NP) and; T_{10}, control (no NPK) were arranged in randomized complete block design (Gomez and Gomez 1984) with four replications. The QUEFTS model was run to drive the fertilizer dose required to achieve higher yields considering the soil type, nutrient available and crop and cultivar specific parameters for the location in R (R-core team).

The crop was planted on ridges 60 cm apart and plant spacing of 25 cm on ridge, at a depth of 5–6 cm using potato cultivar 'Kufri Bahar' at 25 q tuber/ha in the field during the first week of November in 2019 and 2020. The differential doses of NPK were applied through inorganic fertilizers (i.e. Urea as the source of N, single superphosphate for phosphorus and muriate of potash for potassium) as per the treatment schedule. Urea (as the source of N) was applied in two splits, i.e. half at planting and the remaining half at 30–35 days after planting as per the dose of each treatment. The entire amount of potassium and phosphorus fertilizers was applied in furrows at the time of planting as per treatment. The tubers of potato were treated with fungicides mancozeb at 0.2% solution before planting. The package of practices recommended for the Zone was followed for the management of weeds, insect-pest diseases, and irrigation.

The plant observations, viz. emergence per cent at 30 days after planting, plant height and numbers of shoots per plant at 60 days after planting were taken. After harvesting the crop, tubers were graded according to their size, i.e. 0–25, 25–75 and more than 75 g than for each category of grades as well as all sizes of tubers were counted and weighed separately. The net return was calculated as the difference between the cultivation cost and gross realization for each treatment and was expressed in ₹/ha. The benefit-cost ratio (B:C) as a measure of return per unit invested, was calculated as the ratio of profit and cultivation cost.

Bartlett's test was applied to test the homogeneity of variances and was found homogenous for both years. The statistical analysis of the data generated was carried out through the analysis of variance of pooled data as per the procedure for randomized complete block design (Gomez and Gomez 1984) using SAS 9.1 (SAS Institute CA). The yield response was calculated as the ratio of the difference between the yield of fertilized and unfertilized plot (i.e. yield in fertilized plot - yield in unfertilized plot) to the yield from the unfertilized plot.

RESULTS AND DISCUSSION

The results revealed that the application of different combinations of NPK doses significantly influenced the growth and yields of potato as compared to the control (Table 1). A significantly higher emergence was observed with the application of 362.5, 31.25 and 75 kg NPK per ha (T_4) as compared to the control, which was statistically at par with T_1 and T_6. The grade-wise tuber yields and grade-wise numbers of potato tubers were significantly higher with the use of 100% NPK as per QUEFTS model (290:25:60 kg NPK per ha) (T_4) on a pooled basis. The plant height (53.9 cm) and number of shoots per plant (7.5)

Table 1 Effect of nutrient management interventions on emergence, plant height, number of shoots per plant grade wise and total tuber yield of potato (on pooled basis)

Treatment	Emergence (%)	Plant height (cm)	No. of shoots/ plant	Grade-wise yield of tubers (t/ha)				Grade-wise number of tubers (000'/ha)			
				0–25 g	25–75 g	>75 g	Total	0–25 g	25–75 g	>75 g	Total
T_1	93.55	49.05	5.98	3.49	12.59	7.74	23.82	195.6	244.9	77.1	517.7
T_2	94.83	51.30	5.98	5.11	14.96	8.09	28.16	298.1	293.7	80.7	672.6
T_3	95.55	52.90	7.23	4.96	14.71	9.22	28.88	289.0	288.7	92.5	670.2
T_4	93.80	49.80	6.13	5.11	14.43	7.64	27.18	298.1	282.8	76.0	656.9
T_5	96.03	53.90	7.50	5.32	15.61	8.83	29.75	311.1	307.2	88.4	706.7
T_6	96.30	53.85	7.48	6.09	17.71	9.85	33.65	360.3	350.5	99.1	810.1
T_7	93.18	45.73	5.10	2.76	10.99	5.91	19.66	148.9	212.1	57.8	418.9
T_8	93.38	47.23	5.83	3.07	11.93	6.70	21.69	168.4	231.5	66.1	466.0
T_9	93.28	46.73	5.35	3.02	11.83	5.86	20.71	165.8	229.4	57.3	452.5
T_{10}	93.04	43.48	4.93	2.47	10.61	5.87	18.94	130.8	204.1	57.3	392.3
SEm±	0.43	1.08	0.15	0.24	0.54	0.47	1.17	15.06	11.0	4.55	29.46
LSD (P=0.05)	1.25	3.17	0.45	0.69	1.56	1.37	3.41	43.9	32.12	13.9	85.9

Treatment details are given under Materials and Methods.

were significantly higher in the treatment T_4 than that in T_7, T_8, T_9, and T_{10}. Application of 362.5, 31.25 and 75 kg NPK per ha, i.e. T_6 (125% NPK as per QUEFTS model) gave significantly higher potato yield than control, however tuber yield in treatment T_6 was at par with T_4, which were statistically similar to treatment T_1, T_3 and T_5 (Table 2). Duan *et al.* (2014) and Silva *et al.* (2013) also observed an increase in the tuber yield of potato with the balanced use of NPK fertilizers. Sandhu *et al.* (2014) also observed higher shoot growth, improved bulking rate, higher dry matter production and improved quality of tuber resulting from a better supply of N with balanced use of NPK. Desalegn *et al.* (2016) observed increased marketable and total tuber yield of potato with an increasing rate of phosphorus. The grade-wise yields of tubers and grade-wise numbers of tubers were significantly higher with the application of 362.5, 31.25 and 75 kg NPK per ha (125% NPK as per QUEFTS model), i.e. T_6 but at par with (T_3) 125% NPK of recommended and (T_4) 100% NPK as per QUEFTS model (290:25:60 kg NPK per ha) in case of grade-wise tubers yields of size >75 g and grade-wise number of tubers of size >75 g (Table 1). The balanced application of fertilizer as in T_6 may result from favourable interaction of phosphorus and nitrogen for higher marketable tuber yield (Birtukan 2016).

The highest tuber yield was achieved with the application of 125% NPK as per QUEFTS model (T_6), and at par with T_4 (100% NPK as per QUEFTS model) (Table 2). The tuber yield with application of 100% NPK as per QUEFTS model (T_4) was 5.64% higher than soil test based 100% NPK recommendation for potato, whereas fertilizer application @125% NPK as per QUEFTS model (T_6) was 16.5% higher than the T_3 (125% NPK of RDF) treatment. Kumar *et al.* (2016) also reported higher tuber yield when fertilizers were managed as per QUEFTS model owing to high nutrient use efficiency and internal efficiency. The higher yield observed under QUEFTS modelled treatments may be resulted from higher and balanced nutrient supply to the plant and availability of nutrients at right time and stage of crop. Similarly, Firew *et al.* (2016) reported that higher tuber yield resulted from improved and balanced N supply. Remya and Byju (2020) also reported that the present N and K recommendations were lower as compared to the estimated location specific nutrient or soil test based nutrient rates, while the applied phosphorus fertilizer rates were higher compared to the site-specific nutrient or soil test based nutrient rates, that resulted in lower yields and also build-up phosphorus in soil and advocated the use of QUEFTS in developing location specific fertilizer rates.

On pooled basis (Table 2), higher values of gross income, net return and benefit:cost (B:C) ratio were observed with the use of 362.5, 31.25 and 75 kg NPK per ha (125% NPK as per QUEFTS model), i.e. T_6 followed by T_3 and T_4, and lowest values of gross income, net return and benefit:cost ratio were reported under absolute control (without NPK). A higher cost of cultivation was observed in the treatment (T_3) receiving 125% NPK of recommended fertilizer dose followed by (T_1) 100% NPK of recommended (187.5:125:125 kg NPK per ha), and the lowest value of the cost of cultivation reported under absolute control (without NPK). The highest B:C was observed in treatment T_6, which was statistically at par with treatment T_4 and significantly higher compared to the control treatment. Similarly, T_1 (100% NPK of recommended) and T_3 (125% NPK of recommended) treatments have statistically similar B:C.

The highest yield response of nitrogen was observed in T_6 treatment (0.69) followed by T_4 (0.49) compared to the N-control treatment (Table 3). Similarly, yield response compared to phosphorus skipping treatment (T_8) was 0.53 in treatment T_6 followed by T_4 (where 100 NPK was applied as per the QUEFTS model). The fertilizer contributed 75% towards yield improvement in T_6 compared to T_{10} treatment (absolute control). The QUEFTS model derived fertilizer recommendations were found superior for recommending

Table 2 Effect of nutrient management interventions on tuber yield and economics of potato (on pooled basis)

Treatment	Yield (t/ha)	Cost of cultivation (₹/ha)	Gross income (₹/ha)	Net returns (₹/ha)	B:C ratio
T_1	23.82	60259	166705.0	106446.0	1.77
T_2	28.16	62453	197085.0	134632.0	2.16
T_3	28.88	64648	202160.0	137512.0	2.13
T_4	27.18	57903	190225.0	132322.0	2.29
T_5	29.75	59312	208215.0	148903.0	2.51
T_6	33.65	60721	235515.0	174794.0	2.88
T_7	19.66	60133	137585.0	77452.0	1.29
T_8	21.70	58704	151865.0	93161.0	1.59
T_9	20.71	59745	144935.0	85190.0	1.43
T_{10}	18.94	53675	132580.0	78905.0	1.47
LSD (P=0.05)	4.17				
CV	8.99				

Sale price (₹/t), 7000. Note: RDF, *i.e.* NPK is 187.5:125.0:125.0 kg/ha and were calculated as per treatments accordingly. Treatment details are given under Materials and Methods.

Table 3 Potato tuber yield response of different fertilizer application rates

Treatment	Response of fertilizer compared to skipping			
	T_7	T_8	T_9	T_{10}
T_1	0.20	0.09	0.14	0.25
T_2	0.42	0.29	0.35	0.47
T_3	0.45	0.32	0.38	0.50
T_4	0.37	0.24	0.30	0.42
T_5	0.49	0.36	0.42	0.55
T_6	0.69	0.53	0.60	0.75

Treatment details are given under Materials and Methods.

fertilizers for higher nutrient use efficiency and reducing yield gaps (Xu *et al.* 2019).

The study revealed that application of 362.5, 31.25 and 75 kg NPK per ha (125% NPK as per QUEFTS model) gave higher emergence per cent, grade-wise tuber yields and grade-wise numbers of potato tubers and also gave higher values of gross income, net return and benefit:cost ratio. Whereas, the value of plant height and number of shoots per plant were observed higher under the treatment received 100% NPK as per QUEFTS model (290:25:60 kg NPK per ha). The present investigation revealed that the fertilizer management using the QUEFTS model produced significantly superior yield compared to the bulk recommendation of fertilizers. The present study concluded that QUEFTS is capable of calculating the soil nutrient supply and yield responses, thus may help in realizing better yield in a sustainable manner. Further, extensive testing of the QUEFTS model under different soil types and environmental conditions is required to drive location specific dilution and accumulation values, which may help the decision-makers to develop location specific nutrient recommendations for target yields.

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