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SITE SPECIFIC NUTRIENT MANAGEMENT OF POTATO THROUGH QUEFTS MODEL IN NORTHERN TRANSITIONAL ZONE OF KARNATAKA, INDIA

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ABSTRACT

Excessive fertilization negatively impacts nutrient efficiency and the environment. Stagnant potato yields in India results from nutrient imbalance and by intensive cropping practices. Quantitative nutrient application can improve efficiency and yield outcomes. The QUEFTS model focuses on NPK interactions and yield potential adjusted for regional climate. This research sought to quantitatively assess the QUEFTS model for determining NPK requirements for potato yields from 2021 to 2024. A Randomized block design was implemented with three NPK levels (75, 100 and 125 % of RDF) to target a yield of 30 t/ha in Karnataka. Based on soil analysis, the QUEFTS model suggested NPK (100:25:60 kg/ha) for Kufri Jyoti, resulting in the highest yield (20.37 t/ha) and net return (Rs. 231386/ ha) with a B:C ratio of 2.71, along with optimal plant parameters. Conversely, without QUEFTS model, 100 % RDF resulted in lower yield of 16.55 t/ha with a B:C ratio of 2.22.

***Keywords* :** NPK, QUEFTS model and potato.

Introduction

Potato cultivation significantly aids in global food security (Thiele *et al.*, 2010). India ranks second in potato production, with key states including Uttar Pradesh and Punjab. In India, potatoes are primarily cultivated in *rabi* season in northern parts, and in some parts of plateau region areas of Maharashtra, Karnataka and Gujarat states are suitable for *kharif* season. The area for potato cultivation is declining for several reasons. However, Karnataka's potato productivity is notably below national and global averages. In Karnataka, potatoes are grown in four of ten agro-climatic zones: Northern transitional (Dharwad and Belgavi), Southern transitional, Eastern dry, and hilly. In Dharwad and Belgavi districts predominantly cultivate potatoes in unique black cotton/clay loam soils. During *kharif* 2022-23, Belagavi district exhibited 719 hectares of potato cultivation yielding 12,960 metric tons, while *rabi* cultivation accounted 222 hectares with a production of 3,998 metric tons; summer cultivation was 13 hectares with 236 metric tons production, culminating in a total of 954 hectares and 17,193 metric tons overall. Likewise, Dharwad district reported 150 hectares area, resulting in 2,543 metric tons of yield (Anon., 2023). Potato is a heavy feeder of nutrients it demands considerable nutrient inputs over short cycles to exceeding typical soil nutrient availability, requires substantial fertilizer for optimal growth and yield.

Plant nutrition entails the precise delivery of nutrients to plants in terms of quantity, location, and timing (Wastermann, 2005). Nutrient management is vital for improving potato yields by maintaining soil fertility. In this regard, the QUEFTS (Quantitative Evaluation of the Fertility of Tropical Soils) model was first developed by Janseen *et al.* (1990) for estimating crop yield based on soil condition, fertilizer application, and potential yield under ideal nutrient supply. This model assists agricultural stakeholders in making data-driven decisions regarding fertilizers and irrigation for optimal crop performances. To enhance yields, farmers have increased the use of fertilizers, leading to reduced yields and decreased nutrient use efficiency, alongside environmental issues (Chen *et al.*, 2012; Liu *et al.*, 2014). Excessive fertilization has undermined nutrient efficiency and degraded the arable lands while jeopardizing environmental integrity (Xu *et al.*, 2019). The success of QUEFTS model has been documented in cassava (Bharti *et al.*, 2023; Byju *et al.*, 2016). Hence, optimizing nutrient supply, uptake and fertilizer application can significantly narrow the gap between actual and potential yields (Koch *et al.*, 2020), which may be efficiently achieved by using QUEFTS model in potato. With this present study was undertaken.

Material and Methods

The investigation on site-specific nutrient management's impact on potato productivity through QUEFTS model in Northern Transitional Zone of Karnataka was carried out at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, Karnataka, for successive four *Kharif* seasons of 2020–21 and 2023–24. The experimental site is located at 15^{o} 26’ N latitude, 75^{o} 7’ E longitude, with an altitude of 678 m above mean sea level and soil has neutral in soil reaction pH (7.00–7.40), low nitrogen (112.12-158.65 kg/ha) and organic carbon (0.56–0.62), high phosphorus (19.03–25.36 kg/ha) and high potassium levels (335.67–351.78 kg/ha) (Table 1). Prior to tuber planting, soil samples were analyzed to determine NPK requirements based on soil testing. Following analysis, each field received uniform fertilization with N, P, and K according to treatments (Table 2).

The crop was planted in the first week of June in ridges at 60 cm x 20 cm plant spacing and a depth of 5–6 cm using the potato cultivar ‘Kufri Jyoti’ at a density of 25 q tuber/ha in all four years. Inorganic fertilizers comprising urea, single superphosphate, and muriate of potash were applied according to the treatment schedule included 110:65:90 kg/ha for 100% NPK, 82.5:48.75:67.5 kg/ha for 75% NPK, and 137.5:81.25:112.5 kg/ha for 125% NPK, following the QUEFTS model and three level of recommended dose of NPK *i.e.* 100%, 75% and 125%. Nitrogen was administered in two split doses at 30 and 45 days after planting. P and K fertilizers were entirely applied in furrows at the time of planting according to the treatment. Potato tubers were treated with a 0.2% solution of the fungicide mancozeb before planting. The recommended package of practice for potato crop cultivation was Adopted (Anon., 2023). Haulms were cut at 90 days after planting and harvesting of tuber was done 15 days after cutting of haulms. Four-year data on soil status, growth and yield attributes of potato were collected at specified intervals and their averages were subjected to statistical analysis *via* ANOVA. Observations included emergence percentage at 30 days, plant height, and shoot count at 60 days post-planting. Post-harvest, tubers were graded by size (0–25 g, 25–75 g, and >75 g) and counted and weighed by category. Net returns were computed as the difference between cultivation costs and gross realizations for each treatment, expressed in Rs./ha. The benefit-cost ratio (B:C) was derived from the profit to cultivation cost ratio. Statistical analyses were performed using analysis of variance on pooled data (Gomez and Gomez, 1984) employing SAS 9.1 (SAS Institute, CA). Yield response was calculated as the difference between fertilized and unfertilized plot yields, relative to the unfertilized plot yield.

Results and Discussion

The pooled data results revealed that the application of different combinations of NPK doses significantly influenced on growth and yield of potato as compared to the control (Table 3). A significantly higher emergence percentage, plant height, number of leaves and shoots per plant, fresh and dry haulm yield, biological yield and harvest index was observed with application of 125% NPK as per QUEFTS model (137.5, 81.25 and 112.5 kg NPK per ha) (T_6) as compared to the control, which was followed with T_3.

Application of treatment T_6 gave significantly higher tuber yield (20.37 t/ha) followed by T_3 and control. Similar increased tuber yield was observed by Duan *et al.* (2014) and Silva *et al.* (2013) with 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) also 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 125% NPK as per QUEFTS model, *i.e.* T_6 followed by T_3 in Table 4. The balanced application of fertilizer as in treatment T_6 may results in favorable interactions of phosphorus and nitrogen for higher marketable tuber yield (Birtukan, 2016).

The highest tuber yield (20.37 t/ha) was achieved with application of treatment T_6 *i.e.* 125% NPK as per QUEFTS model and was followed by T_3 (Table 3).

The tuber yield with application of 125% NPK as per QUEFTS model (T_6) was 4.73 % higher than soil test based 125% NPK recommendation for potato, whereas fertilizer application of 100 % NPK as per QUEFTS model (T_4) was 3.08 % higher than the T_1 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 modeled 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, the 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.

The Table 5 depicts the economics of potato cultivation, higher values of gross income, net return and benefit: cost (B:C) ratio were observed in T_6 *i.e.* 125% NPK as per QUEFTS model (137.5, 81.25 and 112.5 kg NPK per ha) 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_6, and the lowest cost of cultivation was reported under absolute control (without NPK).

The highest yield response of nitrogen was observed in T_6 treatment (0.57) followed by T_3 (0.50) compared to the N-control treatment. Again yield response compared with phosphorus skipping treatment (T_8) was high in treatment T_6 (0.43) followed with T_3 (0.36) compared to the P-control treatment. Similarly, yield response compared to potassium skipping treatment (T_9) was 0.36 high in treatment T_6 followed by T_3 (0.30) compared to the K-control treatment (Fig. 1). The fertilizer contributed 85% towards yield improvement in T_6 compared to T_{10} treatment (absolute control). The QUEFTS model derived fertilizer recommendations were found superior for higher nutrient use efficiency and reducing yield gaps (Xu *et al.*, 2019). The present study revealed that application of 125% NPK as per QUEFTS model (137.5, 81.25 and 112.5 kg NPK per ha) gave higher emergence per cent growth matrices, grade-wise tuber yields and grade-wise numbers of tubers and also gave higher values of gross income, net return and benefit: cost ratio which suggests 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.

Conclusions

As per QUEFT model, application of 100:25:60 kg/ha NPK for achieving 30 t/ha yield target with variety Kufri Jyoti recorded economically highest yield (20.37 t/ha) along with net return of Rs. 231386/- and the BC ratio was recorded 2.71. At present, the soil test based recommendations are relatively on a stronger footing. This method not only indicates soil test based fertilizer dose but also the level of yield the farmer can hope to achieve if good agronomy is followed in raising the crop. It provides the scientific basis for balanced fertilization not only between the fertilizer nutrients themselves but also that with the soil available nutrients. When fertilizer availability is limited or the resources of the farmers are also' limited, planning far moderate yield targets which are, at the same time, higher than the yield levels normally obtained by the farmer provides means, far saturating more areas with the available fertilizers and ensuring increased total production also.

Table 1 : Soil fertility status of before and after harvest of potato crop experiment

Treatment	OC*	pH	Available N	Available P	Available K
Initial soil fertility status	0.59	7.0	138	24	349
T_1-100% NPK RDF	0.56	7.2	136.45	25.36	341.42
T_2-75% NPK RDF	0.62	7.3	131.34	22.23	345.56
T_3-125% NPK RDF	0.59	7.4	149.56	24.21	348.34
T_4-100% NPK QEFTS	0.59	7.3	158.65	25.32	345.34
T_5-75% NPK QEFTS	0.6	7.2	139.32	21.78	335.67

T_6-125% NPK QEFTS	0.59	7.4	144.34	23.85	349.45
T_7-Without N fertilizer (PK)	0.58	7.3	121.23	23.02	351.03
T_8-Without P (NK)	0.59	7.3	145.41	19.89	349.43
T_9-Without K (NP)	0.62	7.2	145.21	21.12	351.78
T_{10}-Without NPK (control)	0.59	7.4	111.12	19.03	343.78

Table 2 : Treatment wise NPK (kg/ha) application details of the experiment

Treatments detail	N	P	K
T_1-100% NPK RDF	75	75	100
T_2-75% NPK RDF	56.25	56.25	75
T_3-125% NPK RDF	93.75	93.75	125
T_4-100% NPK QEFTS	110	65	90
T_5-75% NPK QEFTS	82.5	48.75	67.5
T_6-5% NPK QEFTS	137.5	81.25	112.5
T_7-Without N fertilizer (PK)	-	75	100
T_8-Without P (NK)	75	-	100
T_9-Without K (NP)	75	75	-
T_{10}-Without NPK (control)	-	-	-

Table 3 : Effect of nutrient management interventions on growth attributes of potato

Treatment	Emergence (%)	Plant height (cm)	No. of leaves / plant	No. of shoots/ plant	Fresh haulm yield	Haulm yield on dry wt. basis	Biological yield	Harvest index
T_1-100% NPK RDF	97.34	42.46	44.19	5.96	18.94	7.02	35.49	46.63
T_2-75% NPK RDF	97.43	41.27	42.16	5.56	17.75	6.57	33.11	46.39
T_3-125% NPK RDF	97.34	44.46	47.46	6.31	21.83	8.09	41.28	47.10
T_4-100% NPK QEFTS	98.32	44.13	44.54	5.94	19.45	7.20	36.51	46.73
T_5-75% NPK QEFTS	97.30	41.98	42.31	5.57	18.77	6.95	35.14	46.60
T_6-125% NPK QEFTS	97.78	45.88	48.48	6.73	22.76	8.43	43.13	47.23
T_7-Without N fertilizer (PK)	97.18	39.03	39.63	5.69	15.33	5.68	28.27	45.77
T_8-Without P (NK)	97.23	41.12	40.11	5.87	16.66	6.17	30.94	46.14
T_9-Without K (NP)	97.37	40.89	40.91	5.75	17.37	6.43	32.35	46.31
T_{10}-Without NPK (control)	96.87	37.69	38.32	5.21	13.42	4.97	24.46	45.11
Mean	**97.42**	**41.89**	**42.81**	**5.86**	**18.23**	**6.75**	**34.07**	**46.40**
SEM±	0.33	0.58	0.48	0.16	0.22	0.08	0.44	0.05
C.D	0.95	1.67	1.39	0.46	0.64	0.24	1.27	0.14

Table 4 : Effect of nutrient management interventions on grade wise yield attributes and yield of potato

Treatment	Grade-wise yield of tubers (t/ha)				Tuber yield on dry wt. basis	Grade-wise number of tubers (000'/ha)			
	0-25g	25-75g	>75g	Total		0-25g	25-75g	>75g	Total
T_1-100% NPK RDF	1.85	10.56	4.10	16.55	6.13	80.65	207.98	52.14	338.28
T_2-75% NPK RDF	1.82	10.70	3.09	15.36	5.69	83.09	206.63	45.06	331.97
T_3-125% NPK RDF	2.27	12.63	4.63	19.45	7.20	114.33	234.37	59.84	405.43
T_4-100% NPK QEFTS	2.13	11.58	3.46	17.06	6.32	107.48	222.83	45.19	372.38
T_5-75% NPK QEFTS	2.00	10.76	3.51	16.38	6.07	96.90	202.69	50.12	347.18
T_6-125% NPK QEFTS	2.25	13.42	4.74	20.37	7.54	116.92	249.09	61.58	424.33
T_7-Without N fertilizer (PK)	1.37	9.24	2.49	12.94	4.79	91.44	207.46	42.74	338.99
T_8-Without P (NK)	1.57	9.85	2.87	14.27	5.29	97.41	202.56	42.38	339.41
T_9-Without K (NP)	1.78	9.82	3.39	14.98	5.55	94.22	196.39	44.78	332.67
T_{10}-Without NPK (control)	1.45	7.70	2.32	11.04	4.09	124.61	178.28	33.28	333.72
Mean	1.85	10.62	3.46	15.84	5.87	100.71	210.83	47.71	356.44
SEM±	0.06	0.16	0.16	0.22	0.08	3.17	8.66	1.66	8.48
C.D	0.19	0.47	0.45	0.64	0.24	9.19	25.14	4.83	24.6

Table 5 : Effect of nutrient management interventions on economics of potato experiment

Treatments	Yield (t/ha)	Cost (Rs/ha)		Net returns (Rs/ha)	B:C ratio
		Inputs	Produce		
T_1-100% NPK RDF	16.55	134113	297900	163787	2.22
T_2-75% NPK RDF	15.36	131173	276480	145308	2.12
T_3-125% NPK RDF	19.45	137054	350100	213047	2.55
T_4-100% NPK QEFTS	17.06	132196	307080	174884	2.32
T_5-75% NPK QEFTS	16.38	130930	294840	163910	2.25
T_6-125% NPK QEFTS	20.37	135274	366660	231386	2.71
T_7-Without N fertilizer (PK)	12.94	133309	232920	99611	1.75
T_8-Without P (NK)	14.27	130855	256860	126005	1.97
T_9-Without K (NP)	14.98	131413	269640	138227	2.05
T_{10}-Without NPK (control)	11.04	122351	198720	76369	1.62

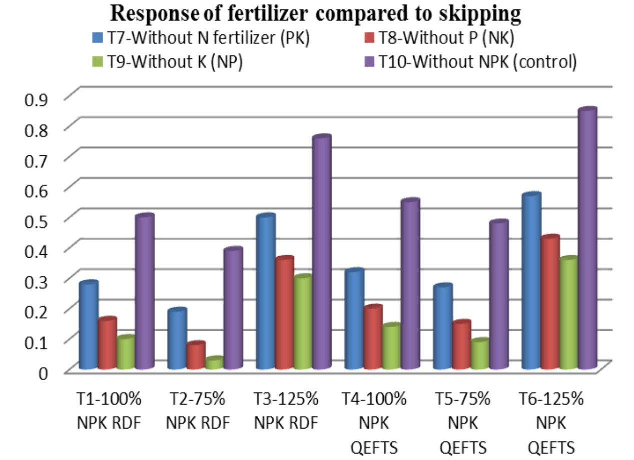

Fig. 1 Response of different fertilizer rates on potato tuber yield

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