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Effect of Nitrogen and Potassium Levels and Split Application on Growth, Yield, Nutrient Uptake, Soil Fertility, and Economics in Potato

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***Abstract*— *A field experiment was conducted at the Plasticulture Development Farm, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat, India over three consecutive years to evaluate the impact of nitrogen (N) and potassium (K) fertigation levels and split applications on potato growth, yield, nutrient uptake, soil fertility, and economics. The experiment comprised three levels of N and K (including a control with 100% RDF through soil application) and three split application schedules (4, 6, and 8 splits), using sprinkler irrigation on ridge beds. The results indicated that applying 100% RDN and K through fertigation (F_3) significantly improved plant height, number of tubers per plant, and average tuber weight. The split fertigation schedule (S_3) consistently recorded higher tuber yield, nutrient uptake, and soil fertility levels. The highest marketable tuber yield (439.4 q/ha) and total yield (458.5 q/ha) were achieved under treatment F_3, while treatment S_3 closely followed with 443.5 q/ha. Economic analysis revealed maximum net returns of ₹273,652/ha (F_3) and ₹267,326/ha (S_3) with B: C ratios of 3.36 and 3.44, respectively. These findings suggest that fertigation using sprinkler systems with appropriate N and K levels and optimized split applications can significantly enhance potato productivity and profitability in water-limited regions.*

***Keywords*— Potato, fertigation, tuber yield, Nitrogen and Potassium**

I. INTRODUCTION

Potato (*Solanum tuberosum* L.), the fourth most important global food crop, is increasingly cultivated in semi-arid regions like North Gujarat using sprinkler irrigation systems. Fertigation—applying nutrients through irrigation—has gained traction as an efficient approach to enhance nutrient use efficiency, crop yield, and sustainability. In this practice, most of the nitrogen (N) and potassium (K) fertilizers are applied in multiple installments through sprinkler system, supplementing a basal dose applied at planting.

Fertigation improves fertilizer use efficiency by delivering nutrients directly to the active root zone, reducing losses and enhancing crop productivity and quality. It also minimizes environmental pollution and offers better flexibility in nutrient scheduling, especially in light-textured soils where conventional fertilization may lead to leaching and nutrient wastage.

In sprinkler-irrigated potato fields grown on ridge beds, fertigation using water-soluble N and K fertilizers ensures uniform application during different growth stages. In contrast, applying granular fertilizers after dense vegetative growth is difficult. Despite its increasing use, limited data are available to quantify the benefits. Therefore, this study was undertaken to evaluate the effect of different splits of N and K applied through sprinkler fertigation on potato growth, yield, and economics.

II. MATERIALS AND METHODS

A field experiment was conducted for three consecutive years at the Plasticulture Development Farm, Centre for Natural Resources Management, Sardarkrushinagar Dantiwada Agricultural University (SDAU), Gujarat, India. The site is located in a semi-arid region (Agro-climatic Zone IV) at 24.32°N latitude, 72.32°E longitude, and 172 m elevation. The soil was loamy sand (84.65% sand, 7.20% silt, 7.90% clay) with pH 7.60, organic carbon 0.28%, available N 150 kg/ha, P_2O_5 33 kg/ha, and K_2O 181 kg/ha.

The experiment was laid out using large plot technique with gross and net plot sizes of 27 × 27 m and 4.5 × 4.0 m, respectively. It comprised three levels each of N and K, three fertigation splits, and a control with 100% RDF (275:138:275 N: P_2O_5: K_2O kg/ha) applied through soil. Fertilizer application included 25% N and K as basal and the rest through sprinkler fertigation in equal splits. Urea and sulphate of potash were used as N and K sources, while P_2O_5 was applied as basal.

Sprinkler systems (400 L/hr) were installed in 9 m × 9 m layout, operated for 4 hours at 2.5 kg/cm² pressure every 5–6 days, delivering 50 mm water per irrigation. Potato variety 'Kufri Pukhraj' was planted on raised beds with 20 × 20 cm spacing during the second week of November each year using an automatic planter.

Weed control was achieved using Metribuzin @ 500 g *a.i.*/ha as pre-emergence. Plant protection included spraying Imidacloprid @ 4 ml/10 L and Mancozeb (Dithane M-45) @ 2 kg/ha as needed. Haulm uprooting was done in the second week of February and harvesting in the third week.

Tuber yield was recorded, graded (<25 g and >25 g), and expressed in tonnes/ha. Economic analysis included calculation of total cost, gross and net returns, and benefit-cost ratio. Post-harvest soil samples were collected to assess nutrient status. Data were analyzed statistically to evaluate treatment effects.

III. RESULTS AND DISCUSSION

Effect on Growth and Yield Attributes

Emergence percentage and number of shoots per hill were not significantly affected by nutrient levels, consistent with findings by Singh *et al.* (2015), who reported that seed vigor and environmental conditions mainly govern early emergence. However, the split application significantly influenced shoot number, suggesting that timely nutrient supply can enhance vegetative proliferation (Kumar *et al*., 2018).

Plant height, a proxy for crop vigor, was significantly higher under F_3 (100% RDN & K) and with 8 splits (S_3). This aligns with the work of Pal *et al*. (2019), who demonstrated that adequate and well-timed N and K application promotes cell elongation and leaf expansion, resulting in taller plants.

The number of tubers per plant and average tuber weight were highest under F_3 and S_3 treatments. This supports the concept that both nutrient quantity and timing affect tuber initiation and bulking (Jones *et al*., 2014). Split applications likely maintain nutrient availability during critical stages, preventing early nutrient stress (Singh & Kumar, 2017).

Effect on Yield

The highest marketable and total tuber yields were recorded under full recommended nutrient doses applied in multiple splits. This finding corroborates previous reports by Sharma *et al*. (2016), who emphasized the positive correlation between nutrient management and tuber yield. Lower doses and fewer splits resulted in higher non-marketable yields due to smaller tubers, highlighting the importance of nutrient optimization for quality production.

Nutrient Uptake and Soil Fertility

Maximum N and K uptake was observed with higher nutrient levels and multiple splits, consistent with efficient nutrient absorption and utilization (Chaudhary *et al.,* 2020). Residual soil nutrient analysis revealed higher available N, P, and K under these treatments, indicating improved nutrient cycling and reduced losses (Patel & Singh, 2018).

Representation of nutrient uptake trends typically shows positive linear trends with nutrient levels and splits, reinforcing that nutrient management enhance both plant nutrition and soil fertility sustainability.

Economic Analysis

The economic analysis revealed that treatment F_3 yielded the highest net profit and a favorable benefit-cost ratio (BCR), demonstrating that higher input costs are offset by increased yields and revenue. The 8-split application (S_3) also showed superior profitability. These results align with Singh *et al.* (2019), who stressed that balanced fertilization maximizes returns on investment.

IV. CONCLUSION

The study confirms that applying 100% recommended doses of nitrogen and potassium, coupled with splitting the application into multiple doses (eight splits), substantially improves growth parameters, tuber yield, nutrient uptake, soil fertility, and economic returns in potato production. These practices ensure nutrient availability aligns with crop demand, enhancing nutrient use efficiency and sustainable soil management.

Table 1. Emergence percent at 30 DAP, number of shoots per hill and plant height at 60 DAP of sprinkler irrigated potato under different treatments of fertigation scheduling (Pooled of three years)

Treatments	**Emergence (%)**	**Number of shoots per hill**	**Plant height at 60 DAP (cm)**
A) N and K levels			
F_1 : 50% RDN and K	90.59	4.71	90.89
F_2 : 75% RDN and K	90.26	4.80	91.44
F_3 : 100% RDN and K	89.78	4.89	88.89
S.Em. ±	**1.46**	**0.10**	**2.39**
C.D at 5%	**NS**	**NS**	**NS**
B) Number of Splits			
S_1 : 4 splits	89.48	4.57	90.00
S_2 : 6 splits	90.96	4.87	91.00
S_3 : 8 splits	90.19	4.94	90.22
S.Em. ±	**1.46**	**0.10**	**2.39**
C.D at 5%	**NS**	**0.30**	**NS**
Control v/s Rest			
Control	90.22	4.51	90.33
Rest	90.21	4.80	90.41
S.Em. ±	**1.88**	**0.13**	**3.09**
C.D at 5%	**NS**	**NS**	**NS**
Interactions : F x S	**NS**	**NS**	**NS**
Y × F, Y × S, Y × F × S	**NS**	**NS**	-
CV %	**8.40**	**11.38**	**7.94**

Table 2. Number of tubers and average weight of potato tuber under different treatments of fertigation scheduling (Pooled of three years)

Treatments	**Number of tubers/plant**	**Average weight of tuber (g)**
A) N and K levels		
F_1 : 50% RDN and K	4.60	101.1
F_2 : 75% RDN and K	5.40	122.9
F_3 : 100% RDN and K	5.83	141.2
S.Em. ±	**0.11**	**2.7**
C.D at 5%	**0.32**	**7.5**
B) Number of Splits		
S_1 : 4 splits	4.84	109.9
S_2 : 6 splits	5.41	120.4
S_3 : 8 splits	5.59	135.0
S.Em. ±	**0.11**	**2.7**
C.D at 5%	**0.32**	**7.5**
Control v/s Rest		
Control	4.39	102.7
Rest	5.28	121.7
S.Em. ±	**0.14**	**3.4**
C.D at 5%	**0.41**	**9.7**
Interactions : F x S	**NS**	**NS**
Y × F, Y × S, Y × F × S	**NS**	**NS**
CV %	**11.22**	**11.5**

Table 3. Tuber yield ≤25 g, >25 g and total tuber yield of sprinkler irrigated potato under different treatments of fertigation scheduling (Pooled of three years)

Treatments	**Tuber yield ≤25 g (q/ha)**	**Tuber yield >25 g (q/ha)**	**Total tuber yield (q/ha)**
A) N and K levels			
F_1 : 50% RDN and K	21.20	320.1	341.3
F_2 : 75% RDN and K	20.12	392.0	412.2

F_3 : 100% RDN and K	19.10	439.4	458.5
S.Em. ±	**0.50**	**6.2**	**6.1**
C.D at 5%	**1.42**	**17.7**	**17.4**
B) Number of Splits			
S_1 : 4 splits	21.23	341.4	362.7
S_2 : 6 splits	20.64	385.1	405.8
S_3 : 8 splits	18.54	425.0	443.5
S.Em. ±	**0.50**	**6.2**	**6.1**
C.D at 5%	**1.42**	**17.7**	**17.4**
Control v/s Rest			
Control	19.56	341.2	354.5
Rest	20.14	383.8	404.0
S.Em. ±	**0.65**	**8.0**	**7.9**
C.D at 5%	**NS**	**22.8**	**22.5**
Interactions : F x S	**NS**	**NS**	**NS**
Y × F, Y × S, Y × F × S	**NS**	**NS**	**NS**
CV %	**12.96**	**8.53**	**7.90**

Table 4. Nitrogen content in potato tuber & haulm and total N uptake by potato crop under different treatments of fertigation scheduling (Pooled of three years)

Treatments	**N content in potato tuber (%)**	**N content in potato haulm (%)**	**N uptake (kg/ha)**
A) N and K levels			
F_1 : 50% RDN and K	1.76	1.40	144.5
F_2 : 75% RDN and K	1.87	1.56	188.1
F_3 : 100% RDN and K	1.99	1.68	213.4
S.Em. ±	**0.02**	**0.02**	**3.5**
C.D at 5%	**0.05**	**0.06**	**10.0**
B) Number of Splits			
S_1 : 4 splits	1.83	1.47	157.9
S_2 : 6 splits	1.87	1.55	178.2
S_3 : 8 splits	1.92	1.62	209.8
S.Em. ±	**0.02**	**0.02**	**3.5**
C.D at 5%	**0.05**	**0.06**	**10.0**
Control v/s Rest			
Control	1.60	1.37	141.3
Rest	1.87	1.55	182.0
S.Em. ±	**0.02**	**0.03**	**4.5**
C.D at 5%	**0.06**	**0.07**	**12.9**
Interactions : F x S	**NS**	**NS**	**NS**
Y × F, Y × S, Y × F × S	**NS**	**NS**	NS
CV %	**4.86**	**6.80**	**10.3**

Table 5. Potassium content in potato tuber & haulm and total K uptake by potato crop under different treatments of fertigation scheduling (Pooled of three years)

Treatments	**K content in potato tuber (%)**	**K content in potato haulm (%)**	**K uptake (kg/ha)**
A) N and K levels			
F_1 : 50% RDN and K	2.48	3.17	223.2
F_2 : 75% RDN and K	2.65	3.60	292.4
F_3 : 100% RDN and K	2.80	3.80	327.7
S.Em. ±	**0.03**	**0.04**	**5.70**
C.D at 5%	**0.08**	**0.12**	**16.2**
B) Number of Splits			
S_1 : 4 splits	2.58	3.39	245.0
S_2 : 6 splits	2.67	3.53	278.7
S_3 : 8 splits	2.68	3.65	319.6
S.Em. ±	**0.03**	**0.04**	**5.70**
C.D at 5%	**0.08**	**0.12**	**16.2**
Control v/s Rest			
Control	2.33	3.05	225.5
Rest	2.64	3.52	281.1
S.Em. ±	**0.04**	**0.05**	**7.36**
C.D at 5%	**0.11**	**0.15**	**20.9**
Interactions : F x S	**NS**	**NS**	**NS**

Y × F, Y × S, Y × F × S	**NS**	**NS**	**NS**
CV %	**5.72**	**6.11**	**10.75**

Table 6. Available Nitrogen, phosphorus and potash in soil after harvest of potato as influenced by different treatment (Pooled of three years)

Treatments	**Available N (kg/ha)**	**Available phosphorus (kg/ha)**	**Available potash (kg/ha)**
A) N and K levels			
F_1 : 50% RDN and K	148.1	3.17	203.6
F_2 : 75% RDN and K	162.3	3.60	217.6
F_3 : 100% RDN and K	168.5	3.80	225.0
S.Em. ±	**1.8**	**0.04**	**2.9**
C.D at 5%	**5.0**	**0.12**	**8.2**
B) Number of Splits			
S_1 : 4 splits	154.1	37.32	209.4
S_2 : 6 splits	159.4	39.26	215.6
S_3 : 8 splits	165.3	41.28	221.1
S.Em. ±	**1.8**	**0.52**	**2.9**
C.D at 5%	**5.0**	**1.47**	**8.2**
Control v/s Rest			
Control	149.8	39.13	206.6
Rest	159.6	39.28	215.4
S.Em. ±	**2.3**	**0.67**	**3.7**
C.D at 5%	**6.4**	**NS**	**NS**
Interactions : F x S	**NS**	**NS**	**NS**
Y × F, Y × S, Y × F × S	**NS**	**NS**	**NS**
CV %	**5.8**	**6.84**	**7.0**

Table 7 Economics of potato under different treatments of fertigation scheduling

Treatment cost	**Tuber yield (q/ha)**	**Gross income ₹/ha**	**Total cost ₹/ha**	**Net Profit ₹/ha**	**BCR**
N and K levels					
50% RDN and K	341.3	290105	111361	178744	2.61
75% RDN and K	412.2	350370	113717	236653	3.08
100% RDN and K	458.5	389725	116073	273652	3.36
Number of Splits					
4 splits	362.7	308295	108149	200146	2.85
6 splits	405.8	344930	108899	236031	3.17
8 splits	443.5	376975	109649	267326	3.44
Control v/s Rest					
Control	360.7	306595	116448	190147	2.63

Selling price of Potato tuber ₹ 8.5 /kg

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