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Effect of nutrient omissions on growth, yield, nutrient uptake and economics of potato (*Solanum tuberosum* L.) in northern Madhya Pradesh

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Abstract
A field experiment was conducted entitled "Effect of nutrient omissions on growth, yield, nutrient uptake and Eco mimics of potato (*Solanum tuberosum* L.) in northern Madhya Pradesh "at research farm, ICAR-CPRI-RS, Gwalior (M.P.) during the winter season of 2019-20 under the agro-climatic and soil conditions of Northern Madhya Pradesh. The experiment was planted under Randomized Block Design having 11 treatment combinations replicated thrice. Highest growth parameters *viz*., plant height (56.09 cm), number of stem per plant (5.71) and number of compound leaves/plant (35.08), yield parameters *viz*. haulm yield (13.75 t/ha), tuber yield (26.67 t/ha) and biological yield (40.42 t/ha) were recorded with 100% recommended dose of NPK. Similarly, chemical parameters *viz*., N uptake (63.73 kg/ha), P uptake (19.66 kg/ha) K uptake (75.03 kg/ha) in tubers; N uptake (45.39 kg/ha), P uptake (10.3 kg/ha) K uptake (50.6 kg/ha) haulms in 100% RDF NPK treatment. N (176 kg/ha), P (43.37 kg/ha) and K (360.12 kg/ha) contents in soil were highest in T_{11} (150% Recommended NPK). Highest cost of cultivation (Rs 123200/ha) in 150% RDF NPK but gross return (Rs 366481/ha) was recorded in 100% RDF NPK. However, highest net return (Rs 251681/ha) was recorded in 100% RDF NPK. In contrast to above, highest benefit cost ratio (3.2) was recorded in 100% RDF NPK which was slightly higher to 75% RDF NPK. Thus, resource poor farmers by reducing 25% dose of NPK, can increase return on per rupee invested on one hand and on other hand will contribute environmental safety.

Keywords: Nutrient, NPK, growth, yield and potato

Introduction
Potato (*Solanum tuberosum* L.) is one of the most important vegetable crops widely grown in the world. It belongs to the family solanaceae and considered to be originated in South America. Potato is world's fourth important food crop after wheat, rice and maize (Rana, 2008). The widely grown potato is an auto tetraploid with 2n=48. The potato is unique and different from other crops in the sense that food material is stored in underground stem parts called tubers. It is a heavy feeder of plant nutrients having very high requirement of nitrogen, phosphorus, potassium and other nutrients. It contains approximately 78% water, 22% dry matter (specific gravity) and less than 1% fat. Potatoes contain at least 12 essential vitamins and minerals and are a source of vitamin c, thiamine, iron and folic acid. It is used for several of purposes and typically used as a vegetable and regarded as "King of vegetable". Moreover it is used in many industries for starch and alcohol production (Abdel *et al.*, 1977) [1]. But in fact, it is likely that less than 50 per cent of potatoes grown worldwide are consumed fresh in form of vegetable. Potato is a short duration, high yielding and high nutrient requiring crop. It is, therefore imperative to apply balanced fertilizers for qualitative and quantitative production from this crop the applications of N and P nutrient elements have been mainly considered. Moreover, within the country, there is a lot of heterogeneity in potato productivity depending upon mostly on nutritional management and climatic conditions. Low use of fertilizers and severely imbalanced use of N, P and K fertilizers are some of the reasons responsible for low production of potato in many parts of the country.

The potato crop requires balanced dose of nitrogen (N), phosphorous (P) and potassium (K) for optimum production (Singh and Trehan, 1998)

Materials and Methods

A field experiment was conducted entitled *"*Effect of nutrient omissions on growth, yield, nutrient uptake and ecomimics of potato (*Solanum tuberosum* L.) in northern Madhya Pradesh*"* at research farm, ICAR-CPRI-RS, Gwalior (M.P.) during the winter season of 2019-20 under the agro-climatic and soil conditions of Northern Madhya Pradesh. The experiment was planted under Randomized Block Design having 11 treatment combinations replicated thrice. The experimental site of research farm, ICAR-CPRS Maharajpura, Gwalior (M.P.) is situated at 26º 13 N latitude and 78º 14' E longitudes at an altitude of 211.5 m above sea level in Gird belt (MLS). It has a subtropical climate with hot and summer where maximum temperature exceeds 45ºC in May- June. The winters are cold and the minimum temperatures reaches as low as 2º C in December and January. Usually monsoon arrives in the second fortnight of June and lasts till September. Soil p^H 7.6, electrical conductivity 0.32 (ds/m), organic carbon 0.45 (%) low, available Nitrogen (197 kg N /ha) low, available phosphorus (35 kg/ha) high, available potash (341kg /ha) medium. All the treatments were randomized separately in each replication. Row to row distance 60 cm, Plant to plant distance 20 cm. Date of planting was 02 – 11 – 2019. Healthy tubers with uniform size of 35-40 mm and about 45-50 g in weight were selected for planting. Pre-planting seed treatment was done with Mancozeb 0.2% solution for 10 minutes and spread at a cool and moist place to check fungal infection. Healthy, uniform and medium sized tubers were used for planting. Recommended dose of fertilizers was 180: 34.9: 100 kg N, P, K/ha^{-1}, respectively. Treatments were T1- minus N, T2- minus P, T3- minus K, T4- minus NK, T5- minus NP, T6- minus PK, T7- minus NPK, T8- NPK (50% RDF), T9- NPK (75% RDF), T10-NPK (100% RDF) and T11-NPK (150% RDF). Recommended doses of nitrogen, phosphorous and potassium according to treatment were applied in each plot. Nitrogen, phosphorous and potassium were applied through Urea, DAP and Muriate of Potash (MOP). The full quantity of potassium and phosphorous were applied as basal dose at the time of planting. Half dose of nitrogen was applied as basal dose and remaining was applied during earthing-up. After planting of potato tubers, irrigation was given as per need of the crop. Over all, six irrigations were applied during entire crop season. Earthing up was done at 25 DAP to protect the tuber from sunlight and potato tuber moth. Weeding was done manually at different growth stages to check the growth of weeds. Imidacloprid @ 6 ml /15 litre water was used to check the aphid population and to prevent the infestation of viral diseases in potato after planting at 35 DAP. Mancozeb @ 30 gm /15 litre of water was sprayed at 60 DAP to check the infestation of late blight in potato. Haulm uprooting was done at 90 DAP. After 10 days of haulm uprooting, tuber digging was done manually on skin hardening of tubers to avoid bruising from each treatment separately. Growth and yield observations were recorded at 30, 60DAP and at harvest.

Harvested tubers were graded in to four grade (<25g, 25-50g, 50-75g and >75g), counted and weighed grade wise. NPK contents of haulm, tuber and soil samples were analysed chemically following standard procedure. N, P and K uptakes were worked out. For different treatments total cost was calculated on the basis of prevailing market rates of fertilizer, field preparation, planting of seeds, labourers charge, cultural and intercultural operations etc.

Results and Discussion

Among the different growth parameters *viz*., plant height, number of shoots per plant and number of compound leaves were significantly influenced by different treatments (Table 1). The maximum plant height (28.02 cm at 30 DAP, 48.91 cm at 60 DAP and 56.09 cm at harvest), number of stems per plant (4.66 at 30 DAP, 5.66 at 60 DAP and 5.71 at harvest) and number of compound leaves (16.58 at 30 DAP, 28.30 at 60 DAP and 35.08 at harvest) were found in 100% recommended NPK. Plant height recorded with 100%RDF NPK was at par with 75% recommended NPK and 150% RDF NPK. At 60 DAP it was statistically on par only with 150% RDF NPK however at harvest 100% RDF NPK height was statistically on par with 50, 75 and 150%RDF NPK treatments. Minimum plant height 21.83 cm at 30 DAP, 39.00 cm at 60DAP and 49.42 cm at harvest was recorded under control. Highest number of stems/plant recorded at all the three stages were significantly superior over all other treatments. Lowest number of stems per plant 2.71 at 30 DAP, 3.71 at 60 DAP and 3.74 at harvest were recorded with control. Highest number of compound leaves recorded at 30 DAP was statistically same compared to 150% RDF NPK. At 60 DAP number of stems under 75, 100 and 150% RDF NPK were statistically same. Similarly, lowest number of compound leaves 11.81 at 30 DAP, 23.88 at 60 DAP and 30.28 at harvest were recorded in control. This could be due to the vital role of macro nutrient root development, chlorophyll content of leaves, starch synthesis, N metabolism and respiration. These nutrients have role in development of meristematic tissues at the growing points or cells are dividing and primary tissues are formed. Thus application of nutrients results in the improvement in plant height, number of shoots per plant and number of compound leaves. These findings are in close harmony with the result of Nandekar *et al.* (1991) [14], Kate *et al.* (2005) [8], Kumar *et al.* (2018) [9] and Marthha *et al.* (2017) [10]. < 0-25 g, the maximum (166.67) number of tubers was found in 150% Recommended NPK and the minimum (121.67) number was found in treatment 75% Recommended NPK. Number of 25-50 g tubers were maximum (121.00) Minus N and the minimum (47.00) number was found in treatment Minus NP. Maximum (162.00) number of tubers 50-75 g was found in treatment Minus NK and the minimum (95.00) in Minus P. Maximum (186.00) number of tubers (above 75 g) was found the in 100% Recommended NPK and the minimum (84.00) number was found in treatment Minus N. Cracked potato was maximum (32.67) in Minus P and the minimum (14.00) in Minus N).Total tuber number was maximum (606.01) in treatment 100% Recommended NPK and the minimum (476.33) number was found in treatment T_2 (Minus P).Maximum (2.30 Kg) yield of 0-25 g tubers was found in treatment 150% Recommended NPK and the minimum (1.44 Kg) yield was found in Minus NK. Maximum (4.82 Kg) yield of 25-50 g tubers was recorded in Minus N and the minimum (1.57 Kg) yield was found in Minus PK. Maximum (11.09 Kg) yield of 50-75 g tubers was found in Minus NK and the minimum (7.01 Kg) yield was found in Minus P. Maximum (21.87 Kg) yield above 75 g of tubers was found in 100% Recommended NPK and the minimum (8.50 Kg) yield was found in Minus NPK. Maximum (39.58 Kg) yield of total tubers was recorded in 100% Recommended NPK and the minimum (23.64 Kg) yield was found in Minus NPK. This may be one of the major reasons behind such increment of plant fresh weight, dry weight of plant and fresh weight, dry weight of tubers and also dry matter production and yield of tuber in each grade. These findings are in agreement with the findings of Moshileh *et al.* (2005) [11], Bishnu and Karki (2006) [3], Islam *et al.* (2017) [7] and Fayera (2017) [5].

Maximum haulm yield (13.75 t/ha) was recorded in 100% RDF which was significantly higher than other treatments except 50, 75, 150% RDF NPK, N and P omissions. Highest tuber yield (26.67 t/ha) was recorded with 100% RDF NPK which was significantly higher than all other treatments except minus K, 75% RDF NPK and150% RDF which were statistically same. Highest biological yield (44.33 t/ha) was recorded with 100% RDF NPK which was significantly higher than other treatments except 150% RDF NPK. It was due to proper supply of nutrients which plays an important role in vegetative growth of potato by increasing chlorophyll content in leaves and accumulating more photosynthates in plant tissue. This may be one of the major reasons behind such increment of plant fresh weight, dry weight of plant and fresh weight, dry weight of tubers and also dry matter production and yield of tuber in each grade. These findings are in agreement with the findings of Moshileh *et al.* (2005) [11], Bishnu and Karki (2006) [3], Islam *et al.* (2017) [7] and Fayera (2017) [5]. Highest harvest index (68.98) was recorded in 100% RDF NPK. It might due to proper and better nutrient supply to plant from soil as macro nutrients play important role in starch formation in potato and major element improved photosynthesis in plant and leaf area and number of leaves these plant part produce starch for plant and plant convert starch in the form of potato tubers. These findings are in agreement with the findings of Bose *et al.* (2008) [4], Najm *et al.* (2010) [12], Prativa and Bhattarai (2011) [15], Bansal and Trehan (2011) [2] and Islam *et al.* (2017) [7].

Maximum nitrogen, phosphorus and potash uptake in haulms, tuber and content in soil were significantly influenced by different treatment of NPK in potato. The maximum nitrogen uptake (45.39) by haulm was recorded with 100% RDF NPK which was significantly higher than all other treatments. Highest P uptake (10.3 kg/ha) with potato haulm was recorded in 100% RDF NPK which was significantly higher over all other treatments. Highest K uptake (50.46 kg/ha) in haulm was recorded with 100% RDF NPK which was significantly higher over all other treatments.

The maximum nitrogen uptake by tuber (63.73 kg/ha) was recorded with 100% RDF NPK which was significantly higher than all other treatments. Highest P uptake (19.66 kg/ha) with potato tuber was recorded in 100% RDF NPK which was significantly higher over all other treatments. Marschner (2002) reported about role of phosphorus, which performs functions in plants, such as a structural element forming part of the macromolecular structures such as nucleic acids (RNA and DNA) and in the phospholipids of cell membranes.

Highest K uptake (75.03 kg/ha) in tuber was recorded with 100% RDF NPK which was significantly higher over all other treatments.

The maximum nitrogen uptake by tuber + Haulm (109.12 kg/ha) was recorded with 100% RDF NPK which was significantly higher than all other treatments. Highest P uptake (29.96 kg/ha) by potato tuber + haulm was recorded in 100% RDF NPK which was significantly higher over all other treatments. Highest K uptake (125.49 kg/ha) in tuber + haulm was recorded with 100% RDF NPK which was significantly higher over all other treatments. The findings are in close harmony with the result of Nakashgir *et al.* (1996) [13], Grzebisz *et al.* (2015) [6] and Najm *et al.* (2010) [12].

Cost of cultivation (Rs 122400/ha) was highest with 150% RDF NPK. However, gross return (Rs 320000 / ha) was highest with 100% RDF NPK. Highest net return was also recorded with the treatment 100% RDF NPK. Highest B:C was recorded 75% RDF NPK. Maximum harvest index (66.05%) was found in 100% RDF and the minimum harvest index (62.49%) and net return (Rs 142000 / ha) was recorded in Minus NPK. Lowest benefit: cost (2.4) was recorded in Minus NPK. It might be due to proper and better nutrient supply to plant from soil as macro nutrients play important role in starch formation in potato and major element improved photosynthesis in plant and leaf area and number of leaves these plant part produce starch for plant and plant convert starch in the form of potato tubers. These findings are in agreement with the findings of Bose *et al.* (2008) [4], Najm *et al.* (2010) [12], Prativa and Bhattarai (2011) [15], Bansal and Trehan (2011) [2], Ahmed *et al.* (2017) and Islam *et al.* (2017) [7]. This may be one of the major reasons behind such increment of yield of tuber in each grade. These findings are in agreement with the findings of Moshileh *et al.* (2005) [11], Bishnu and Karki (2006) [3], Islam *et al.* (2017) [7] and Fayera (2017) [5].

Highest N content (176 kg/ha) in soil was recorded in 150% RDF NPK treatment which was significantly higher over other treatments. Highest P content (43.37 kg/ha) in soil was recorded in 150% RDF NPK treatment which was significantly higher over other treatments except 100% RDF NPK. Highest K content (360.12 kg/ha) in soil was recorded in 150% RDF NPK treatment which was significantly higher over other treatments.

Table 1: Effect of NPK omissions on growth attributes of potato

Treatment Detail	Plant height (cm)			Stems/plant			Compound leaves/plant		
	30 DAP	60 DAP	At harvest	30 DAP	60 DAP	At harvest	30 DAP	60 DAP	At harvest
Minus N	25.38	44.01	52.75	3.60	4.60	4.63	13.92	25.53	31.80
Minus p	25.49	44.07	53.12	3.65	4.61	4.63	14.66	25.93	31.94
Minus K	25.99	45.15	54.01	3.95	4.75	4.77	15.20	27.19	32.53
Minus NK	24.18	43.18	52.38	3.36	4.36	4.39	12.73	24.71	31.68
Minus NP	24.02	42.92	52.07	3.33	4.33	4.35	12.46	24.41	31.51
Minus PK	24.18	43.55	52.63	3.57	4.57	4.58	13.45	24.73	31.73
Minus NPK	21.83	39.00	49.42	2.71	3.71	3.74	11.81	23.88	30.28
50% RDF NPK	25.84	44.87	53.59	3.75	4.63	4.65	14.74	26.55	32.30
75% RDF NPK	26.50	45.93	54.43	4.00	5.00	5.04	15.58	27.45	32.56
100% RDF NPK	28.02	48.91	56.09	4.66	5.66	5.71	16.58	28.30	35.08
150% RDF NPK	26.85	46.94	54.95	4.07	5.07	5.10	16.04	27.85	32.75
S.Em ±	0.601	0.729	0.893	0.160	0.138	0.133	0.244	0.312	0.730
CD 5%	1.773	2.149	2.634	0.471	0.406	0.391	0.719	0.920	2.153

Table 2: Effect of NPK omissions on grade wise number of tubers

Treatment Detail	Grade wise number of tubers							
	(0-25g)	(25-50g)	(50-75g)	(>75g)	Cracked	Cut	Rotted	Total
Minus N	152.67	121.00	119	84	32.00	11.67	4.00	524.34
Minus p	140.67	76.33	95	122	32.67	6.33	3.33	476.33
Minus K	145.67	93.67	117	109	17.00	5.67	4.00	492.01
Minus NK	144.67	56.33	162	118	14.00	13.00	4.00	512.00
Minus NP	136.33	47.00	155	110	19.67	11.33	4.33	483.66
Minus PK	147.67	61.33	162	116	22.33	9.00	4.33	522.66
Minus NPK	130.67	64.67	154	99	24.67	13.33	5.33	491.67
50% RDF NPK	154.33	82.67	121	146	19.00	9.33	5.67	538.00
75% RDF NPK	121.67	86.00	132	161	18.00	10.67	4.00	533.34
100%RDF NPK	156.67	65.67	156	186	26.00	9.67	6.00	606.01
150% RDF NPK	166.67	79.00	128	155	22.67	7.67	5.67	564.68
S.Em+	4.069	4.577	3.952	5.225	5.429	2.293	0.673	18.356
CD 5%	12.005	13.502	11.65	15.415	NS	NS	NS	54.152

Table 3: Effect of NPK omissions on grade wise yield of tubers

Treatment detail	Grade wise yield of tubers (kg)							
	(0-25g)	(25-50g)	(50-75g)	(>75g)	Cracked	Cut	Rotted	Total
Minus N	2.16	4.82	9.74	11.05	3.41	1.01	0.51	32.70
Minus p	1.90	2.68	7.01	14.85	2.68	0.37	0.42	29.91
Minus K	1.95	3.17	8.67	13.23	1.67	0.40	0.34	29.43
Minus NK	1.44	2.18	11.09	12.68	1.16	0.73	0.38	29.66
Minus NP	1.67	1.58	9.45	11.68	1.69	0.76	0.91	27.74
Minus PK	1.71	1.57	10.05	13.77	2.04	0.72	0.38	30.24
Minus NPK	1.52	2.05	8.95	8.50	1.64	0.46	0.52	23.64
50% RDF NPK	1.90	3.03	8.38	17.97	1.93	0.65	0.74	34.60
75% RDF NPK	1.55	3.08	8.88	19.45	1.76	0.71	0.44	35.87
100%RDF NPK	1.92	2.27	9.87	21.87	2.00	0.76	0.89	39.58
150% RDF NPK	2.30	2.82	8.26	18.20	2.35	0.45	0.54	34.92
S.Em+	0.175	0.0740	0.313	0.153	0.513	0.215	0.221	0.328
CD 5%	0.515	0.219	0.923	0.463	NS	NS	NS	0.968

Table 4: Effect of NPK omissions on yield and economics

Treatment detail	Haulm yield (t/ha)	Tuber yield (t/ha)	Biological yield (t/ha)	Harvest index (%)	Tuber yield (kg/plot)	Cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	B:C
Minus N	13.20	25.23	38.62	65.35	32.70	Cost of cultivation	Gross return (Rs/h)	Net return (Rs/h)	B:C
Minus p	13.31	23.08	36.38	63.41	29.91	110800	302809	192009	2.7
Minus K	13.38	22.72	35.91	63.24	29.43	108000	276944	168944	2.6
Minus NK	13.14	22.89	36.03	63.53	29.66	108800	272623	163823	2.5
Minus NP	12.84	21.41	34.24	62.50	27.74	104800	274722	169922	2.6
Minus PK	13.19	23.33	36.63	63.99	30.24	104000	256914	152914	2.4
Minus NPK	12.00	18.24	30.23	60.30	23.64	102000	279938	177938	2.7
50% RDF NPK	13.35	26.67	40.02	66.64	34.60	98000	218858	120858	2.2
75% RDF NPK	13.38	27.67	41.05	67.41	35.87	106400	320370	213970	3.0
100%RDF NPK	13.75	30.58	44.33	68.98	39.58	110600	332120	221529	3.0
150% RDF NPK	13.39	26.92	40.31	66.78	34.92	114800	366481	251681	3.2
S.Em ±	0.160	0.38	0.340	_	0.328	_	_	_	_
CD 5%	0.472	1.12	1.003	_	0.967	_	_	_	_

Table 5: Effect of NPK omissions on NPK content of haulm, tuber, total uptakes and NPK contents of soil

Treatment Detail	Uptake by haulm (kg/ha)			Uptake by tuber (kg/ha)			Total uptake (kg/ha)			Nutrient content in soil (kg/ha)		
	N	P	K	N	P	K	N	P	K	N	P	K
Minus N	41.58	9.45	47.56	54.26	18.31	67.90	95.84	27.76	115.46	172.44	38.54	321.79
Minus p	42.49	9.48	48.25	55.55	18.44	68.30	98.04	27.92	116.55	172.52	38.70	327.82
Minus K	43.41	9.61	48.59	57.52	18.64	71.08	100.93	28.25	119.67	172.80	39.57	342.88
Minus NK	40.65	9.31	47.04	51.21	18.13	65.67	91.86	27.44	112.71	172.34	37.49	316.10
Minus NP	40.06	8.87	46.92	50.26	18.06	64.79	90.32	26.93	111.71	171.66	37.44	314.92
Minus PK	41.23	9.37	47.45	52.31	18.21	66.56	93.54	27.58	114.01	172.42	38.22	317.56
Minus NPK	38.03	8.00	46.00	48.01	17.08	63.12	86.04	25.08	109.12	170.13	36.04	310.00
50% Recommended NPK	42.55	9.56	48.49	56.51	18.53	69.28	99.06	28.09	117.77	172.59	39.50	334.65
75% Recommended NPK	43.83	9.76	48.93	58.54	18.73	72.57	102.37	28.49	121.5	172.85	40.69	355.37
100%RDF NPK	45.39	10.30	50.46	63.73	19.66	75.03	109.12	29.96	125.49	173.03	41.54	357.55
150% Recommended NPK	44.04	9.81	49.35	59.93	18.84	73.92	103.97	28.65	123.27	176.00	43.37	360.12
S.Em ±	0.312	0.138	0.369	0.533	0.206	0.370	0.612	0.236	0.382	0.816	0.645	0.833
CD 5%	0.919	0.408	1.089	1.571	0.609	1.091	1.836	0.708	1.146	2.407	1.902	2.458

Conclusion

On the basis of result among the treatments 100% recommended NPK was significantly superior in respect of growth, yield and chemical parameters as compared to other treatments. The maximum growth, yield and chemical parameters were found in treatment 100% Recommended NPK and minimum found in minus NPK treatment. Economically, the maximum cost of cultivation recorded with 150% RDF NPK, gross return with 100% RDF NPK. Whereas the maximum net returns was found in 100% RDF NPK while highest benefit: cost was recorded in 75% Recommended NPK. Fertility status was better in 150% RDF NPK.

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