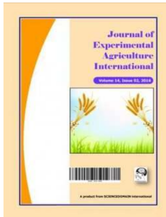

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Response of Potato Crop to Integrated Nutrient Management in the Indo-Gangetic Alluvial Soils of West Bengal, India

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Authors' contributions

This work was carried out in collaboration between all authors. SD carried out the experiment in field. ASK wrote first draft of the manuscript. AKC and ASH managed chemical analysis in laboratory. AD and RM helped in statistical analysis and producing figures. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was carried out to investigate the influence of Integrated Nutrient Management (INM) on nutrient uptake and yield of potato (*Solanum tuberosum* L.) in the Gangetic alluvium belt of West Bengal during two consecutive years i.e. 2011-12 to 2012-13. The experiment was laid out in a randomized complete block design with three replications. Different levels and combinations of organic (crop residue, farm yard manure and bio-fertilizer) and chemical fertilizers were tested. Plots receiving only organic manures reported least amount of nutrient uptake (36.00-44.65, 7.57-11.0

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and 44.66-72.66 kg·ha^{-1} for N, P and K respectively). The nutrient uptake was significantly higher when chemical fertilizers were applied. Maximum response was found (up-to 161, 221 and 354% increment for N, P and K respectively compared to control) when different sources were combined together. Strong correlation has been found between nutrient uptake, tuber dry weight, specific gravity, ascorbic acid and reducing sugar content suggesting role of nutrients uptake on tuber yield and quality. With increasing nutrient uptake, up to 80% increment in yield was found from those plots. It was noted from our experiment that sole use of organics was not effective enough for supplying nutrients. However, the integration of organic fertilizers with chemical ones had significantly improved soil and crop health, providing better crop yield and quality.

Keywords: Potato crop; crop nutrient uptake; integrated nutrient management; tuber quality; organic manure.

1. INTRODUCTION

Potato is the one of the most important vegetable crops in India. It removes large amount of nutrients from soil in a very short time scale for supporting faster biomass production [1]. Moreover, its' root system is shallow and poorly developed [2]. Thus farmers are forced to apply huge amount of inorganic fertilizer for profitable return in terms of yield. Ever-increasing cost of inorganic fertilizer and its increasing use resulted in high cost of cultivation and soil health deterioration, and decline in crop production in long run [3]. On the other hand, excessive nitrogen fertilization reduces starch, dry matter and sugar contents in tubers, compromising tuber quality [4,5]. Thus, it is necessary to develop techniques for sustainable crop production which is not only cheap and affordable, but also helps to restore soil health [6,7].

Integrated nutrient management holds the key for sustaining soil health and crop production. Studies have indicated enhanced efficiency of applied inorganic fertilizers in the presence of organic manure [8]. Combining both organic and inorganic sources of plant nutrients helped in maintaining the fertility status of the soil and production of field crops [9] over the use of each component separately [10]. The most widely used organic manure is farm yard manure (FYM) and vermicompost. The FYM is a mixture of plant and animal waste. The animal waste is rich in nitrogen (N) whereas the crop waste, generally rice straw is rich in potassium [K; 11]. The potato is known to be voracious feeder of both N and K. Thus, increased plant nutrition and crop yield from organic manure application was expected [12-14]. Not only tuber production, reports were available on reduced disease and pest incidence upon organic manure application [15-19]. Bio-fertilizers help in fixing atmospheric N, supply many other micronutrients and growth promoting substances to associated plants. Therefore, integrated use of bio, organic and inorganic fertilizers may meet the crop nutrient requirement in a sustainable manner and help in achieving target yield [20-23].

Kufri Jyoti cultivar of potato is one of the most cultivated varieties of the entire Indo-Gangetic alluvial plain of India. However, very little information is available on the nutrient management strategies for this variety [24]. Keeping this in view the present study was undertaken with an objective to evaluate the performance of potato crop under the combined use of organic and inorganic fertilizers.

2. MATERIALS AND METHODS

2.1 Field Experiment

Field experiment was conducted at the farmers' field of Adisaptagram Block, Hooghly district, West Bengal, India (22°76' N, 88°21' E and Altitude 9.75 m above MSL) with Groundnut (*Arachis hypogea* L.)-Fallow-Potato cropping sequence during winter season (December-March) of 2012 and 2013 under irrigated condition. *Kufri Jyoti,* being the mostly cultivated potato variety in the Indo-Gangetic alluvial tract, was chosen for the present study. The initial soil physico-chemical properties were listed in Table 1. The experiment was set up with 4 m×3 m plot size in randomized block design (RBD) with three replicates. The treatments were as follows: T_1 (Control, native nutrient), T_2 (Full N as Crop residue; Rice straw), T_3 (Full N as Crop residue + Bio-fertilizer), T_4 (50% N as Crop residue + Bio-fertilizer + 50% N as Bio dynamics, Enmite), T_5 (50% N as Crop residue + Bio-fertilizer + 50% N as farm yard manure, FYM), T_6 (Full N as FYM), T_7 (100% recommended dose of fertilizer, RDF), T_8 (⅓rd Crop residue + ⅓rd FYM + Bio-fertilizer +

50% RDF), T_9 (⅓rd Crop residue + ⅓rd FYM + Bio-fertilizer + 75% RDF), T_{10} (⅓rd Crop residue + ⅓rd FYM + Bio-fertilizer + 100% RDF) and T_{11} (⅓rd Crop residue + ⅓rd FYM + Bio-fertilizer + 150% RDF). The bio-fertilizer inoculation was done with *Azotobacter* @10g kg^{-1} potato seed before planting in both the years. The recommended fertilizer dose (RDF) for winter potato was 150:100:100 kg N: P_2O_5: K_2O ha^{-1}. The ¾th of N and full dose of P_2O_5 and K_2O were applied as basal and the remaining ¼th N was top dressed at first earthing up as per the treatments planned. Recommended amount of FYM (0.6% N, 0.23% P_2O_5 and 0.5% K_2O) @ 25 $t \cdot ha^{-1}$, Enmite (3.7% N, 2% P_2O_5 and 1.5% K_2O) @ 3.2 $t \cdot ha^{-1}$ and crop residue (0.37% N, 0.08% P_2O_5 and 0.69% K2O) @ 32.5 $t \cdot ha^{-1}$ were applied at the time of final land preparation as per the treatments. After harvest in each year, the composite soil samples from 0-15 cm and 15-30 cm depth from each plot were collected and prepared for analysis.

Specific gravity of tuber was determined after weighing tubers in air and re-weighing them suspended in water following [25].

$$\text{Specific gravity} = \frac{\text{weight of tuber in air}}{\text{weight of tuber in air} - \text{weight of tuber in water}}$$

Ascorbic acid content of the harvested tubers was determined following the method developed by [26] using 2,6-Dichlorophenol indophenol dye. The 'Lane and Eynon method' [27] was followed for estimating reducing sugar content of tubers. Total nitrogen content of tuber was determined by micro-Kjeldahl method. Phosphorus content in tuber extract was determined colorimetrically using Vanado-molybdate yellow colour method [28] after tri-acid digestion. Potassium was estimated in Flame Photometer after tri-acid digestion [28]. Finally the nutrient uptake by the crop was worked out by multiplying the dry matter yield of crop with nutrient concentration of each element.

2.2 Statistical Interpretation

The pooled and individual year data were statistically analyzed following the technique of analysis of variance (ANOVA) at 5% probability levels for randomized block design for the interpretation of results as described by [29]. Correlations between N, P and K uptake and potato quality and yield parameters were calculated in MS Excel software (version 2007).

3. RESULTS AND DISCUSSION

3.1 Nutrient Uptake

The uptake of nitrogen (N), phosphorus (P) and potassium (K) by potato crop varied significantly due to different organic, inorganic and integrated fertilizer treatment (see Table 2). Highest uptake was found for K nutrient, followed by N and P. Among the treatments, maximum uptake of N, P and K were recorded in T_{11} (93.84, 24.28 and 202.77 $Kg \cdot ha^{-1}$ respectively) followed by T_{10} (93.16, 23.75 and 198.03 $Kg \cdot ha^{-1}$ N, P and K). However, the differences between these two treatments were statistically insignificant. The nutrient uptake was increased only up to 50% over the control when only organics sources were applied (T_2 to T_6). The lower nutrient uptake from solely organics treated plots showed incapability of organic manures to supply nutrients when applied alone. Slower mineralization process at lower temperature during winter time [30] might cause lesser nutrient available to plants causing slower uptake. The nutrient uptake increased immediately by a factor of two with the introduction of inorganic fertilizers. There were 161, 221 and 354% (for N, P and K respectively) increase in nutrient uptake in T_{11} over T_1. Though, solely inorganic fertilizer treated plots were able to deliver significant amount of plant nutrients, their uptake was enhanced significantly when applied together with organic and bio-fertilizer. Similar findings were reported earlier [30-35].

Table 1. Soil classification and some selected physico-chemical properties of the experimental soil

Parameter(s)	
Agro-climatic Zone	New Gangetic Alluvial zone, West Bengal
Texture	Sandy loam
Order	*Inceptisol*
Bulk density	1.51 $g \cdot cc^{-3}$
Porosity	48.42%
Organic carbon	0.65%
Available N ($kg \cdot ha^{-1}$)	244
Available P_2O_5 ($kg \cdot ha^{-1}$)	65
Available K_2O ($kg \cdot ha^{-1}$)	181
pH	7.15
EC	0.15 $dS \cdot m^{-1}$

3.2 Quality of Potato Tuber

The positive influence of enhanced nutrient uptake was observed in both the tuber quality and production. Data on tuber quality upon different nutrient management are presented in Table 3A and 3B.

The specific gravity of tuber is important indicator of potato seed quality. It indicates the dry matter content of tubers. Generally, higher the specific gravity, higher is the dry matter content. Tubers with higher specific gravity (~ 1.09) were found in plots with integrated nutrient source. We found six percent increase in tuber specific gravity in T_{10} and T_{11} compared to controlled treatment (T_1). Specific gravity of potato tuber was strongly correlated with nutrients uptake (r= 0.85, 0.88 and 0.83 for N, P and K respectively, $p<0.001$; Table 4). The nutrients like N, P and specially K promoted dry matter and starch content of tuber [36,37] leading to higher specific gravity of potato.

The vitamin C, also known as ascorbic acid, content of tuber was reported to be influenced by nutrient management. Increase in organic acid concentration due to higher concentrations of K was reported to have positive influence on ascorbic acid content of potato tuber [36]. Maximum ascorbic acid content was recorded in T_{11} (15.70 mg·100 g^{-1}) followed by T_{10} (15.55 mg·100g^{-1}), which corresponded to ~ 50% increase in INM practices than control. Strong positive correlation between NPK and ascorbic acid content (r = 0.84 and 0.88 and 0.88, $p<0.001$ for N, P and K respectively) suggested influence of INM on the vitamin content of tuber. Studies suggesting influence of N, P and K on ascorbic acid content of tubers are also reported elsewhere [32,38,39].

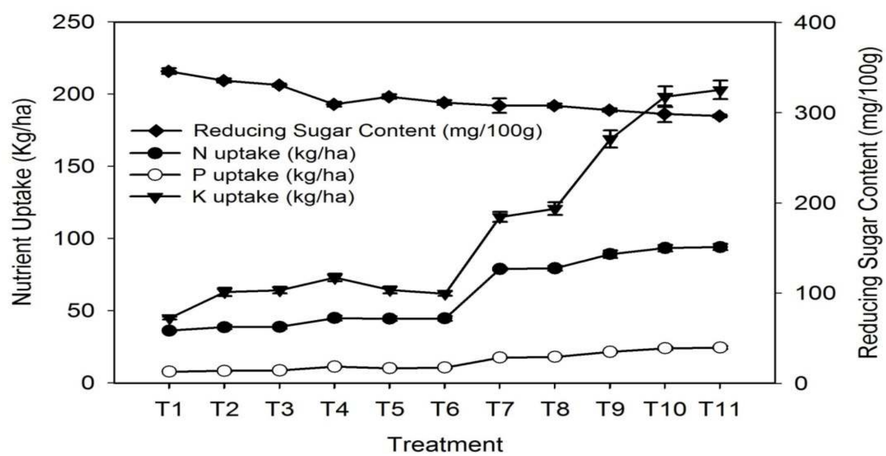

Fig. 1. Influence of integrated nutrient management on reducing sugar (mg/100g) content of tuber

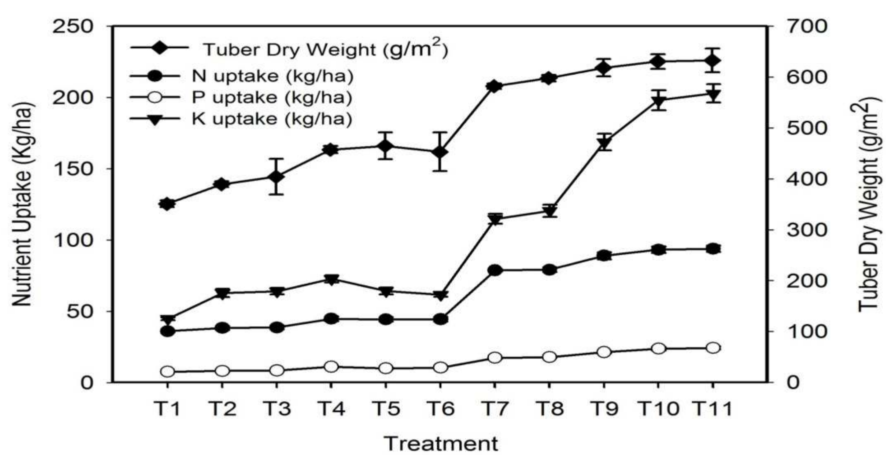

Fig. 2. Influence of integrated nutrient management on potato tuber yield (g·m^{-2})

Table 2. Effect of integrated nutrient management on nutrient uptake by potato tuber

	N uptake (kg·ha^{-1})				P uptake (kg·ha^{-1})				K uptake (kg·ha^{-1})			
	2012	**2013**	**Pooled**	**% Increase**	**2012**	**2013**	**Pooled**	**% Increase**	**2012**	**2013**	**Pooled**	**% Increase**
T1	35.57	36.43	36.00	-	7.43	7.70	7.57	-	44.01	45.30	44.66	-
T2	37.32	39.32	38.32	6	7.71	8.44	8.08	7	60.68	64.83	62.75	41
T3	37.58	39.65	38.62	7	8.10	8.67	8.39	11	62.43	65.62	64.03	43
T4	43.47	45.83	44.65	24	10.64	11.46	11.05	46	70.81	74.52	72.66	63
T5	43.14	45.34	44.24	23	9.49	10.41	9.95	31	62.56	65.91	64.24	44
T6	43.25	45.56	44.40	23	9.96	10.82	10.39	37	60.51	62.76	61.64	38
T7	77.95	79.42	78.69	119	16.91	17.67	17.29	128	112.32	117.24	114.78	157
T8	77.97	80.26	79.11	120	17.62	18.08	17.85	136	117.35	123.54	120.44	170
T9	87.16	90.70	88.93	147	20.77	21.76	21.27	181	164.55	172.91	168.73	278
T10	91.53	94.79	93.16	159	22.90	24.61	23.75	214	193.03	203.04	198.03	343
T11	92.30	95.37	93.84	161	23.50	25.06	24.28	221	198.23	207.31	202.77	354
SEm(±)	0.97	0.82	0.64		0.66	0.78	0.51		0.83	1.26	0.76	
CD at 5%	2.87	2.41	1.82		1.93	2.31	1.46		2.44	3.73	2.16	

Table 3A. Effect of integrated nutrient management on tuber quality (specific gravity and ascorbic acid content)

Treatment	Specific gravity (g·cc^{-1})				Ascorbic acid (mg·100g^{-1})			
	2012	**2013**	**Pooled**	**% Increase**	**2012**	**2013**	**Pooled**	**% Increase**
T1	1.03	1.02	1.03	-	10.04	10.03	10.04	-
T2	1.04	1.04	1.04	1	12.60	12.20	12.40	24
T3	1.05	1.04	1.04	1	11.80	12.40	12.10	21
T4	1.07	1.07	1.07	4	13.70	13.30	13.50	34
T5	1.07	1.07	1.07	4	12.80	13.00	12.90	28
T6	1.07	1.06	1.06	3	13.40	13.20	13.30	32
T7	1.06	1.07	1.07	4	13.10	13.70	13.40	33
T8	1.08	1.08	1.08	5	13.70	14.10	13.90	38
T9	1.08	1.08	1.08	5	15.00	13.90	14.45	44
T10	1.09	1.09	1.09	6	15.40	15.70	15.55	55
T11	1.09	1.08	1.09	6	15.60	15.80	15.70	56
SEm(±)	0.01	0.01	0.00		0.12	0.12	0.09	
CD at 5%	0.02	0.02	0.01		0.37	0.36	0.25	

Table 3B. Effect of integrated nutrient management on tuber quality (tuber grades)

Treatment	Grade A (>100 g, %)				Grade B (50-100 g, %)				Grade C (<50 g, %)			
	2012	2013	Pooled	% increase	2012	2013	Pooled	% Increase	2012	2013	Pooled	% decrease
T1	17.76	19.36	18.56	-	25.37	23.43	24.40	-	57.03	57.12	57.08	-
T2	21.24	20.90	21.07	14	27.40	27.28	27.34	12	51.75	52.02	51.89	9
T3	24.12	22.82	23.47	26	28.38	26.01	27.20	11	47.10	50.83	48.96	14
T4	21.86	23.15	22.51	21	33.69	41.07	37.38	53	44.16	36.09	40.13	30
T5	21.94	26.00	23.97	29	38.19	38.43	38.31	57	38.24	35.07	36.66	36
T6	26.59	28.29	27.44	48	37.88	35.78	36.83	51	35.70	36.93	36.32	36
T7	26.07	28.40	27.24	47	38.85	36.52	37.69	54	35.23	34.34	34.78	39
T8	30.31	29.00	29.66	60	36.57	38.19	37.38	53	34.40	32.11	33.25	42
T9	30.98	33.45	32.22	74	44.28	42.59	43.43	78	26.05	24.06	25.06	56
T10	31.13	34.11	32.62	76	43.14	44.61	43.87	80	25.56	22.05	23.81	58
T11	32.91	31.73	32.32	74	40.90	42.79	41.85	72	27.95	26.16	27.05	53
SEm(±)	1.29	1.33	0.93		1.09	1.12	0.78		1.06	1.21	0.80	
CD at 5%	3.79	3.93	2.65		3.21	3.30	2.23		3.12	3.56	2.30	

Table 4. Correlation between nutrient uptake and tuber quality and yield

	N uptake	P uptake	K uptake	Tuber wt.	Specific gravity	Ascorbic acid	Reducing sugar	Grade A	Grade B	Grade C
N uptake	1.00									
P uptake	0.99**	1.00								
K uptake	0.96**	0.98**	1.00							
Tuber wt.	0.98**	0.97**	0.92**	1.00						
Specific gravity	0.85**	0.88**	0.83*	0.93**	1.00					
Ascorbic acid	0.84*	0.88**	0.88**	0.89**	0.93**	1.00				
Reducing sugar	-0.82*	-0.85**	-0.80*	-0.91**	-0.97**	-0.95**	1.00			
Grade A	0.92**	0.93**	0.90**	0.94**	0.88**	0.91**	-0.90**	1.00		
Grade B	0.80*	0.83**	0.78*	0.88**	0.97**	0.90**	-0.96**	0.87**	1.00	
Grade C	-0.87**	-0.89**	-0.85**	-0.94**	-0.96**	-0.93**	0.96**	-0.95**	-0.98**	1

*"**" denotes Significant at p< 0.001 and "*" denotes Significant at p< 0.01*

Reducing sugar content in potato tubers was reported to have a strong influence on chipping quality of potato. Generally, lower the content of reducing sugar, better is the quality of tubers. The maximum reducing sugar content (345.97 $mg\cdot100\ g^{-1}$) was found in T_1, probably due to K nutrient deficiency [40]. Crop suffering from K nutrient deficiency were reported to accumulate reducing sugar in harvested tubers [41]. The reducing sugar content decreased with increasing level of applied fertilizer (Fig.1). The minimum reducing sugar content (296.30 $mg\cdot100\ g^{-1}$) was recorded in the treatment T_{11} where plots were followed by T_{10}. Similar results were reported elsewhere [32,37,42]. Decrease in glucose content upon balanced and increased uptake of NPK in INM plots was responsible for decreased reducing sugar content of tubers [43].

Grade of potato tuber is an important parameter in tuber quality perspective. Higher percentage of Grade A (>100 g) and B (50-100 g) represents better quality of potato, whereas higher percentage of Grade C tuber qualifies for poor quality tuber. The highest amount of grade A and B tubers were found in the plots receiving higher levels of inorganic fertilizers associated with various combinations of organic and bio-fertilizers (T_{10} and T_{11}). On the other hand, the percentage of Grade C tubers was maximum (57.08%) under the controlled treatment (T_1), which was reduced to half as in T_{10} and T_{11} (23.81 and 27.05% respectively). The results indicated that the size of potato tuber was deteriorated due to insufficient application of fertilizers either in the form of organic and inorganic solely or in combination. Similar findings were reported elsewhere [30,31].

3.3 Tuber Yield

Fig. 2 shows the variation in potato tuber yield under different nutrient management practices. The tuber dry weight was maximum (632.38 $g\cdot m^{-2}$) in the treatment T_{11}, followed by T_{10} (630.21 $g\cdot m^{-2}$) where nutrient uptake by potato crop was highest. Lower yield in solely organic treated plots (only up to 30% increase over control treatment) indicated that use of organics alone was not enough to supply plant nutrient for optimum yield. However, the yield can be increased with the incorporation of inorganic and organic fertilizer together. We found 80% hike in tuber production from integrated use of fertilizers over control treatment. Strong positive correlation ($r= 0.98$, 0.97 and 0.92, $p<0.001$ respectively) was found between N, P, K and tuber yield, suggesting their primary role in potato yield.

4. CONCLUSION

The study revealed that application of organic and inorganic sources of nutrient to potato crop increased the nutrients uptake by plants which were strongly correlated with tuber yield and other quality parameters. Lower yield was found when only organic sources were applied (T_2 to T_6) probably due to inability of supplying nutrient to crop. However, it increased several folds when inorganic fertilizers were introduced along with organics. Maximum increment (161, 221 and 354% for N, P and K respectively) was recorded in T_{11} over the control treatment. The better quality large and medium grade (Grade A and B; with higher specific gravity and ascorbic acid content) tuber yield was increased against enhanced nutrient uptake, whereas poor quality small grade (Grade C) tuber yield had decreased. Strong inverse relationship between nutrient uptake and reducing sugar content of potato suggested improved quality tuber under better nutrient management practice. The tuber weight was strongly correlated with N, P and K uptake. Thus, highest tuber yield (632.38 $g\cdot m^{-2}$) was recorded from plot (T_{11}) receiving ⅓rd Crop residue + ⅓rd farm yard manure (FYM) + Bio-fertilizer + 150% recommended dose of fertilizer (RDF) followed by T_{10} (630.21 $g\cdot m^{-2}$) where 100% RDF were practiced along with organics.

It was noted that integrated management (T_8 to T_{11}) had produced better result in each and every aspect. These treatments varied from each other only in respect of RDF. From this experiment it was evident that T_{10} and T_{11} both had produced similar (statistically insignificant) results in nutrient uptake, tuber quality and yield. Where the cost of cultivation is concerned, T_{11} comprises 150% of RDF and T_{10} include only 100% of RDF. Thus it can be concluded that application of ⅓rd Crop residue + ⅓rd FYM + Bio-fertilizer + 100% RDF (T_{10}) was more economical than ⅓rd Crop residue + ⅓rd FYM + Bio-fertilizer + 150% RDF (T_{11}).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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