

Original Research Article

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

Running head: INM and potato crop production

Key words: *potato crop, crop nutrient uptake, integrated nutrient management, tuber quality, organic manure*

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, farmyard manure and bio-fertilizer) and chemical fertilizers were tested. Plots receiving only organic manures reported least amount of nutrient uptake (36-44.6, 7.5-11.0 and 44.66-72.66 kg/ha for N, P and K respectively). The nutrient uptake was significantly higher when chemical fertilizer was 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 nutrients 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 one had significantly improved soil and crop health, providing better crop yield and quality.

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 (Singh and Trehan, 1998). Moreover, its' root system is shallow and poorly developed (Dey *et al.*, 2015). 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 (Khan *et al.*, 2008). On the other hand, excessive nitrogen fertilization reduces starch, dry matter and sugar contents in tubers, thus compromising tuber quality (Simanaviciene *et al.*, 1996; Baniuniene and Zekaite, 2008). Thus, it was necessary to develop techniques for sustainable crop production which is not only cheap and affordable, but also helps to restore soil health (Sepehya, 2011; Singh and Kushwah, 2006).

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 (Singh and Biswas, 2000). By combining both organic and inorganic sources of plant nutrients it helped in maintaining the fertility status of the soil and production of field crops (Chandrasoorian *et al.*, 1994) over the use of each component separately (Palaniappan and Annadurai, 2007). 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; Fowler *et al.*, 1993). 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 (Srikumar, 1990; Preston, 1990; Floyd *et al.*, 1988). Not only tuber production, reports were available on reduced disease and pest incidence upon organic manure application (Chen *et al.*, 1988; Hoitnik *et al.*, 1993; Rich and Hodge, 1993; Tunlid *et al.*, 1989; Volland and

Epstain, 1994). 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 (Islam *et al.*, 2011; Sood, 2007; Mahendran and Chandramani, 1998; Singh and Lal, 2006).

Kufri Jyoti cultivar of potato is the one most cultivated variety of the entire Indo-Gangetic alluvial plain of India. However, very little information is available on the nutrient management strategies for this variety (Chatterjee *et al.*, 2010). 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.

MATERIALS AND METHODS

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 4m×3m plot size in randomized block design (RBD) with three replicates. The treatments were as follows: T₁ (Control, native nutrient), T₂ (Full N as Crop residue; Rice straw), T₃ (Full N as Crop residue + Bio-fertilizer), T₄ (50% N as Crop residue + Bio-fertilizer +50% N as Bio dynamics, Enmite), T₅ (50% N as Crop residue + Bio-fertilizer + 50% N as FYM), T₆ (Full N as FYM), T₇ (100% RDF), T₈ (1/3rd Crop residue + 1/3rd FYM +

Bio-fertilizer + 50% RDF), T₉ (1/3rd Crop residue + 1/3rd FYM + Bio-fertilizer + 75% RDF), T₁₀ (1/3rd Crop residue + 1/3rd FYM + Bio-fertilizer + 100% RDF) and T₁₁ (1/3rd Crop residue + 1/3rd 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: P₂O₅: K₂O ha⁻¹. The 3/4th of N and full dose of P₂O₅ and K₂O were applied as basal and the remaining 1/4 N was top dressed at first earthing up as per the treatments planned. Recommended amount of FYM (0.6% N, 0.23% P₂O₅, and 0.5% K₂O) @ 25 t ha⁻¹, Enmite (3.7% N, 2% P₂O₅, and 1.5% K₂O) @ 3.2 t ha⁻¹ and crop residue (0.37% N, 0.08% P₂O₅, and 0.69% K₂O) @ 32.5 t 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 following underwater weight method using 2.5 kg of medium sized tuber by the following formula:

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

Ascorbic acid content of the harvested tubers was determined following the method developed by Rangana (1979). The 'Lane and Eynon method' (Ruck, 1963) was followed for estimating reducing sugar content of tubers. The 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 (Jackson, 1973) after tri-acid digestion. Potassium was estimated using Flame Photometry after tri-acid digestion (Jackson, 1958). Finally the nutrient uptake by the crop was worked out by multiplying the dry matter yield of crop with nutrient concentration of each element.

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 Gomez and Gomez (1984). Correlations between N, P and K uptake and potato quality and yield parameters were made using MS Excel software 2007.

RESULTS AND DISCUSSION

Nutrient uptake

The uptake of N, P and 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 T₁₁ (93.84, 24.28 and 202.77 Kg ha⁻¹ respectively) followed by T₁₀ (93.16, 23.75 and 198.03 Kg ha⁻¹ N, P and K). However, the differences between these two treatments were statistically insignificant. The lowest uptake of nutrients (36.00, 7.57 and 44.66 Kg ha⁻¹ respectively for N, P and K) by potato crop was found in controlled plot. Their uptake was increased only up-to 50 % over the control when only organics sources were applied (T₂ to T₆). The lowest nutrients uptake from solely organics treated plots showed incapability of organic manures to supply nutrients alone. Slower mineralization process at lower temperature during winter time (Kumar *et al.*, 2011) might cause lesser nutrient available to plants causing slower uptake. The nutrient uptake was 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 T₁₁ over T₁. Though, solely inorganic fertilizer treated plots were able to deliver significant amount of plant nutrients, their uptake enhanced significantly when applied together with organic and bio-fertilizer. Similar findings

were reported earlier (Bohm and Dewes, 1997; Kumar *et al.*, 2011; Sarkar *et al.*, 2007; Roy *et al.*, 2001; Kumar *et al.*, 2008; Baishya, 2009).

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. The maximum specific gravity (1.09) was recorded in INM plots, whereas least (1.03) was recorded from control (Table 3A). We had found six percent increase in tuber specific gravity in T₁₀ and T₁₁ compared to controlled treatment (T₁). 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). Nutrients like N, P and specially K promoted dry matter and starch content of tuber (Bergmann, 1992; Acharya, 2006) 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 (Bergmann, 1992). The minimum ascorbic acid content (10.04 mg/100 g) was recorded in controlled plot. Whereas, T₁₁ recorded the maximum ascorbic acid content (15.70 mg/100 g), followed by T₁₀ (15.55 mg/100 g). Thus, over 50 % increase in ascorbic acid content was recorded in INM practices. 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

147 ascorbic acid content of tubers are also reported elsewhere (Imas and Bansal, 1999; Sud *et*
148 *al.*, 1990; Sarkar *et al.*, 2007).

149 Reducing sugar content in potato tubers was reported to have a strong influence on
150 chipping quality of potato. Generally, lower the content of reducing sugar, better is the
151 quality of tubers. The maximum reducing sugar content (345.97 mg/100 g) was found in T₁,
152 probably due to K nutrient deficiency (Perrenoud, 1993). Crop suffering from K nutrient
153 deficiency were reported to accumulate reducing sugar in harvested tubers (Usherwood,
154 1985). The reducing sugar content decreased with increasing level of applied fertilizer
155 (Fig.1). The minimum reducing sugar content (296.30 mg/100 g) was recorded in the
156 treatment T₁₁ where plots were followed by T₁₀. Similar results were reported elsewhere
157 (Mondal *et al.*, 1996; Acharya, 2006; Sarkar *et al.*, 2007). Decrease in glucose content upon
158 balanced and increased uptake of NPK in INM plots was responsible for reduced the reducing
159 sugar content of tubers (Singh and Singh, 1995).

160 Grade of potato tuber is an important parameter in tuber quality perspective. Higher
161 percentage of Grade A (>100g) and B (50-100g) represents better quality of potato, whereas
162 higher percentage of Grade C tuber qualifies for poor quality tuber. The highest amount of
163 grade A and B tubers were found in the plots receiving higher levels of inorganic fertilizers
164 associated with various combinations of organic and bio-fertilizers (T₁₀ and T₁₁). On the other
165 hand, the percentage of Grade C tubers was maximum (57.08 %) under the control treatment
166 (T₁), which was reduced to half as in T₁₀ and T₁₁ (23.81 and 27.05 % respectively). The
167 results indicated that the size of potato tuber was deteriorated due to insufficient application
168 of fertilizers either in the form of organic and inorganic solely or in combination. Similar
169 findings were reported elsewhere (Bohm and Dewes, 1997; Kumar *et al.*, 2011).

170 *Tuber yield*

Figure 2 shows the variation in potato tuber yield under different nutrient management practices. The tuber dry weight was maximum (632.38 g m^{-2}) in the treatment T_{11} , followed by T_{10} (630.21 g m^{-2}) where nutrient uptake by potato crop was highest. Lower yield in solely organic treated plots (only upto 30 % increase over control treatment) indicated that use of organics alone was not enough to supply plant nutrient for best 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.

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. The nutrient uptake didn't increase in appreciable manner (only up to 50 % over the control) when only organics were applied (T_2 to T_6). However, it increased several folds when inorganic fertilizers were introduced. Maximum increment (161, 221 and 354 % for N, P and K respectively) was recorded in T_{11} over the control treatment. Slower mineralization process at lower temperature during winter time was responsible for reduced nutrient uptake in organics treated plots. The better quality large and medium grade (Grade A and B; with higher specific gravity and ascorbic acid content) tuber yield increased against enhanced nutrient uptake, whereas poor quality small grade (Grade C) tuber yield was decreasing. Strong inverse relation 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 gm m^{-2}) was recorded from plot receiving $\frac{1}{3}^{\text{rd}}$ Crop residue + $\frac{1}{3}^{\text{rd}}$ FYM + Bio-

fertilizer + 150% RDF (T₁₁) followed by T₁₀ (630.21 gm m⁻²) where 100% RDF were practiced along with organics.

It was found that integrated management (T₈ to T₁₁) 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 T₁₀ and T₁₁ both produced similar (statistically insignificant) results in nutrient uptake, tuber quality and yield. Where the cost of cultivation is concerned, T₁₁ comprises 150 % of RDF and T₁₀ include only 100% of RDF. Thus it can be concluded that application of 1/3rd Crop residue + 1/3rd FYM + Bio-fertilizer + 100% RDF (T₁₀) was more economical than 1/3rd Crop residue + 1/3rd FYM + Bio-fertilizer + 150% RDF (T₁₁).

REFERENCES

- Acharya D. 2006. Studies on production potential, quality improvement and fertility build-up of soil under intensive cropping system through integrated nutrient management. A Ph.D. Thesis, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal.
- Baishya L K. 2009. Response of potato varieties to organic and inorganic sources of nutrients. A Ph.D. thesis submitted to Visva- Bharati University, Santiniketan, West Bengal. pp. 99-102.
- Baniuniene A and Zekaite V. 2008. The effect of mineral and organic fertilizers on potato tuber yield and quality. *Agronomijas vēstis Latvian J Agronomy* **11**: 202-210.
- Bergmann W. 1992. *Nutritional Disorders of Plants*, Gustav Fischer Verlag, Z. Pflanzenernaehr. Bodenk. 156: 377. doi:10.1002/jpln.19931560416.

- 218 Bohm H and Dewes T. 1997. Effects of increasing rate of farm yard manure on yield, quality
219 and post-harvest quality of selected potato cultivars. *Schriftenreihe institute fur*
220 *organischen. Landbau*. **4**: 368 – 374.
- 221 Chandrasoorian S, Palaniappan S P and Martin G J. 1994. Studies on soil fertility changes in
222 a rice based cropping system. *(in) XIII National Symposium on Integrated Nutrient*
223 *Management for efficient crop production* held on 23rd – 25th of February at
224 Tamilnadu Agricultural University, Coimbatore, TN, pp 22-25.
- 225 Chatterjee D, Srivastava A and Singh R K. 2010. Fertilizer recommendations based on
226 targeted yield concept involving integrated nutrient management for potato (*Solanum*
227 *tuberosum* L.) in tarai belt of Uttarakhand. *Indian Journal of Agricultural Sciences* **80**
228 **(12)**: 1048–53.
- 229 Chen,W, Hoitnik, H A J, and Schmitthenner, A F. 1988. Factors affecting the soppression of
230 Pythium damping off in container media amended with compost. *Phytopatology*
231 **77**:755.
- 232 Dey A, Dasgupta S, Bhattarcharya S, Chaitanya A K, Pati S and Pal B. 2015. Soil physical
233 fertility and performance of potato crop as affected by integration of organic and
234 inorganic fertilizers in new alluvial soil of West Bengal. *Journal Crop and Weed*
235 **11**(1):132-137.
- 236 Floyd C N, DSousa, E J, and lefroy, R D B. 1988. Soil fertility and sweet potato production
237 on volcanic ash soils in the highlands of Papua New Guinea. *Field Crops Research*
238 **19**:1.
- 239 Fowler, S M, Watson, C A and Wilman, D. 1993. N, P and K on organic farms: herbage and
240 cereal production, purchases and sales. *Journal of Agricultural Science, Cambridge*
241 **120**:353-360.

- 242 Gomez K A and Gomez A A. 1984. *Statistical Procedures for Agricultural Research*, John
243 Wiley and Sons, New York, USA.
- 244 Hoitnik, H A J, Inbar, R and Boehm, M J. 1993. Compost can suppress soil-borne diseases in
245 container media. *American Nurseryman* (USA) **178(16)**:91.
- 246 Imas P and Bansal S K. 1999. Potassium and Integrated Nutrient Management in Potato.
247 Global Conference on Potato. 6-11 December 1999, New Delhi, India.
- 248 Islam M M, Karim A J M S, Jahiruddin M, Majid N M, Miah M G, Ahmed M M and Hakim
249 M A. 2011. Effects of organic manure and chemical fertilizers on crops in the Radish-
250 Stem Amaranth-Indian spinach cropping pattern in homestead area. *Australian*
251 *Journal of Crop Science* **5**:1370-1378.
- 252 Jackson M L. 1958. *Soil Chemical Analysis*, Prentice Hall of India Pvt. Ltd., New Delhi,
253 India.
- 254 Jackson M L. 1973. *Soil Chemical Analysis*, Prentice Hall of India Pvt. Ltd. New Delhi, India.
- 255 Khan M S, Shil N C and Noor S. 2008. Integrated Nutrient Management for sustainable yield
256 of major vegetable crops in Bangladesh. *Bangladesh Journal of Agriculture and*
257 *Environment* **4**: 81-94.
- 258 Kumar M, Baishya L K, Ghosh D C and Gupta V K. 2011. Yield and quality of potato
259 (*Solanum tuberosum* L.) tubers as influenced by nutrient sources under rainfed
260 condition of Meghalaya. *Indian Journal of Agronomy* **56** (3): 105-111.
- 261 Kumar M, Jadav M K and Trehan S P. 2008. Contribution of organic sources to potato
262 nutrition at varying nitrogen levels. (in) *Proceedings of Global Potato Conference*, 9th
263 –12th December, New Delhi.

- 264 Mahendran P P and P Chandramani. 1998. NPK-uptake, yield and starch content of potato cv.
265 kufri Jyoti as influenced by certain biofertilizers. *Journal of Indian Potato*
266 *Association* **25 (1-2)**: 50-52.
- 267 Mondal S S, Saha B C, Mandal B K, Chatterjee B N and Chowdhury P P. 1996. Effect of
268 potassium, sulphur, farm yard manure and crop residues on the yield of rice, mustard,
269 potato in a Gangetic alluvial soil of W.B. *Journal of Potassium Research* **12**: 282-90.
- 270 Palaniappan S P and Annadurai K. 2007. *Organic Farming: Theory and Practices*, Scientific
271 Publishers, Jodhpur, p-257.
- 272 Perrenoud S. 1993. Fertilizing for High Yield Potato. *Bulletin no.8*, 2nd edn, International
273 Potash Institute, Basel, Switzerland.
- 274 Preston S R. 1990. Investigation of compost x fertilizer interactions in sweet potato grown on
275 volcanic ash soils in the highlands of Papua New Guinea. *Tropical Agriculture*
276 **67(3)**:239.
- 277 Ranganna S. 1986. *Manual of analysis and Quality Control of fruits and vegetables products*,
278 Tata McGraw Hill Co. Ltd., New Delhi, p-1112.
- 279 Rich, J R, and Hodge, C H. 1993. Utilization of blue crab scrap compost to suppress
280 *Meloidogine javanica* on tomato. *Nematropica* **23(1)**:1.
- 281 Roy S K, Sharma R C and Trehan S P. 2001. Integrated nutrient management by using FYM
282 and fertilizer in Potato-Sunflower- Rice rotation in Punjab. *Journal of Agricultural*
283 *Science* **137**: 271-78
- 284 Ruck J A. 1963. Chemical methods for analysis of fruit and vegetable products. Canada
285 Department of Agriculture Publications. No. 1154.

- 286 Sarkar B, Mondal S S, Nayek S S, Saha M and Biswas S. 2007. Integrated nutrient
287 management for the productivity and quality improvement of potato under irrigated
288 condition. *Potato Journal* **34** (1-2): 99-100.
- 289 Sepehya S. 2011. A long-term effect of integrated nutrient management on dynamics of
290 nitrogen, phosphorus and potassium in rice-wheat system. Ph.D. Thesis. Himachal
291 Pradesh Krishi Vishvavidyalaya. Palampur, 176 062 (H.P.) India.
- 292 Simanavicien O, Staugaitis G, Antanaitis A. 1996. Dirvožemio agrocheminių savybių įtaka
293 bulvių ir lauko daržovių derliui ir kokybei. *Zemės ūkio mokslai*, **2**: 60-67.
- 294 Singh G B and Biswas P P. 2000. Balanced and integrated nutrient management for
295 sustainable crop production. *Indian Journal of Fertilizers* **45**(5): 55-60.
- 296 Singh J P and Trehan S P. 1998. Balanced fertilization to increase the yield of potato. (in)
297 *IPI-PRII-PAU Workshop on Balanced Fertilization in Punjab Agriculture*. PAU,
298 Ludhiana, 15-16 December 1997, pp 129-39.
- 299 Singh S P and Kushwah V S. 2006. Effect of integrated use of organic and inorganic sources
300 of nutrients on potato (*Solanum tuberosum* L.) production. *Indian Journal of*
301 *Agronomy* **51**(3): 236–8.
- 302 Singh S K and Lal S S. 2006. Effect of organic sources of nutrients on potato production in
303 South Bihar. (in) *National symposium on Conservation Agriculture and Environment*,
304 Benaras Hindu University, Varanasi, 26th -28th October, p 284.
- 305 Singh V N and Singh S P 1995. Effect of potassium application on yield and yield attributes
306 of potato. 1995. *Journal of potassium Research* **11** (3-4): 338-343.
- 307 Sood M C. 2007. Integrated nutrient supply and management for potato production in Mid
308 Hills of Shimla. *Potato Journal* **34**: 101-102.

- 309 Srikumar, T S 1990. The effects of fertilization and manuring on the content of some
310 nutrients in potato (var. Provita). *Food Chemistry* 37(1), pp.47-60.
- 311 Sud K C, Grewal J S and Trehan S P. 1990. Effect of farm yard manure and nitrogen on
312 potato (*Solanum tuberosum* L.) production and phosphorus and potassium availability
313 in hill soils of Simla. *Indian Journal of Agricultural Sciences* **60** (8): 529-532.
- 314 Tunlid, A, Hoitnik, H A J, Low, C, and White, D C.1989. Characterization of bacteria that
315 suppress *Rhizoctonia* damping off in bark compost media by analysis of fatty acid
316 biomarkers. *Applied and Environmental Microbiology* **55**(6):1368.
- 317 Usherwood N R. 1985. The role of potassium in crop quality. (in) *Potassium in Agriculture*.
318 Munson R S (Eds). ASA-CSSA-SSSA, Madison, WI, pp. 489-513.
- 319 Volland, R P and Epstein, A H. 1994. Development of suppressiveness to disease caused by
320 *Rhizoctonia solani* in soils amended with composted and noncomposted manure.
321 *Plant Disease* **78**(5):461.
- 322

Figure Captions:

1. Influence of integrated nutrient management on Reducing Sugar (mg/100g) Content of tuber
2. Influence of integrated nutrient management on potato tuber yield (g/m^2)

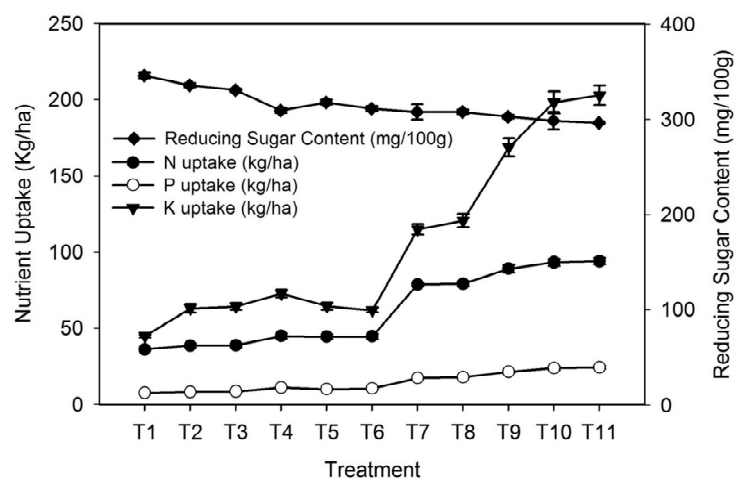


Fig. 1: Influence of Integrated nutrient management on Reducing Sugar (mg/100g) Content of tuber

Fig. 1

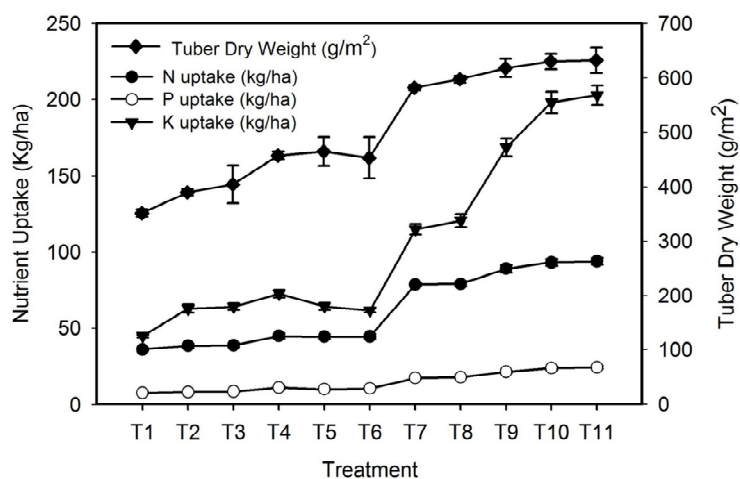


Fig. 2: Influence of integrated nutrient management on potato tuber yield (g/m^2)

Fig. 2

332 **Table 1: Soil classification and some selected physic-chemical properties of the**
 333 **experimental soil.**

Agro-climatic Zone	New Gangetic Alluvial zone, West Bengal
Texture	Sandy loam
Order	<i>Inceptisol</i>
Bulk density	1.51 Mg m ⁻³
Porosity	48.42%
Organic carbon	0.65%
Available N (kg ha ⁻¹)	244
Available P ₂ O ₅ (kg ha ⁻¹)	65
Available K ₂ O (kg ha ⁻¹)	181
pH	7.15
EC	0.15 dsm ⁻¹

334

335

336 **Table 2: Effect of integrated nutrient management on nutrient uptake by potato tuber**

	N uptake (Kg/ha)				P uptake (Kg/ha)				K uptake (Kg/ha)			
	2012	2013	Pooled	%	2012	2013	Pooled	%	2012	2013	Pooled	%
				Increase				Increase				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	

337

338

339

340

341 **Table 3A: Effect of integrated nutrient management on tuber quality (Specific gravity and Ascorbic acid content)**

Treatment	Specific Gravity (g/cc)				Ascorbic acid (mg/100g)			
	2012	2013	Pooled	% Increase	2012	2013	Pooled	% Increase
T1	1.03	1.02	1.03	NA	10.04	10.03	10.04	NA
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	

342

343

344

345

346 **Table 3B: Effect of integrated nutrient management on tuber quality (Tuber grades).**

Treatme nt	Grade A (>100g, %)				Grade B (50-100g, %)				Grade C (<50g, %)			
	2012	2013	Pooled	%	2012	2013	Pooled	% Increase	2012	2013	Pooled	%
				Increase								Decrease
T1	17.76	19.36	18.56	NA	25.37	23.43	24.40	NA	57.03	57.12	57.08	NA
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	

347

348

349 **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

350 “***” denotes Significant at $p < 0.001$ and “*” denotes Significant at $p < 0.01$