

**Integrated Nutrient Management of Hilly Soil of Meghalaya Cropped with Potato  
(*Solanum tuberosum*)**

**ABSTRACT**

Irrespective of treatment combinations total N, available P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O and S decreased with the age of potato crop. However, changes in organic C in soil showed an opposite trend of results. Irrespective of treatments, organic C content increased with increase in the period of crop growth. Pooled data of two years revealed that comparatively higher amount of total N, available P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O and S is accumulated in soil at maturation stage of potato which received recommended doses of N, P and K along with FYM at 10 t ha<sup>-1</sup> as well as biofertilizer and S at 40 kg ha<sup>-1</sup> (T<sub>9</sub>). Statistical analysis of the results also revealed that T<sub>9</sub> treatment is highly significant with respect to control. Results thus pointed out that balanced and proper dose of fertilization increased available nutrient contents in soils.

Keywords: Integrated nutrient management; organic carbon; available macro nutrients; potato; hilly soil.

**1. INTRODUCTION**

Potato, the second most important cash crop after rice, plays major role in the livelihood of resource-poor farmer in hilly region of Meghalaya. The significance of this crop to the rural economy as well as agriculture of the state could be comprehended from the fact that potato occupies more than 18 thousands hectares of land which accounts for 8.56% of the total cultivable area of the state. The potato productivity in Meghalaya is mere 9.78 tonnes ha<sup>-1</sup>, which is far below the national average of 17.57 tonnes ha<sup>-1</sup> as well as productivity figures of major potato producing states of the country viz., Uttar Pradesh (22.63 tonnes ha<sup>-1</sup>), West Bengal (21.03 tonnes ha<sup>-1</sup>), Punjab (18.73 tonnes ha<sup>-1</sup>), (*Directorate of Economics and Statistics, Govt. of India* 2001). Potato crop is grown in Meghalaya both in summer and autumn seasons. The summer season is the main potato-growing season extends from the month of February to June-July, while autumn season lasts from the month of July- August to November- December. The area under potato in the autumn is comparatively less than in summer season [13]. However, 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 crop in the region.

Potato requires higher amount of nutrients which may come from fertilizers as well as organic sources namely, well rotten FYM, vermicompost, biofertilizer etc. Balanced use of organic and inorganic fertilizers plays an important role in improving quality of produce besides good yield of potato [21]. Crop receiving 50% of the recommended dose of NPK through inorganic fertilizers and remaining 50% of the recommended dose of N (RDN) through organic manures (FYM, PM or VC) or 100% recommended dose of NPK (60 kg N, 120 kg P<sub>2</sub>O<sub>5</sub> and 60 kg K<sub>2</sub>O ha<sup>-1</sup>) through inorganic fertilizers alone favorably influenced yield of different grades tubers and total tuber yield [31]. Keeping above information in view, two field experiments were conducted in succession consecutively for two years (2014-15 and 2015-16) in a farmer's field situated at Shillong in East Khasi Hills district of Meghalaya. The field used for experimentation purpose is generally cultivated for potato crop.

## 46 2. MATERIALS AND METHODS

47 Composite soil sample (0-15cm depth) was collected from the experimental field before the  
48 start of experiment. The collected soil sample was air-dried, ground and passed through  
49 0.5mm sieve. The soil sample is analyzed for different physical, chemical and physico-  
50 chemical properties and the results are presented in Table 1.

51 The experiment on potato crop was conducted following simple Randomized Block Design.  
52 The plot size was 3m x 2m. Altogether 30 plots were included in the field experimentation.  
53 10 treatments were adopted to study the effect of INM practices on potato. All the treatments  
54 were replicated thrice. Potato variety Kufri Jyoti (tuber size 40-50gm) was selected for the  
55 experimentation purpose. Row-to-row spacing is maintained at 60cm x 20cm.

56 All the treatments received both organic and inorganic fertilizers such as Farm Yard Manure  
57 (10 tonnes ha<sup>-1</sup>) and N: P<sub>2</sub>O<sub>5</sub>: K<sub>2</sub>O at 60:120:60 kg ha<sup>-1</sup>. Nitrogen (N), Phosphorus (P<sub>2</sub>O<sub>5</sub>) and  
58 Potash (K<sub>2</sub>O) were applied in the form of Urea, Single Super Phosphate and Muriate of  
59 Potash respectively. Two doses of sulphur *i.e.* 20 kg ha<sup>-1</sup> and 40 kg ha<sup>-1</sup> as Elemental sulphur  
60 (applied 3 weeks prior to sowing) and biofertilizer (BF) in the form of *Azotobacter* and  
61 phosphorus solubilizing bacteria (PSB) mixed with FYM were included in the treatment  
62 combinations. Only well sprouted seed tubers were planted. After preparation of furrows,  
63 fertilizer mixtures were applied along with well decomposed FYM. Full dose of P and K and  
64 half dose of N fertilizers were applied as basal application. The rest half dose of N was  
65 applied in two split doses at vegetative and flowering stages of potato crop. Two doses of S  
66 were applied as basal along with N, P and K fertilizers as treatment material. Biofertilizer  
67 were applied as basal in the treatment plots and then the tubers were placed in the furrows.  
68 The potato crop was raised with best possible management practices. The seed tubers were  
69 immediately covered with soil after planting and ridges were made to a height of 8-10 cm.  
70 The treatments followed were as follows:

71

72 Chart: The treatments followed

T <sub>0</sub>	=	Control
T <sub>1</sub>	=	N <sub>60</sub> P <sub>120</sub> K <sub>60</sub>
T <sub>2</sub>	=	T <sub>1</sub> +FYM (FYM at 10t ha <sup>-1</sup> )
T <sub>3</sub>	=	T <sub>1</sub> +S <sub>1</sub> (S <sub>1</sub> is equal to S at 20 kg ha <sup>-1</sup> )
T <sub>4</sub>	=	T <sub>1</sub> +S <sub>2</sub> (S <sub>2</sub> is equal to S at 40 kg ha <sup>-1</sup> )
T <sub>5</sub>	=	T <sub>3</sub> +FYM
T <sub>6</sub>	=	T <sub>4</sub> +FYM
T <sub>7</sub>	=	T <sub>2</sub> + BF (BF is equal to 4kg Biofertilizer mixed with 80 kg FYM)
T <sub>8</sub>	=	T <sub>5</sub> +BF
T <sub>9</sub>	=	T <sub>6</sub> +BF

73

74 Rhizosphere soil samples were collected from each of 30 plots at vegetative, tuber initiation  
75 and maturation stages of potato. Soil samples were analyzed for organic carbon [23], total N  
76 [30], available P<sub>2</sub>O<sub>5</sub> [4], available K<sub>2</sub>O [10] and available S [6]. Data of soil samples were  
77 analyzed statistically to study the significance of means among treatments at different growth  
78 stages of potato crop [14].

79

80

81  
82  
83  
84

**Table 1. Physical, chemical and physico-chemical properties of the initial soil samples collected from experimental field**

Parameters	Unit	Results	Methods adopted
pH	Soil:water=1:2.5	4.48	Glass electrode pH meter[3]
pH	CaCl <sub>2</sub> =1:2.5	3.45	
Electrical conductivity	dSm <sup>-1</sup> at 25 <sup>0</sup> C	0.09	Electrical conductivity meter [3]
Oxidizable organic carbon	%	0.57	Wet digestion method [23]
Cation Exchange Capacity	(C mol p <sup>+</sup> kg <sup>-1</sup> )	7.00	Ammonium Acetate Leaching [28]
Mechanical analysis			Hydrometer method [5]
Sand	%	63.56	
Silt	%	16.00	
Clay	%	25.44	
Textural class		Sandy loam	ISSS(Soil textural triangle) Keen Rackzaw Ski[27]
Water Holding Capacity	%	27.83	
Available N	(mg kg <sup>-1</sup> )	98.88	Bremner and Keeney[26]
Available P <sub>2</sub> O <sub>5</sub>	(mg kg <sup>-1</sup> )	21.00	Spectro photometer [4]
Available K <sub>2</sub> O	(mg kg <sup>-1</sup> )	186.56	Flame photometry with Ammonium acetate [10]
Available S	(mg kg <sup>-1</sup> )	0.86	Turbidimetric method with CaCl <sub>2</sub> and nephelometer [6]
Available Zn	(mg kg <sup>-1</sup> )	0.43	DTPA extraction and atomic absorption spectrophotometer [29]

85

### 86 3. RESULTS AND DISCUSSION

#### 87 3.1 Changes in Oxidizable Organic Carbon Content in Soil

88 Irrespective of treatments, organic carbon increased with increase in the growth of potato.  
89 Highest amount of organic carbon is accumulated in soil at maturity stage of potato (Table 2).  
90 This trend of increase in organic carbon is observed in both the years of experimentation.  
91 Furthermore, comparatively higher amount of organic carbon is accumulated in the 2<sup>nd</sup> year  
92 of experimentation. The increase in organic carbon in soil with the age of crop is due to  
93 decomposition of rootlets of potato. Accumulation of comparatively higher amount of  
94 organic carbon in the 2<sup>nd</sup> year is due to enrichment of organic matter in soil. The results find  
95 support of earlier works carried out by Pervez [15] and Bashir [2]. Closer examination of the  
96 data in Table 2 further revealed that FYM treated systems showed comparatively higher  
97 amount of organic carbon in soil. This is the effect of added organic matter to soil [7][16].  
98 Furthermore, significantly highest amount of organic carbon is accumulated in soil treated  
99 with FYM and recommended doses of N, P and K fertilizers along with biofertilizer and  
100 higher dose of sulphur (40 kg ha<sup>-1</sup>). Addition of balanced inorganic fertilizers including  
101 sulphur and biofertilizer encouraged growth and proliferation of both roots and

102 microorganisms which in turn increased organic carbon content in soil. Similar observation  
 103 was also recorded earlier by Farag[8]. Perusal of the data in Table 2 also revealed that  
 104 comparatively higher amount of organic carbon is accumulated in soils which received FYM  
 105 treatment along with inorganic fertilizers. Combined application of organic, inorganic and  
 106 biofertilizer accentuated higher order of accumulation of organic carbon in soils.

107

### 108 3.2 Changes in Total N content in Soil

109 Results in Table 3 revealed that irrespective of treatments, total N decreased with increase in  
 110 the period of crop growth of potato. This trend of results is observed during both the years of  
 111 experimentation. The decrease in total N in soil is due to its uptake by the growing potato  
 112 crops. Perusal of the data in Table 3 also revealed that highest amount of total N is  
 113 accumulated in soil treated combinedly with FYM along with recommended doses of N, P  
 114 and K fertilizers and higher dose of sulphur as well as biofertilizer. Addition of inorganic N  
 115 and FYM increased total nitrogen content in soil. Furthermore, presence of *Azotobacter* in  
 116 biofertilizer fixes atmospheric N<sub>2</sub> which in turn increased total N content in soil [8].  
 117 Significantly highest amount of total N is accumulated in soil which received combined  
 118 application of organic and inorganic along with biofertilizer (Table 3). Addition of only  
 119 inorganic N fails to increase total N content in soil. This is due to loss of N either through  
 120 volatilization [2] or leaching [25]. It has been reported earlier that the loss of N is  
 121 comparatively less in soil treated with both organic and inorganic N fertilizers [12].

122

123 **Table 2. Changes in the amount of organic C (g 100gm<sup>-1</sup>) in soil at different growth**  
 124 **stages of potato grown consecutively for two years (2014-15 and 2015-16) under**  
 125 **different treatment combinations**

Treatments	Different growth stages of potato								
	Vegetative			Tuber initiation			Maturation		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
T <sub>0</sub>	0.55	0.69	0.62	0.73	0.80	0.77	0.82	0.88	0.85
T <sub>1</sub>	0.68	0.78	0.73	0.77	0.93	0.85	1.00	1.04	1.02
T <sub>2</sub>	0.76	0.84	0.80	0.86	1.07	0.97	1.12	1.15	1.14
T <sub>3</sub>	0.84	0.87	0.86	0.91	1.06	0.99	1.24	1.28	1.26
T <sub>4</sub>	0.88	0.97	0.93	0.95	1.24	1.09	1.39	1.45	1.42
T <sub>5</sub>	0.93	1.08	1.00	0.99	1.35	1.17	1.44	1.56	1.50
T <sub>6</sub>	1.07	1.16	1.11	1.12	1.41	1.27	1.55	1.64	1.59
T <sub>7</sub>	1.18	1.24	1.21	1.22	1.59	1.40	1.62	1.71	1.67
T <sub>8</sub>	1.26	1.37	1.32	1.46	1.67	1.57	1.120	1.84	1.79
T <sub>9</sub>	1.38	1.43	1.41	1.67	1.77	1.72	1.87	1.91	1.89
CD(P=0.05)	0.02	0.03	0.06	0.01	0.03	0.16	0.02	0.02	0.04
SEm(±)	0.01	0.01	0.01	0.01	0.01	0.05	0.01	0.01	0.01

126 Note: T<sub>0</sub>=Control; T<sub>1</sub>=Recommended doses of NPK at 60:120:60 kg ha<sup>-1</sup> as Urea, SSP and MOP; T<sub>2</sub>=T<sub>1</sub>+FYM at 10 t ha<sup>-1</sup>;  
 127 T<sub>3</sub>=T<sub>1</sub>+S at 20 kg ha<sup>-1</sup> as Elemental Sulphur, T<sub>4</sub>=T<sub>1</sub>+S at 40 kg ha<sup>-1</sup>; T<sub>5</sub>=T<sub>2</sub>+S at 20 kg ha<sup>-1</sup>; T<sub>6</sub>=T<sub>2</sub>+S at 40 kg ha<sup>-1</sup>;  
 128 T<sub>7</sub>=T<sub>2</sub>+Biofertilizer at 4 kg per 80 kg FYM as *Azotobacter* and Phosphorus Solubilizing Bacteria; T<sub>8</sub>=T<sub>7</sub>+S at 20 kg ha<sup>-1</sup>;  
 129 T<sub>9</sub>=T<sub>7</sub>+S at 40 kg ha<sup>-1</sup>

130

131

132  
133  
134  
135  
136  
137  
138

**Table 3. Changes in the amount of total N (g 100gm<sup>-1</sup>) in soil at different growth stages of potato grown consecutively for two years (2014-15 and 2015-16) under different treatment combinations**

Treatments	Different growth stages of potato								
	Vegetative			Tuber initiation			Maturation		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
T <sub>0</sub>	0.09	0.11	0.10	0.08	0.09	0.08	0.05	0.06	0.06
T <sub>1</sub>	0.09	0.11	0.10	0.07	0.09	0.08	0.05	0.07	0.06
T <sub>2</sub>	0.10	0.12	0.11	0.08	0.11	0.09	0.07	0.08	0.07
T <sub>3</sub>	0.10	0.13	0.12	0.10	0.12	0.11	0.07	0.09	0.08
T <sub>4</sub>	0.11	0.14	0.12	0.11	0.12	0.12	0.09	0.10	0.09
T <sub>5</sub>	0.11	0.15	0.13	0.11	0.13	0.12	0.10	0.11	0.10
T <sub>6</sub>	0.13	0.17	0.15	0.12	0.13	0.12	0.11	0.12	0.12
T <sub>7</sub>	0.14	0.17	0.16	0.12	0.14	0.13	0.11	0.13	0.12
T <sub>8</sub>	0.15	0.18	0.16	0.13	0.15	0.14	0.12	0.13	0.13
T <sub>9</sub>	0.16	0.19	0.17	0.14	0.16	0.15	0.13	0.14	0.14
CD(P=0.05)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
SEm(±)	0.003	0.04	0.004	0.004	0.003	0.003	0.004	0.003	0.002

139 Note: T<sub>0</sub>=Control; T<sub>1</sub>=Recommended doses of NPK at 60:120:60 kg ha<sup>-1</sup> as Urea, SSP and MOP; T<sub>2</sub>=T<sub>1</sub>+FYM at 10 t ha<sup>-1</sup>;  
140 T<sub>3</sub>=T<sub>1</sub>+S at 20 kg ha<sup>-1</sup> as Elemental Sulphur, T<sub>4</sub>=T<sub>1</sub>+S at 40 kg ha<sup>-1</sup>; T<sub>5</sub>=T<sub>2</sub>+S at 20 kg ha<sup>-1</sup>; T<sub>6</sub>=T<sub>2</sub>+ S at 40 kg ha<sup>-1</sup>;  
141 T<sub>7</sub>=T<sub>2</sub>+Biofertilizer at 4 kg per 80 kg FYM as *Azotobacter* and Phosphorus Solubilizing Bacteria; T<sub>8</sub>=T<sub>7</sub>+S at 20 kg ha<sup>-1</sup>;  
142 T<sub>9</sub>=T<sub>7</sub>+S at 40 kg ha<sup>-1</sup>

143  
144  
145  
146  
147

**Table 4. Changes in the amount of available P<sub>2</sub>O<sub>5</sub> (mg kg<sup>-1</sup>) in soil at different growth stages of potato grown consecutively for two years (2014-15 and 2015-16) under different treatment combinations**

Treatments	Different growth stages of potato								
	Vegetative			Tuber initiation			Maturation		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
T <sub>0</sub>	22.03	26.22	24.13	16.84	21.25	19.04	11.02	19.88	15.45
T <sub>1</sub>	24.40	28.58	26.49	17.58	22.70	20.14	13.71	21.81	17.76
T <sub>2</sub>	27.50	30.92	29.21	21.27	26.69	23.98	16.95	24.22	20.59
T <sub>3</sub>	28.32	33.70	31.01	25.20	28.50	26.85	19.07	24.48	21.78
T <sub>4</sub>	33.19	37.33	35.26	30.94	31.45	31.19	21.49	28.10	24.79
T <sub>5</sub>	38.05	40.09	39.07	33.10	36.120	34.93	27.59	31.29	29.44
T <sub>6</sub>	36.93	42.88	39.91	32.06	35.73	33.90	28.11	33.52	30.81
T <sub>7</sub>	39.66	45.67	42.66	37.42	39.38	38.40	30.93	35.65	33.29
T <sub>8</sub>	40.30	46.35	43.32	36.90	39.71	38.30	32.42	35.99	34.20
T <sub>9</sub>	40.33	48.39	44.36	37.31	39.37	38.34	33.85	36.40	35.13
CD(P=0.05)	3.07	1.18	2.74	1.94	3.05	2.45	1.07	1.30	3.35
SEm(+)	1.02	0.39	0.84	0.64	1.18	0.120	0.36	0.43	1.03

148 Note: T<sub>0</sub>=Control; T<sub>1</sub>=Recommended doses of NPK at 60:120:60 kg ha<sup>-1</sup> as Urea, SSP and MOP; T<sub>2</sub>=T<sub>1</sub>+FYM at 10 t ha<sup>-1</sup>;  
149 T<sub>3</sub>=T<sub>1</sub>+S at 20 kg ha<sup>-1</sup> as Elemental Sulphur, T<sub>4</sub>=T<sub>1</sub>+S at 40 kg ha<sup>-1</sup>; T<sub>5</sub>=T<sub>2</sub>+S at 20 kg ha<sup>-1</sup>; T<sub>6</sub>=T<sub>2</sub>+S at 40 kg ha<sup>-1</sup>;  
150 T<sub>7</sub>=T<sub>2</sub>+Biofertilizer at 4 kg per 80 kg FYM as *Azotobacter* and Phosphorus Solubilizing Bacteria; T<sub>8</sub>=T<sub>7</sub>+S at 20 kg ha<sup>-1</sup>;  
151 T<sub>9</sub>=T<sub>7</sub>+S at 40 kg ha<sup>-1</sup>

152

153 **3.3 Changes in the Available P<sub>2</sub>O<sub>5</sub> Content in Soil**

154 Irrespective of treatments, like total N, available P<sub>2</sub>O<sub>5</sub> decreased with increase in the period  
155 of crop growth (Table 4). This trend of result is observed in both the years of  
156 experimentation. Again, irrespective of treatments, comparatively higher amount of available  
157 P<sub>2</sub>O<sub>5</sub> is accumulated in the 2<sup>nd</sup> year of experiment. The decrease in available P<sub>2</sub>O<sub>5</sub> with  
158 increase in the period of crop growth is due to its utilization by the growing potato crop.  
159 Significantly highest amount of available P<sub>2</sub>O<sub>5</sub> is accumulated in T<sub>9</sub> treatment which received  
160 recommended doses of N, P and K along with FYM at 10 tonnes ha<sup>-1</sup> as well as biofertilizer  
161 and S at 40 kg ha<sup>-1</sup>. Presence of phosphate solubilizing bacteria (PSB) in biofertilizer makes  
162 organic P in available form which in turn increased available P content in soil. The results are  
163 in accordance with earlier works carried out by Sayed [17] and Congera [7]. The pooled data  
164 of available P<sub>2</sub>O<sub>5</sub> also showed similar trend of results. Results in Table 4 further revealed that  
165 on an average an increase of about 20mg kg<sup>-1</sup> was recorded in T<sub>9</sub> over that of control. The  
166 recorded increase in available P<sub>2</sub>O<sub>5</sub> is more or less same in both the years of experimentation.  
167 Perusal of the data in Table 4 also pointed out that application of P-solubilising bacteria even  
168 in absence of added sulphur significantly increased available P content in soil.

169

170 **3.4 Changes in the Available K<sub>2</sub>O Content in Soil**

171 Like N and P, available K decreased with increase in the period of crop growth of potato  
172 (Table 5). However, like P<sub>2</sub>O<sub>5</sub> the decrease in available K<sub>2</sub>O ranged from 64 to 110 mg kg<sup>-1</sup>  
173 depending upon the treatment combinations as well as year of cultivation. It is interesting to  
174 note that irrespective of treatments, the intensity of decrease in available K<sub>2</sub>O is more  
175 prominent in the 2<sup>nd</sup> than that of 1<sup>st</sup> year of experiment over the whole cropping season of  
176 potato. Recorded significant higher amount of depletion of available K<sub>2</sub>O in the 2<sup>nd</sup> year of  
177 experiment is due to comparatively higher amount of uptake of K by potato crop. The  
178 demand of K for potato is comparatively higher than other staple food crops [22]. Results in  
179 Table 5 further revealed that significantly highest amount of available K<sub>2</sub>O is accumulated in  
180 T<sub>9</sub> treatment which received recommended doses of N, P and K along with FYM at 10t ha<sup>-1</sup>  
181 as well as biofertilizer and sulphur at 40 kg ha<sup>-1</sup>. Critical examination of the data in Table 5  
182 also showed that application of biofertilizer significantly increased available K content in  
183 soil. This trend of results is observed both in presence and absence of added sulphur.  
184 Addition of inorganic K increased available K content in soil [1]. Application of free living  
185 N<sub>2</sub> fixing *Azotobacter* and P- solubilising bacteria increased available K content in soil  
186 through proliferation of K- mobilizing bacteria in soil [11]. The pooled data of two years also  
187 showed similar trend of results.

188

189

190

191

192

193

194

195

196  
197  
198  
199

**Table 5. Changes in the amount of available K<sub>2</sub>O (mg kg<sup>-1</sup>) in soil at different growth stages of potato grown consecutively for two years (2014-15 and 2015-16) under different treatment combinations**

Treatments	Different growth stages of potato								
	Vegetative			Tuber initiation			Maturation		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
T <sub>0</sub>	187.09	210.46	198.78	141.25	171.12	156.18	123.95	154.12	139.04
T <sub>1</sub>	193.35	249.31	221.33	159.12	203.87	181.49	152.10	1120.90	164.00
T <sub>2</sub>	225.72	334.29	280.01	203.72	237.53	220.63	191.95	212.04	202.00
T <sub>3</sub>	276.67	386.94	331.80	226.13	274.33	250.23	202.30	249.89	226.09
T <sub>4</sub>	304.55	410.03	357.29	267.39	362.13	314.76	219.39	295.00	257.20
T <sub>5</sub>	315.10	423.87	369.48	268.69	384.51	326.60	238.71	312.12	2120.42
T <sub>6</sub>	324.98	441.42	383.20	296.30	396.42	346.36	274.00	350.99	312.50
T <sub>7</sub>	337.03	465.48	401.26	305.98	408.85	357.42	287.52	394.37	340.95
T <sub>8</sub>	344.80	485.34	415.07	315.95	427.30	371.63	303.03	402.78	352.91
T <sub>9</sub>	353.15	493.84	423.50	328.49	463.80	396.15	312.01	425.42	368.72
CD(P=0.05)	4.58	47.89	60.03	7.65	23.91	62.45	1.32	6.87	56.26
SEm(±)	1.53	15.99	18.50	2.55	7.98	19.25	0.44	2.29	17.34

200 Note: T<sub>0</sub>=Control; T<sub>1</sub>=Recommended doses of NPK at 60:120:60 kg ha<sup>-1</sup> as Urea, SSP and MOP; T<sub>2</sub>=T<sub>1</sub>+FYM at 10 t ha<sup>-1</sup>;  
201 T<sub>3</sub>=T<sub>1</sub>+S at 20 kg ha<sup>-1</sup> as Elemental Sulphur, T<sub>4</sub>=T<sub>1</sub>+S at 40 kg ha<sup>-1</sup>; T<sub>5</sub>=T<sub>2</sub>+S at 20 kg ha<sup>-1</sup>; T<sub>6</sub>=T<sub>2</sub>+S at 40 kg ha<sup>-1</sup>;  
202 T<sub>7</sub>=T<sub>2</sub>+Biofertilizer at 4 kg per 80 kg FYM as *Azotobacter* and Phosphorus Solubilizing Bacteria; T<sub>8</sub>=T<sub>7</sub>+S at 20 kg ha<sup>-1</sup>;  
203 T<sub>9</sub>=T<sub>7</sub>+S at 40 kg ha<sup>-1</sup>

204  
205  
206  
207  
208  
209

**Table 6. Changes in the amount of available S (mg Kg<sup>-1</sup>) in soil at different growth stages of potato grown consecutively for two years (2014-15 and 2015-16) under different treatment combinations**

Treatments	Different growth stages of potato								
	Vegetative			Tuber initiation			Maturation		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
T <sub>0</sub>	0.88	0.90	0.89	0.79	0.64	0.71	0.67	0.32	0.49
T <sub>1</sub>	1.33	1.36	1.35	1.05	1.19	1.12	1.03	1.08	1.05
T <sub>2</sub>	1.56	1.59	1.57	1.24	1.87	1.56	1.30	1.23	1.27
T <sub>3</sub>	2.31	2.37	2.34	2.00	2.71	2.36	2.07	1.70	1.88
T <sub>4</sub>	4.00	4.04	4.02	3.95	3.19	3.57	3.19	2.59	2.89
T <sub>5</sub>	4.91	5.01	4.96	4.15	3.90	4.03	3.95	3.77	3.86
T <sub>6</sub>	5.82	5.97	5.90	4.86	4.37	4.61	4.10	4.27	4.19
T <sub>7</sub>	6.94	7.08	7.01	5.98	5.78	5.88	4.91	5.85	5.38
T <sub>8</sub>	7.26	7.26	7.26	6.90	6.81	6.85	5.47	6.23	5.85
T <sub>9</sub>	7.77	7.96	7.86	7.04	7.21	7.12	6.08	6.99	6.53
CD(P=0.05)	0.30	0.05	0.10	0.07	0.39	0.74	0.07	0.21	0.90
SEm(±)	0.10	0.01	0.03	0.02	0.13	0.22	0.02	0.07	0.28

210 Note: T<sub>0</sub>=Control; T<sub>1</sub>=Recommended doses of NPK at 60:120:60 kg ha<sup>-1</sup> as Urea, SSP and MOP; T<sub>2</sub>=T<sub>1</sub>+FYM at 10 t ha<sup>-1</sup>;  
211 T<sub>3</sub>=T<sub>1</sub>+S at 20 kg ha<sup>-1</sup> as Elemental Sulphur, T<sub>4</sub>=T<sub>1</sub>+S at 40 kg ha<sup>-1</sup>; T<sub>5</sub>=T<sub>2</sub>+S at 20 kg ha<sup>-1</sup>; T<sub>6</sub>=T<sub>2</sub>+S at 40 kg ha<sup>-1</sup>

212 <sup>1</sup>T<sub>7</sub>=T<sub>2</sub>+Biofertilizer at 4 kg per 80 kg FYM as *Azotobacter* and Phosphorus Solubilizing Bacteria; T<sub>8</sub>=T<sub>7</sub>+S at 20 kg ha<sup>-1</sup>;  
213 T<sub>9</sub>=T<sub>7</sub>+S at 40 kg ha<sup>-1</sup>  
214  
215

216

### 217 3.5 Changes in the Available S Content in Soil

218 Irrespective of treatments, like N, P and K available S decreased with increase in the period  
219 of crop growth of potato (Table 6). This trend of results is observed in both the years of  
220 experimentation. The pooled data of two years also showed similar trend of results. Results  
221 further revealed that addition of sulphur as treatment material increased available S content in  
222 soil. However, significantly highest amount of available sulphur is accumulated in T<sub>9</sub>  
223 treatment which received recommended doses of N, P and K along with FYM at 10 tonnes  
224 ha<sup>-1</sup> as well as biofertilizer and S at 40 kg ha<sup>-1</sup>. Addition of higher dose of S along with  
225 biofertilizer increased available S content in soil. Addition of biofertilizer increased  
226 proliferation of S oxidizing bacteria which in turn mineralise organic S present in FYM as  
227 well as in soil and increased available S content in the system. The present result finds  
228 support of earlier investigation carried out by Sharma [20] and Shaheen [19]. Statistical  
229 analysis of the data in Table 6 revealed that addition of either dose of S in presence of  
230 biofertilizer did not show significant variation in results between T<sub>8</sub> and T<sub>9</sub> treatment.  
231 However, critical analysis of the pooled data revealed that the intensity of increase in  
232 available S is more prominent in soil which received added sulphur. This is due to uptake of  
233 comparatively higher amount of S by potato crops from the available pool. Similar  
234 observations were also reported earlier by Pervez[15], Khan [12] and Islam[9].

### 235 4. CONCLUSION

236 Integrated nutrient management promotes accumulation of comparatively higher amount of  
237 organic C at the maturity stage of potato. However, total N, available P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O and S  
238 decreased with increase in the period of crop growth. Significantly highest amount of total N,  
239 available P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O and S is recorded in T<sub>9</sub> treatment which received recommended doses of  
240 N, P and K along with FYM at 10t ha<sup>-1</sup> as well as biofertilizer and S at 40 kg ha<sup>-1</sup>.

### 241 COMPETING INTERESTS

242 Authors have declared that no competing interests exist.

### 243 References

- 244 1. Bansal SK, Trehan S. Effect of potassium on yield and processing quality attributes  
245 of potato. Journal. Agric. Sci, 2011;24 (1): 48-54.
- 246 2. Bashir U, Qureshi F. Effect of nitrogen and farmyard manure on yield, nutrient  
247 content and quality of potato (*solanum tuberosum* l.) Biolife. 2014; 2(3):786-791.
- 248 3. Black CA. Method of soil analysis part I and II Am. Soc. Agron. Inc. Madison Wisconsin,  
249 USA; 1965.
- 250 4. Bray RH, Kurtz LT. Determination of total, organic, and available forms of phosphorus in  
251 soils. Soil Sci. 1945; 59: 39-45.

- 252 5. Buoyoucos GJ. Hydrometer method improved for making parking size analysis of soils.  
253 Agron. Journal.1926; 54: 4661-4665.
- 254 6. Chesnin L, Yien CH. Turbidimetric determination of available sulphur. Proceeding Soil  
255 Science Society Amarica. 1950; 14: 149-151.
- 256 7. Congera A, Anjanapp M, Indiresk KM, Kumara BS. Effect of integrated nutrient management  
257 on tuber dry matter accumulation and uptake of nutrients by potato (*Solanum tuberosum* L.)  
258 Crop Res. 2013; 46 (1, 2 & 3): 174-177.
- 259 8. Farag Jr, Aly Abdalla M, Mohamed MF, Aboul-Nasr MH. Effect of Biofertilization on  
260 Yield and Quality of some Potato Cultivars (*Solanum Tuberosum* L.) International  
261 Journal of Agriculture and Food Science Technology. 2013; 4 (7):695-702.
- 262 9. Islam MMAF, Khan MA, Bari AS, Hosain MF, Sabikunnaheer MT. Effect of fertilizer  
263 and manure on the growth, yield and grain nutrient concentration of boro rice (*Oryza*  
264 *sativa* L.) under different water management practices. The Agriculturists. 2013; 11(2): 44-  
265 51.
- 266 10. Jackson ML. Soil Chemical Analysis. Printice Hall of India (Pvt.) Ltd., New Delhi; 1973.
- 267 11. Kelling KA, Panique E, Speth PE, Stevenson WR. Effect of potassium rate, source and  
268 application timing on potato yield and quality. Presented at Idaho Conference on January  
269 23, 2002.
- 270 12. Khan HZ, Nadeem M, Iqbal S, Akbar N, Iqbal A. Response of spring maize (*Zea mays* L.) to  
271 integrated nitrogen management. Crop Environ. 2013; 4:6-10.
- 272 13. Kumar S, Singh PH, Gupta PH, Sah U, Pandey SK. Integrated development of  
273 Horticulture in North Eastern states of India (MM- I), Technical bulletin no 76, Central Potato  
274 Research Institute, Shimla.2006; pp. 4.
- 275 14. Panse VG, Sukhatme PV. Statistical Method for Agricultural Workers; 1967.
- 276 15. Pervez MA, Muhammed F, Mullah E. Effect of organic and inorganic manures on physical  
277 characteristics of potato (*Solanum tubeyosum* L.). International. Journal. Agr. and Bio.  
278 2000; 2(1-2): 34-36.
- 279 16. Roghayyeh SMS, Mehdi T, Rauf S. Effects of Nano-Iron Oxide Particles on Agronomic  
280 Traits of Soybean. Not Sci Biol. 2010; (2): 2.
- 281 17. Sayed F, El-Sayed H, Hassan A, Mohamed M, El-Mogy, Wahab AA. Growth, Yield  
282 and Nutrient Concentration of Potato Plants Grown under Organic and Conventional  
283 Fertilizer Systems. American-Eurasian Journal. Agric. & Environ. Sci. 2014; 14 (7): 636-  
284 643.
- 285 18. Sayed F, El-Sayed H, Hassan A, Mohamed M, El-Mogy. Impact of Bio and Organic  
286 Fertilizers on Potato Yield, Quality and Tuber Weight Loss after Harvest. Potato Research.  
287 2015; 58(1):67-81.
- 288 19. Shaheen AM, Rizk FA, Behairy AG, Helmy YI. The role of sulphur and bio-phosphorus  
289 in potato plant growth and its productivity in newly soil. Journal of Agriculture and  
290 Biological Sciences. 2013; 9(3): 119-126.
- 291 20. Sharma DK, Kushwah SS, Nema PK, Rathore SS. Effect of sulphur on yield and quality of  
292 potato (*Solanum tuberosum* L.). International Journal of Agricultural Research. 2011;  
293 6(2): 143-148.
- 294 21. Singh S, Singh JP, Singh V, Baliyan V. Effect of integrated nutrient management on  
295 nutrients availability and yield of rice in recently reclaimed sodic soil. Environ and Ecol.  
296 2010; 28(1B): 654-656.
- 297 22. Singh SK, Lal SS. Effect of potassium levels and its uptake on correlation between tuber  
298 yield and yield attributing characters in potato (*Solanum tuberosum* L.) var. Kufri  
299 Pukhraj the Asian Journal of Horticulture. 2012; 7(2): 392-396.

- 300 23. Walkley A, Black IA. An examination of the Degtjareff method for determining soil  
301 organic matter and a proposed modification on the chronic acid titration method. *Soil Sci.*  
302 1934; 37: 29-39.
- 303 24. Williams CH, Steinbergs A. Soil sulphur fractions as chemical indices of available sulphur  
304 in some Australian soils. *Aust. J. Agric. Res.* 1959; 1C: 840-852.
- 305 25. Zewide I, Mohammed A, Tulu S. Effect of different rates of Nitrogen and Phosphorus on  
306 yield and yield components of potato (*Solanum tuberosum* L.) at Masha District,  
307 Southwestern Ethiopia. *International Journal of Soil Science.* 2012; 7(4):146-156.
- 308 26. Bremner JM, Keeney DR. Determination of exchangeable ammonia, nitrate and nitrite by  
309 extraction distillation methods. *Soil Science Society of America Proceedings.* 1966; 30:577-  
310 587.
- 311 27. Piper CS. Soil and plant analysis. A laboratory manual of methods for the examinations of  
312 soils and the determination of the inorganic constituents of plants. University of Adelaide,  
313 Adelaide; 1942.
- 314 28. Schollenberger CJ, Simon RH. Determination of Exchange Capacity and Exchangeable Bases  
315 in Soil-Ammonium Acetate Method. *Soil Science.* 1945; 59:13-24.
- 316 29. Lindsay WL, Norvell WA. Development of DTPA soil test for zinc, manganese, iron and  
317 copper. *Soil Science Society of America Journal.* 1978; 42: 421-428.
- 318 30. Stevenson FJ. Nitrogen-Organic forms. In *Methods of soil analysis*, part 3, ed.D. L. Sparks,  
319 1185–1200. Madison, Wisc: Soil Science Society of America; 1996.
- 320 31. Kumar B, Ghosh DC, Gupta VK. Yield and quality of potato (*Solanumtuberosum*) tubers  
321 as influenced by nutrient sources under rainfed condition of Meghalaya. *Indian Journal of*  
322 *Agronomy.* 2011; 56(3): 260-266.

323

324