

1
2
3
4
5
6
7
8
9

Impact of humic acid-based bio-stimulant 'Humetsu' on growth and yield attributes of potato (*Solanum tuberosum* L.)

ABSTRACT

Aims: The current study was carried out to examine the impact of humic-acid-based bio-stimulant (liquid formulation) 'Humetsu' on growth and yield attributes of potato variety Kufri Chipsona-4.

Study design: The study used a Randomized Block Design with 3 replications and 8 treatments.

Place and Duration of Study: The existing experiment was worked out at Teaching Farm, College of Agriculture under BCKV, Burdwan Sadar during *Rabi*, 2019-20 and *Rabi*, 2020-21.

Methodology: The test product humic-acid based bio-stimulant (liquid formulation) 'Humetsu' was used for seed treatment at the rate of 5 ml/kg tuber before sowing of potato and 2.5 ml /L water was sprayed treatment-wise as per protocol using a water volume of 500 liters per ha with knapsack sprayer fitted with flat fan deflector nozzle in potato.

Results: The results elucidated that significantly maximum plant emergence, number of branches per plant and increased available N, P, K and Organic carbon (OC) in both years were recorded in treatment T₄ (100% NPK + 3 application of 'Humetsu' (Seed treatment at the rate of 5 ml/kg of tuber and 2 foliar sprays at the rate 2.5ml L⁻¹ water at 30 DAS & 55 DAS). The highest plant height, TSS (%), and fewer days to harvest were found in treatment T₇ (80% NPK + 3 application of 'Humetsu' (Seed treatment at the rate 5ml/kg of tuber and 2 foliar sprays at the rate 2.5ml L⁻¹ water at 30 DAS & 55 DAS) followed by treatment T₄, T₅, and T₆. The maximum number of tubers per plant, total tuber yield, and marketable tuber yield were noticed in the treatment T₇ during both years. The highest microbial population in the soil was noticed in the T₇ during both the years. On the other hand, the least plant height, TSS (%), plant emergence, number of tubers per plant, total tuber yield, marketable yield per ha, more days to harvest, and the least microbial population in soil were observed in (control) treatment (T₈) during both the years.

Conclusion: Application of 80% NPK + 3 application of 'Humetsu' (Seed treatment at the rate 5ml/kg of tuber and 2 foliar sprays at the rate 2.5ml l⁻¹ water at 30 DAS& 55 DAS) has a significant impact in yield of potato with 20% reduction of the recommended dose of NPK fertilizers.

10 *Keywords: Humestu, Potato, NPK, Humic acid.*

1. INTRODUCTION

11
12
13 The potato, or *Solanum tuberosum* L., is a member of the Solanaceae family and is
14 grown in about 150 nations. It is the most prominent tuberous crop in the world,
15 contributing significantly to both food security and the global food chain [1] and is
16 considered as the poor man's friend [2,12,13,14]. After rice, wheat, and maize, it is
17 the fourth-largest crop in the world [3]. The potato is said to have originated in South
18 America's Andes and then spread around the world [4]. The Food and Agriculture
19 Organization (FAO) designated potatoes as the crop to address future global food

20 security and poverty reduction in 2008 due to their capacity to generate the highest
 21 level of nutrition and dry matter on a per unit area and time basis among major food
 22 crops [5]. According to projections, India's domestic potato consumption is expected
 23 to reach 125 million metric tonnes by 2050 [6]. Humetsu is a naturally generated
 24 organic matter and nutrient blend. It is designed specifically for Indian crops and agro-
 25 climatic conditions. Humetsu is developed from a special natural feedstock obtained
 26 from Russia's Siberian Leonardites field, which is the result of millions of years of
 27 spontaneous fermentation by soil bacteria. Humetsu is quickly absorbed by plants,
 28 where it contributes to the nutritional Bio-chemical process as well as the development
 29 of intrinsic resistance to unfavorable weather conditions.

30

31 **2. MATERIAL AND METHODS**

32 The current study was conducted in the Rabi (October to March), 2019–20 and Rabi (October
 33 to March), 2020–21 at the Teaching Farm, College of Agriculture under BCKV, Burdwan
 34 Sadar, to investigate the effects of the liquid formulation of the humic acid-based bio stimulant
 35 "Humetsu" on the growth and yield characteristics of the Kufri Chipsona-4 variety of potato.
 36 Utilizing a Randomized Block Design with three replications and 8 treatments.

37

Table 1: The details of treatments

Treatments	Details
T ₁	100% NPK + 1 application of 'Humetsu' (Seed treatment at the rate 5 ml/kg of tuber)
T ₂	100% NPK + 1 application of 'Humetsu' (Foliar spray at the rate 2.5 ml/L water at 30 DAS)
T ₃	100% NPK + 2 application of 'Humetsu' (Seed treatment at the rate 5 ml/kg of Tuber & 1 foliar spray at the rate 2.5 ml/L water at 30 DAS)
T ₄	100% NPK + 3 application of 'Humetsu' (Seed treatment at the rate 5 ml/kg of tuber and 2 foliar spray at the rate 2.5 ml/L water at 30 DAS & 55 DAS)
T ₅	100% NPK + 2 application of 'Humetsu' (2 foliar spray at the rate 2.5 ml/L water at 30 DAS & 55 DAS)
T ₆	100% NPK + 2 application of 'Humetsu' (Seed treatment at the rate 5 ml/kg of Tuber & 1 foliar spray at the rate 2.5 ml/L water at 55 DAS)

38

T ₇	80% NPK + 3 application of 'Humetsu' (Seed treatment @ 5 ml/kg of tuber and 2 foliar spray at the rate 2.5 ml/L water at 30 DAS & 55 DAS)
T ₈	100% NPK(Control)

39

40 Data on quantitative and qualitative parameters like plant emergence (%), plant height (cm),
41 no. of branches/plant, days to physiological maturity, no. of tubers /plant, grade of tubers, TSS
42 (%) [°Brix], marketable yield and total yield (t ha⁻¹) were recorded.

43 **2.1 Experimental Soil**-The soil of the experimental fields was sandy loam to loam in texture
44 with a normal pH (5.5 to 6.5) and medium fertility status with high water holding capacity. The
45 crop was grown under irrigated condition.

46 **2.2 The climatic condition of the experimental plot**- The climate of the *Inceptisol* of
47 West Bengal is typically warm and humid. The average maximum temperature starts falling in
48 June and reaches a minimum in January. The mean monthly rainfall is higher in July-August
49 and lower in December. The average rainfall is 1700 mm per annum of which around 70 %
50 rainfall occurs during June to September. The lowest relative humidity is observed in
51 December while the maximum is in July-August.

52

53 3. RESULTS AND DISCUSSION

54 The analysis of variance showed a significant ($p < 0.05$) difference among the treatments in
55 most of the parameters. The application of humic acid-based bio-stimulant significantly
56 influenced the growth, yield and yield-attributing parameters of potato in consecutive two
57 years.

58 3.1 Growth and quality parameters

59 Growth parameters of potatoes were evaluated in terms of plant emergence (%), plant height,
60 number of branches/plant, days to physiological maturity and TSS (%) [°Brix]. Significant
61 results for these characters were obtained by the application of humic acid-based bio-stimulant
62 'Humetsu' (Table-2). The maximum plant emergence (92.41% and 93.11%) and the number
63 of branches/plants (5.92 and 5.97) in both the years (2019-20 and 2020-21) were recorded in
64 treatment T₄. The treatment T₄ was found statistically at par for plant emergence with the
65 treatments T₁, T₃, T₆ and T₇ where seed treatment was done by humic acid @ 5 ml/kg of tuber.
66 The lowest plant emergence was recorded in control T₈ (100% NPK) (84.15% in 2019-20) and
67 T₅ (86.11% in 2020-21) followed by T₂ where tubers were not treated with 'humetsu' before
68 sowing. Similarly, the number of branches per plant was highest in treatment T₄ which was
69 statistically at par with treatment T₇ (5.82 and 5.85 in both consecutive years) and the lowest
70 was recorded in treatment T₁ and T₈ (4.11 in 2019-20 and 2020-21). The highest plant height
71 (62.31 cm in 2019-20 and 62.14 in 2020-21), fewer days to harvest (110.33 and 109.85) and
72 maximum TSS (%) [°Brix] (6.58-6.72) were found in treatment T₇ followed by treatment T₄, T₅
73 and T₆. On the other hand, least plant height (54.46 cm in 2019-20 and 55.12 cm in 2020-21),
74 more days to harvest (117.24 to 118.85) and minimum TSS (%) [°Brix] (5.53-5.56) was noted
75 from control (T₈) followed by treatment T₁, T₂, and T₃. It was observed that when potato plants
76 get treated with humic acid 3 times or at least 2 times up to 55 DAS showed significantly better
77 results in terms of growth parameters than sole application within 30 DAS. This might be due
78 to the application of humic acid-based bio-stimulant in combination with inorganic fertilizers

79 which increased the nutrient-use efficiency through modification of soil physical condition and
 80 resulted in higher total uptake of nutrients because of better root penetration leading to better
 81 absorption of nutrients and moisture [7].

82

83 **Table 2. Effect of humic acid-based bio-stimulant (liquid formulation) 'Humetsu' on**
 84 **growth attributes of potato**

Treatments	Plant emergence (%)		Plant height (cm)		Number of branches/plant		Days to physiological maturity		TSS (%) [°Brix]	
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
T ₁	91.44	91.48	55.35	55.42	4.11	4.18	116.47	117.21	5.76	5.82
T ₂	85.24	87.10	56.65	56.32	4.87	4.92	115.99	115.21	5.81	5.84
T ₃	90.56	90.70	57.12	57.78	4.67	4.76	114.12	113.82	5.92	5.99
T ₄	92.41	93.11	61.95	62.14	5.92	5.97	112.52	111.99	6.49	6.52
T ₅	86.28	86.11	59.44	58.99	5.11	5.14	113.14	113.11	6.12	6.23
T ₆	91.25	92.10	57.82	58.22	4.96	4.99	115.08	114.95	6.02	6.15
T ₇	91.62	92.52	62.31	61.95	5.82	5.85	110.33	109.85	6.58	6.72
T ₈	84.15	86.78	54.46	55.12	4.25	4.11	117.24	118.85	5.56	5.53
SEm(±)	1.58	1.73	1.137	1.142	0.24	0.27	1.417	1.531	0.12	0.15
LSD(5%)	4.11	4.25	3.449	3.464	0.74	0.82	4.298	4.644	0.37	0.45

85

86 3.2 Yield parameters

87 Application of humic acid-based bio-stimulant showed a significant positive effect on the
 88 number of tubers/plant, grade of tubers and yield of potato (Table 3). During the first year
 89 (2019-20) of investigation, the maximum number of tubers per plant (12.68) was observed
 90 under the treatment. Though, it was at par with the treatment T₄. The minimum number of
 91 tubers per plant (9.28) was counted under treatment T₈ (control). A recitation of the data
 92 indicates that a significant maximum number of tubers/plants (13.45) during 2020-21 was
 93 counted under the treatment T₇ followed by T₄, T₅ and T₃. The minimum number of tubers per
 94 plant was counted in the treatment control (8.99) which was at par with treatment T₁ and T₂.
 95 The total tuber yield as well as marketable yield and average processing grade tuber weight
 96 were significantly higher during 2020-21 than in 2019-20. Ranking of tubers in terms of grades
 97 revealed that the application of humic acid significantly influenced the number of different
 98 grades of potato tubers. The increasing levels of humic acid application (3 times in T₄ and T₇)
 99 in different stages of crop growth increased the quantity of the large size of tubers. On the
 100 other side application of 100% recommended doses of NPK fertilizers alone (T₈) recorded a
 101 higher percentage of small-size tubers (<30 g). Noticeable variation was observed among
 102 different treatments on total tuber yield and marketable tuber yield. During the first year (2019-
 103 20) of investigation, the highest total tuber yield (26.12 t/ha) and second year (2020-21) the

104 highest total tuber yield (27.68 t/ha) was recorded under the treatment T₇ which is statistically
 105 at par with treatment T₄ and T₅. While the lowest total tuber yield (21.26 and 20.95 t/ha) was
 106 observed under the treatment T₈ (Control) in both years. The same trend was also observed
 107 in the case of marketable tuber yield per ha. Treatment T₇ recorded the highest marketable
 108 tuber yield (24.74 t/ha in 2019-20 and 26.22 t/ha in 2020-21) followed by T₄ (24.12 t/ha & 25.56
 109 t/ha), T₅ (23.32 t/ha & 23.51 t/ha) and T₆ (22.11 t/ha & 22.32 t/ha). On the other hand lowest
 110 marketable yield per ha was calculated in T₈ (18.99 t/ha in 2019-20 and 18.52 t/ha in 2020-
 111 21) which was at par with treatment T₁ and T₂. In the comparison of yield, it was revealed that
 112 treatments T₇ and T₄ resulted in 20-22% more yield than T₈ (100% RDF). Table 3 indicates
 113 that there is a declining trend of yield in the use of chemical fertilizers continuously. The
 114 possible reason for the declining productivity of 100 per cent inorganic treatment may be due
 115 to deterioration of soil health (organic carbon and available NPK) [8]. Therefore, on a long-
 116 term basis, the combination of humic acid-based bio-stimulant and inorganic fertilizers may be
 117 a wise option to sustain the tuber yields in present-day intensive agriculture [9].

118
 119
 120

Table 3. Effect of humic acid-based bio-stimulant (liquid formulation) 'Humetsu' on yield parameters of potato

Treatments	No. of tubers/plant		A' grade tuber (%) per plot [Diameter >5.0 cm and weight 60- 90 g & above]		B' grade bulb (%) per plot [Diameter 3.0 cm – 5.0 cm and weight 30-60 g]		C' grade bulb (%) per plot [Diameter <3.0 cm and weight < 30 g]		Total tuber yield (t/ha)		Marketable tuber yield (t/ha)	
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
T ₁	9.50	9.55	32.14	32.16	35.12	35.14	32.74	32.70	22.12	22.21	19.44	19.52
T ₂	9.78	9.85	36.46	36.56	30.92	30.98	32.62	32.46	22.74	22.85	20.62	20.96
T ₃	10.98	11.09	43.16	43.29	30.62	30.77	26.22	25.94	23.67	23.75	22.55	22.83
T ₄	12.64	13.40	51.42	51.86	34.55	34.86	14.03	13.28	25.88	27.43	24.12	25.56
T ₅	11.48	11.72	46.22	46.75	38.95	39.05	14.83	14.20	25.08	25.13	23.32	23.51
T ₆	10.55	10.59	41.55	41.93	35.68	35.89	22.80	22.18	24.22	24.56	22.11	22.32
T ₇	12.68	13.45	53.42	53.62	33.16	33.56	13.42	12.82	26.12	27.68	24.74	26.22
T ₈	9.28	8.99	30.52	30.49	33.65	33.70	35.83	35.81	21.26	20.95	18.99	18.52
SEm(±)	0.32	0.34	1.91	1.96	0.76	0.83	1.712	1.815	0.81	0.91	1.03	1.13
LSD (5%)	0.96	1.04	5.80	5.95	2.32	2.52	5.193	5.505	2.47	2.76	3.13	3.43

121

122 3.3 Soil chemical properties

123 The nutrient status of nitrogen, phosphorus and potassium in soil were significantly influenced
 124 by the effect of humic acid and inorganic source of nutrients on potato (Table 4). The data on
 125 chemical properties of post-harvest soil of the experimental field revealed that there were
 126 increases in the soil chemical properties in post-harvest soil. The available N, P, K and OC
 127 were slightly increased from (360.52kg N; 23.42 kg P, 167.52kg K per ha and 0.52% OC in
 128 2019-20) to (372.41 kg N; 25.04 kg P, 173.12 kg K per ha and 0.56% OC in 2020-21) in T₄

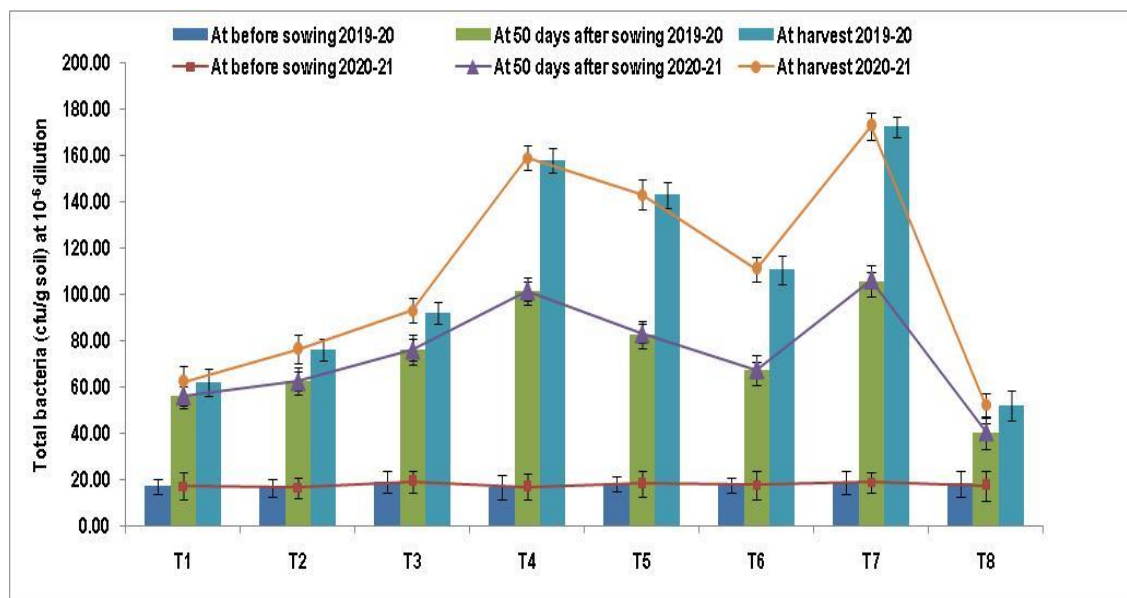
129 was superior among the treatments (T₇, T₅, T₆, T₃, T₂, T₁) and the control T₈ (351.42 kg N;
 130 21.46 kg P, 160.32 kg K per ha and 0.47% OC in 2019-20 and 350.11 kg N; 21.47 kg P,

Treatments	Nutrient availability in soil after first year (2019-20) crop harvest				Nutrient availability in soil after second year (2020-21) crop harvest			
	N (kg/ha)	P (kg/ha)	K (kg/ha)	Organic Carbon (%)	N (kg/ha)	P (kg/ha)	K (kg/ha)	Organic Carbon (%)
T ₁	352.68	21.87	162.11	0.48	352.66	22.21	161.31	0.48
T ₂	352.45	22.05	164.02	0.49	358.66	22.16	166.52	0.51
T ₃	353.88	22.63	163.45	0.51	360.42	23.02	167.12	0.53
T ₄	360.52	23.42	167.52	0.52	372.41	25.04	173.12	0.56
T ₅	358.71	22.36	166.14	0.51	368.42	23.38	172.51	0.55
T ₆	354.55	22.65	164.32	0.51	363.44	22.98	167.58	0.54
T ₇	359.45	23.31	166.31	0.52	373.54	25.09	171.55	0.56
T ₈	351.42	21.46	160.32	0.47	350.11	21.47	158.45	0.46
SEm(±)	1.89	0.19	1.46	0.02	1.92	0.20	1.58	0.021
LSD(5%)	5.74	NS	4.42	NS	5.83	0.65	4.79	0.06

131 158.45 kg K per ha and 0.46% OC in 2020-21). The build-up of available nitrogen, phosphorus,
 132 potassium and oxidizable organic carbon in the soil could be due to the organic acids which
 133 were released by increased microbial population in soil by the application of humic acid bio-
 134 stimulant [10].

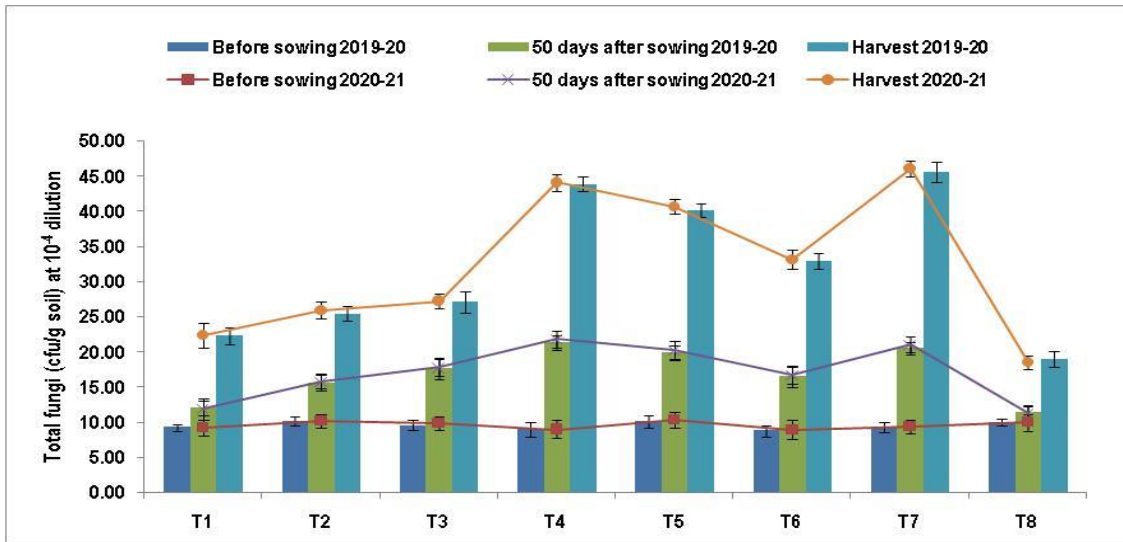
135 **Table 4. Effect of humic acid-based bio-stimulant (liquid formulation) ‘Humetsu’ on**
 136 **nutrient availability in soil after crop harvest of potato**

137
 138



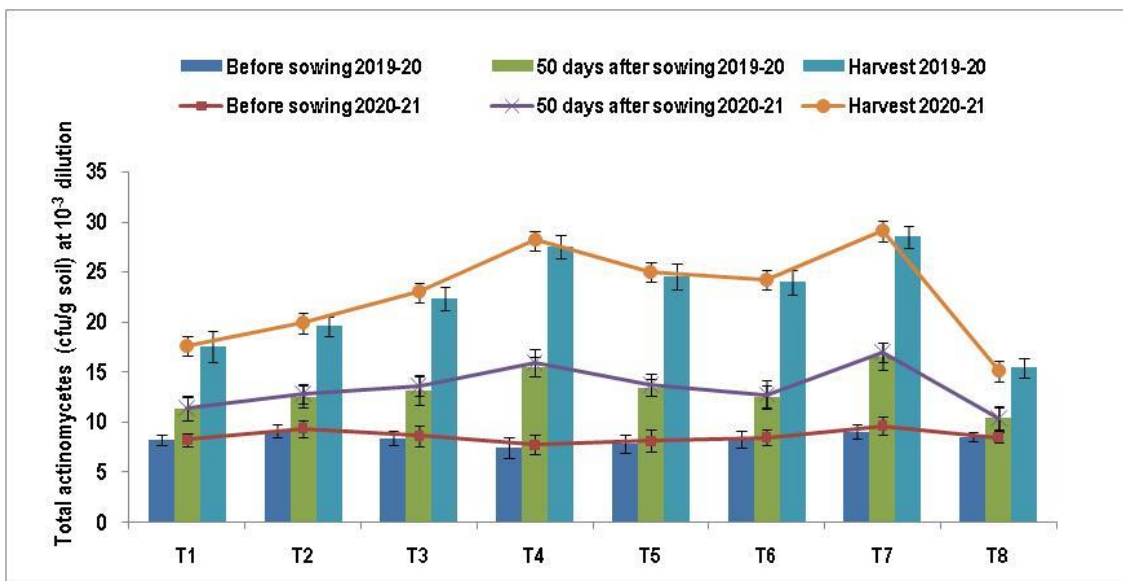
139
 140
 141

Fig. 1. Effect of humic acid based bio-stimulant (liquid formulation) ‘Humetsu’ on total bacteria population of soil at different DAS of potato



142
143
144
145

Fig. 2. Effect of humic acid based bio-stimulant (liquid formulation) 'Humetsu' on total fungi population of soil at different DAS of potato



146
147
148
149
150

Fig. 3. Effect of humic acid-based bio-stimulant (liquid formulation) 'Humetsu' on total actinomycetes population of soil at different DAS of potato

3.4 Microbial population of soil

151 Profound dissimilarity in microbial population of soil was found among different treatments of
152 humic acid-based bio-stimulant on potato in both consecutive two years of investigation. The
153 bacterial population at 10⁻⁶ dilution varied significantly due to different treatments (Figure 1)
154 The higher bacterial population of 105.67 and 172.32 *cfu*/gram soil in first year and 106.11
155 and 172.65 *cfu*/gram soil in second year were observed under T₇ at 50 DAS and harvesting
156 respectively which was statistically at par with treatment T₄. From the Figure 1 it is clearly

157 observed that bacterial population increased rapidly in soil after the humic acid-based bio-
158 stimulant application. While, minimum number of cell count was observed in T₈ with 100 %
159 RDF (40.26 and 40.85 *cfu/g* soil in 2019-20 and 2020-21 at 50 DAS) and (52.16 and 52.24
160 *cfu/g* soil in 2019-20 and 2020-21 at harvesting) at 10⁻⁶ dilution. All other treatments showed
161 significant variations in bacterial population within them by application of different combination
162 of humic acid-based bio-stimulant. With regard to total fungus population (Figure 2) in soil at
163 10⁻⁴ dilution, the higher fungi biomass of 45.62 (2019-20) and 46.10 (2020-21) *cfu* per gram
164 of soil was noticed in treatment T₇ followed by T₄ and T₅ at harvesting. Whereas it was 9.26
165 (2019-20) and 9.41 (2020-21) *cfu* per gram of soil in T₇ before the sowing of tubers. On the
166 other hand, treatment T₈ (100% RDF) recorded least number of fungal colonies (18.95 in 2019-
167 20 and 18.54 in 2020-21 *cfu/g* soil at harvesting) at 10⁻⁴ dilution followed by treatment T₁ and
168 T₂ where humic acid-based bio-stimulant was applied only once. Similarly, the higher
169 actinomycetes biomass (Figure 3) of 28.48 and 29.08 *cfu* per gram of soil at 2019-20 and
170 2020-21 at 10⁻³ dilution respectively was reported with the application of 80% NPK + 3
171 application of 'Humetsu' (Seed treatment @ 5ml/kg of tuber and 2 foliar spray @ 2.5ml l⁻¹
172 water at 30 DAS & 55 DAS) (T₇) at harvesting. However, the treatment T₈ (100 % RDF)
173 recorded lowest number of colonies of 15.44 in 2019-20 and 15.12 in 2020-21 *cfu/gram* of soil
174 at 10⁻³ dilution respectively. It is clearly observed from Figure 3 that there are near about 215%
175 and 268% increment of actinomycetes biomass from sowing of tuber to harvesting in treatment
176 T₇ and T₄ where humic acid-based bio-stimulant was applied thrice in different stages of crop.
177 The increase in bacterial, fungus and actinomycetes biomass under these treatments might
178 be due to increased microbial activity and multiplication by application of humic acid [11] based
179 bio-stimulant 'Humetsu'.

180

181 **4. CONCLUSION**

182 Application of 80% NPK + 3 application of 'Humetsu' (Seed treatment @ 5ml/kg of tuber and
183 2 foliar sprays @ 2.5ml l⁻¹ water at 30 DAS & 55 DAS) (T₇) has a significant impact in yield of
184 potato with 20% reduction of the recommended dose of NPK fertilizers. Application of humic
185 acid increases bacterial, fungus and actinomycetes biomass in the soil it might be due to
186 increased microbial activity and multiplication.

187

188 Disclaimer (artificial intelligence)

189 Option 1:

190 Author(s) hereby declare that no generative ai technologies such as large language
191 models (chatgpt, copilot, etc) and text-to-image generators have been used during
192 writing or editing of manuscripts.

193

194 Option 2:

195 Author(s) hereby declare that generative ai technologies such as large language
196 models, etc have been used during writing or editing of manuscripts. This explanation

197 will include list the name, version, model, and source of the generative ai technology
198 and as well as the all input prompts provided to a generative ai technology

199

200 Details of the ai usage are given below:

201 1.

202 2.

203 3.

204 REFERENCES

205

206 1. Hilly M, Adams ML, Nelson SC. A study of digit fusion in the mouse embryo. Clin Exp
207 Allergy. 2002;32(4):489-98.

208 1. Singh M. Projection of potato export from India: a markov chain approach. Potato J.
209 2010;37:48-55.

210 2. Yadav RS, Kushwaha RR, Maurya K, Singh, AK, Singh RK, Verma AK. A Study on Costs
211 and Returns of Potato in Azamgarh District of Eastern Uttar Pradesh, India. J. Exp. Agric.
212 Int. 2024;46(5):825-831.

213 3. Ahmadu T, Abdullahi A, Ahmad K. The role of crop protection in sustainable potato
214 (*Solanum tuberosum* L.) production to alleviate global starvation problem: An
215 overview. *Solanum tuberosum-A Promising Crop for Starvation Problem*. 2021;19-51.

216 4. De Haan S, Rodriguez F. Potato origin and production. In Advances in potato chemistry
217 and technology. 2016;(pp. 1-32). Academic Press.

218

219 5. Devaux A, Goffart JP, Petsakos A, Kromann P, Gatto M, Okello J, Hareau G. Global food
220 security, contributions from sustainable potato agri-food systems. The potato crop: Its
221 agricultural, nutritional and social contribution to humankind. 2020;3-35.

222

223 6. Paul V, Ezekiel R, Pandey R. Effective utilization of cold storage space demands for more
224 multi-chamber cold stores and increased utilization of potatoes for processing. Indian Food
225 Ind. 2018;37:44-48.

226

227 7. Mofokeng MM, Araya HT, Araya, N A, Makgato MJ, Mokgehle SN, Masemola MC, Amoo
228 SO. Integrating biostimulants in agrosystem to promote soil health and plant growth.
229 In Biostimulants for Crops from Seed Germination to Plant Development. 2021;(pp. 87-108).
230 Academic Press.

231

232 8. Indoria AK, Sharma KL, Reddy KS, Srinivasarao C, Srinivas K, Balloli SS, Raju NS.
233 Alternative sources of soil organic amendments for sustaining soil health and crop productivity
234 in India—impacts, potential availability, constraints and future strategies. Curr.
235 Sci. 2018;115(11):2052-2062.

236

237 9. Olt J, Kikas T, Meneses L. 10th International Conference on Biosystems Engineering 2019;
238 Book of Abstracts: May 8-10 in Tartu, Estonia.

239

240 10. Ampong K, Thilakaranthna MS, Gorim LY. Understanding the role of humic acids on crop
241 performance and soil health. *Front. Agron.* 2022;**4**:848621.

242

243 11. Maji D, Misra P, Singh S, Kalra A. Humic acid rich vermicompost promotes plant growth
244 by improving microbial community structure of soil as well as root nodulation and mycorrhizal
245 colonization in the roots of *Pisum sativum*. *Appl. soil ecol.* 2017;**110**:97-108.

246 12 CHAUHAN APS, SINGH D, KUSHWAH N, SHARMA A, PARIHAR C, RICHHARIYA RK, SINGH SP.
247 EVALUATION OF POTATO (*SOLANUM TUBEROSUM* L.) GROWTH ATTRIBUTES UNDER NATURAL
248 FARMING SYSTEM IN GIRD REGION OF MADHYA PRADESH, INDIA. *J. EXP. AGRIC. INT.* [INTERNET].
249 2023 DEC. 9 [CITED 2024 MAY 28];**45**(11):271-7. AVAILABLE FROM:
250 [HTTPS://JOURNALJEA.COM/INDEX.PHP/JEAI/ARTICLE/VIEW/2258](https://journaljeai.com/index.php/jeai/article/view/2258)

251

252 13 AHMED F, MONDAL MMA, AKTER MB. ORGANIC FERTILIZERS EFFECT ON POTATO (*SOLANUM*
253 *TUBEROSUM* L.) TUBER PRODUCTION IN SANDY LOAM SOIL. *INT. J. PLANT SOIL SCI.* [INTERNET]. 2019
254 AUG. 21 [CITED 2024 MAY 28];**29**(3):1-11. AVAILABLE FROM:
255 [HTTPS://JOURNALIJPSS.COM/INDEX.PHP/IJPSS/ARTICLE/VIEW/1007](https://journalijpss.com/index.php/ijpss/article/view/1007)

256

257 14 ROSEN CJ, KELLING KA, STARK JC, PORTER GA. OPTIMIZING PHOSPHORUS FERTILIZER
258 MANAGEMENT IN POTATO PRODUCTION. *AMERICAN JOURNAL OF POTATO RESEARCH.* 2014
259 APR;**91**:145-60.