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Influence of Varying Levels of Organic Manure, Phosphorus and Bio-inoculants on Biological Properties of Soil under Mungbean [*Vigna radiata* (L.) Wilczek]

Prahlad Ram Raiger [a++*], Ram Hari Meena [b#], Ummed Singh [c†], Hanuman Prasad Parewa [d‡], Manoj Kumar [e^], Bheru Lal Kumhar [f^], Anil Kumar Verma [f##] and Pankaj Lavania [g#^]

[a] Department of Soil Science, College of Agriculture, Agriculture University, Jodhpur, Rajasthan, India.
[b] Department of Soil Science & Agricultural Chemistry, Rajasthan College of Agriculture (MPUAT), Udaipur-Rajasthan, India.
[c] Rajasthan Agricultural Research Institute (Sri Karan Narendra Agriculture University, Jobner) Durgapura, Jaipur, Rajasthan, India.
[d] College of Horticulture (Sri Karan Narendra Agriculture University, Jobner) Durgapura, Jaipur, Rajasthan, India.
[e] AICRP on Pearl Millet, Unit, Agricultural Research Station, Agriculture University, Jodhpur, Rajasthan, India.
[f] Agricultural Research Station, Agriculture University, Jodhpur, Rajasthan, India.
[g] College of Agriculture, Agriculture University, Jodhpur, Rajasthan, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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[++] *Assistant Professor;*
[#] *Professor;*
[†] *Professor (Agronomy) & Associate Dean (Academics);*
[‡] *Associate Professor;*
[^] *Assistant Professor (Agronomy);*
[##] *Assistant Professor (Soil Science);*
[#^] *Assistant Professor (Animal Production);*
**Corresponding author: E-mail: prahlad.raiger2011@gmail.com;*

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ABSTRACT

A field experiment was conducted for two consecutive years (during *Kharif* 2019 and 2020) at Instructional Farm, College of Agriculture, Jodhpur (Rajasthan) to assess the impact of varying levels of FYM, phosphorus and bio-inoculants on biological properties of soil under Mungbean. The experiment was laid out in factorial randomized block design with three replications. The experiment comprised of two levels of FYM (0 and 5 t/ha), four levels of phosphorus (0, 50, 75 and 100% P_2O_5 /ha) and three levels of bio-inoculations (No inoculation, *Enterobacter cloacae* and *Bacillus amyloliquefaciens*). Mungbean variety GM-4 was used for exprimentation. The results revealed that addition of FYM @ 5 t ha^{-1} recorded significantly higher soil microbial biomass carbon (217.92 mg /kg), soil microbial biomass phosphorus (15.47 mg/kg), acid phosphatase (1.019 µg PNP/g soil/h), alkaline phosphatase (7.13µg PNP/g soil/h**)** and dehydrogenase activity (6.10 µg TPF/g soil/ h) of soil at 40 DAS as compared to without FYM application. Among the phosphorus levels, application of 100% P_2O_5 /ha gave significantly highest soil microbial biomass carbon (219.13mg/kg), soil microbial biomass phosphorus (15.71 mg/kg), acid phosphatase (1.010 µg PNP/g soil/h), alkaline phosphatase (7.21µg PNP/g soil/h**)** and dehydrogenase activity (5.91µg TPF/g soil/h) over rest of P levels, however, it was found at par with 75 % P_2O_5 /ha. Similarly, the seed inoculation with *B. amyloliquefaciens* recorded significantly higher values of all above biological properties as compared to un-inoculated control but it was found at par with seed inoculation with *E. cloacae*. Thus, the results reaveal the positive effect of the application of FYM, Phosphorus and seed inoculation with biofertilizers (*E. cloacae or B. amyloliquefaciens*) on the biological properties of soil (soil microbial biomass carbon, soil microbial biomass phosphorus, acid phosphatase, alkaline phosphatase and dehydrogenase activity) for management of sustainable environment.

Keywords: FYM; phosphorus, bio-inoculants; biological properties; mungbean.

1. INTRODUCTION

Mungbean (*Vigna radiata* (L.) Wilczek) is a leguminous pulse crop cultivated in both *kharif* and zaid seasons under arid and semi-arid regions of India. Mungbean is an excellent source of dietary protein with high quality of lysine and tryptophan. It have a unique ability of maintaining and restoring soil fertility through biological nitrogen fixation besides addition of ample quantity of residues to the soil. At present, the intensive land use in relation with continuous use of high analytical inorganic fertilizers has found to realize enhanced crop production but only at the cost of soil health. Thus a vital research priority is to sustain soil productivity and to supervision changes in physico-chemical and biological soil properties as influenced by management [1]. It is well established fact that application of biofertilizers and organic ameliorates to the soil can definitely influence the soil productivity [2 & 3] through rising soil properties involving microbial as well as enzymatic activities.

The soils of the Western region of Rajasthan have multiple challenges like desertic nature, coarse texture, slight alkalinity, and poor fertility status [4]. Addressing nutrient deficiency is crucial, necessitating attention to nutrient management strategies involving organic manures, inorganic fertilizers, and biofertilizers [5]. Among essential nutrients, phosphorus holds particular significance for legumes, being regarded as the 'energy currency element [6]. However, applying phosphorus in problematic soils poses challenges due to its fixation, resulting in limited availability to plants. To enhance phosphorus availability, phosphorus solubilizing bacteria (PSB) like Pseudomonas sp. and Bacillus sp. play a crucial role in converting insoluble phosphorus into a readily available form in the soil. Seed inoculation with suitable PSB strains is a cost-effective approach that enhances yield by solubilizing unavailable phosphorus into an accessible form, reducing the dependency on costly inorganic phosphorus fertilizers [7]. Evaluating the feasibility and efficiency of organic manures and biofertilizers is essential not only for improving soil fertility but also for increasing phosphatic fertilizer efficiency. The management of chemical fertilizers, organic manures, and biofertilizers has shown great promise in sustaining crop production stability, soil health, and productivity compared to using each component alone [8]. While chemical fertilizers have raised concerns regarding their impact on microbial activity and soil productivity, the application of organic manures and biofertilizers has been found to boost nutritional status, microbial activity, and soil productive potential. Soil microorganisms, being crucial sources and sinks of mineral nutrients, significantly contribute to soil fertility [8]. Soil organic matter, including living microorganisms, acts as a transitory nutrient reservoir, releasing nutrients from organic matter for plant use. Understanding the microbial processes is essential for managing farming systems, especially those relying on organic nutrient inputs [9].

The current study aimed to assess the effects of various levels of organic manure, phosphorus, and bio-inoculants on biological properties of soil for two years in mungbean cultivation in arid and semi -arid climatic condition. By exploring these aspects, we strive to contribute to the knowledge and understanding of sustainable agricultural practices that promote soil health and crop productivity while considering environmental concerns in the long term.

2. MATERIALS AND METHODS

A field experiment was carried out during the *kharif* 2019 and 2020 at Instructional Farm, College of Agriculture, Agriculture University, Jodhpur, Rajasthan. The initial soil properties of experimental field were loamy sand in texture, soil reaction 8.32, having EC 0.89 dS/m at 25 ºC and low in organic carbon (1.3 g/kg). The experiment was laid out in factorial randomized block design (FRBD) in three replications. Treatments comprising of two levels of FYM (0 and 5 t/ha), four levels of recommended dose of phosphorus (0, 50, 75 and 100 % P_2O_5 /ha) and three levels of bio-inoculants (no inoculation, *Enterobacter cloacae and Bacillus amyloliquefaciens*). Recommended dose of nitrogen and zinc were uniformly applied to all the plots as basal application through urea and zinc sulphate, respectively. The whole quantities of FYM and phosphorus (through single super phosphate) were applied as per treatment prior to sowing and incorporated manually in top 15 cm of soil. As per treatments, seeds of mungbean variety GM-4 were inoculated with PSB strains *i.e*. *Enterobacter cloacae* (PSB-17) and *Bacillus amyloliquefaciens* (PSB-41) before sowing as per the standard method and dried in shade and used for sowing.The general view of the experimental site of the mungbean crop is depicted in Fig .1. The fresh soil samples were collected at 0-15 cm depth from experimental field at 40 DAS and stored in refrigerator and were sieved through 2.0 mm sieve. The soil microbial biomass carbon was estimated by adopted fumigation extraction method [10], soil microbial biomass phosphorus was determined by chloroform fumigation-extraction method [11]. The soil enzymatic activities like acid and alkaline phosphatases (µg PNP/g soil/h) were analyzed by measuring the amount of p-nitrophenol released as described by [12] and dehydrogenase activity (µg TPF/g soil/h) in soil was determined by using the reduction of 2,3,5-triphenyle teterazolium chloride [13].

Fig .1. The general view of the experimental site of the Mungbean (Var. GM-4) crop

3. RESULTS AND DISCUSSION

3.1 Effect of FYM on Biological Properties

3.1.1 Soil microbial biomass

Incorporation of FYM had significant influence on soil microbial biomass carbon (SMBC) and soil microbial biomass phosphorus (SMBP) content in soil at 40 DAS of mungbean (Table 1). Significantly higher SMBC (217.92 mg/kg) and SMBP (15.47 mg/kg) were recorded with the incorporation of FYM @ 5 t/ha over control (198.10 and 14.21 mg/kg) respectively. It might be due to the fact that FYM is a steady source of organic carbon to encourage the soil microbial community [14]. Moreover, build-up of soil microbial biomass is largely due to the contained of microbial biomass in the organic manures, resulting addition of substrate carbon, which encourage the native soil micro-biota [15,16,17,18].

3.1.2 Soil enzymatic activity

The enzymatic activities were increased significantly with incorporation of FYM. The maximum acid phosphatase activity (1.0919 µg PNP/g soil/h), alkaline phosphatase activity (7.13 µg PNP/g soil/h**)** and dehydrogenase activity (6.10 µg TPF/g soil/h) at 40 DAS of soil were recorded under the treatment of FYM @ 5 t/ha. Application of FYM @ 5 t/ha increases the APA, AlPA and DHA of soil to the tune of 6.81, 2.15 and 12.34 per cent, respectively over control. A significant increase in acid phosphatase activity under FYM manured treatments might be due to better growth and number of fine roots of lesser diameter and thus producing exudation of intracellular acid phosphate [19]. This might be due to fact that FYM is a batter source of carbon resultant enhanced microbial activity which secreted more alkaline phosphatase enzymes [19]. Comparable consequences were also reported by Bargaz [20]. Significant improvement in dehydrogenase enzyme activity under FYM treated plots might be due to increase in microbial growth with the addition of carbon substrate [21].

3.2 Effect of Phosphorus on Soil Biological Properties

3.2.1 Soil microbial biomass

Significantly higher SMBC (219.13 mg/kg) and SMBP (15.71 mg/kg) content was observed under application of super optimal phosphorus level (100 % P_2O_5 /ha) over control and 50% P_2O_5, while it was found statistically at par with 75% P_2O_5. Soil microbial biomass carbon augmented by increasing levels of inorganic fertilizers, might be due primarily increase in microbial population [22] besides secondary formation of root exudates, mucigel soughed off cells and underground roots of previous cut crops which besides play a significant role in increasing biomass carbon [23]. Soil microbial biomass phosphorus increase with increases graded levels of phosphorus. It provided substrates indispensable for microbial growth and their activity, which in term accountable for increase soil microbial biomass phosphorus [17].

3.2.2 Soil enzymatic activity

The highest activities of all enzymes in soil at 40 DAS were observed under the crop fertilized with 100% P_2O_5 followed by 75% and 50% P_2O_5 while, minimum activity was noticed in control. The maximum values of APA, AlPA and DHA were 1.010, 7.21 µg PNP/g soil/h and 5.91 µg TPF/g soil/h under the 100% P_2O_5 application, respectively on pooled mean basis. However, 75 and 100% P_2O_5 were being at par to each other. The increases the level of inorganic P fertilizers has led to an increased the activity of dehydrogenase as well as phosphatase. It might be ascribed to the fact that inorganic sources of nutrient encouraged the enzymes activity of soil microorganisms which utilize the native pool of organic carbon as a source of carbon [18]. Comparable findings were also reported by [17].

3.3 Effect of Biofertilizers on Biological Properties

3.3.1 Soil microbial biomass

Significantly higher SMBC (218.87mg/kg) and SMBP (15.78mg/kg) content was observed in *B. amyloliquefaciens* inoculated plots as compared to un-inoculated plots and it was found at par with seed inoculation by *E. cloacae*. Increase in biomass carbon as a result of the secretion of cellulolytic or lignolytic enzymes which in turn might have improved the SMBC. Higher microbial activities obviously make the microbes to transform small fraction of available P into microbial biomass phosphorus [24].

3.3.2 Enzymatic activity

It is evident from data presented (Table 2 & Fig. 2) indicated that that acid phosphatase

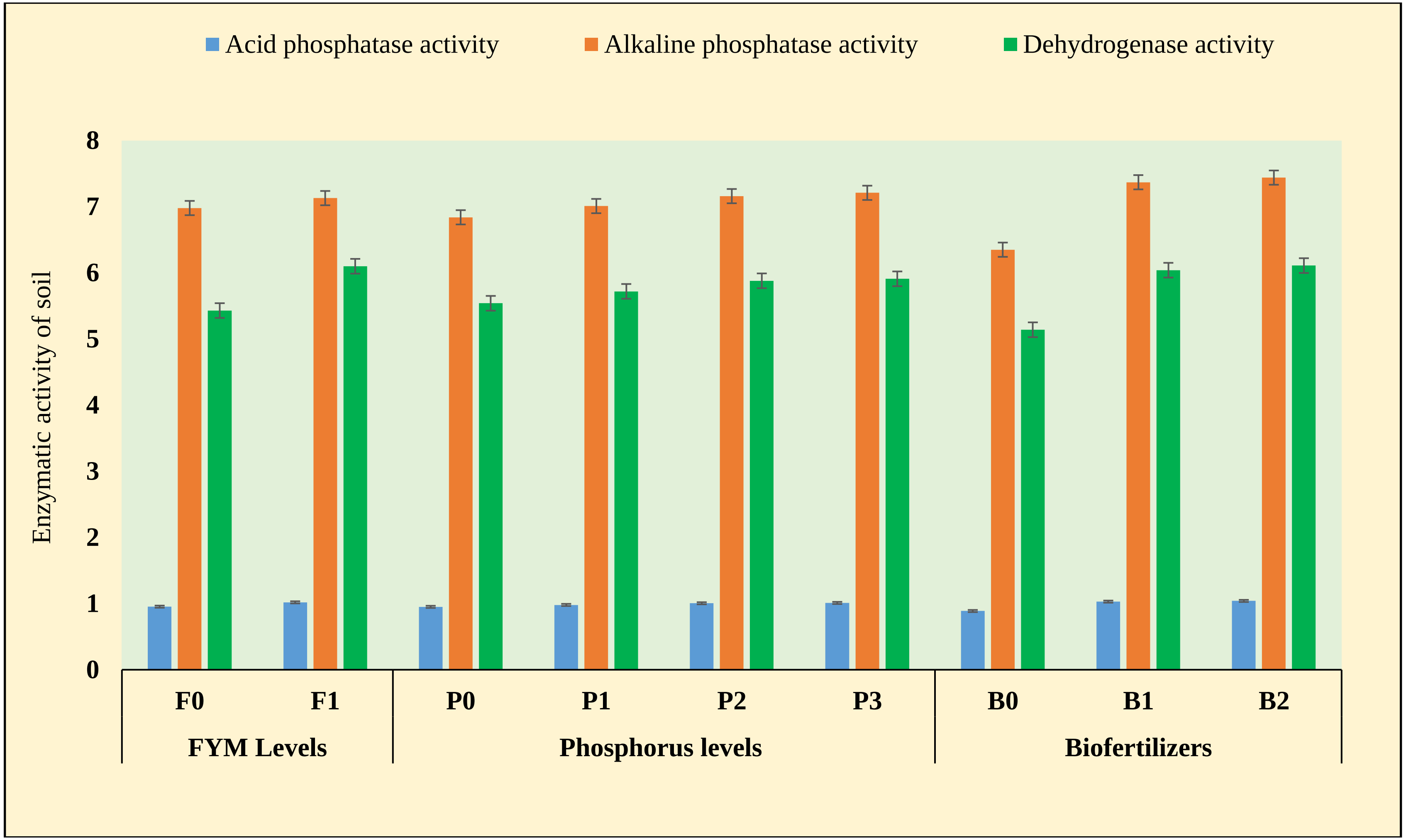

Fig. 2. Effect of different levels of FYM, phosphorus and bio-inoculants on enzymatic activity of soil at 40 DAS (Pooled basis)
[F_0: 0 t/ha, F_1: 5 t/ha; P_0: 0%P_2O_5, P_1: 50%P_2O_5, P_2: 75%P_2O_5, P_3: 100%P_2O_5; B_0: Control, B_1: E. cloacae, B_2: B. amyloliquefaciens]

Table 1. Effect of varying levels of FYM, phosphorus and bio- inoculants on soil microbial biomass at 40 DAS

Treatments	Soil microbial biomass carbon (mg/kg)			Soil microbial biomass phosphorus (mg/kg)		
	2019	2020	Pooled	2019	2020	Pooled
FYM Levels						
0 t/ha	197.61	198.59	198.10	14.19	14.22	14.21
5 t/ha	214.35	221.50	217.92	15.16	15.78	15.47
SEm±	1.30	1.39	0.90	0.11	0.12	0.08
CD (*P*=.05)	3.70	3.94	2.53	0.30	0.34	0.22
Phosphorus levels (Recommended dose of P_2O_5)						
0% P_2O_5 /ha	188.24	189.17	188.70	13.17	13.31	13.24
50% P_2O_5 /ha	205.45	208.84	207.14	14.63	14.92	14.78
75% P_2O_5 /ha	214.34	219.81	217.07	15.40	15.86	15.63
100% P_2O_5 /ha	215.88	222.38	219.13	15.50	15.91	15.71
SEm±	1.84	1.96	1.27	0.15	0.17	0.11
CD (*P*=.05)	5.23	5.58	3.58	0.43	0.48	0.30
Biofertilizers						
Un-inoculated control	185.98	189.03	187.50	13.04	13.15	13.09
E. cloacae	215.08	220.25	217.66	15.38	15.90	15.64
B. amyloliquefaciens	216.87	220.86	218.87	15.61	15.95	15.78
SEm±	1.59	1.70	1.10	0.13	0.15	0.09
CD (*P* =.05)	4.53	4.83	3.10	0.37	0.42	0.26

Table 2. Effect of varying levels of FYM, phosphorus and bio- inoculants on enzymatic activity of soil

Treatments	Enzymatic activity of soil at 40 DAS								
	Acid phosphatase activity (µg PNP/g soil/h)			Alkaline phosphatase activity (µg PNP/g soil/h)			Dehydrogenase activity (µg TPF/g soil/h)		
	2019	**2020**	**Pooled**	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
FYM Levels									
0 t/ha	0.950	0.958	0.954	6.95	7.01	6.98	5.40	5.45	5.43
5 t/ha	1.000	1.038	1.019	7.00	7.26	7.13	5.98	6.22	6.10
SEm±	0.006	0.007	0.004	0.04	0.05	0.03	0.038	0.040	0.026
CD (*P*=.05)	0.017	0.019	0.011	NS	0.13	0.08	0.10	0.12	0.07
Phosphorus levels (Recommended dose of P_2O_5)									
0% P_2O_5 /ha	0.944	0.958	0.951	6.79	6.89	6.84	5.49	5.58	5.54
50% P_2O_5 /ha	0.971	0.990	0.980	6.94	7.08	7.01	5.66	5.78	5.72
75% P_2O_5 /ha	0.990	1.019	1.005	7.07	7.25	7.16	5.80	5.97	5.88
100% P_2O_5 /ha	0.994	1.026	1.010	7.10	7.33	7.21	5.81	6.01	5.91
SEm±	0.008	0.009	0.006	0.06	0.07	0.04	0.054	0.057	0.036
CD at 5%(*P*=.05)	0.024	0.027	0.016	0.17	0.19	0.12	0.15	0.16	0.10
Biofertilizers									
Un-inoculated control	0.882	0.895	0.888	6.31	6.40	6.35	5.10	5.18	5.14
E. cloacae	1.017	1.044	1.030	7.28	7.46	7.37	5.96	6.13	6.04
B. amyloliquefaciens	1.026	1.056	1.041	7.34	7.55	7.44	6.01	6.20	6.11
SEm±	0.007	0.008	0.005	0.05	0.06	0.04	0.047	0.049	0.031
CD (*P*=.05)	0.021	0.023	0.014	0.15	0.16	0.10	0.13	0.14	0.09

activity (APA), alkaline phosphatase activity (AlPA) and dehydrogenase activity (DHA) of soil at 40 DAS were significantly influenced with biofertilizers seed inoculation. Significantly higher acid phosphatase activity (1.041 µg PNP /g soil /h), alkaline phosphatase activity (7.44 µg PNP/g soil/h) and dehydrogenase activity (6.11 µg TPF /g soil /h) were observed in *B. amyloliquefaciens* inoculated plots as compared to un-inoculated control, however it was found statistically at par with *E. cloacae* inoculated plot. Acid phosphatase activity increase with seed inoculation with PSB might due to secretion of acid phosphatase from legumes roots into rhizosphere to hydrolyze organic- P [25,26]. Secondly microorganisms, in addition to roots, are another vital source of acid phosphatase activity in rhizosphere [27,28]. Alkaline phosphatase activity increase with seed inoculation with PSB, which might due to producing of alkaline phosphatase phosphate solubilizing bacteria [29]. Alkaline phosphatase activity was found to be better than acid phosphatase activity in the rhizosphere soil due to the slightly alkaline reaction of experimental soil.Significantly increase in dehydrogenase activity through seed inoculation by biofertilizers. It might be due to increases microbial and root activity in the rhizosphere may largely account for higher activity including phosphatase [30].Similar results were also reported by [24 & 31].

4. CONCLUSIONS

On the basis of above results, it is concluded that application of FYM @ 5.0 t/ha, 75 percent recommended dose of phosphorus and seed inoculation with biofertilizers (either with *E. cloacae* or *B. amyloliquefaciens*) significantly improved the biological properties of soil at 40 DAS under mungbean. Further, different sources of nutrient will be suitable approach for enhancing soil heath and productivity.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (Chat GPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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