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Research Article

PHOSPHORUS RELEASE PATTERN OF ROCK PHOSPHATE APPLIED AS P- FERTILIZER INCUBATED WITH AMENDMENTS IN VERTISOLS OF CENTRAL INDIA

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Abstract- A pot experiment was conducted to determine the phosphorus release pattern of Jhabua Rock phosphate (JRP) in Vertisols, when it was applied with eighteen fertilizer treatments under three soil moisture regimes *viz.* 50% of field capacity (MR1), field capacity (MR2) and saturation (MR3). The result was found that JRP@120 kg P ha^{-1}+PSB@ 150 g ha^{-1}+FYM@5 t ha^{-1} with field capacity (F_{17} MR2) was the most effective treatment amongst all treatment combinations (61.52 kg P_2O_5 ha^{-1}). The maximum release in available-P was obtained at 90 DAI in case of F_{17} (262%) and minimum in case of F_2 (19%) over control. The trend of per cent change in cumulative in available-P release was $F_2 < F_3 = F_4 < F_5 < F_6 = F_7 < F_8 < F_{15} > F_{10} = F_{13} < F_9 = F_{11} < F_{14} < F_{12} = F_{16} < F_{18} < F_{17}$ and almost similar change was observed on other sampling dates. Rock phosphate can be used as a source of available P when applied with acidifying amendments, which, help in dissolution of RP and released available P.

Keywords- Jhabua rock phosphate, soil moisture regimes, Vertisols, Phosphorus release pattern, Industrial waste.

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Introduction

Rock phosphate (RP) is a general term that describes natural occurring mineral assemblages containing a high concentration of phosphate minerals. Phosphorus fertilizers in India are too much expensive because it is an imported commodity. Because of high cost only resource rich farmers can able to use phosphatic fertilizers in their P-deficient soil and other poor farmers need alternate substitute rock phosphate for fulfill P requirement. Phosphate rock (PR) is suitable material as a source of phosphorus (P) for plants. Direct application of phosphate rock (PR) is considered as soil ameliorant in acid soils but it is not recommended for alkaline soils [1]. Though it is slowly releases P in soil, so that we have to enhance the rate of solubility of rock phosphate which is essential for phosphorus (P) management in different crops. Phosphorus solubilizing and mobilizing organisms such as phosphor-bacterium and mycorrhizae are helpful in augmenting P availability of the soil.

According to an estimate, about 158 mt of rock phosphate reserves are available in Jhabua, Sagar and Sidhi districts of MP, which is the second largest producer of rock phosphate in India [2]. Two types of rock phosphate reserves in Jhabua district which have the range of P_2O_5 from 12-15 % and categorized of JRP in low-grade rock phosphate [3]. Rock phosphate is basically tri-calcium phosphate with non available to plant and is the main raw material for preparing chemical phosphatic fertilizers by treating mostly with sulphuric acid (H_2SO_4) [4]. The acids play a very vital role in the composting of organic materials and solubility of RP to the soluble P in the composting process [5].

The highest percent utilization of P from JRP was for the treatment that 50 % SSP+ 50 % JRP with compost under the cotton crop [6]. The rate of P solubilization increased with soybean leaf litter composition time, reaching its peak at 60 days with rock phosphates alone and at 90 days with pyrite-blended rock phosphates. The maximum P solubilization (as a percentage of total P added) with different rock phosphates and their mixtures with pyrite followed this order: HRP (11.4%)<HRP+pyrite (16.5%)<JRP (20.2%)<JRP+pyrite (26.5%) [7]. The efficacy and economics of Jhabua rock phosphate applied alone and in combination with bio fertilizers has been evaluated and recommendation is formed that there is scope of using Jhabua rock phosphate (JRP) for economizing fertilizer costs, which is available indigenously, as a substitute of single super phosphate when applied with FYM @ 5t ha^{-1} and/or blended with PSB either as seed treatment (10 g kg^{-1}) or as soil application (3 kg PSB with 50 kg FYM ha^{-1}) [8]. The objective of present study was to assess the P release pattern of Jhabua Rock phosphate when applied alone and in combination with organic manures, bio-fertilizers and industrial wastes in Vertisols with different moisture regimes.

Materials and Methods

A pot culture experiment was conducted to study the release pattern of Jhabua rock phosphate (JRP) and it was collected from Jhabua district of Madhya Pradesh, India, under All India Coordinated Research Project for Dry land Agriculture, College of Agriculture, Indore (M.P.). The study area is situated at an altitude of 555.7 meters above the mean sea level with latitude of 22°43'N and longitude of 75°56'E. The experiment comprised with 18 fertility treatments and three moisture regimes, and the details of treatments such as F_1:Control (No fertilizer), F_2:Elemental-S @ 40 kg S ha^{-1}, F_3:Spent wash 5 cm, F_4: Jhabua Rock Phoaphate @120 kg P ha^{-1}, F_5:Vermicompost @ 5 t ha^{-1}, F_6:Poultry manure @ 5 t ha^{-1}, F_7:Farm Yard Manure @ 10 t ha^{-1}, F_8: Single Super Phasphate @ 30 kg P ha^{-1}, F_9: Single Super Phasphate @ 30 kg P ha^{-1}+ JRP @ 60 kg P ha^{-1} (1:1), F_{10}:JRP @ 120 kg P ha^{-1} + Vermicompost @ 5 t ha^{-1}, F_{11}: JRP @120 kg P ha^{-1}+Poultry manure @ 2.5 t ha^{-1}, F_{12}:JRP @ 120 kg P ha^{-1} + Spent wash 5 cm, F_{13}: JRP @120 kg P ha^{-1}+ FYM @ 10 t ha^{-1}, F_{14}: JRP@120 kg P ha^{-1}+Elemental-S @40 kg S ha^{-1} , F_{15}:JRP @120 kg P ha^{-1} + Phosphorus Solubilizing Bacteria,

F_{16}:SSP @ 60 kg P ha^{-1}, F_{17}: JRP@120 kg P ha^{-1}+PSB@ 150 g ha^{-1}+FYM@5 t ha^{-1} , F_{18}: Di-Amonium Phosphate @ 60 kg P ha^{-1}. Soil moisture regimes were MR_1: 50% Field capacity, MR_2: Field capacity and MR_3: saturation. The incubation study was conducted for 90 days at room temperature. The experimental design used for the analysis of the data was CRD factorial with three replications. Soil samples were collected from pots at 15 days intervals up to 90 days after incubation. The Olsen method used for determining available P [9]. Soil classified as clayey texture soil (52.89% clay), Typic Haplusterts having slightly alkaline pH of 7.9, (1:2.5, soil:water), having normal electrical conductivity (0.32 dSm^{-1} at 25°C), low in $KMnO_4$ extractable-N (231 kg N ha^{-1}), medium in $NaHCO_3$ extractable–P (14.3 kg ha^{-1}), high in NH_4OAc-extractable-K (556.3 $kgha^{-1}$).

Result and Discussion

Characterization of amendments used for incubation:

The present investigation was started with the hypothesis that the incubation of rock phosphate with certain amendments, which can produce acids during incubation period, may help in dissolution of rock phosphate and will release the P in available form. For this purpose, the amendments were used *viz*. FYM, PSB, elemental-S, vermicompost, poultry manure, spent wash and SSP etc. Before conducting experiment, these amendments were characterized specially for pH and P content. The characteristics of amendments have been presented in [Table-1]. Many workers have attempted to study the effect of various amendments in soil to enhance the efficacy of RP. The strategies for increasing the efficiency of rock phosphate include: mixing it with soluble P fertilizer [10] mixing it with elemental S or iron pyrite [11] inoculating rock phosphate and S mixture with sulphur oxidizing bacteria such as *thiobacillus thiooxidous* and *T. thioporus* popularly known as biosuper [12] use of phosphate solubilizing organisms (PSO or PSB) [13, 14] use of vesicular arbascular mycorrhyzae (VAM) [15] and use of organic manure.

Table-1 *Characterization of amendment materials used in the study*

Amendment materials	Characterization
Jhabua Rock Phasphate	Alkaline in reaction, Contains 30% of its total P_2O_5 as tri-calcium phosphate which is neither water-soluble nor citrate soluble. Its solubility can be increased by adding acid or acid forming substances in to the soil where rock phosphate is applied.
FYM	Well decomposed farm yard manure used in the study was neutral in reaction pH was 6.8 and contains 0.46% P_2O_5.
Vermicompost	Neutral in reaction (pH 7.3), and contains 0.43% P_2O_5.
Poultry manure	Acidic in reaction with a pH of 5.3 and it contains 0.78% P_2O_5
Spent wash	It is a distillery waste, is quite acidic (pH 5.8) the percent P_2O_5 content is 0.56. The organic carbon content is also very high.
DAP	Di-ammonium phosphate is water soluble P fertilizer and it is acidic in reaction (pH 5.6) with 46% P_2O_5.
SSP	Single super phosphate is water soluble P fertilizer acidic in nature and contains 16% P_2O_5
Elemental -S	Elemental S is used as amendment in reclaiming saline and alkaline soils and as a source of S in neutral soils. It contains > 80% S and acid in nature.
PSB	Phosphorus solubilizing bacteria are heterotrophic in nature and have ability to solubilize P present in soluble form. The group includes bacteria like *Bacillus megatherium*, *B. circulans*, *B. subtilis*, *Pseudomonas straita, P.rathonis*, etc. These micro organisms produce H_2S, CO_2 and organic acids (lactic, glycolic, citric, succinic, oxalis, tartaric, malic, acetic etc.) which helps in solubilizing the P.

Temporal Changes in available-P as influenced by different treatments

The persuasion of the data [Table-2] revealed that the P availability has been increased in all the treatments with incubation period. Among fertility treatments the highest available-P was recorded after 90 day of incubation, in the treatment F17: JRP @120 kg P ha^{-1}+PSB +FYM (55.24 P_2O_5 ha^{-1}) which was closely followed by the treatment F18: DAP@60kg P ha^{-1}(50.2 P_2O_5 ha^{-1}), F16 SSP @60 kg P ha-(47.67 P_2O_5 ha^{-1}), F12:JRP@120 kg P ha^{-1}+ spent wash 5cm (45.70 P_2O_5 ha^{-1}), F14:JRP @120 kg P ha^{-1}+ elemental-S@40 ha^{-1} (44.25 P_2O_5 ha^{-1}), F15: JRP @120 kg P ha^{-1}+PSB (44.56 P_2O_5 ha^{-1}). Treatment F1 to F7 were at par with each other and treatment F10:JRP @120 kg P ha^{-1}+ vermicompost @ 5tha^{-1} was found significantly inferior to F17 and F18 and was found at par with rest of the treatments except the treatments F1,F2 and F3, which were significantly inferior to it. Results further suggested that when rock phosphate and other amendments were applied alone did not significantly increase the available P content as compared to control except treatments comprising of application of SSP (30 and 60 kg ha^{-1}), DAP 60 kg ha^{-1}. But, when rock phosphate was applied in soil blended with different amendments enhanced the P availability significantly during various incubation periods. Khan et al. [16] reported the increasing P availability trend with time was higher in the treatments where RP was added to poultry litter (PL), irrespective of the treatments, compared to the control where no RP was added. The enhanced P availability in PL+RP+EM with time could be due to the enhanced activities of effective microorganisms (EM) which have solubilized phosphate rock. Biswas et al. [17] reported that cow dung mobilized the insoluble P from Mussoorie rock phosphate for 15-20 days, which was reflected well in the P extracted by 2 % formic acid, 2% citric acid and Olsen's reagent. Mussoorie rock phosphate has been extensively used as a phosphorus source in acid soils [18] directly applied along with organic materials or phosphate solubilizing microorganisms (PSM) in neutral to slightly alkaline soils [19].

Table-2 *Available P status as influenced by different fertility treatments during incubation period*

Treatment	Available P_2O_5 (kg ha^{-1}) day after incubation (DAI)					
	15 (DAI)	30 (DAI)	45 (DAI)	60 (DAI)	75 (DAI)	90 (DAI)
F_1	12.11	12.69	13.82	14.38	14.95	15.26
F_2	13.97	14.08	15.17	15.75	16.81	18.19
F_3	14.65	14.68	15.96	16.57	17.86	19.16
F_4	14.52	16.48	18.12	18.83	20.12	20.78
F_5	14.75	17.64	19.44	21.35	23.02	23.42
F_6	14.96	16.99	19.89	22.06	25.16	23.30
F_7	15.01	16.97	19.16	19.88	20.89	22.78
F_8	16.41	19.46	20.88	24.84	28.65	32.12
F_9	23.58	28.15	31.55	33.75	37.71	41.24
F_{10}	22.48	24.76	26.88	30.91	35.12	38.09
F_{11}	23.62	26.15	30.90	32.02	38.72	42.68
F_{12}	27.39	31.58	36.25	39.60	42.84	45.70
F_{13}	22.72	26.00	30.24	37.03	37.78	41.85
F_{14}	23.73	28.89	35.36	39.02	41.92	44.25
F_{15}	22.33	27.40	34.06	36.84	40.68	44.56
F_{16}	27.81	33.29	38.55	41.38	45.23	47.67
F_{17}	34.17	37.82	41.56	46.18	51.51	55.24
F_{18}	31.92	34.76	39.58	41.83	47.11	50.21
CD 5%	6.96	7.91	8.91	10.01	11.07	11.88

Treatment comprising of application of elemental S along with rock phosphate has been effective in releasing the P was mainly due to formation of sulphur trioxide which reacts with H_2O and forms H_2SO_4. The formation of H_2SO_4 can help in enhancing the P availability in soil. Similarly, the application of spent wash due to its acidic nature (pH 4.2 – 6.2) might have helped in the dissolution of P from the RP. The mechanism involved in solubilizing P from rock phosphate by PSO include production of CO_2, H_2S and organic acids (lactic, glycolic, citric, succinic, oxalis, tartaric, malic, acetic etc.) by micro organisms [20].

From soil moisture regimes data it is clear that field capacity is the most suitable one for P availability point of view. If the moisture content of the soil either below or above the field capacity then P availability will be decrease. The magnitude of decrease is more at higher moisture content than lower one to that of field capacity [Table-3]. Among moisture regimes after 90 day incubation MR2 gave significantly more available P (41.24 kg P_2O_5 ha^{-1}) than MR1 (33.07 kg P_2O_5 ha^{-1}) and MR3 (30.10 kg P_2O_5 ha^{-1}) and MR1 and MR3 were at par each other. Kundu et al. [21] reported that in the mixture of rock phosphate and super phosphate in the ratio of 1:3, super phosphate dissolved the rock phosphate upto 45 days of application under 50 per cent WHC.

Table-3 *Available P status as influenced by soil moisture regimes during incubation period*

Treatment	Available P_2O_5 (kg ha^{-1})					
	15 (DAI)	30(DAI)	45(DAI)	60(DAI)	75(DAI)	90(DAI)
MR3 (saturation)	19.06	21.22	23.59	26.03	28.86	30.10
MR1 (50% FC)	20.37	23.09	26.37	28.55	31.07	33.67
MR2 (FC)	23.37	26.88	30.87	33.52	37.80	41.24
CD 5%	2.84	3.23	3.64	4.09	4.52	4.84

The enhanced dissolution of phosphate rocks in the rhizosphere was mainly due to the release of organic acids [22] studied parameters including high soil pH, high soil $CaCO_3$, low soil organic matter and drought which decrease P availability to plants in the calcareous soils of Iran, with arid and semiarid climates.

The significance of the interaction indicates that there are real differential effects of the incubation treatments and with the variation in the soil moisture regimes. So far as the treatment combinations are concerned, the highest P availability (61.52 kg P_2O_5 ha^{-1}) is obtained in case of F_{17} MR2 which, was found at par with the treatment F12,F14,F15,F16,F17 and F18 in moisture regime MR1 (50% FC); F8,F_9, F_{10} F_{11}, F_{12}, F_{13}, F_{14}, F_{15}, F_{16} and F_{18} in moisture regime MR2 (FC), and treatment F_{16}, F_{17}, F_{18} in moisture regime MR3 (Saturation) rest of the treatment combinations were inferior to it [Table-4]. Debnath and Basak [23] reported that irrespective of soils, seasons and moisture regimes the efficiency of rock phosphate was in the order of Basic slag > Mussoorie rock phosphate > Puluria rock phosphate. In increasing the available P, all the fertilizers were more effective in winter season than in summer and 50 per cent of water holding capacity regime was more favorable than submergence.

Table-4 *Interactive effect of different treatments on Available-P status after 90 days of incubation*

Treatment	Soil Moisture Regime		
	50% Field capacity (MR1)	Field Capacity (MR2)	Saturation (MR3)
F_1	14.82	16.13	14.82
F_2	16.91	20.72	16.92
F_3	18.62	21.13	17.72
F_4	18.25	24.82	19.25
F_5	20.01	30.92	19.32
F_6	22.92	31.25	15.71
F_7	20.72	27.72	19.90
F_8	29.92	40.82	25.62
F_9	39.92	51.90	31.90
F_{10}	33.22	48.82	32.22
F_{11}	40.82	50.90	36.31
F_{12}	47.36	50.91	38.82
F_{13}	37.80	50.82	36.92
F_{14}	43.82	51.13	37.79
F_{15}	41.13	54.62	37.91
F_{16}	45.82	52.28	44.91
F_{17}	55.26	61.52	48.92
F_{18}	47.91	55.89	46.82
CD5%	Interaction (Fertility x Moisture Regime)= 20.58		

P- Release pattern as influenced by fertility and moisture regime

The release pattern of different as compared to control the percent change in cumulative available-P over control was determined on 15,30,45,60,75 and 90 DAI and result are presented in [Fig-1]. It is evident from the data that at 15 DAI the maximum changes in available-P was obtained in case of F17 (182%) and minimum in case of F_2 (15%). Almost similar change was observed on other sampling dates. In almost all the treatments, the percent change (11% to 198%) was more at 30 DAI as compared to 15 DAI (15% to 198%). At 45 and 60 DAI the changes were almost at par in different treatments. The maximum cumulative percent change in available-P was recorded at 90 DAI (19 to 262 %).

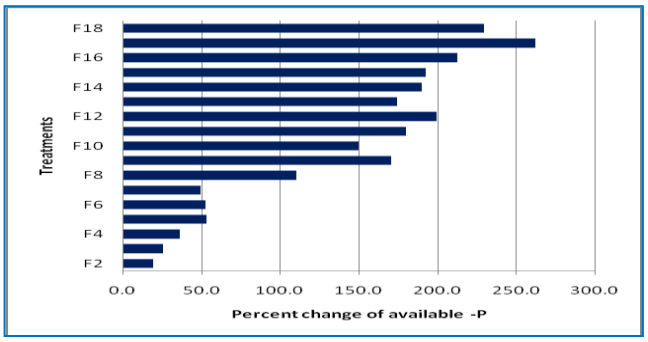

Fig-1 Percent change in available -P under different fertility treatments as compared to control

Higher reduction in P availability was observed at MR3: saturation moisture regime at all the sampling dates where it ranged from -23 to -37 %, while, in case of MR1: 50% Field capacity the per cent reduction was ranged from -15 to -25 %. Thus, highest P availability was obtained at MR2: field capacity [Fig-2].

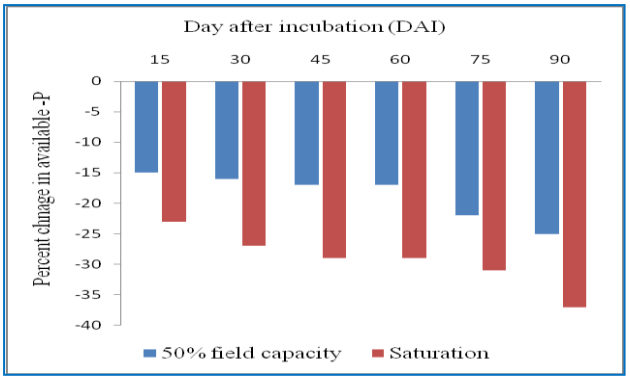

Fig-2 Percent change in available P over field capacity moisture regimes

For ascertaining the rate of P release during incubation period the best-fit equations were derived by plotting the available P vs time i.e. DAI. In all the cases the best fit equation has the form of equation [Eq-1].

$$Y = mx + c$$

In this equation Y= available P, x is time in days, m and c are the constants, where c is intercept and m is tan Ɵ which represents the slope of the curve and gives the rate of change of available P. The higher value of 'm' means higher rate of change thus higher release of available P. The overall results of P release pattern suggest that conjoint use of RP and amendments helps in releasing the available P when applied in Vertisols. It is seen [Table-5] that the highest value of rate of change of Available-P was obtained in the treatment F17(4.31) which was followed by treatment F15(4.30), F14 (4.15), F16(3.94), F13(3.93), F11(3.83), F18(3.73), F12(3.67), F9(3.44), F10(3.23), F8(3.10), F4(1.22), F6(1.95), F5(1.75), F7(1.46), F3(0.93), F2(0.79), and lowest in F1(0.54). These trends suggested that the rate of release of Av. P is more in case of conjoint use of rock phosphate and amendments in place of their individual application. The cumulative available P was more in F18, F17, than of F13, F14 and F15 but rate of release of P was less in treatments. Thus overall results suggest that conjoint use of JRP and amendments helps in releasing the available P when applied in Vertisols. The most effective treatments from this view point are F17, F18, F12, F16, F13, F14, F11, F10 and F9. In case of soil moisture regime the highest rate of release of P was obtained in MR2: field capacity moisture regime (3.56) followed by MR1: 50 % field capacity (2.55) and lowest in MR3: saturation (2.29). The cumulative available P was also highest in MR2 followed by MR1 and MR3. Kumari et al. [24] also studied under laboratory conditions and reported that citric and oxalic acids which, were generated from decomposition of rice straw were responsible for P solubilization from tri-calcium phosphate (TCP) and Udaipur rock phosphate. This might be the main reason for the higher rate of P release in the treatments where the RP was blended with amendments as compared to their individual application. At field capacity the production of these acids might be higher that why this moisture regime has resulted in higher P release. As observed in the present investigation, Tarabily et al. [25] first time reported that rhizosphere-competent actinomycetes are capable of solubilizing SP or PRP in soils. They isolated *Micromonospora endolithica*, which caused a significant drop in pH in a liquid medium amended with PRP, produced acid and alkaline phosphates, as well as a variety of organic acids and thus solublised considerable amounts of P from PRP.

Table-5 *Equations derived for determining the rate of change of available P along with R^2 values.*

Treatment	Equation	R^2 value	Available P at 90 DAI
Fertility treatments			
F_1	y = 0.549x + 12.095	0.875	15.26
F_2	y = 0.7931x + 12.991	0.875	18.19
F_3	y = 0.9343x + 13.21	0.958	19.16
F_4	y = 1.2266x + 13.849	0.967	20.78
F_5	y = 1.7543x + 13.797	0.961	23.42
F_6	y = 1.9537x + 13.555	0.887	23.30
F_7	y = 1.4666x + 13.982	0.975	22.78
F_8	y = 3.1069x + 13.076	0.996	32.12
F_9	y = 3.4431x + 20.391	0.994	41.24
F_{10}	y = 3.2331x + 18.391	0.985	38.09
F_{11}	y = 3.8323x + 18.935	0.973	42.68
F_{12}	y = 3.6766x + 24.359	0.992	45.70
F_{13}	y = 3.9366x + 18.825	0.973	41.85
F_{14}	y = 4.1529x + 20.993	0.966	44.25
F_{15}	y = 4.3034x + 18.935	0.984	44.56
F_{16}	y = 3.9414x + 25.193	0.979	47.67
F_{17}	Y= 4.3154x + 29.309	0.996	55.24
F_{18}	y = 3.7357x + 27.827	0.992	50.21
Soil Moisture regimes			
MR1 (50% FC)	y = 2.2903x + 16.861	0.993	30.10
MR2(FC)	y = 2.5571x + 18.13	0.994	33.07
MR3(Saturation)	y = 3.5646x + 19.804	0.998	41.24

Conclusion

Over all conclusion drawn from the study on the application of JRP along with various amendment and their effects on P availability and dissolution of JRP clearly suggest that JRP can be used as a source of available P when it is applied in conjunction with any of FYM + PSB, PSB, spent wash, vermicompost, poultry manure, SSP (1:2), elemental-S. etc. These treatments were at par with those of P fertilizers such as SSP and DAP. It is further concluded that the efficiency of P release of these treatments was higher at field capacity moisture regime as compared to 50% of field capacity and saturation moisture regime. The most effective treatment combination was F_{17} MR_3 amongst all combinations. All the other fertility treatments gave best results at field capacity moisture regime.

Conflict of Interest: None declared

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