UNDER PEER REVIEW

Original Research Article

GEO-SPATIAL SOIL FERTILITY MAPPING FOR KHAPRADIH FARM AT DKS COLLEGE OF AGRICULTURE, BHATAPARA CHHATTISGARH

Abstract

The present study aimed to assess various chemical properties and available macro and micronutrients in the soil. 101 geo-referenced soil surface samples were collected at 100-meter intervals and analyzed in the laboratory for pH, electrical conductivity (EC), organic carbon (OC), and available macro-nutrients (N, P, K, S) and micro-nutrients (Fe, Mn, Cu, Zn, B). The results showed that the soil was generally neutral in pH, with a range of 5.7 to 7.6. The electrical conductivity indicated non-saline, varying from 0.11 to 0.26 dSm^{-1}. Available nutrients were categorized as low, medium, or high based on nutrient index values. The study revealed that the soil in the area had low levels of available nitrogen and sulfur, medium levels of available phosphorus and potassium, and high levels of available iron, manganese, and copper. Zinc was found to be in the medium category, while boron was low. Significant correlations were observed between various physico-chemical properties and available macro and micro nutrients. Using ArcGIS 10.4.1, thematic maps were created, representing the spatial distribution of soil properties and nutrient status. Based on these findings, fertilizer recommendations were developed for major crops grown in the area, resulting in enhanced crop productivity. The study concludes that GPS and GIS-based tools are valuable for soil fertility mapping, monitoring, and site-specific nutrient management, leading to sustainable and optimal crop yields.

Keywords: Soil fertility map, physico-chemical parameters, Geographic Information System (GIS), Global Positioning System (GPS)

Introduction

Intensive farming and conventional resource use disturb our ecosystem and threaten soil health, leading to reduced crop production and food insecurity. Effective nutrient management practices can ensure long-term sustainability of our agricultural ecosystem and it's vital for enhancing plant productivity. To address this, understanding the essentiality of nutrients for growth and development of plants and the Soil-Plant-Atmosphere Continuum (SPAC) relationship is crucial for maintaining or increasing soil fertility and sustaining agricultural production. Whatever the technological advances achieved, soil will always be necessary for humans to grow most of the food, fodder and fiber they need (Chen *et al.*, 2022) [4]. Continuous supply of food for growing population to improve the productivity of our soil would be change our ability. Hence, a pressing challenges and difficulties to develop and implement soil, crop, and nutrient management technologies that optimizing plant productivity and soil quality. Describing the spatial variability of soil across a field has been difficult until new technologies such as Global Positioning Systems (GPS) and Geographic Information Systems (GIS) were introduced (Reddy *et al.*, 2018) [16]. GPS and GIS technologies enable easy collection of soil samples and creation of thematic fertility maps, supporting geo-statistical analysis to characterize spatial variability. GIS-generated soil fertility maps serve as valuable decision-support tools for long-term monitoring and management. Soil testing and modern approaches like STCR/targeted yield ensure balanced nutrient management and sustainable soil fertility. These methods provide precise fertilizer recommendations, aiming to achieve specific crop yield goals while maintaining soil health.

Materials and Methods

The study area will be the Khapradih Farm of DKS College of Agriculture & Research Station, district Balodabazar-Bhatapara of Chhattisgarh state, located between Latitude-19°44′ 02.93″ to 21°44′33.56″ N Longitude - 81°57′59.43" to 81°58′44.41″ E Altitude - 268-270 m above the mean sea level. 101 surface soil samples were collected on the basis of grid point which covered almost more than 80% cultivated area of the Khaparadih farm. Surface soil samples (15 cm) were collected from soil with the help of auger. Soil samples collected from the study area were dried and crushed and passed through 2 mm sieve and stored in properly labeled plastic bags for analysis. The pH (1:2.5) and electrical conductivity (EC) (1:2.5) of soils were measured using standard procedures as described by Jackson (1973) [6] Soil pH was determined by glass electrode pH meter, electrical conductivity with Solu-bridge organic C by wet digestion method (Walkley and Black's, 1934) [19]. Available nitrogen was estimated by alkaline KMnO4 method (Subbiah and Asija, 1956) [13], Available phosphorus extracted by 0.5M $NaHCO_3$ solution buffer at pH 8.5 (Olsen *et al*.,1954) [11] was used for neutral-alkaline soils. Available potassium was estimated through neutral normal ammonium acetate by flame-photometer. (Jackson, 1967) [7]. Available Sulphur (S) by method of Williams and Steinbergs (1959) [20]. The micronutrients (Zn, Cu, Fe and Mn) were extracted with 0.005M diethylene triamine penta acetic acid (DTPA), 0.01M calcium chloride dehydrate and 0.1M tri ethanol amine buffered at pH 7.3 (Lindsay and Norvell, 1978) [5] and concentrations were analyzed by atomic absorption spectrophotometer. Berger and Troug (1939) [3] identified a method for determining available B in soil. Using this method, hot water was used as the extracting agent. The analytical results of soil sample were categorized as low, medium and high categories for organic carbon and macronutrients based on standard rating values.

Nutrient index and fertility rating

According to Ramamoorthy and Bajaj (1969). nutrient index values (NIV) for various soil parameters were determined from the amount or proportion of samples with low, medium, or high nutrient status and classified into different fertility groups.

$$NIV = 1 \times PL + 2 \times PM + 3 \times PH\ 100$$

Where, NIV = nutrient index value PL= % samples fall under low category. PM= % samples fall under medium category. PH= % samples fall under high category. In this assessment, NIV of less than 1.33, 1.33-2.33 and 2.33 indicates low, medium and high fertility level respectively for each nutrient.

Soil Fertility Map

Soil fertility maps were prepared by using GPS reading for the physicochemical parameters: pH, EC and OC and available soil macronutrients: N, P, K, and S and available micronutrients: Fe, Mn, Cu, Zn and B for depicting the spatial variability using sophisticated geospatial tools viz. ArcGIS- 10.4.1 software.

RESULTS AND DISCUSSION

The soils under study were evaluated for nutrient availability with respect to the major nutrients and nutrient index figures for categorization of soils into different fertility classes.

Soil reaction (pH)

A study on the soil reaction (pH) of the study area revealed that the soils were slightly acidic to slightly alkaline and the pH varied from 5.74 to 7.644 with a mean value of 7.07 ± 0.44. Indicated that the overall soil pH of the study area rating under neutral category. Soil reaction (pH) generally affects the solubility of minerals and can influence the plant growth by stimulating activity of beneficial microorganisms (Amara and Patil, 2014) [1]. Percentage distribution of soil samples are depicted in Table no. 1. The spatial distribution and status of pH at the Khapradih Farm is depicted in Fig.1.

Table 1 Distribution of soil samples under different pH rating

Soil pH			
Classes	Range	No. of Samples	Samples (%)
Slightly acidic	< 6.5	12	12
Neutral	6.5 – 7.5	86	85
Slightly alkaline	7.5 – 8.5	3	3

Soil electrical conductivity (dSm^{-1})

The electrical conductivity of the soil water suspension ranged from 0.11 to 0.26 dSm^{-1} with a mean value of 0.17 ± 0.03 dSm^{-1}. All the soil samples recorded under the normal range. Electrical conductivity of entire soil samples of study area was rated under non-saline or safe limit category with NIV value 1.0 in Table 2. Spatial distribution of total soluble salt content of soils of Khapradih Farm in the form of EC is depicted in Fig.1. Similar findings were recorded by Meher *et al.*, (2020) [10].

Table 2 Distribution of soil samples under different EC rating

Soil EC dSm^{-1}			
Classes	Range (dSm^{-1})	No. of Samples	Samples (%)
Good (No any harmful effect on crop)	< 1	101	100

Soil Organic Carbon (%)

The variations in the soil organic carbon content were 0.41 to 0.74% with an average of (0.59 ± 0.07) %. Percentage distribution of soil samples are depicted in Table no. 3. Overall, OC content of study area fertility rating under medium category with NIV 1.92 in Table 3. Spatial distribution of soil OC content of Khapradih Farm is illustrated in Fig. 1. Similar findings were recorded by Bal Krishna, (2018) [8].

Table 3 Distribution of soil samples under different OC rating

Soil organic carbon (%)					
Classes	Range (%)	No. of Samples	Samples (%)	NIV	Fertility Rating
Low	< 0.5	8	8	1.92	Medium
Medium	0.5 – 0.75	93	92		

MACRO-NUTRIENT STATUS

Available nitrogen (N)

The available nitrogen content in the soil samples ranged from 169.7 to 256.8 kg ha^{-1} with a mean value of 227.9 ±18.61 kg ha^{-1}. Percentage distribution of soil samples are depicted in Table no. 4. All the soil samples were found in low nitrogen category. Entire soil sample of study area available N content, fertility rating under low category with NIV 1.0 in Table 4. Spatial distribution of soil N content of Khapradih Farm is depicted in Fig. 1. Similar findings were recorded by Awanish Kumar (2017) [2].

Table 4 Distribution of soil samples under different Nitrogen rating

Soil available nitrogen (kg ha^{-1})					
Classes	Range (kg ha^{-1})	No. of Samples	Samples (%)	NIV	Fertility Rating
Low	< 280	101	100	1	Low

Available phosphorus (P)

The status of the available phosphorus varied from 11.2 – 22.06 kg ha^{-1} with an average value of 16.74 ± 2.54 kg ha^{-1}. Percentage distribution of soil samples are depicted in Table no. 5. Overall soil sample of study area available P content, fertility rating under medium category based on NIV 2.0 as presented in table 5. Spatial distribution of soil P content of Khapradih Farm is illustrated in Fig. 1. Similar findings were recorded by Patel *al.*, (2018) [12].

Table 5 Distribution of soil samples under different phosphorus rating

Soil available phosphorus (kg ha^{-1})					
Classes	Range (kg ha^{-1})	No. of Samples	Samples (%)	NIV	Fertility Rating
Low	< 12.5	3	23.80	2	Medium
Medium	12.5 – 25	97	72.22		

Available potassium (K)

The available potassium of the study area varied from 259.6 to 399.3 kg ha^{-1} with a mean value of 352.3 ± 36.5 kg ha^{-1} Percentage distribution of soil samples are depicted in Table no. 6. Overall soil samples of study area for available K concentrated under high category based on NIV 2.74 as presented in table 6. Spatial distribution of soil K content of Khapradih Farm is illustrated in Fig. 1. Similar findings were recorded by Singh *et al.,* (2018) [14].

Table 6 Distribution of soil samples under different potassium rating

Soil available potassium (kg ha^{-1})					
Classes	Range (kg ha^{-1})	No. of Samples	Samples (%)	NIV	Fertility Rating
Medium	135 – 335	26	26	2.74	High
High	> 335	75	74		

Available Sulfur (S)

The sulfur status varied from 11.3 to 35.1 kg ha^{-1} with a mean value of 22.09 ± 6.05 kg ha^{-1}. Percentage distribution of soil samples are depicted in Table no. 7. Overall soil samples of study area available S content, fertility rating under low category based on NIV 1.48 in Table 7. Spatial distribution of soil S content of Khapradih Farm is depicted in Fig. 2. Similar findings were recorded by Iyer *et al*., (2020) [5].

Table 7 Distribution of soil samples under different sulfur rating

Soil available sulfur (kg ha^{-1})					
Classes	Range (kg ha^{-1})	No. of Samples	Samples (%)	NIV	Fertility Rating
Low	< 22.5	53	52	1.48	Medium
Medium	22.5 – 35	48	48		

The available micronutrients status

Available iron (Fe) status in soil

The status of the available Fe varied from 6.9 to 16.4 mg kg^{-1} with a mean value of 11.52 ± 1.90 mg ha^{-1}. Percentage distribution of soil samples are depicted in Table no.8. Overall available Fe content in soil samples of study area were rated under high category based on NIV 2.91 (Table 8). Spatial distribution of soil Fe content of Khapradih Farm is illustrated in Fig. 2. Similar findings were recorded by Singh *et al*., (2018) [14].

Table 8 Distribution of soil samples under different iron rating

Soil available iron (mg kg^{-1})					
Classes	Range (mg/kg)	No. of Samples	Samples (%)	NIV	Fertility Rating
Sufficient	4.5 – 9.0	9	9	2.91	High

Available Manganese (Mn) status in soil

The status of the available Mn ranged from 8.14 to 32.4 mg kg^{-1} with a mean value of 19.14 ± 6.4 mg ha^{-1}. Percentage distribution of soil samples are depicted in Table no.9. Overall soil samples of study area available Mn content, fertility rating under high category based on NIV 3.0 as presented in table 9. Spatial distribution of soil Mn content of Khapradih Farm is illustrated in Fig. 2. Similar findings were recorded by Bal Krishna *et al.*, (2018) [8].

Table 9 Distribution of soil samples under different manganese rating

Soil available manganese (mg kg^{-1})					
Classes	Range (mg kg^{-1})	No. of Samples	Samples (%)	NIV	Fertility Rating
High	7.0	101	100	3	High

Available Copper (Cu)

The status of the available Cu in the study area ranged from 0.42 to 2.66 mg kg^{-1} with a mean value of 1.25 ± 0.6 mg ha^{-1}. Percentage distribution of soil samples are depicted in Table no.10. All the samples were found to be high in Cu. Overall soil samples of study area available Zn content, fertility rating under high category based on NIV 3.0 (Table 10). Spatial distribution of soil Cu content of Khapradih Farm is illustrated in Fig. 2. Similar findings were recorded by Singh *et al*., (2018) [14].

UNDER PEER REVIEW

Table 10 Distribution of soil samples under different copper rating

Soil available copper (mg kg^{-1})					
Classes	Range (mg kg^{-1})	No. of Samples	Samples (%)	NIV	Fertility Rating
High	> 0.4	124	98.41	3	High

Available Zinc (Zn)

The status of the available Zn varied from 0.33 to 1.69 mg kg^{-1} with a mean value of 0.86 ± 0.33 mg ha^{-1}. Percentage distribution of soil samples are depicted in Table no.11. Accordingly, it was found that 26 %, 52 %, 22 % samples were recorded under deficient, sufficient and high range for available Zn, respectively. Overall soil samples of study area available Zn content, fertility rating under medium category based on NIV 1.96. Spatial distribution of soil Zn content of Khapradih Farm is illustrated in Fig. 2. Similar findings were recorded by Mehar *et al*., (2020) [10].

Table 11 Distribution of soil samples under different zinc rating

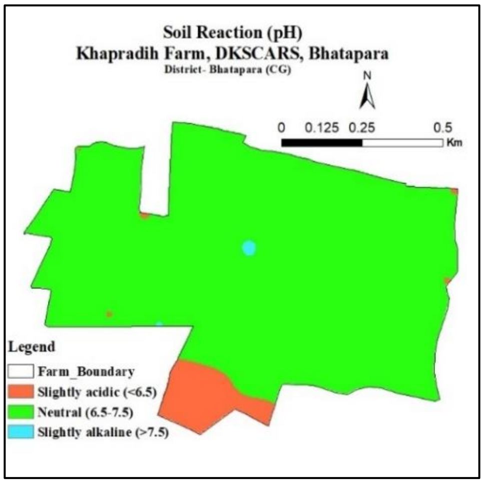
Soil available zinc (mg kg^{-1})					
Classes	Range (mg kg^{-1})	No. of Samples	Samples (%)	NIV	Fertility Rating
Deficient	< 0.6	26	26	1.96	Medium
Sufficient	0.6 – 1.2	53	52		
High	> 1.2	22	22		

4.5.5 Available boron (B)

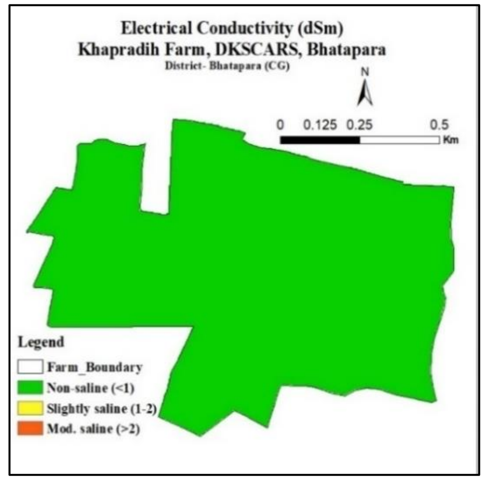
The status of the available B varied from 0.13 to 0.28 mg kg^{-1} with a mean value of 0.19 ± 0.03 mg ha^{-1}. Percentage distribution of soil samples are depicted in Table no.11. All the samples were found to be low rating in available B content with NIV 1.0 as presented in table 11. Spatial distribution of soil B content of Khapradih Farm is illustrated in Fig. 2. Similar findings were recorded by Rawal *et al.*, (2018) [18].

Table 12 Distribution of soil samples under different boron rating

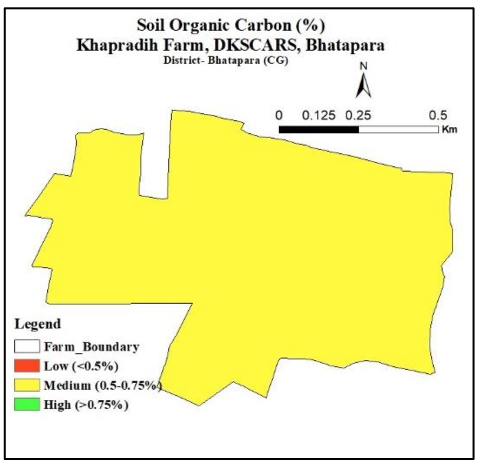
Soil available boron (mg kg^{-1})					
Classes	Range (mg kg^{-1})	No. of Samples	Samples (%)	NIV	Fertility Rating
Deficient	< 0.5	101	100	1	Low



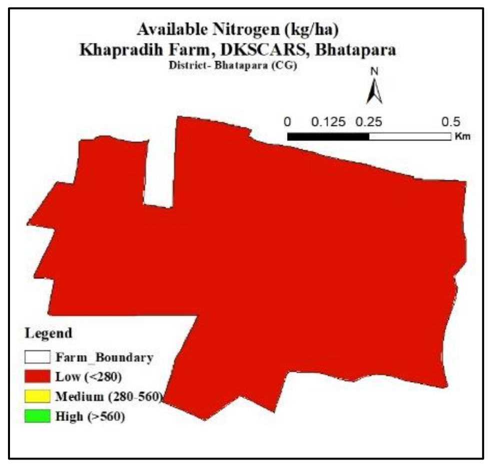
Soil Reaction (pH)



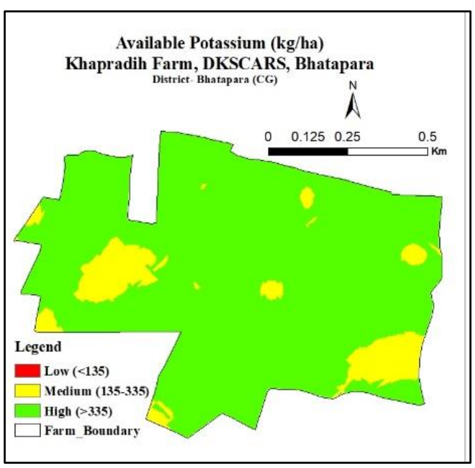
Electrical Conductivity



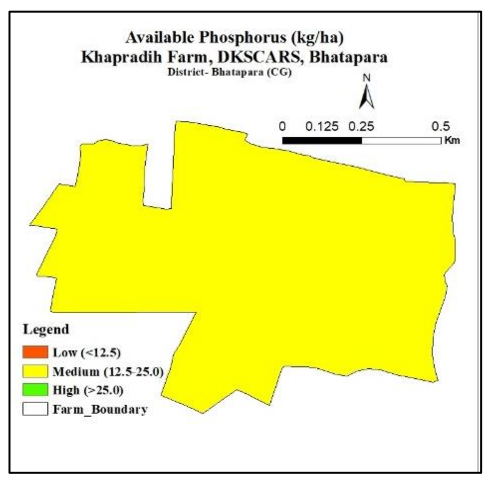
Available Nitrogen



Available Phosphorus

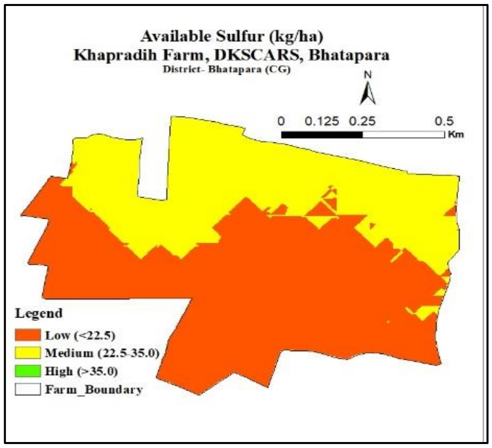


Available Potassium

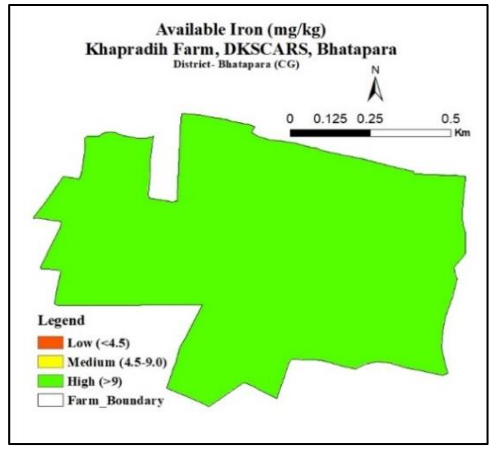


Available Potassium

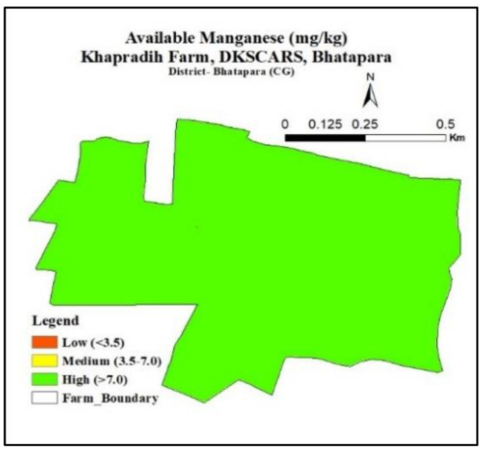
Fig.1 Spatial distribution of Available nutrient in soils of Khapradih farm, DKS College of Agriculture and Research Station, Balodabazar-Bhatapara district (C.G.).



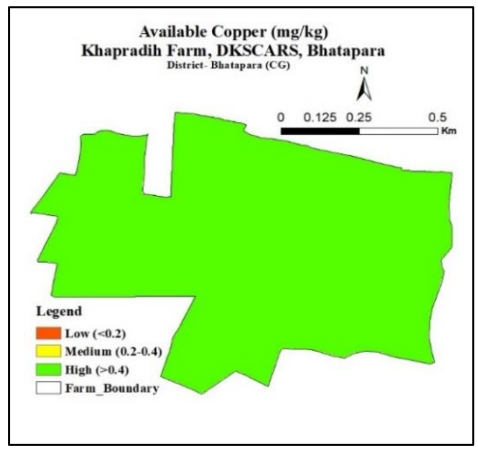
Available Sulfur



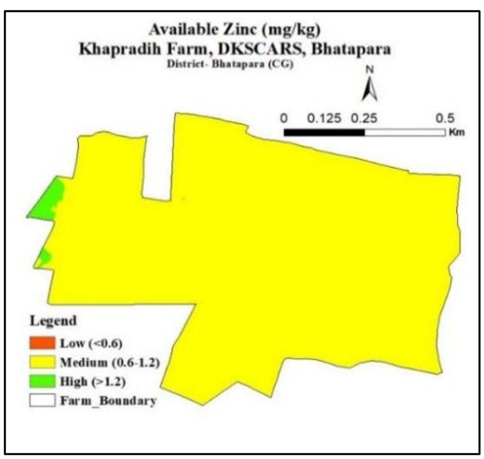
Available Iron



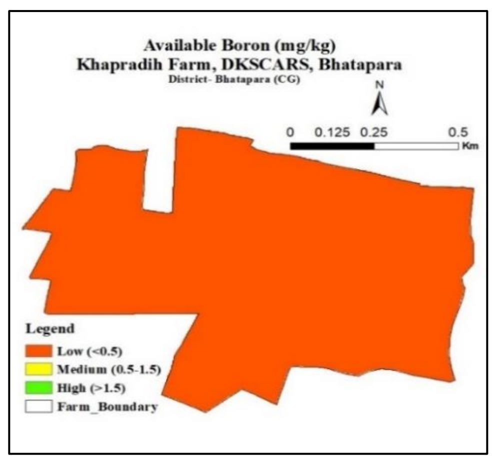
Available Manganese



Available Copper



Available Zinc



Available Boro

Fig.2 Spatial distribution of Available nutrient in soils of Khapradih farm, DKS College of Agriculture and Research Station, Balodabazar-Bhatapara district (C.G.).

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