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Economic Evaluation of Maize (*Zea mays* L.) as Influenced by Soil Nutrient Availability and Benefit-Cost Ratio under the Malwa Region

Ankit Labana[1], Matukdhari Singh[2], Ajanta Borah[3], Kamal Kumar Suthar[4], Lekhani Soni[5] and Narendra Patidar[6]

[1,4,5,6]Mandsaur University, Mandsaur 458 001, M.P., India
[2]Faculty of Agriculture Sciences, Mandsaur University, Mandsaur 458 001, M.P., India
[3]Faculty of Agriculture, Medicaps University, Indore 453 331, M.P., India

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ABSTRACT

The present investigation titled "Economic Evaluation of Maize (*Zea mays* L.) as Influenced by Soil Nutrient Availability and Benefit–Cost Ratio under the Malwa Region". The present experiment was conducted at Research Farm, under Mandsaur University, Mandsaur (Madhya Pradesh). Mandsaur (Madhya Pradesh) which is situated at latitude 24^0C 4'36.61''N, longitude $75^0$4'9.46'' E and at an altitude of 442.16 meters above the mean sea level. The experiment involved two main plot treatments: B_1 for flat bed sowing and B_2 for raised bed sowing. There were four sub-plot treatments based on spacing: S_1 for broadcasting, S_2 for 30×25 cm spacing, S_3 for 45×25 cm spacing, and S_4 for 60×25 cm spacing. The treatment combinations were as follows: T_1: Flat bed + Broadcasting (B_1S_1), T_2: Flat bed + 30×25 cm spacing (B_1S_2), T_3: Flat bed + 45×25 cm spacing (B_1S_3), T_4: Flat bed + 60×25 cm spacing (B_1S_4),T_5: Raised bed + Broadcasting (B_2S_1), T_6: Raised bed + 30×25 cm spacing (B_2S_2), T_7: Raised bed + 45×25 cm spacing (B_2S_3) andT_8: Raised bed + 60×25 cm spacing (B_2S_4). There were eight treatments in total, and the experiment was conducted in 24 plots. The gross plot size 4.0 × 5.0 = 20 m^2 and net plot size was 3.5 ×4.5 = 15.75 m^2. The gross plot area was calculated to be 383 m^2. The seed rate used for the experiment was 25 kg per hectare. Results revealed that the **raised bed sowing method** significantly enhanced the availability of major soil nutrients- nitrogen (278.6 kg/ha), phosphorus (24.2 kg/ha), and potassium (230.5 kg/ha) as compared to the flat bed method. Raised bed sowing with 60×25 cm spacing (T_8) recorded the maximum availability of nutrients, with 292.5 kg/ha of nitrogen, 26.5 kg/ha of phosphorus, and 242.0 kg/ha of potassium. Flat bed sowing with broadcasting (T_1), which resulted in 255.3 kg/ha of nitrogen, 20.2 kg/ha of phosphorus, and 210.4 kg/ha of potassium. From an economic standpoint, the treatment Raised bed sowing with 60×25 cm spacing (T_8) yielded the highest gross return (Rs 91,000/ha), net return (Rs 44,000/ha), and benefit-cost ratio (1.94). Conversely, the Flat bed sowing with broadcasting (T_1) recorded the lowest gross return (Rs 56,000/ha), net return (Rs 14,000/ha), and B:C ratio (1.33). These findings clearly demonstrate that raised bed sowing combined with wider spacing (60×25 cm) is a superior agronomic strategy for enhancing both nutrient availability and profitability in maize cultivation under the agro-climatic conditions of the Malwa region.

Keywords: *Cost, Benefit, Economics, Flat bed, Growth and Maize.*

([1,4,5]MSc. (Ag.) Agronomy Scholar, [2]Assistant Professor, [3]Assistant Professor)

Introduction

Maize (*Zea mays* L.), a globally important cereal crop, widely recognized for its adaptability and high yield potential. As a member of the Poaceae family, it is a diploid species with a chromosome number of 2n = 20 and follows the C_4 photosynthetic pathway. The plant exhibits a fibrous root system and is cultivated as an annual across a wide range of agro-climatic conditions (Ahmed *et al*., 2011). In India's Malwa region, maize is primarily grown during the Kharif season, thriving in the region's black cotton and loamy soils, supported by monsoonal rainfall.

Maize serves as a key source of carbohydrates and proteins and is extensively utilized for food, animal feed, and as raw material in various industrial sectors including biofuel and starch production (Attia *et al*., 2009). Nutritionally, maize grains are composed of approximately 60–70% carbohydrates, 8-10% protein, and are enriched with essential vitamins such as thiamine and niacin (Ahmad *et al*., 2014).

India ranks among the top five maize-producing nations globally, following the United States, China, Brazil, and Argentina (Stanford and English, 1949). During the 2023-24 cropping season, maize was grown on nearly 108.87 lakh hectares in India, up from 105.24 lakh hectares in the previous year. A significant portion-around 85.79 lakh hectares or 78.8%-was under Kharif maize cultivation, highlighting its importance during the monsoon season (Stanford and English, 1949).

Efficient maize production hinges not only on genetic and environmental factors but also on the judicious management of soil nutrients. Nitrogen (N), phosphorus (P), and potassium (K) are the three primary macronutrients essential for plant growth, influencing critical physiological functions such as chlorophyll formation, energy transfer, root development, and grain filling in Maize (Dwipa *et al*., 2020). The availability of these nutrients in the soil directly impacts biomass accumulation, yield attributes, and overall productivity (Jalia *et al*., 2008).

Alongside agronomic performance, economic viability is a key concern for maize growers. Rising input costs, especially for fertilizers and labor, demand a thorough evaluation of cost–benefit dynamics (Metson, 1956). Parameters such as cost of cultivation, gross return, net return, and benefit-cost (B:C) ratio serve as vital indicators of the profitability and sustainability of farming practices (Nandeha *et al*., 2017). Understanding how soil nutrient availability correlates with these economic outputs can help farmers make more informed decisions on input management and resource allocation.

In the Malwa region, farmers often adopt traditional nutrient management practices without adequate soil testing, leading to nutrient imbalances and economic inefficiencies. Therefore, a comprehensive assessment of the relationship between available soil N, P, and K levels and economic indicators is essential for developing optimized, site-specific, and cost-effective maize production strategies (Raza *et al*., 2019)

This research aims to evaluate the influence of available macronutrients (N, P, K) on the economic performance of maize in terms of cost of cultivation, gross return, net return, and benefit–cost ratio under the agro-climatic conditions of the Malwa region

Materials and Methods

The present investigation titled Economic Evaluation of Maize (*Zea mays* L.) as Influenced by Soil Nutrient Availability and Benefit–Cost Ratio under the Malwa Region. The present experiment was conducted at Research Farm, under Mandsaur University, Mandsaur (Madhya Pradesh). Mandsaur which is situated at latitude 24^0C 4′36.61′′N, longitude $75^0$4′9.46′′ E and at an altitude of 442.16 meters above the mean sea level. The experiment involved two main plot treatments: B_1 for flat bed sowing and B_2 for raised bed sowing. There were four sub-plot treatments based on spacing: S_1 for broadcasting, S_2 for 30×25 cm spacing, S_3 for 45×25 cm spacing, and S_4 for 60×25 cm spacing. The treatment combinations were as follows: T_1: Flat bed + Broadcasting (B_1S_1),T_2: Flat bed + 30×25 cm spacing (B_1S_2),T_3: Flat bed + 45×25 cm spacing (B_1S_3),T_4: Flat bed + 60×25 cm spacing (B_1S_4),T_5: Raised bed + Broadcasting (B_2S_1),T_6: Raised bed + 30×25 cm spacing (B_2S_2), T_7: Raised bed + 45×25 cm spacing (B_2S_3) andT_8: Raised bed + 60×25 cm spacing (B_2S_4). The experiment was laid out using a split plot design with three replications. There were eight treatments in total, and the experiment was conducted in 24 plots. The gross plot size 4.0 × 5.0 = 20 m^2 and net plot size was 3.5 ×4.5 = 15.75 m^2. The gross plot area was calculated to be 383 m^2. The seed rate used for the experiment was 25 kg per hectare.

Determination of Available Nutrients in Soil

Available Nitrogen (N) (kg/ha)

Available nitrogen in soil was estimated using the alkaline permanganate method as described by (Subbiah and Asij, 1956). Soil samples were extracted with alkaline KMnO solution, and the amount of nitrogen released was measured colorimetrically. The available nitrogen content was expressed in kg per hectare using the following formula:

$$\text{Available N (kg/ha)}=\frac{[(\text{N content in soil (mg/kg)}\times\text{soil bulk density (g/cm}^3)\times\text{soil depth (cm)}\times 10]}{1{,}000}$$

2. Available Phosphorus (P) (kg/ha)

Available phosphorus was determined by the Olsen method using 0.5 M sodium bicarbonate extractant (pH 8.5). The extracted P was measured spectrophotometrically using the molybdenum blue color method. The available phosphorus content was calculated in kg/ha using:

$$\text{Available P (kg/ha)}=\frac{[\text{P content in soil (mg/kg)}\times\text{soil bulk density (g/cm}^3)\times\text{soil depth (cm)}\times 10]}{1{,}000}$$

Available Potassium (K) (kg/ha)

Available potassium was estimated using ammonium acetate extraction (1 N NHOAc, pH 7.0) followed by flame photometry (Stanford and English, 1949). The potassium concentration was converted into kg/ha with the formula:

$$\text{Available K (kg/ha)}=\frac{[(\text{K content in soil (mg/kg)}\times\text{soil bulk density (g/cm}^3)\times\text{soil depth (cm)}\times 10)]}{1{,}000}$$

Economic Parameters Calculation

Cost of Cultivation (Rs/ha)

The total cost of cultivation includes all expenses on inputs incurred during maize production such as land preparation, seed, fertilizers, labor, irrigation, plant protection, harvesting, and transportation:
Cost of Cultivation (Rs/ha) = Σ(Cost of all inputs per hectare)

Gross Return (Rs/ha)

Gross return was calculated based on the total market value of maize grain and by-products harvested from one hectare:
Gross Return (Rs/ha) = Yield (kg/ha)×Market Price (Rs/kg)

Net Return (Rs/ha)

Net return was obtained by subtracting the total cost of cultivation from the gross return:

Net Return (Rs/ha) = Gross Return (Rs/ha)-Cost of Cultivation (Rs/ha)

Benefit–Cost (B:C) Ratio: The benefit–cost ratio was calculated to assess the economic efficiency of maize production:

$$\text{B:C Ratio}=\frac{\text{Gross Return (Rs/ha)}}{\text{Cost of Cultivation (Rs/ha)}}$$

Results and Discussion

Available Nitrogen (kg/ha)

Main Effect of Sowing Methods

The data in Table 1 shows that raised bed sowing (B_2) recorded a higher available nitrogen content (278.6 kg/ha) compared to flat bed sowing (B_1) (268.4 kg/ha). Nitrogen availability was higher under raised bed conditions (278.6 kg/ha) than in flat beds (268.4 kg/ha), likely due to improved aeration and reduced denitrification losses. Similarly, phosphorus content increased in the raised bed system (24.2 kg/ha), potentially as a result of better root development and reduced fixation. Similar findings were reported by (Ahmad *et al.*, 2014; Attia *et al.*, 2009; Sharanabasappa and Basavanneppa, 2019) in Maize.

Main Effect of Spacing

Among the spacing treatments, the widest spacing (S_4: 60×25 cm) exhibited the highest nitrogen content (285.5 kg/ha), followed by S_3 (280.0 kg/ha), S_2 (270.5 kg/ha), and the lowest value was observed under broadcasting (S_1) at 260.1 kg/ha. The higher nitrogen content observed under the widest spacing treatment (S4: 60×25 cm) can be attributed to reduced plant density, which minimizes intra-specific competition for soil nutrients, especially nitrogen. With more space between plants, root systems can expand more freely, improving nutrient absorption efficiency from the surrounding soil volume. Additionally, wider spacing enhances aeration and microbial activity in the rhizosphere, promoting better nitrogen mineralization and availability. In contrast, broadcasting (S_1), which leads to overcrowded conditions, likely, resulted in greater competition among plants and limited nutrient uptake per plant, thereby reducing the overall available nitrogen content in the soil. A corresponding trend was reported by (Sharanabasappa and Basavanneppa, 2019; Stanford and English, 1949;Yadav *et al.*, 2019) under similar maize-growing conditions.

Interaction effect (Sowing Method × Spacing)

The interaction effects showed that the highest available nitrogen (292.5 kg/ha) was found in T_8 (B_2S_4 - Raised bed + 60×25 cm spacing), while the lowest nitrogen content (255.3 kg/ha) was recorded in T_1 (B_1S_1 – Flat bed + Broadcasting). The improved drainage and root zone conditions associated with raised beds may facilitate more efficient nutrient cycling and uptake. These results are in conformity with the findings of (Raza *et al.*, 2019; Simic and Stefanovic, 2007) in Maize.

Effect on Available Phosphorus (kg/ha)

Main Effect of Sowing Methods

Phosphorus availability was influenced by sowing methods, with raised bed (B_2) showing higher phosphorus levels (24.2 kg/ha) compared to flat bed (B_1) at 22.5 kg/ha. This improvement under raised bed conditions may be attributed to better root proliferation and reduced phosphorus fixation (Table 1) demonstrated a gradual increase in nutrient availability with increased spacing, highlighting the importance of optimal plant density in nutrient management. The present results are in consonance with (Sharanabasappa and Basavanneppa, 2019 and Yadav *et al.*, 2019) in Maize.

Main Effect of Spacing

The widest spacing (S_4: 60×25 cm) again resulted in the highest phosphorus content (25.3 kg/ha), followed by S_3 (24.8 kg/ha), S_2 (23.0 kg/ha), and the lowest under broadcasting (S_1) at 21.0 kg/ha. The highest phosphorus content observed under the widest spacing (S4: 60×25 cm) can be attributed to reduced plant competition and more efficient utilization of soil resources. Phosphorus is relatively immobile in the soil, and when plants are spaced wider apart, each plant can access a larger, less-exploited volume of soil, improving nutrient availability per unit area. Wider spacing also enhances soil

Table 1. Available nutrients N (kg/ha), P (kg/ha) and K (kg/ha) of Maize

		Main Plot			
S. No.	Treatments	Sowing method	N(kg/ha)	P(kg/ha)	K(kg/ha)
1	B_1	Flat bed	268.4	22.5	221.0
2	B_2	Raised bed	278.6	24.2	230.5
	Sub plot treatments				
1	S_1	Broadcasting	260.1	21.0	215.8
2	S_2	30×25cm	270.5	23.0	222.3
35.66	143.66				
3	S_3	45×25cm	280.0	24.8	232.1
4	S_4	60×25cm	285.5	25.3	236.4
S.No.	Treatments	Treatment combination	N(kg/ha)	P(kg/ha)	K(kg/ha)
1.	T_1	B_1S_1 (Flat bed+Broadcasting)	255.3	20.2	210.4
2.	T_2	B_1S_2 (Flat bed +30×25 cm spacing)	265.7	22.1	219.6
3.	T_3	B_1S_3 (Flat bed +45×25 cm spacing)	275.0	23.5	228.4
4.	T_4	B_1S_4 (Flat bed +60×25 cm spacing)	278.5	24.1	230.6
5.	T_5	B_2S_1 (Raised bed + Broadcasting)	265.0	21.8	221.2
6.	T_6	B_2S_2 (Raised bed + 30×25 cm spacing)	275.2	23.8	225.0
7.	T_7	B_2S_3 (Raised bed + 45×25 cm spacing)	285.0	26.1	235.8
8.	T_8	B_2S_4 (Raised bed + 60×25 cm spacing)	292.5	26.5	242.0

Factors	C.D.	SE (m) ±	C.D.	SE (m) ±	C.D.	SE(m) ±
Factor A (Sowing methods)	1.88	1.19	2.54	1.27	1.20	0.56
Factor B (Spacing)	2.20	1.11	2.09	1.02	2.19	1.16
Factor (A×B)	2.12	1.10	2.01	1.99	2.38	1.17

aeration and microbial activity, particularly of phosphorus-solubilizing microorganisms, which play a crucial role in converting unavailable forms of phosphorus into absorbable forms. In contrast, broadcasting (S_1) leads to overcrowding, which intensifies competition for phosphorus in the root zone and limits its availability, resulting in the lowest recorded phosphorus content. These findings are in line with those reported by (Nandeha *et al*., 2017; Simic and Stefanovic, 2007) in maize.

Interaction Effect (Sowing Method × Spacing)

The maximum phosphorus content (26.5 kg/ha) was recorded in T_8 (B_2S_4- Raised bed + 60×25 cm spacing), followed by T_7 (B_2S_3) at 26.1 kg/ha. The lowest phosphorus level (20.2 kg/ha) was observed in T_1 (B_1S_1 -Flat bed + Broadcasting). This improvement can be attributed to the combined benefits of raised bed sowing and wider spacing, which enhance soil aeration, microbial activity, and root proliferation-factors that collectively improve phosphorus solubilization and uptake. Raised beds also reduce waterlogging and surface compaction, creating a favorable micro-environment for nutrient availability. In contrast, the lowest phosphorus level (20.2 kg/ha) in T_1 (B_1S_1 - Flat bed + Broadcasting) may be due to excessive plant competition, poor soil aeration, and limited root access to phosphorus, which is relatively immobile in the soil. This interaction clearly demonstrates that adopting proper sowing methods along with optimal spacing significantly enhances phosphorus availability in maize. Consistent trends were also noted by (Dwipa *et al*., 2020; Jalia *et al*., 2008; Sharanabasappa and Basavanneppa, 2019) during their study on maize.

Effect on Available Potassium (kg/ha)

Main Effect of Sowing Methods

The raised bed sowing (B_2) recorded a higher available potassium content (230.5 kg/ha) as compared to flat bed sowing (B_1) (221.0 kg/ha). The improved drainage and root zone conditions associated with raised beds may facilitate more efficient nutrient cycling and uptake. These results are in conformity with the findings of (Sharanabasappa and Basavanneppa, 2019; Simic and Stefanovic, 2007 and Yadav *et al*., 2019) in Maize.

Main Effect of Spacing

The widest spacing (S_4: 60×25 cm) had the highest available potassium at 236.4 kg/ha, followed by S_3 (232.1 kg/ha), S_2 (222.3 kg/ha), and broadcasting (S_1) which recorded the lowest (215.8 kg/ha). Intermediate spacing treatments (30×25 cm and 45×25 cm) demonstrated a gradual increase in nutrient availability with increased spacing, highlighting the importance of optimal plant density in nutrient management. The present result are in consonance with (Nandeha *et al*., 2017; Raza *et al*., 2019; Yadav *et al*., 2019) in Maize.

Interaction Effect (Sowing Method × Spacing)

Among the treatment combinations, T_8 (B_2S_4 -Raised bed + 60×25 cm spacing) recorded the maximum potassium content (242.0 kg/ha), while the lowest value (210.4 kg/ha) was found in T_1 (B_1S_1- Flat bed

Table 2. Economics of the Maize

S.No.	Treatments	Treatment combination	Cost of cultivation (Rs ha^{-1})	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})	B:C ratio
1.	T_1	B_1S_1 (Flat bed+Broadcasting)	42,000	56,000	14,000	1.33
2.	T_2	B_1S_2 (Flat bed +30×25 cm spacing)	43,000	60,600	17,600	1.41
3.	T_3	B_1S_3 (Flat bed +45×25 cm spacing)	44,000	70,600	26,600	1.61
4.	T_4	B_1S_4 (Flat bed +60×25 cm spacing)	44,000	67,600	23,600	1.54
5.	T_5	B_2S_1 (Raised bed + Broadcasting)	45,000	78,400	33,400	1.74
6.	T_6	B_2S_2 (Raised bed + 30×25 cm spacing)	46,000	83,800	37,800	1.82
7.	T_7	B_2S_3 (Raised bed + 45×25 cm spacing)	47,000	89,400	42,400	1.90
8.	T_8	B_2S_4 (Raised bed + 60×25 cm spacing)	47,000	91,000	44,000	1.94

Factors	C.D.	SE (m) ±	C.D.	SE (m) ±	C.D.	SE (m) ±
Factor A (Sowing methods)	4937.51	3149.10	6217.79	2233.68	0.42	0.17
Factor B (Spacing)	5512.01	3144.22	4212.59	2225.63	0.41	0.15
Factor (A×B)	6317.45	2145.56	5231.51	2535.60	0.40	0.13

+ Broadcasting). The interaction between sowing method and spacing revealed a synergistic effect on nutrient dynamics. The combination of raised bed sowing with the widest spacing (B_2S_4, T_8) produced the most favorable results, with maximum nutrient levels: 292.5 kg/ha of N, 26.5 kg/ha of P, and 242.0 kg/ha of K. This outcome reflects the combined benefit of improved soil structure, moisture retention, and root development. In contrast, the flat bed with broadcasting (B_1S_1, T_1) yielded the lowest nutrient values across all three parameters, suggesting that densely planted flat beds may create less favorable conditions for nutrient availability due to poor aeration and limited root access. This agrees with the work of (Nandeha et al., 2017; Raza et al., 2019) who found comparable nutrient responses in maize.

Economics of Maize

Cost of Cultivation

The cost of cultivation as stated in (Table 2) for maize varied across the different treatments, ranging from Rs 42,000 per hectare in T_1 (B_1S_1 - Flat bed + Broadcasting) to Rs 47,000 per hectare in both T_7 (B_2S_3 - Raised bed + 45×25 cm spacing) and T_8 (B_2S_4 - Raised bed + 60×25 cm spacing). Generally, raised bed treatments involved slightly higher cultivation costs compared to flat bed treatments. The higher costs associated with raised bed treatments can be attributed to additional field preparation, labor, and inputs required for bed formation and precise row planting. In contrast, flat bed sowing, especially with broadcasting, incurred lower expenses due to reduced labor and mechanization requirements. Overall, while raised bed methods may increase initial cultivation costs, they are often offset by improved resource use efficiency and higher yield potential. Parallel findings have been recorded by (Attia et al., 2009;Subbiah and Asij, 1956) while studying maize.

Gross Return

Gross returns showed a clear increasing trend with spacing and sowing methods. The highest gross return of Rs 91,000 per hectare was recorded in T_8 (Raised bed + 60×25 cm spacing), followed closely by T_7 (Raised bed + 45×25 cm spacing) with Rs 89,400. Among flat bed treatments, T_3 (Flat bed + 45×25 cm spacing) achieved the highest gross return at Rs 70,600. These results indicate that raised bed sowing combined with appropriate spacing significantly enhances economic returns by supporting better crop growth, nutrient use efficiency, and yield. Among the flat bed treatments, the maximum gross return was observed in **T_3 (B_1S_3 - Flat bed + 45×25 cm spacing)** with **Rs 70,600/ha,** which also reflects the positive influence of proper plant spacing even under conventional sowing methods. This trend underscores the importance of optimized agronomic practices in maximizing gross income from maize cultivation. A similar pattern was reported by (Attia et al., 2009; Dwipa *et al*., 2020;Raza *et al*., 2019) regarding gross return in maize.

Net Return

Net returns, calculated as the difference between gross return and cost of cultivation, were highest in T_8 (Raised bed + 60×25 cm spacing) at Rs 44,000, followed by T_7 (Raised bed + 45×25 cm spacing) with Rs 42,400. Among flat bed treatments, T_3 (Flat bed + 45×25 cm spacing) showed the highest net return of Rs 26,600. The lowest net return was observed in T_1 (Flat bed + Broadcasting) at Rs 14,000.This may be primarily due to lower productivity and poor input utilization. These findings emphasize the role of agronomic precision in enhancing profitability in maize cultivation. These results resonate with those published by Raza *et al*., 2019; Sharanabasappa and Basavanneppa, 2019; Yadav *et al*., 2019 in the context of maize.

Benefit-Cost (B:C) Ratio

The B:C ratio, indicating the economic efficiency of each treatment, was highest in T_8 (Raised bed + 60×25 cm spacing) at 1.94, followed by T_7 (Raised bed + 45×25 cm spacing) at 1.90. The lowest B:C ratio was in T_1 (Flat bed + Broadcasting) with 1.33, suggesting this treatment was the least profitable among those tested. Overall, raised bed sowing combined with wider spacing enhanced economic returns and profitability. Earlier studies by (Ahmed *et al*., 2011), have shown similar responses in maize crops.

Authors' contributions

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

Competing Intrests

The authors declare that there are no competing interests regarding the publication of this research.

The study was conducted without any financial or personal relationships that could have influenced the results or interpretation of the findings.

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