



Identification And Comparison Of Fingerprint Damages Among Cardamom Plantation Laborers

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ABSTRACT

Fingerprints, unique to individuals, formed during embryonic development, and remaining constant throughout life, have long been acknowledged as an essential forensic science identification technique. Their permanence, universality, inimitability, and classifiability make them invaluable in criminal investigations, often serving as crucial evidence. Beyond mere visual inspection, the analysis extends to macro details, Galton characteristics, and dimensional attributes, unveiling practical observations of an individual's occupation and activities related to the workplace. Occupational marks within fingerprints offer crucial forensic indicators, particularly among manual laborers engaged in diverse professions. This study focuses on cardamom plantation workers, elucidating the impact of gender on occupational tasks and associated marks faced by cardamom plantation workers, including stress, chronic pain, and fatigue, exacerbated by harsh environmental conditions. The meticulous examination and analysis of 105 individuals reveals prevalent patterns, such as loops, whorls, and composites, alongside gendered divisions in labor tasks.

Physical examinations uncover many damages, from scars to calluses, providing insights into damage prevalence and informing targeted injury prevention and management interventions. Microscopic examination further illuminates fingerprint damages, emphasizing the need for comprehensive assessments to mitigate occupational risks effectively. Despite the tangible consequences of labor-intensive tasks, this study catalyzes improvements in workplace conditions, occupational health, and safety in agriculture. The findings of this investigation have significant implications in forensic science, particularly in the realm of fingerprint analysis and identification. Furthermore, identifying occupation-related patterns within fingerprints may aid law enforcement agencies in narrowing down suspects and establishing connections in criminal investigations, offering hope and optimism for the future of forensic science and occupational health and safety.

KEYWORDS: Fingerprint, occupational marks, amputated finger, cardamom plantation laborers,

INTRODUCTION

Fingerprints, the unique impressions of friction ridges on human skin, are developed during embryonic development and remain unchanged throughout life [1]. The embryological development of these ridges determines their uniqueness, making fingerprints a crucial tool in personal identification [2]. The examination of fingerprinting, known as dactylography, encompasses a multifaceted approach to identifying individuals based on the distinctive features present in their fingerprints [3]. At its core lies the recognition of fingerprints as unique, permanent, universal, and inimitable identifiers, making them invaluable tools in forensic investigations [4]. The analysis of fingerprints extends beyond mere visual inspection, delving into three levels of information: macro details, Galton characteristics or minutiae, and dimensional attributes [5]. Additionally, occupational marks can be present within fingerprints that offer informative observations of an individual's profession and related activities [6]. Occupational marks, such as roughness, hardness of skin, and scars related to tool handling, are imprinted onto fingertips, offering valuable forensic indicators in investigations [7]. These marks, borne out of the repetitive motions and specific activities associated with various professions, provide details about an individual's occupation and participation in particular tasks [8]. The significance of occupational marks in forensic investigations cannot be overstated, as they can serve as crucial evidence for personal identification in a myriad of scenarios, including mass disasters, plane crashes, fires, explosions, and cases involving grossly decomposed or traumatized bodies [9].

Occupational marks manifest in a diverse array of professions, spanning carpenters, tailors, blacksmiths, farmers, electricians, washer-men, brass turners, bricklayers, joiners, plasterers, coal baggers, drop-stampers, hammer drivers, armature winders, grinders, maintenance fitters, machine tool fitters, collier, molders, electrode jointers, cold rollers, workers in rolling mills, etc. [10]. These marks, including scars, calluses, abrasions, and blisters, are particularly prominent among manual laborers, impacting various body parts such as hands, feet, and toes [11]. Identifying these occupational marks within fingerprints provides forensic investigators with a wealth of information, aiding in the search for antemortem records (records of an individual's fingerprints taken while they are alive) and narrowing down potential work environments [12].

This study aims to analyze and contrast the occupational markings found on fingerprints, with a specific emphasis on cardamom plantation workers. Cardamom plantation workers, with women comprising most of the population, engage in diverse physical tasks, such as planting, harvesting, and cleaning, while working on drying, controlling shade, conserving soil, and rubbing [13]. These tasks expose them to harsh environmental conditions, including hot and rainy weather. The working conditions they experience contribute to stress, chronic pain, fatigue, and weakened immune function. Repetitive motions associated with these tasks can lead to specific occupational hand marks (physical changes to the hands due to the nature of the work), including blisters, abrasions, calluses, scars, and even the absence of ridges [14].

In this research, the primary objective is to compare and identify fingerprint damages among cardamom plantation workers by analyzing the fingerprints of individuals in this occupation and comparing them with reference samples; the study aims to identify consistent patterns or distinctive characteristics of each other [15]. Analyzing the fingerprints of individuals engaged in cardamom cultivation helps to elucidate the importance of occupational marks in forensic investigations and their potential utility in identifying suspects based on occupational characteristics [12]. We will investigate the impact of gender on the distribution of occupational tasks and associated marks among cardamom workers.

Moreover, by highlighting the occupational hazards and physical demands faced by cardamom plantation workers, this research contributes to our understanding of occupational health and safety in agriculture [16]. Identifying specific marks associated with certain tasks or working conditions can improve workplace conditions and reduce the risk of injuries among agricultural workers [17]. The subsequent sections will examine the procedures used to collect and process fingerprint data from cardamom plantation workers. I will then present findings regarding the prevalence and traits of their fingerprint's occupational marks, followed by the significance of these results for forensic identification and occupational health and safety [18].

METHODOLOGY

The study was conducted in Munnar Idukki, Kerala, India. The principal investigator, who has personal experience with plantation work in the region, performed data collection. This study involves a total of 1047 fingerprints in 105 individuals, including 54 females (51.42%) and 51 males (48.58) were observed where a total of 3 fingers were amputated in two different volunteers. One hundred five volunteer samples were collected, and their age, sex, and ambidexters were noted. Samples were collected from all participants, encompassing all ten fingers of both hands. The most commonly used fingers – thumb, index, and ring – were emphasized due to their frequent contact with work-related surfaces. The duration of the data collection was a 10-day period in the principal investigator's semester vacation, during which the investigator actively engaged with participants in the field. The ethical standards were upheld by obtaining informed consent from all participants before data collection and prioritizing participant privacy and confidentiality throughout the research process. Inclusion criteria involved individuals who were actively working in cardamom plantations and who volunteered to participate in the study. Smudged fingerprints, amputation of fingers, and other occupational workers were excluded. The collected samples underwent physical, microscopic, and visual examinations of their fingers. The physical examination of fingerprints was conducted so all participants could observe patterns such as arches, loops, whorls, composites, and accidentals. The parameters analyzed include various fingerprint patterns observed and categorized; damages, cuts, abbreviation, absence of ridges, blisters, calluses, thickness, and hardness were noted during the examinations with strict adherence to ethical guidelines that

ensured participant privacy and confidentiality regarding their fingerprint and physical conditions. Statistical analysis was performed to evaluate and conclude the results. The project was financed by the principal investigator, who is a native of Munnar and has personal experience working in cardamom plantations. The investigator recognized the challenges faced by plantation workers and sought to contribute to understanding the impact of such work on their physical conditions.

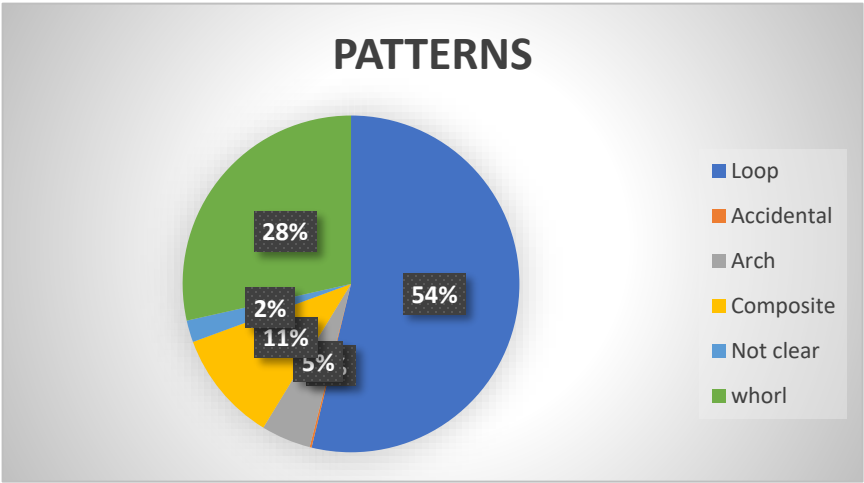
RESULT

This study involves 1047 fingerprints in 105 individuals, including 54 females (51.42%) and 51 males (48.58), where three fingers were amputated in two different volunteers. Table 1 showed that 105 volunteer samples were collected, and their age, sex, and ambidexters were noted. In this study, the fingerprint patterns were found to loop (53.71 %), whorl (28.47%), composites (Double loop + Central pocket loop) (10.76%), Arch (4.76%), Accidentals (0.19%), smudged/ not clear (2.09%). The graph 1 shows that the pattern distribution of the fingers.

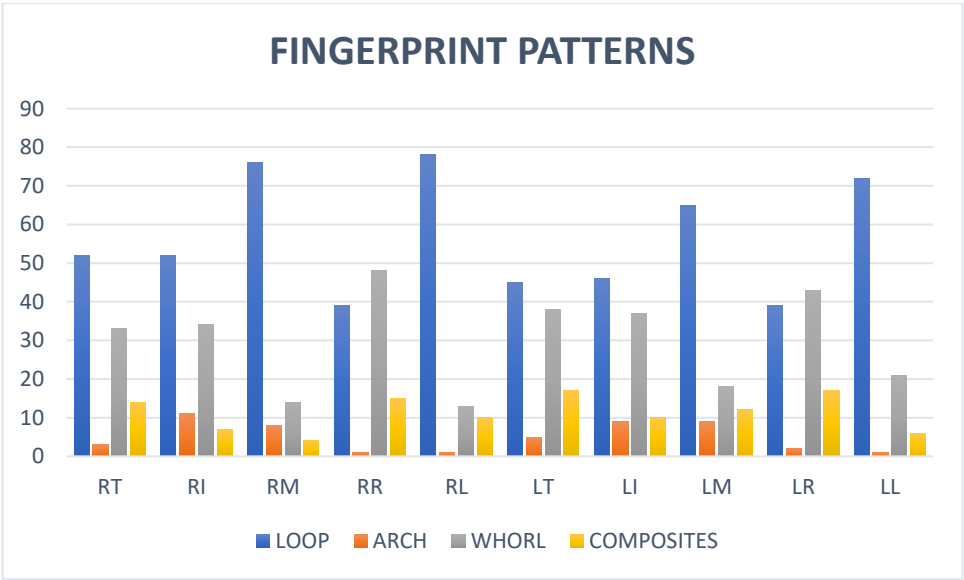
Table 1. Patterns of the fingerprints

PATTERNS	RT	RI	RM	RR	RL	LT	LI	LM	LR	LL	total
LOOP	52	52	76	39	78	45	46	65	39	72	564
ARCH	3	11	8	1	1	5	9	9	2	1	50
WHORL	33	34	14	48	13	38	37	18	43	21	299
DOUBLE LOOP	13	3	3	1	0	12	2	4	0	0	
CENTRAL POCKET	1	4	1	15	10	5	8	8	17	6	
ACCIDENTAL	0	0	1	0	0	0	1	0	0	0	2
NOT CLEAR/ABSENT	3	1	2	1	3	0	2	1	4	5	22
COMPOSITES	14	7	4	16	10	17	10	12	17	6	113

(Composites = Double loop + Central pocket loop)



PIE CHART 1. TOTAL PATTERNS AND THEIR PERCENTAGE



Graph 1. Patterns Of The Fingers Of Individuals In A Population

A notable gendered division of labor is apparent, with women predominantly engaging in tasks requiring repetitive use of the thumb, index, and ring fingers during harvesting, planting, and cleaning activities. Conversely, men are primarily tasked with reducing shade, pitting, conserving soil, drying, and cleaning rub. Tables 2 &3 show that the fingers most commonly used during labor exhibited signs of damage and discomfort, including the absence of ridges (21.84%), cut marks (37.23%), blisters (17.42%) amputated (0.286%), and clear (23.23%). These findings provide valuable insights into the types and prevalence of injuries sustained by cardamom plantation workers, informing

targeted interventions for injury prevention and management. Pie chart 2 shows the total damage to the fingers, and graph 2 shows the damage to 10-digit fingers.

Table 2. Damages of Finger

SI. NO	NAME	AGE	GENDE R	RT	RI	RM	RR	RL	LT	LI	LM	LR	LL
1	2024/1	47	M	BL	CM	CM	CL	ABR	CM	CM	CM	CM	CM
2	2024/2	56	F	ABR	CM	CM	CM	CM	CM	CM	CM	CM	CM
3	2024/3	63	M	BL	ABR	AM	AM	ABR	ABR	BL	ABR	CM	CM
4	2024/4	63	F	ABR	ABR	CM	CM	ABR	CM	ABR	C	CM	ABR
5	2024/5	51	F	ABR	ABR	BL	CM	BL	B	ABR	CM	CM	CM
6	2024/6	50	F	CL	CL	CL	CL	CL	CM	CL	CL	CL	CL
7	2024/7	51	M	ABR	CM	CL	CL	CM	CM	CM	CM	CL	CM
8	2024/8	48	F	CM	CM	CL	CL	CM	CM	CM	ABR	BL	CM
9	2024/9	50	M	CM	CM	CM	CM	ABR	CM	ABR	CM	CM	CM
10	2024/10	2	F	ABR	CM	CM	CM	CM	BL	BL	CM	CM	CM
11	2024/11	49	F	BL	CM	CM	CM	CL	CM	CM	BL	CM	CM
12	2024/12	43	M	CL	CM	CL	BL	ABR	CM	CL	CL	BL	CL
13	2024/13	28	M	CL	CL	CL	CL	CL	CL	CL	CL	CL	CL
14	2024/14	21	M	ABR	CL	ABR	CL	BL	CL	CM	CL	CL	BL
15	2024/15	40	M	BL	ABR	ABR	ABR	BL	ABR	CM	CL	ABR	CM

16	2024/1 6	24	M	CM	CM	CM	CM	CM	CM	CM	CM	CM	CM
17	2024/1 7	38	M	ABR	ABR	CM	ABR	ABR	BL	BL	BL	CL	CL
18	2024/1 8	47	M	BL	BL	CL	CL	BL	CM	CL	CL	CM	CM
19	2024/1 9	47	M	CL	CL	C	BL	BL	CL	CL	CL	CL	CL
20	2024/2 0	32	M	BL	CL	CL	CL	CL	CL	CL	CL	CL	CL
21	2024/2 1	40	M	ABR	ABR	ABR	CL	CL	CM	CM	CL	CL	BL
22	2024/2 2	47	M	CM	CM	CM	BL	CM	CM	CM	CM	CM	CL
23	2024/2 3	39	M	CL	CL	CL	CL	BL	CL	CL	CL	CL	BL
24	2024/2 4	40	M	CM	CL	CM	ABR	ABR	CM	ABR	CM	CL	CM
25	2024/2 5	67	M	ABR	ABR	ABR	ABR	ABR	ABR	ABR	ABR	ABR	ABR
26	2024/2 6	37	M	BL	CL	CL	BL	CL	CL	BL	CL	BL	CL
27	2024/2 7	43	M	ABR	CM	CM	BL	CL	BL	CL	CL	ABR	ABR
28	2024/2 8	48	M	BL	CM	CL	CL	CL	CL	CL	CM	CL	CM
29	2024/2 9	40	M	ABR	ABR	CM	CM	ABR	BL	BL	CM	CL	BL
30	2024/3 0	32	F	ABR	BL	CL	CL	CM	CM	ABR	BL	BL	ABR
31	2024/3 1	49	M	CM	BL	BL	BL	BL	CL	CL	BL	CL	CL

32	2024/3 2	49	F	ABR	CM	CM	BL	CM	ABR	ABR	ABR	CM	CM
33	2024/3 3	35	F	ABR	BL	BL	BL	BL	ABR	CM	CL	CL	BL
34	2024/3 4	50	F	CM	CM	ABR	CM	CM	CM	ABR	CM	ABR	CM
35	2024/3 5	52	M	ABR	CM	CL	CL	CL	CM	CL	BL	BL	BL
36	2024/3 6	58	M	CM	CM	BL	CL	BL	ABR	BL	BL	CL	CM
37	2024/3 7	55	F	CM	ABR	ABR	ABR	ABR	CM	ABR	CM	CL	ABR
38	2024/3 8	60	F	CL	CL	CL	CL	CL	CM	CL	CL	CL	CM
39	2024/3 9	20	F	CM	CL	CM	CM	CL	CM	CM	CM	CM	CM
40	2024/4 0	53	F	ABR	CM	CM	CM	BL	CM	ABR	CM	CM	CM
41	2024/4 1	25	F	CM	CL	CM	CM	CM	CM	CM	CM	CM	CM
42	2024/4 2	62	F	ABR	ABR	ABR	CL	ABR	ABR	CM	CL	CL	CM
43	2024/4 3	55	F	ABR	ABR	CM	ABR	ABR	A BR	CM	CM	ABR	ABR
44	2024/4 4	72	F	ABR	ABR	ABR	ABR	ABR	ABR	CM	ABR	ABR	ABR
45	2024/4 5	51	F	BL	CM	CM	CM	CM	ABR	ABR	CM	CM	ABR
46	2024/4 6	39	F	CM	ABR	BL	BL	ABR	CM	CM	BL	ABR	ABR
47	2024/4 7	40	F	BL	CL	BL	CM	CM	ABR	BL	BL	CL	CM

48	2024/4 8	36	F	CL	ABR	ABR	BL	BL	CM	ABR	CM,	CL	CM
49	2024/4 9	33	F	CM	CM	CM	BL	ABR	CM	CM	CM	CL	ABR
50	2024/5 0	42	F	ABR	ABR	CM	ABR	BL	ABR	CM	ABR	ABR	CM
51	2024/5 1	43	F	BL	CM	BL	BL	BL	CM	CM	BL	ABR	ABR
52	2024/5 2	71	F	CM	ABR	CM	CL	BL	CM	CM	CM	ABR	ABR
53	2024/5 3	60	F	ABR	ABR	CM	CM	BL	BL	BL	CL	BL	BL
54	2024/5 4	32	F	CM	CM	BL	BL	CM	CM	CM	CM	CM	CM
55	2024/5 5	52	M	CM	CL	CL	BL	CM	CL	CM	CL	CL	CL
56	2024/5 6	51	F	ABR	CM	CM	ABR	CM	CM	ABR	ABR	CL	ABR
57	2024/5 7	58	F	CM	CM	CM	CM	CM	CM	CM	CM	CM	CM
58	2024/5 8	67	M	CM	CM	BL	CM	BL	BL	BL	BL	BL	CM
59	2024/5 9	70	M	CM	CM	CM	CM	CM	CM	CM	CM	CM	CL
60	2024/6 0	48	M	BL	CL	CM	CM	CL	ABR	ABR	CL	ABR	ABR
61	2024/6 1	63	M	CL	CM	BL	CL	CL	CL	CM	CM	CL	CM
62	2024/6 2	39	M	ABR	ABR	ABR	ABR	ABR	ABR	ABR	ABR	AMP	ABR
63	2024/6 3	63	M	ABR	CL	ABR	BL	CL	CM	CL	ABR	ABR	BL

64	2024/6 4	63	F	CM	CM	CM	CM	CM	CM	CM	CM	CM	CM
65	2024/6 5	54	M	CL	CM	CL	CL	CM	CL	CM	CL	BL	CL
66	2024/6 6	47	F	ABR	CM	BL	BL	ABR	BL	CM	CM	CL	ABR
67	2024/6 7	72	M	CM	BL	BL	BL	BL	CM	BL	BL	BL	BL;
68	2024/6 8	43	F	ABR	CM	CM	CM	ABR	ABR	CM	CM	CM	ABR
69	2024/6 9	70	F	BL	CM	CL	BL	CL	CM	CL	CL	BL	CL
70	2024/7 0	67	F	CM	BL	BL	BL	CL	CM	CL	CL	BL	BL
71	2024/7 1	55	M	CM	BL	CM	CM	CM	BL	CL	CL	CL	BL
72	2024/7 2	44	F	CM	ABR	CM	CM	CM	ABR	BL	CM	CM	ABR
73	2024/7 3	60	F	BL	CM	BL	BL	BL	BL	CM	CM	BL	BL
74	2024/7 4	56	F	CM	CL	BL	ABR	ABR	CM	CM	CM	ABR	ABR
75	2024/7 5	49	M	ABR	ABR	ABR	BL	BL	BL	ABR	ABR	ABR	ABR
76	2024/7 6	62	F	CM	CM	CM	CM	CM	CM	BL	CL	CL	CL
77	2024/7 7	56	M	CM	ABR	BL	BL	CM	CM	CM	CM	CL	CM
78	2024/7 8	57	M	ABR	ABR	ABR	CM	CM	CM	CM	BL	CBL	CM
79	2024/7 9	30	M	CL	CL	CM	ABR	ABR	CL	CL	CL	CL	CL

[illegible]

96	2024/9 6	52	F	CM	CM	CM	ABR	CM	ABR	ABR	CM	CM	CM
97	2024/9 7	39	F	CL	CL	CL	CL	CL	CM	BL	CL	CL	BL
98	2024/9 8	76	M	ABR	CM	ABR	ABR	BL	CM	ABR	ABR	ABR	ABR
99	2024/9 9	55	M	CL	ABR	CL	CL	CL	CM	CL	CL	L	ABR
10 0	2024/1 00	42	F	BL	ABR	CL	CL	CL	BL	CL	CL	CL	CL
10 1	2024/1 01	71	M	CM	CM	CL	CM	CL	CM	CM	CM	CM	CM
10 2	2024/1 02	68	F	CM	BL	ABR	CM	ABR	CL	BL	CM	BL	BL
10 3	2024/1 03	61	F	BL	BL	CL	CL	CL	CL	BL	CL	CL	CL
10 4	2024/1 04	32	F	CM	CL	BL	CL	CL	CM	CM	CM	CM	CL
10 5	2024/1 05	50	F	CL	BL	BL	BL	CM	CL	BL	BL	ABR	CL

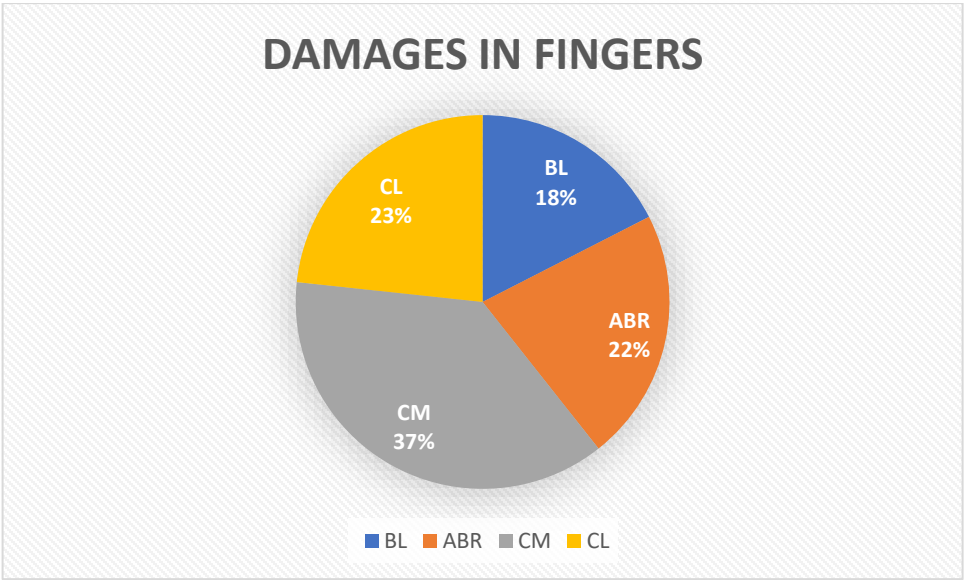
CL- Clear, ABR- Absence Of Ridges, BL- Blisters, CM- Cut Marks

M- Male, F- Female

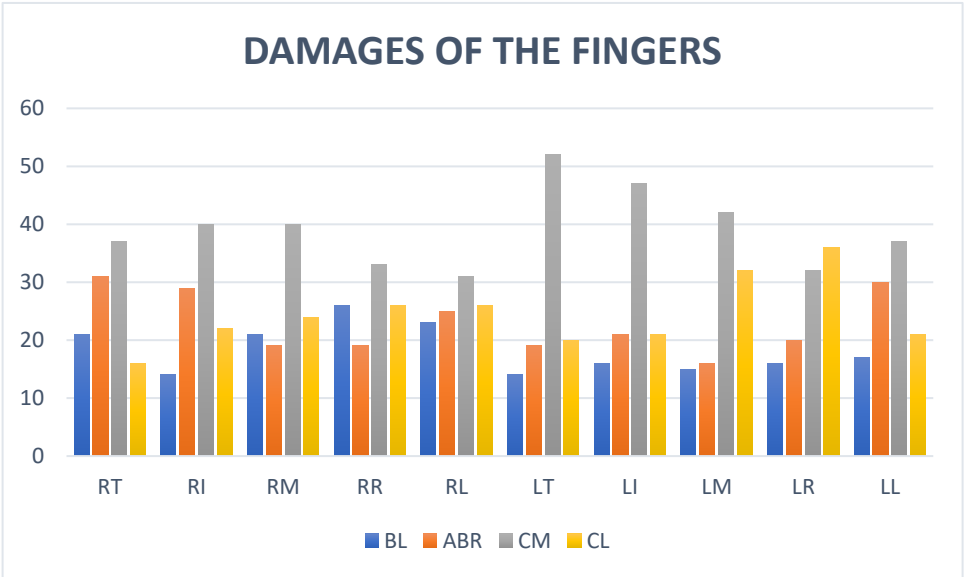
Table 3. Total number of fingerprint damages

FINGERS	BL	ABR	CM	CL
RT	21	31	37	16
RI	14	29	40	22
RM	21	19	40	24
RR	26	19	33	26
RL	23	25	31	26
LT	14	19	52	20

LI	16	21	47	21
LM	15	16	42	32
LR	16	20	32	36
LL	17	30	37	21
TOTAL	183	229	391	245



Pie Chart 2. Damages Of Fingers And Their Percentage

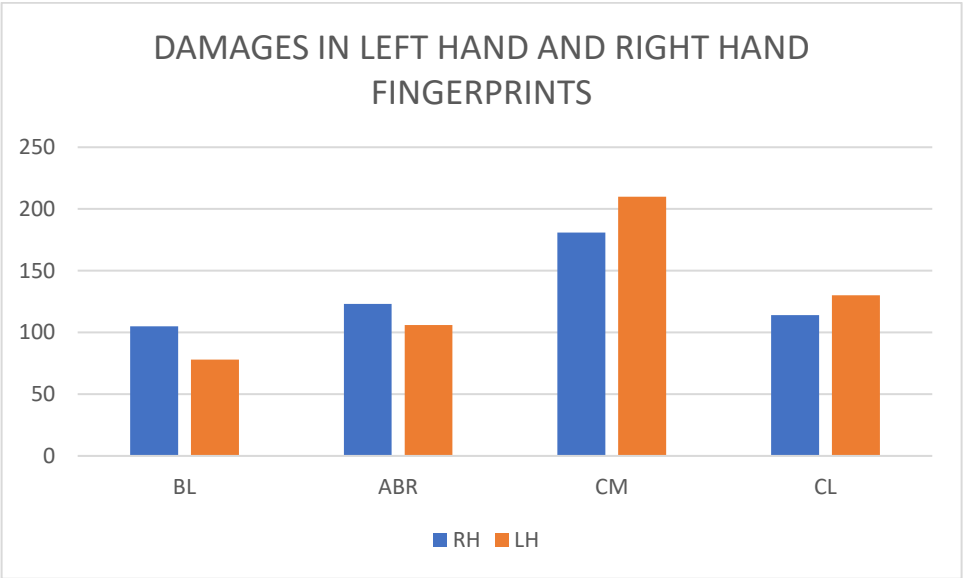


Graph 2. Damages Of The 10 Fingers Of An Individual

We also analyzed the distribution of damages and unmistakable fingerprints between the right and left hands. Table 4 and Graph 3 showed that both hands exhibited significant damage, with slightly higher percentages of damaged fingers observed in the right hand (39.06%) compared to the left hand (37.63%). The left hand showed a slightly higher rate of unmistakable fingerprints (12.41%) than the right hand (10.9%). This finding highlights the bilateral nature of hand-related occupational injuries and suggests the need for comprehensive preventive measures targeting both hands.

Table. 4 Damages in right-hand and left-hand fingerprints

	BL	ABR	CM	CL
RH	105	123	181	114
LH	78	106	210	130

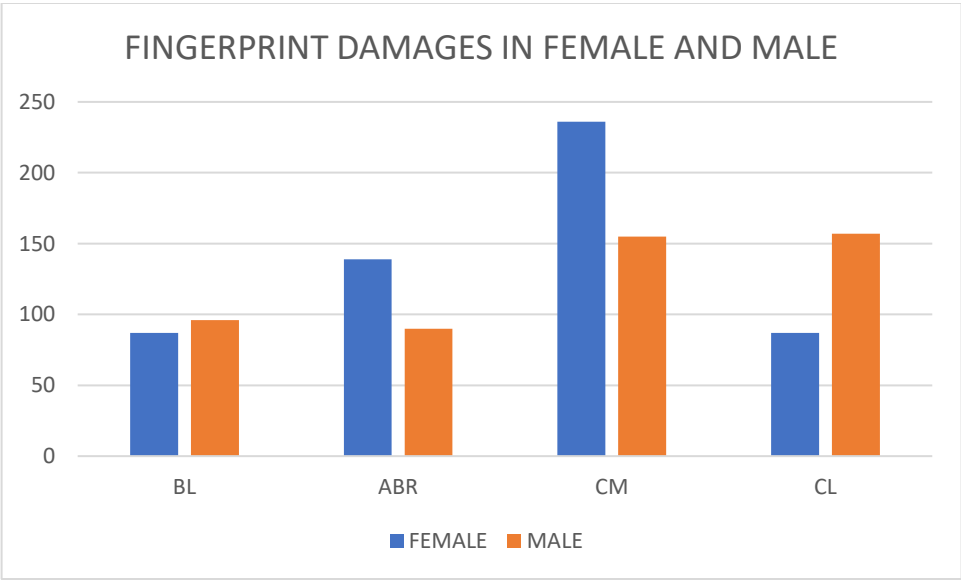


Graph 3 Damages In Left-Hand And Right-Hand Fingerprints

Our findings indicated gender disparities in fingerprint damage, with a higher prevalence of damages among female laborers than their male counterparts. Table 5 and graph four female laborers exhibited higher rates of damaged fingerprints (44.2%) compared to males (32.6%), while males showed a slightly higher percentage of unmistakable fingerprints (14.8%) compared to females (8.4%).

Table 5 Fingerprint damages in females and males

	BL	ABR	CM	CL
FEMALE	87	139	236	87
MALE	96	90	155	157



Graph 4. Fingerprint Damage in Females and Males

Moreover, the observed damage and discomfort experienced by workers highlight the tangible consequences of their labor-intensive tasks. Particularly during the rainy season, the propensity for seed slippage exacerbates the risk of

injury, leading to wrinkles and heightened susceptibility to damage. The summer season presents challenges, with dried weed edges causing abrasions and scratches on workers' fingers.

Microscopic examination using stereo microscopy provides a nuanced understanding of fingerprint damages, offering clear visualization of the extent of injury sustained by workers. This analytical approach validates the observed physical manifestations and underscores the need for comprehensive assessments to inform interventions to mitigate occupational risks.

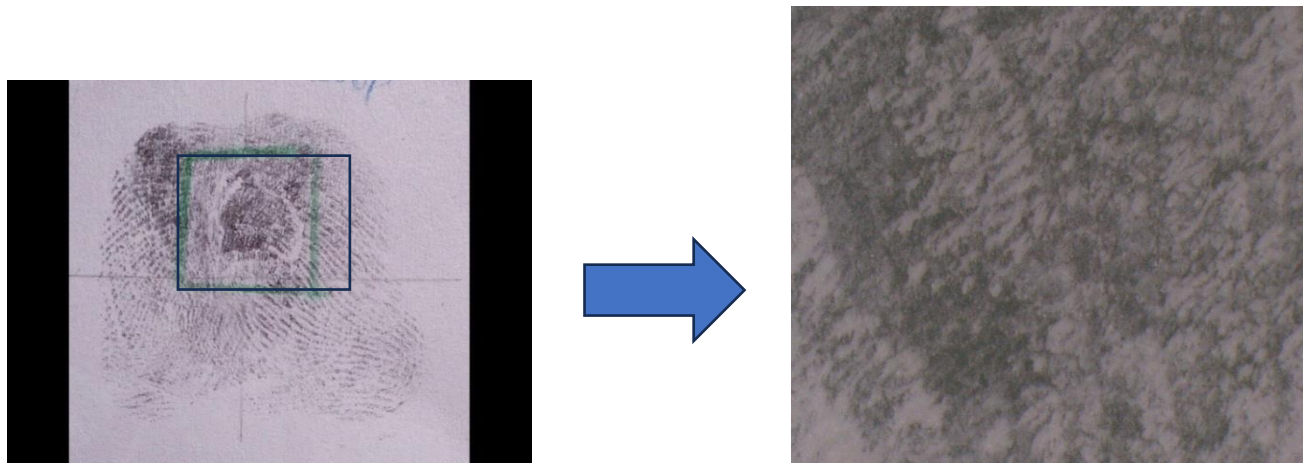


FIG 1,2 BLISTERS OF A FINGER (microscopic visual in Fig 2)

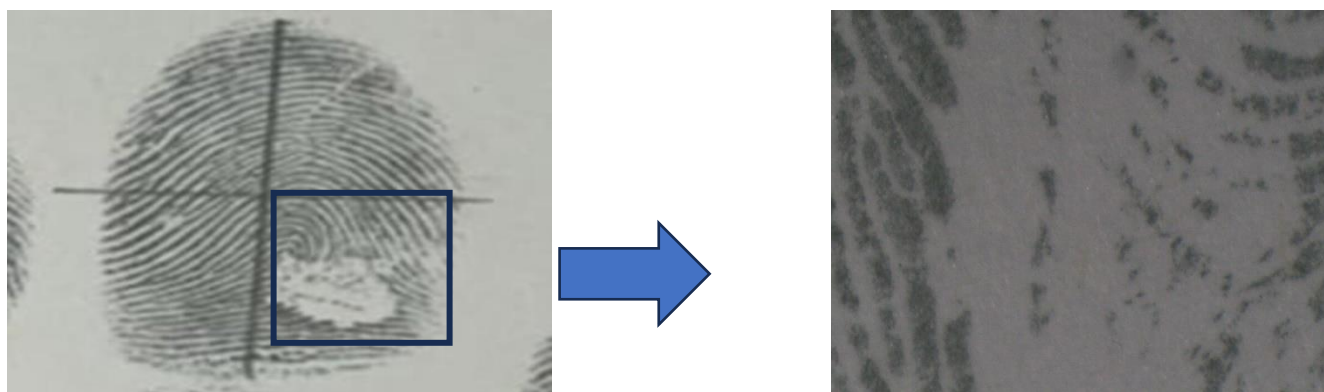


FIG 3,4 BLISTERS IN A FINGERS(microscopic visual in Fig 4)

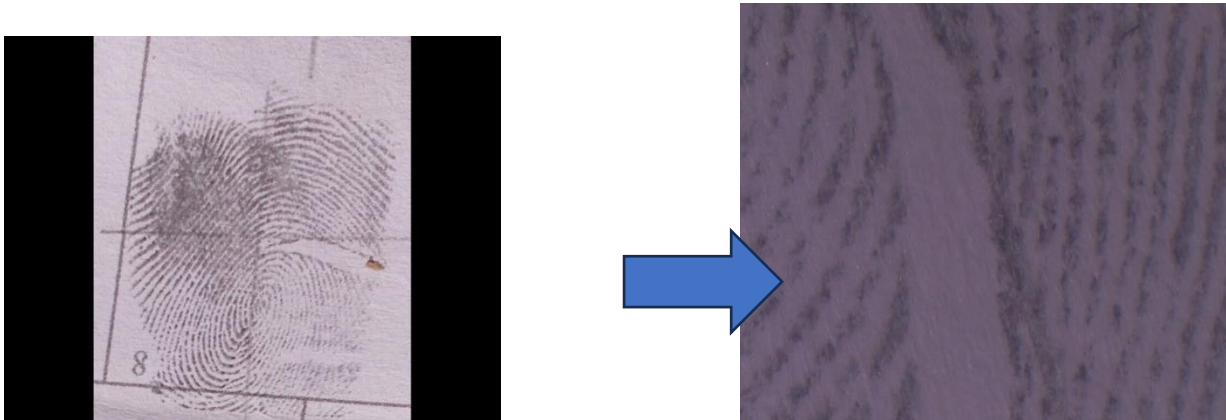


FIG 5,6 CUT MARKS ON A FINGER (microscopic visual in Fig 6)

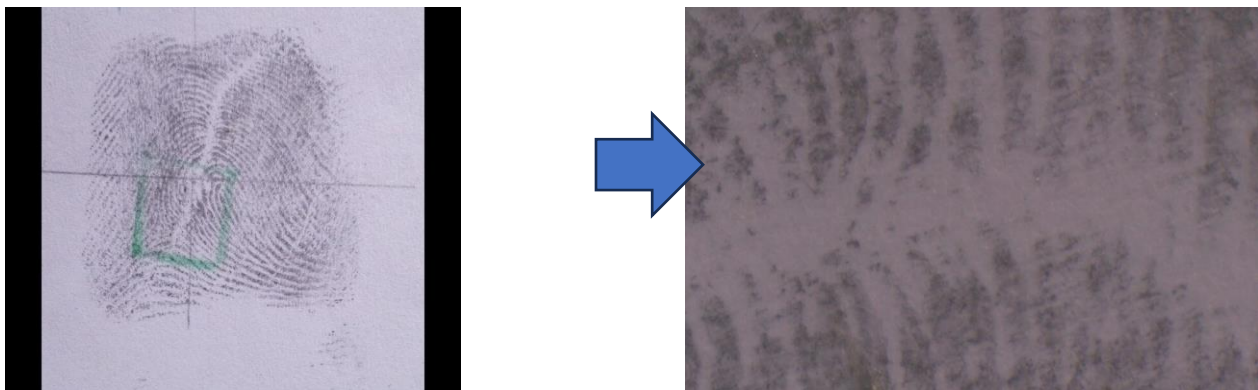


FIG 7,8 CUT MARKS ON A FINGER (microscopic visual in Fig 8)

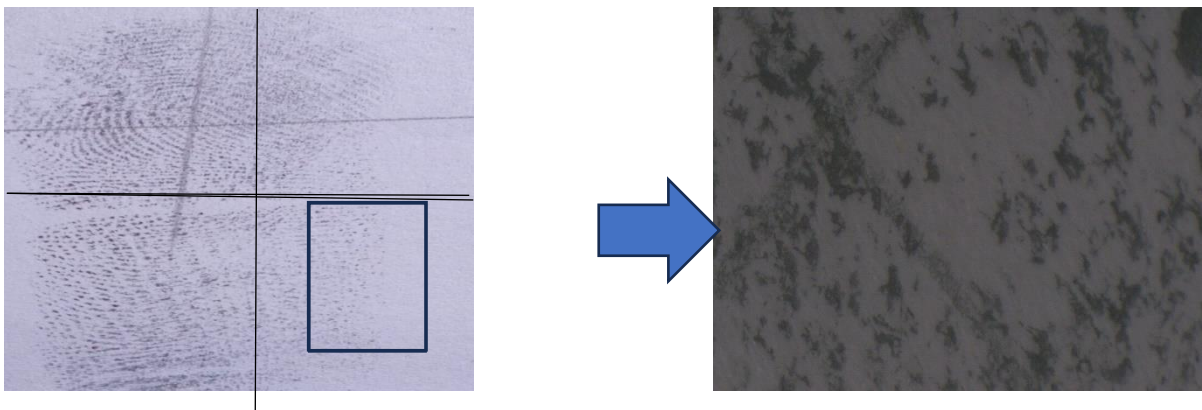


FIG 9,10 ABSENCE OF RIDGES (microscopic visual in Fig 10)

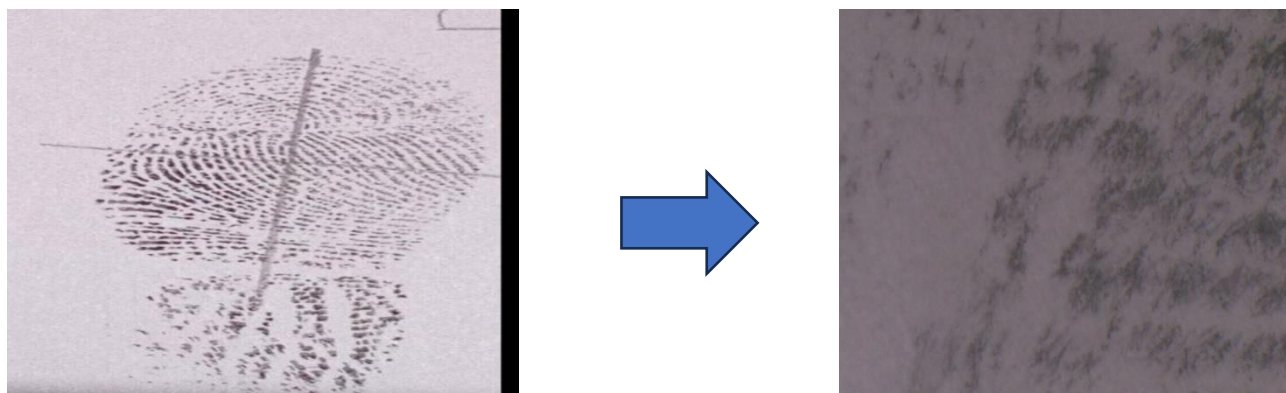


FIG 11,12 ABSENCE OF RIDGES (microscopic visual in Fig 12)

DISCUSSION

Our research on fingerprint patterns among cardamom plantation workers uncovers unique identifiers. It sheds light on the prevalent patterns, gendered divisions of labor, types of injuries sustained, and seasonal variations in occupational risks. This discussion aims to delve into the most common fingerprint patterns found among workers, the types of finger damage, and the significant implications for their health and well-being. The study reveals substantial findings regarding the physical demands and risks associated with different tasks, sparking concern and empathy among our audience of researchers, forensic scientists, occupational health professionals, and policymakers.

One key aspect illuminated by the research is the gendered division of labor within cardamom plantation work; this observation aligns with traditional roles within agricultural settings but also sheds light on the potential impact of these tasks on the physical well-being of workers. Loops are the most common fingerprint pattern observed. The analysis of fingerprint patterns revealed a predominance of loop patterns (53.71%), followed by whorl (28.47%) and composite patterns (10.76%). This distribution provides valuable insight into the baseline fingerprint characteristics of the studied population. Additionally, the observed occurrence of arch patterns (4.76%) underscores the unique and intriguing variability in fingerprint morphology within the community, a factor that adds depth and interest to our research. Fingerprint patterns are unique to each individual, but specific patterns are more common among populations [19]. Loops are one of the primary fingerprint patterns observed in cardamom plantation workers. Understanding these unique patterns can provide insights into their genetic predispositions and aid in forensic investigations.

The study's findings indicate that the fingers most frequently utilized during labor demonstrate signs of damage and discomfort, including scars, absence of ridges, cut marks, abrasions, and blisters; physical examinations revealed that a significant proportion of workers experienced discomfort, with 22% exhibiting absence of ridges, 37% displaying cut marks, and 18% presenting with blister [7]. These occupational marks provide tangible evidence of

the strains and hazards encountered by cardamom plantation workers in their daily tasks. A significant observation was the gendered divisions of labor, with women predominantly engaged in tasks requiring repetitive use of the thumb, index, and ring fingers. Conversely, men assumed roles involving shade control, soil conservation, and drying activities; this gender disparity extends to the prevalence of fingerprint damages, with females exhibiting higher damage rates (44.2%) than males (32.6%). Moreover, clear fingerprint patterns were less prevalent among females (8.4%) than males (14.8%) [5]. Notably, the study underscores the heightened risk of injury during specific seasons, such as the rainy season, the slippery nature of seeds, the formation of wrinkles, increased risk of finger injuries., and the summer season, characterized by dried weed edges causing abrasions and scratches.

Our examination further revealed disparities in damage between the right and left hands. In the right hand, 39.06% of fingers exhibited damage, while only 10.9% displayed clear patterns. Similarly, the left hand showed a higher prevalence of damaged fingers (37.63%) compared to clear patterns (12.41%), particularly the left thumb, as more susceptible to damage, indicating a localized impact of occupational activities on fingerprint integrity; notably, the most common fingerprint damages were observed on the upper side of the fingers, likely attributed to the nature of tasks performed and the associated movements involved [20].

Microscopic examination using stereo microscopes and micamps lite software further elucidates the extent of fingerprint damage. This advanced imaging technique allows for a detailed analysis of scars, abrasions, and other damages, providing valuable data for occupational health research and a thorough understanding of worker injuries [15]. This analytical approach validates the observed physical manifestations and emphasizes the necessity of comprehensive assessments to inform interventions to mitigate occupational risks and improve workplace conditions.

Our study also explored detection methods for identifying smudged or damaged areas of fingerprints. Visible light examination emerged as a promising technique for distinguishing between intact and damaged portions of fingerprints, offering potential applications in forensic investigations and workplace safety assessments.

In addition to finger damage, cardamom plantation workers often suffer from back pain due to prolonged standing and bending during work hours; finger injuries can lead to chronic pain, reduced dexterity, and decreased productivity, affecting the workers' overall quality of life. Despite experiencing physical discomfort, many workers continue to perform their duties, highlighting the economic necessity and lack of alternatives in their livelihoods [17].

The identified drawbacks in the system include issues related to criminal investigations, and the inability to detect fingerprints can hinder the process of identifying suspects and gathering evidence. Fingerprint evidence is essential for forensic investigations, aiding in identifying and prosecuting individuals involved in criminal activities. Therefore, the failure to detect fingerprints can impede the progress of criminal cases and hinder justice delivery—additionally, biometric identification systems such as Aadhaar, ration shops, and criminal investigations. One

significant drawback is the challenge of detecting fingerprints in biometric systems. This limitation can lead to difficulties in accurately identifying individuals, potentially impacting services such as Aadhaar authentication and access to ration shops, which rely on biometric data for verification purposes.

CONCLUSION

In conclusion, this study unravels crucial insights into the occupational challenges faced by cardamom plantation workers by meticulously examining fingerprint patterns. It sheds light on the gendered division of labor, prevalent injuries, and potential implications for forensic identification and occupational health and safety.

Furthermore, our study highlights the multifaceted nature of fingerprint analysis, encompassing macro details, Galton characteristics, and dimensional attributes, each supporting a comprehensive understanding of an individual's unique fingerprint profile. By identifying consistent patterns and features among cardamom workers, we advance forensic science and underscore the importance of occupational health and safety measures in agriculture. Beyond the realm of occupational health, the identification of specific occupational marks within fingerprints holds immense forensic significance. By analyzing fingerprint data from cardamom plantation workers, this study underscores the potential utility of occupational characteristics in forensic investigations, aiding in identifying suspects and narrowing down potential work environments. Such insights contribute to advancing forensic science and its application in diverse scenarios, including mass disasters and criminal investigations.

Despite the invaluable insights gained from our research, certain limitations and drawbacks must be acknowledged, particularly in biometric systems where damaged fingerprints may pose challenges for accurate identification. Future research endeavors should explore innovative fingerprint analysis techniques, incorporate biometric technology advancements, and continue to address the evolving needs of agricultural laborers. Ultimately, our study underscores

the interconnectedness of forensic science, occupational health, and societal well-being, emphasizing the imperative of holistic approaches to address the complex challenges faced by workers in agriculture.

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Practical Forensic Advantages of Studying Cardamom Plantation Laborers Fingerprints

Cardamom plantation laborers represent a unique subgroup within the broader context of agricultural workers. The specific demands and environment of cardamom harvesting can uniquely affect the physical characteristics of their fingerprints. Understanding these nuances can provide forensic scientists with critical insights that can enhance identification processes in both criminal and civil cases.

Cardamom harvesting involves repetitive hand movements, frequent handling of abrasive plant material, and exposure to specific environmental conditions such as high humidity and varying soil compositions. These factors collectively contribute to the unique wear and distortion patterns on the fingerprints of these laborers.

Enhanced Identification Accuracy: Forensic scientists can leverage specialized knowledge about the fingerprint patterns commonly altered by cardamom plantation work. This awareness helps identify individuals from this subgroup, even when their fingerprints are worn or distorted, by focusing on areas likely to retain identifiable ridges.

Support in Humanitarian and Missing Person Cases: Many individuals might go missing in regions with prevalent cardamom cultivation. Forensic experts with specialized knowledge can use fingerprint analysis to assist in locating and identifying missing persons, providing closure to families, and aiding humanitarian efforts.

Differentiation from Other Agricultural Workers: By understanding the unique wear patterns specific to cardamom laborers, forensic experts can distinguish between the fingerprints of different agricultural workers. This can be crucial in cases involving large numbers of potential suspects from various agrarian backgrounds.

Identification in Post-Mortem Scenarios: In forensic pathology, identifying deceased individuals who were laborers in cardamom plantations can be challenging due to advanced decomposition or damage. Knowledge of the unique fingerprint distortions can provide clues that assist identification, even when conventional methods fail.

Advancements in Biometric Systems: Knowledge about the specific alterations in fingerprints due to cardamom plantation work can lead to more robust biometric systems that can accommodate and accurately process fingerprints

affected by such labor. This can improve the reliability of identification systems in regions where cardamom is a significant industry.

Forensic Analysis in Industrial Accidents: This involves identifying individuals in industrial accidents where fingerprints are the primary means of identification. Forensic experts can adjust their methods to account for the specific fingerprint alterations due to cardamom plantation work, leading to more accurate identifications.

Detailed Profiling in Civil and Labor Disputes: Understanding the fingerprint characteristics of cardamom plantation laborers can aid in civil cases, such as disputes over employment or worker compensation. Forensic analysis can verify claims about an individual's occupation or the duration of their job based on the condition of their fingerprints.

Manual labor in cardamom plantations involves unique activities that can cause distinct alterations in fingerprints, such as

Handling Cardamom Pods: Frequent handling of the rough, textured pods can cause abrasions and wear on the skin, leading to specific patterns of fingerprint erosion.

Use of Tools: Tools, knives, sickles, and shovels used in cardamom harvesting and processing can create pressure points and calluses that alter fingerprint patterns differently than other manual labor types.

Moisture and Temperature Conditions: Working in the often rainy and hot environments where cardamom is grown can affect fingerprint wrinkles and slippery nature during the rainy season; abrasions are formed in the hot season, and fingerprints appear. Kerala experienced continuous rain for six months, leading to more intense damage in the ridges.

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