



Ethnobotany of Green Tea (*Camellia sinensis* (L.) Kuntze) and its combinations with medicinal plants in the Beni Mellal region, Morocco

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Research

Abstract

Background: Green tea (*Camellia sinensis* (L.) Kuntze) is widely consumed worldwide, and has a particular importance for several ethnic populations, mainly Asian and North African. This study assessed, for the first time, the ethnobotany of green tea intake and its combination with medicinal and aromatic plants (MAPs) in Morocco.

Methods: A cross-sectional survey was conducted in the Beni Mellal-Khenifra region, (Morocco), consisting of 212 informants. Data were collected using a structured, paper-based questionnaire to collect comprehensive ethnobotanical information regarding the practices related to green tea consumption.

Results: Results revealed a high prevalence of daily green tea consumption (88.68%), with most participants reporting an intake twice per day (40.57%) and two cups per consumption (50%). Green tea was mainly consumed alone or with food and was generally preferred at moderate concentration and in sweetened form. About 83% of participants reported combining green tea with MAPs, either individually or in a mixture. Seventeen species belonging to seven botanical families were used individually, with Lamiaceae being the most represented and Asteraceae showing the highest FIV (0.462). Regarding mixtures, 31 species from 13 families were recorded, with Geraniaceae, Verbenaceae and Lamiaceae being the most prominent families.

Conclusions: This study demonstrates the integral role of green tea in dietary habits of the local population and highlights the ethnobotanical richness of MAPs used in its preparation, reflecting the transmission and conservation of traditional knowledge. Further investigations are required to assess the safety of the most commonly used species and their combinations, particularly in cases of regular and long-term consumption.

Keywords: Green Tea; Medicinal and Aromatic Plants; Ethnobotany; Traditional practices; Beni Mellal-Khenifra region; Morocco

Background

Green tea, *Camellia sinensis* (L.) Kuntze, is a cultivated plant species belonging to the subgenus *Thea*, section *Thea*, within the family Theaceae (Wachira *et al.* 2013). It represents the unfermented type of tea based on the transformation and treatment processes (Ahmed & Stepp 2025). Green tea is widely recognized for its diverse biological activities and associated health benefits. Numerous studies have demonstrated its strong antioxidant (Sung *et al.* 2000), antidiabetic (Wei *et al.* 2024), anti-inflammatory (Truong & Jeong 2022), and anticancer properties (El Omari *et al.* 2021; Alam *et al.* 2022), as well as beneficial effects on cardiovascular risk factors (Zamani *et al.* 2023), and potential role as an epigenetic modulator (Dorna *et al.* 2025).

These medicinal properties are mainly attributed to its richness on polyphenols (He *et al.* 2015), particularly catechins like epigallocatechin-3-gallate (EGCG), epigallocatechin (EGC), epicatechin gallate (ECG) and epicatechin (EC) (Samanta 2022). Moreover, studies identified 29 amino acids using different extraction methods. These amino acids, mainly L-theanine, play a key role in organoleptic and biological activities attributed to green tea (Saeed *et al.* 2017, Das *et al.* 2019). Green tea is also a rich source of caffeine, with an average of 2 to 5% of dry weight, which explains its stimulant effect (Vuong & Roach 2014).

In Morocco, green tea is commonly known as “Atay”. It is the most popular hot beverage, with annual consumption per person of about 1.89 kg/year in 2018 (FAO 2018). Originally imported from China, according to the Observatory of Economic Complexity, Morocco was the 11th largest importer of tea in 2023 in the world, with a total of \$182 million, predominantly represented by green tea at \$177.6 million for 60,989.2 tons (OEC 2025; WITS 2025). Indeed, these values emphasize that green tea represents an essential element of the national identity, deeply rooted in the gastronomy, culture and social practices of Moroccan people. It is also an integral part of Moroccan oral traditions, literature, and arts, representing a symbol of hospitality, dialogue, unity and celebration (Sabti & Lakhssassi 1999; Zighighi *et al.* 2024).

From an ethnobotanical point of view, green tea is fully integrated into Moroccan’s herbal practices and knowledge systems (Bellakhdar 1997). The preparation of green tea by Moroccan people is frequently associated with the use of a wide range of medicinal and aromatic plants (MAPs) as flavoring herbs (Mouhadjir 2002). Green tea can also serve as a vehicle for plant-based remedies. The nature of the added MAPs basically depends on the season, the region, and the health status of the consumers. Despite the popularity and cultural significance of these practices, their scientific documentation remains limited, particularly regarding the nature of MAPs combined with green tea, their modes of use (e.g., individually or as a mixture), and their potential health implications. In this context, the present ethnobotanical investigation aims to document and analyze local knowledge and practices related to green tea preparation and consumption, focusing on the Beni Mellal-Khenifra region as a case study.

Materials and Methods

Study area

The Beni Mellal–Khenifra region is located in central Morocco (Fig. 1), and covers an area of approximately 28,374 km². It includes five provinces: Beni Mellal, Azilal, Fquih Ben Salah, Khenifra, and Khouribga, with a total population exceeding 2.5 million inhabitants according to the most recent Moroccan General Census of Population and Housing conducted in 2024 (HCP 2025). The region is characterized by a pronounced geomorphological heterogeneity, resulting from the juxtaposition of the Tadla plain and the Middle Atlas to the northwest, and the High Atlas Mountain to the east and the south. Bioclimatic conditions range from sub-humid in the high altitudes to semi-arid in the lowlands (i.e., plains), with annual temperatures varying from 2°C to 40°C (Achbah *et al.* 2024). This geomorphological and bioclimatic heterogeneity has generated a high plant diversity, notably in medicinal plant species (El Azzouzi & Zidane 2015). The present survey was conducted in 19 communes, belonging to three administrative provinces (Fig. 1) namely:

- Beni Mellal (8 communes): Beni Mellal, Foum El Anceur, Oulad Yaich, Sidi Jaber, Oulad M'barek, Oulad Gnaou, Foum Oudi and Tagzirt ;
- Fquih Ben Salah (9 communes): Fquih Ben Salah, Souk Sebte Oulad Nemma, Oulad Bourahmoune, Oulad Zmam, Sidi Aissa Ben Ali, Sidi Hammadi, Bradia, Hel Merbaa and Krifate ;
- Azilal (2 communes): Afourar and Timoulite.

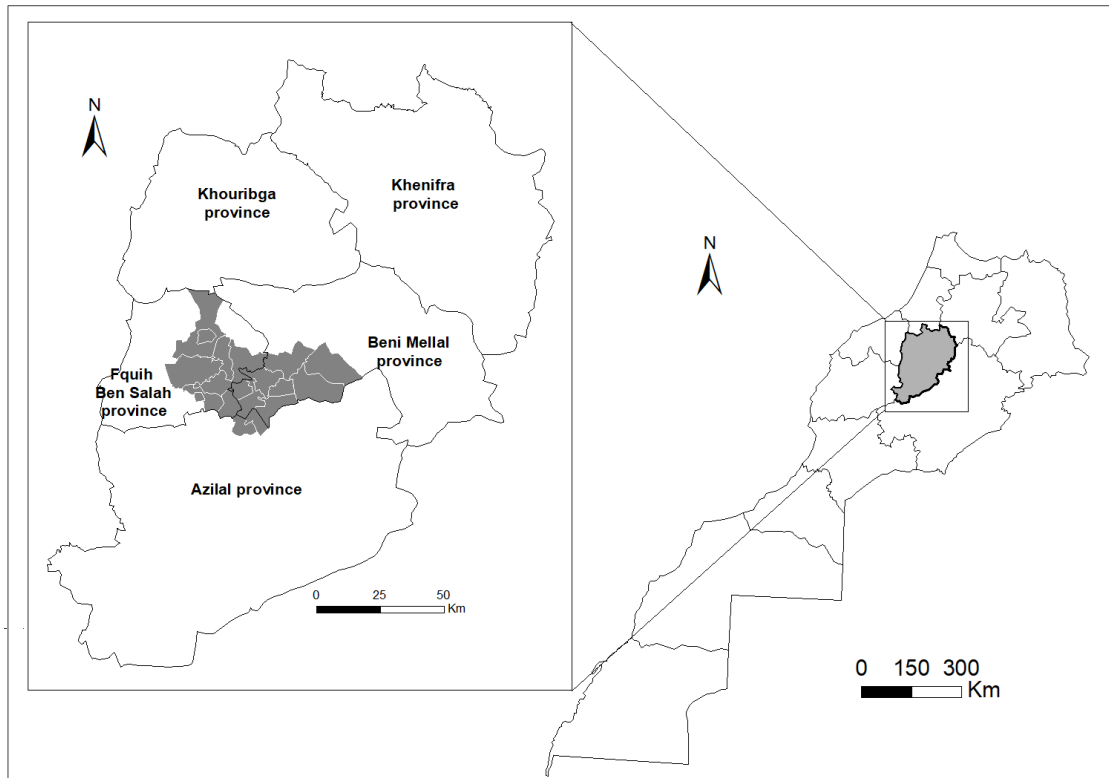


Figure 1. Geographic location of the study area within the Beni Mellal-Khenifra region, one of the twelve administrative regions of Morocco.

Ethnobotanical data collection

Data from the present cross-sectional field survey were collected using a structured, paper-based ethnobotanical questionnaire. The questionnaire was developed to collect comprehensive information regarding both the sociodemographic characteristics of informants and their practices related to green tea consumption.

A total of 212 participants were randomly selected from the local population using a simple random sampling method. Data collection was conducted between March and July 2025 through face-to-face interviews in both urban and rural sites. Interviews were carried out in households, cafés, public spaces, villages, weekly markets (souks), and green areas, in order to capture a broad diversity of information. The interviews were carried out in Arabic, Tamazight and French, to facilitate communication and ensure accurate data collection.

All participants were informed of the objectives and procedures of the study, and voluntary participation was obtained through verbal informed consent. Anonymity and confidentiality of the collected data were strictly maintained throughout the research process. Participants were free to withdraw from the interview at any time they wanted. Only residents of the study region, who consume green tea, were included, while non-residents, people reporting no tea consumption and incomplete or inconsistent questionnaires were excluded to ensure data reliability.

Data Analysis

All data collected through the ethnobotanical survey were organized and structured into four main sections: i) sociodemographic characteristics of participants, ii) green tea consumption habits, iii) individual MAPs associated with green tea, and iv) MAP mixtures combined with green tea. Data management and preliminary organization were performed using Microsoft Excel.

Medicinal and aromatic plant species reported by the informants were initially identified by Bakha Mohamed, Mariem Ben Said (authors) and Dr. Chaouki Al-Faiz from INRA-Rabat, Morocco, using "*La pharmacopée marocaine traditionnelle*" (Bellakhdar, 1997) and "*Flore pratique du Maroc*" (Fennane *et al.* 2014) as primary references. Subsequently, all species names were taxonomically verified using the World Flora Online (WFO, 2025), and only currently accepted scientific names

were retained. The vouchers specimens were deposited in the Herbarium of the Department of Biology & Geology, Polydisciplinary Faculty of Beni Mellal, Sultan Moulay Slimane University, Morocco.

Descriptive statistics were used to summarize the collected data. In addition, three quantitative ethnobotanical indices were calculated.

- **Frequency Citation (FC):** was defined as the number of informants who mentioned a given species.
- **Relative Frequency of Citation (RFC):** showed the importance of each medicinal plant species in the region studied, whose value lies in the range of 0-1. It is calculated as the ratio of the number of respondents who cited the species (FC) by the number of respondents (N) according to the following formula (Tardio & Pardo-de Santayana 2008):

$$RFC = \frac{FC}{N}$$

- **The Family Importance Value (FIV):** assesses the relative importance of medicinal plant families and is calculated by dividing the number of respondents revealing the family (FC family) by the number of species within each family (Ns) using the following formula (Sreekeesoon & Mahomoodally 2014):

$$FIV = \frac{FC \text{ family}}{Ns}$$

Associations between sociodemographic characteristics and variables related to green tea consumption habits and practices were assessed using the chi-square (χ^2) test. Since all analyzed variables were categorical, the chi-square test was considered the most appropriate method to evaluate potential associations. Statistical analyses were performed using SPSS software, and the level of statistical significance was set at $p < 0.05$.

Results and Discussion

Sociodemographic characteristics of the respondents

The survey included 212 participants, of which 51.89% (N=110) were male and 48.11% (N=102) were female (Table 1). Regarding age distribution, the largest portion of respondents (35.38%) were within the range of 40-60 years, while the age of the smallest (13.21%) percentage was superior to 60 years old. The majority of participants (77.83 %) resides in urban areas. Concerning educational level, respondents with higher education were the most represented group (41.04%), followed by individuals with no formal education (26.89%) and those with secondary education (20.28%), while participants with primary education were the least represented (11.79%).

Table 1. Sociodemographic characteristics of the respondents.

		Number (N)	Percentage (%)
Gender	Female	102	48.11
	Male	110	51.89
Age	<25	44	20.75
	25-40	65	30.66
	40-60	75	35.38
	>60	28	13.21
Residential area	Rural	47	22.17
	Urban	165	77.83
Educational level	No formal education	57	26.89
	Primary level	25	11.79
	Secondary level	43	20.28
	High level	87	41.04

Green tea consumption' patterns

The collected data revealed a significant high frequency of green tea consumption within the local population, with the majority of participants (88.68%) reporting a daily use. Among the respondents, 40.57% consumed tea twice a day, and 50% reported an intake of two cups per consumption (Table 2). Additionally, more than 25% of participants consumed green tea

three times or more per day, with also 25% reported drinking three or more cups per intake (Table 2). These data are consistent with the large quantities of green tea importation by Morocco (OEC 2025; WITS 2025), as well as with the high annual consumption of green tea among the Moroccan population (1.89 Kg/ person/year) (FAO 2018).

The Chi-square test showed no relation between consumption frequency and the socio-demographic characteristics of participants. However, a statistically significant relationship was observed between the number of daily intakes and both gender and area of residence. Higher levels of tea consumption were primarily recorded among males and rural residents (Table 3). These findings highlight the integrality of green tea in local dietary habits and its popularity in the study area, as documented by Sabti & Lakhssassi (1999), El Hassouni (2022) and Zighighi *et al.* (2024). Thereby, they reinforce and justify the need to document its ethnobotanical significance, to characterize local consumption practices, and to investigate its potential health impacts.

Table 2. Frequency of green tea consumption among participants.

		Number	Percentage %
Consumption frequency	Daily use (6-7 days per week)	188	88.68
	Regular use (3-5 days per week)	11	5.19
	Weekly use (1-2 days per week)	6	2.83
	Monthly use (<4 days per month)	7	3.3
Number of times per day	1	44	20.75
	2	86	40.57
	3	57	26.89
	>3	25	11.79
Number of glasses per intake	1	29	13.68
	2	106	50.00
	3	52	24.53
	>3	25	11.79

Table 3. Chi-square analysis of the association between green tea consumption frequency and sociodemographic characteristics.

Use frequency	Socio-demographic characteristics	Khi 2	p-value
Consumption frequency	Gender	7.399	0.060
	Age	8.459	0.489
	Residence area	0.853	0.837
	Education	2.534	0.980
Daily consumption frequency	Gender	9.498	0.023
	Age	16.382	0.059
	Residence area	22.206	0.000
	Education	6.788	0.659
Number of cups per intake	Gender	10.455	0.015
	Age	14.223	0.115
	Residence area	26.923	0.000
	Education	5.248	0.812

Tea consumption periods and habits

Regarding temporal consumption patterns, morning and evening were identified as the preferred periods for green tea intake, reported by 97.64% and 79.25% of respondents, respectively. In contrast, only about 20% of participants reported consuming tea in the afternoon or at night (Table 4). Concerning the place of consumption, the vast majority of participants (97.17%) reported drinking tea at home, whereas lower proportion indicated consumption at work (23.59%) or in a cafés (30.66%).

With respect to associated dietary habits, participants reported consuming green tea either alone (58.02%) or in combination with various foods, including cakes and pastries (59.91%), nuts (53.30%), savory food (38.68%) and/or as part of regular meals (97.64%) (Table 4). Green tea was most frequently consumed during breakfast and afternoon snack times (94.34%

and 66.98%, respectively), a pattern correlated with the reported preferred periods of consumption. These temporal and dietary habits confirm that green tea represents an integral part of eating habits of the population as an essential beverage and dietary element. Considering the potent effect of green tea as an inhibitor of intestinal absorption, notably of lipids and iron, its simultaneous consumption with regular meals may be associated with potential health risks (Zijp *et al.* 2000; Koo & Noh 2007). Moreover, the high percentage (79.72%) of participants who do not drink tea at night suggests that people are aware of its stimulant action (Vuong & Roach 2014).

Table 4. Periods and habits of green tea consumption among participants.

		Response	Number	Percentage %	
Tea consumption period	In the morning	No	5	2.36	
		Yes	207	97.64	
	In the afternoon	No	169	79.72	
		Yes	43	20.28	
	In the evening	No	64	30.19	
		Yes	168	79.25	
	At night	No	169	79.72	
		Yes	43	20.28	
	Place	At home	No	6	2.83
			Yes	206	97.17
At work		No	162	76.42	
		Yes	50	23.59	
In a café		No	147	69.34	
		Yes	65	30.66	
Green tea consumption habit	Alone	No	89	41.98	
		Yes	123	58.02	
	With cake / pastry	No	85	40.09	
		Yes	127	59.91	
	With savory food	No	130	61.32	
		Yes	82	38.68	
	With nuts	No	99	46.70	
		Yes	113	53.30	
	With meals (in general)	No	5	2.36	
		Yes	207	97.64	
Green tea consumption with meals	With breakfast	No	12	5.66	
		Yes	200	94.34	
	With lunch	No	190	89.62	
		Yes	22	10.38	
	With afternoon snack	No	70	33.02	
		Yes	142	66.98	
	With dinner	No	186	87.74	
		Yes	26	12.26	

Additives added to green tea

Data related to the preparation practice indicated that green tea is predominantly consumed at a moderate concentration, as reported by 70.75% of respondents (Table 5). Preparation at high concentration was more frequently reported among males than females, while low concentration preparation remained uncommon and was more often preferred by female participants (Table 6). This preference, in addition to the reported frequency of green tea consumption (generally twice a day, with two cups per intake), may be considered as a moderate to relatively high level of consumption among the sampled population.

A recent study reported that even brief and low-dose consumption of green tea could induce physiological and psychological benefits, including stress reduction, improved mental performance, and enhanced feelings of refreshment. These beneficial effects may be relevant to regular and long-term consumption (Kurosaka *et al.* 2024). However, these health benefits could be modified by the preparation practices and the nature of additives (El Hassouni 2022; Jaouad *et al.* 2025).

Regarding the additives, the majority (89.15%) of participants reported a preference for sweetened green tea, more typically with sugar that is usually added at a moderate concentration (68.78%). Indeed, statistical analysis showed that the consumption of green tea without sugar is more frequent among females than males (Table 6). In contrast, the use of honey as a sweetener was rarely (2.36%) reported, while no participants mentioned the use of alternative non-caloric sweeteners, whether in natural or synthetic forms (Table 5). These findings showed a strong cultural dependence on sugar in the preparation of green tea against a limited diversification in sweetening practices within the study population. From a historical and anthropological perspective, Moroccan green tea is distinguished by its pronounced sweetness. The addition of sugar is deeply rooted in Moroccan tea culture and contributes to the symbolic significance of green tea, as a marker of hospitality, generosity, and social interactions (Sabti & Lakhssassi 1999; Cornwell 2018). Sugar consumption increased and became more popular mainly during and after the colonial period, which promoted sugar availability and the expansion of the sugar market (Cornwell 2018).

In parallel, consumption patterns revealed that green tea is frequently consumed both in its plain form without the addition of MAPs (57.55%), as well as in combination with MAPs (83.49%). The interference between these percentages indicates that a significant part of the participants alternates between plain and flavored green tea with MAPs. A significant association was found between plain tea consumption and gender (Table 6), with males showing a strong preference (64%) over females (36%). Additionally, the high level of consumption of green tea in combination with MAPs reflects the integrality of this practice in the daily dietary habits, unfortunately being insufficiently explored in the literature. The biological activities of green tea may be modified when it is consumed in combination with one or more medicinal plants, depending on the plant species used, the number of plants combined, and their respective proportions (Bey-Ould Si Said *et al.* 2024). For that reason, the present study represents an original and comprehensive documentation of this dietary habit, particularly to identify the most used MAP species.

Table 5. Additives added to green tea.

	Categories	Number	Percentage %
Tea concentration	Low	13	6.13
	Medium	150	70.75
	High	49	23.11
Tea with sugar	No	23	10.85
	Yes	189	89.15
Sugar concentration	Low	39	20.64
	Medium	130	68.78
	High	20	10.58
Tea with honey	No	207	97.64
	Yes	5	2.36
Tea with non-caloric sweetener	No	212	100
	Yes	0	0
Plain tea (without MAPs)	No	90	42.45
	Yes	122	57.55
Tea with MAPS	No	35	16.51
	Yes	177	83.49

Table 6. Association between green tea preparation habits and socio-demographic characteristics.

Preparation habits	Socio-demographic characteristic	Khi 2	p-value
Tea concentration	Gender	10.957	0.004
	Age	2.062	0.914
	Residence area	0.534	0.765
	Education	6.792	0.340
Tea with sugar	Gender	12.297	0.000
	Age	2.991	0.393
	Residence area	1.245	0.264
	Education	0.667	0.881
Plain tea (without medicinal plants)	Gender	16.708	0.000

	Age	4.429	0.219
	Residence area	0.469	0.493
	Education	2.607	0.456
Tea with medicinal plants	Gender	0.097	0.756
	Age	9.520	0.023
	Residence area	0.614	0.433
	Education	6.497	0.090

Knowledge about green tea medicinal properties

Given its regular consumption, understanding the level of consciousness of the local population regarding both the beneficial and side effects of green tea is essential. In this context, the present study also aimed to assess whether the local population is aware of the health benefits and side effects of green tea, and whether this knowledge aligns with current scientific evidence.

The results revealed that only 44% and 34% of the respondents had some knowledge of the health benefits and side effects associated with green tea consumption with 145 and 93 citations, respectively (Fig. 2). Nevertheless, the majority of participants declared having no knowledge about the health properties of green tea. This limited level of awareness within the studied population suggests that green tea consumption is mainly linked to cultural heritage and social habits rather than to conscious practice based on scientific or health considerations.

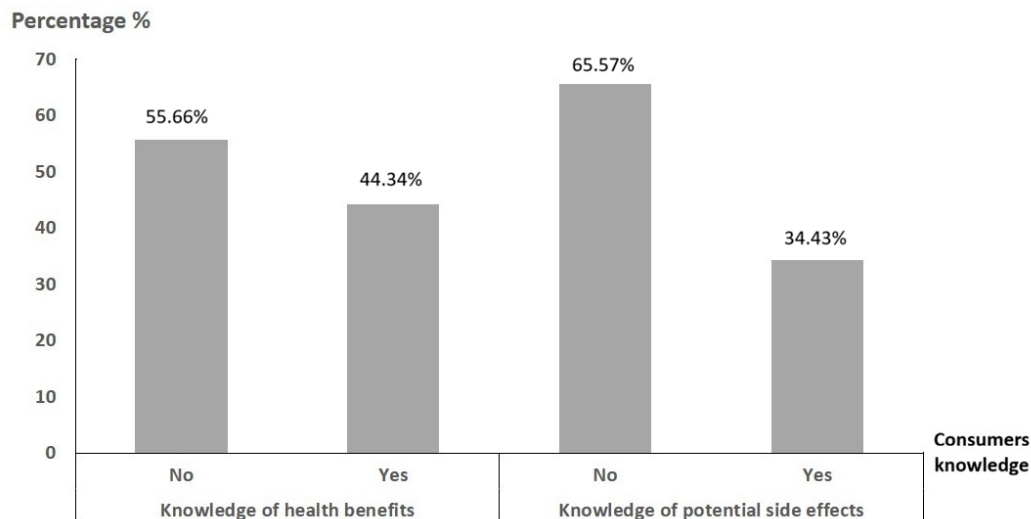


Figure 2. Consumers' awareness of the health benefits and potential side effects of green tea.

The main health benefits of green tea recognized by participants, was its stimulant (27 citations), antioxidant (26 citations), and relaxant effects (21 citations) (Table 7). These characteristics are consistent with scientific evidence, which attributes the antioxidant activity mainly to its richness in polyphenols. The stimulant effect is due to caffeine, while the relaxation property is related to the L-theanine amino acid implicated in the reduction of stress and anxiety (Sung *et al.* 2000; Vuong & Roach 2014).

Furthermore, 17 citations reported an anticancer property, suggesting a form of medicinal consumption associated with cancer prevention, which could be scientifically supported by previous scientific findings (Alam *et al.* 2022; Singh *et al.* 2024). The digestive benefits were relatively cited, notably improvement of digestion, which is in contradiction with scientific evidence reporting rather an anti-digestive effect of green tea (Lochocka *et al.* 2015). However, cardiovascular, immune, anti-inflammatory, antidiabetic, and dermatological benefits were rarely cited, generally between 1 and 8 citations, despite several scientific data supporting some of these properties (Choi *et al.* 2023; Nakadate *et al.* 2023; Zheng *et al.* 2024).

On the other hand, knowledge of the potential side effects of green tea was more limited among participants. The most cited side effect was anemia (29 citations) and reduction of iron absorption (24 citations) (Table 7). These adverse effects represent accurate local knowledge that align with scientific confirmation of the iron chelating effect of green tea (Mandel *et al.* 2006).

Citations of neurological and psychological disorders induced by green tea were limited, including sleep disturbances or insomnia (12 citations) and other neurological disturbances (4 citations). These side effects are principally associated with the stimulant effect of caffeine (Vuong & Roach 2014). This population awareness is consistent with our finding of the high percentage of respondents who do not drink tea either at night (79.72%) or with dinner (87.74%), as mentioned above (See Table 4). However, other side effects affecting the cardiovascular or urogenital system were rarely reported (two citations each).

Nevertheless, the potential risk of green tea contamination by pesticides or toxins, such as heavy metals and mycotoxins, remains largely underestimated by consumers (only one citation, Table 8). Sifou *et al.* (2023) reported the detection of lead and cadmium in green tea samples collected from some Moroccan markets. Although the detected concentrations were below internationally regulatory limits, their potential adverse health effects require careful consideration, particularly in the context of the frequent and excessive consumption that we documented in this present findings. Other studies reported the presence of mycotoxins in numerous samples of green tea from different Moroccan markets, with high levels of aflatoxins, notably aflatoxin B1 (AFB1) (Mannani *et al.* 2020; El Jai *et al.* 2021). The reported AFB1 concentrations reached up to 41.8 ng/g, exceeding the maximum accepted levels (10 ng/g) set by Moroccan regulations (Mannani *et al.* 2020). In this regard, the associated health risks of heavy metals and mycotoxins to consumers cannot be neglected, and highlight, the urgent need for reinforced quality control measures and systematic monitoring to mitigate potential risks.

In general, our results reflect a moderate knowledge of the beneficial health and potential side effects of green tea, which indicates certain gap between its widespread consumption and consumers' awareness. These findings support, therefore, a cultural practice rather than a scientific-based consumption. Although green tea is widely recognized for its diverse health benefits, such an uninformed empirical practice may lead to negative health consequences, particularly in cases of excessive and inappropriate consumption. Statistical analysis revealed a significant association between consumers' knowledge of tea benefits and side effects with their age, residential area and educational level. Young and urban participants, as well as those with a high educational level, were more informed compared to other categories, while people with no formal education were the most uninformed class (Table 8). Thereby, enhancing public awareness, through awareness-raising campaigns and educational initiatives, of both scientifically known health benefits and side effects of green tea is of major importance to promote rational use and public health prevention for healthy dietary practices. Non-governmental organizations may fill in this gap, along with official outreach programs through Television and Radio since the rural areas still largely depend on these basic information channels. Social media also constitutes a rapid, efficient way to reach people, mainly the young.

Table 7. Main health benefits and side effects of green tea reported by the participants.

	Level of influence	Main effects	Citations
Health benefits	Digestive system	Improvement of digestion	17
		Antidiarrheal	1
Cardiovascular system		Heart-health support	3
		Enhancement of blood circulation	4
		Antihypertensive	1
Neurological system / Psychological status		Antistress and anxiolytic	3
		Relaxant and calming	21
		Improvement of cognitive function	3
		Stimulant	27
Immune function		Immune-boosting	3
Anti-inflammatory effect		Anti-inflammatory	2
Analgesic effect		Analgesic	4
Infections		Antibacterial	4
		Antifungal	1
Cancer		Anticancer	15
Antioxidant activity		Antioxidant	26
Metabolic regulation		Antidiabetic	4
Dermatological effects		Skin protection	1
Weight management		Weight-loss	2
Intoxication		Antitoxin	3
		Total	145

Potential side effects	Digestive system	Reduction of intestinal absorption	3
		Reduction of iron absorption	24
		Digestive disorders	4
		Gastroesophageal acidity and heartburn	2
		Peptic ulcer / ulcer	2
		Intestinal pain at high doses	1
	Digestive system/Cancer	Stomach cancer	2
	Cardiovascular system	Enhancement of blood pressure & Increase of heart rate	2
	Anemia	Anemia	29
	Neurological system / Psychological status	Sleep disturbances / insomnia	12
		Neurological disturbances	4
		Anxiety	2
		Fatigue	1
	Urogenital system	Renal dysfunction	1
		Excess urea (hyperuricemia)	1
	Dental problem	Dental staining / tooth discoloration	1
Skeletal system	Bone weakness	1	
Intoxication	Pesticide contamination	1	
	Total	93	

Table 8. Chi-square analysis of the association between participants' socio-demographic characteristics and their knowledge of the health properties and side effects of green tea.

Knowledge	Socio-demographic characteristics	Khi 2	p-value
Knowledge of the health benefits	Gender	0.115	0.734
	Age	6.364	0.095
	Residence area	10.724	0.001
	Education	22.329	0.000
Knowledge of the side effects	Gender	0.105	0.745
	Age	21.196	0.000
	Residence area	2.120	0.145
	Education	28.742	0.000

Consumption patterns of green tea with MAPs

The consumption of green tea in combination with MAPs was revealed as a common ethnobotanical practice in the study area. The addition of MAPs generally aims not only at enhancing tea flavor, but also represents a phytotherapeutic practice. The majority of participants (83.49%) reported that they consume green tea with MAPs (Table 9). Among these participants, 56.50% indicated the use of a single MAP per preparation, while 41.24% reported the alternation between individual and plant mixture. A plant mixture refers to the simultaneous use of at least two MAPs with green tea per preparation.

Table 9. Combination of MAPs with green tea.

	Categories	Number	Percentage %
Green tea with MAPs	No	35	16.51
	Yes	177	83.49
Individual, mixture or both	Only individual	99	56.50
	Only mixture	4	2.26
	Individual and mixture	74	41.24

Individual MAPs added to green tea

The data of simple MAP combinations (*i.e.*, the use of a single plant per preparation) with green tea showed that the respondents used from one to seven species, with the majority of citations reporting one to three species used individually (Fig. 3). The present findings revealed that the use of MAPs is a common practice among the study population.

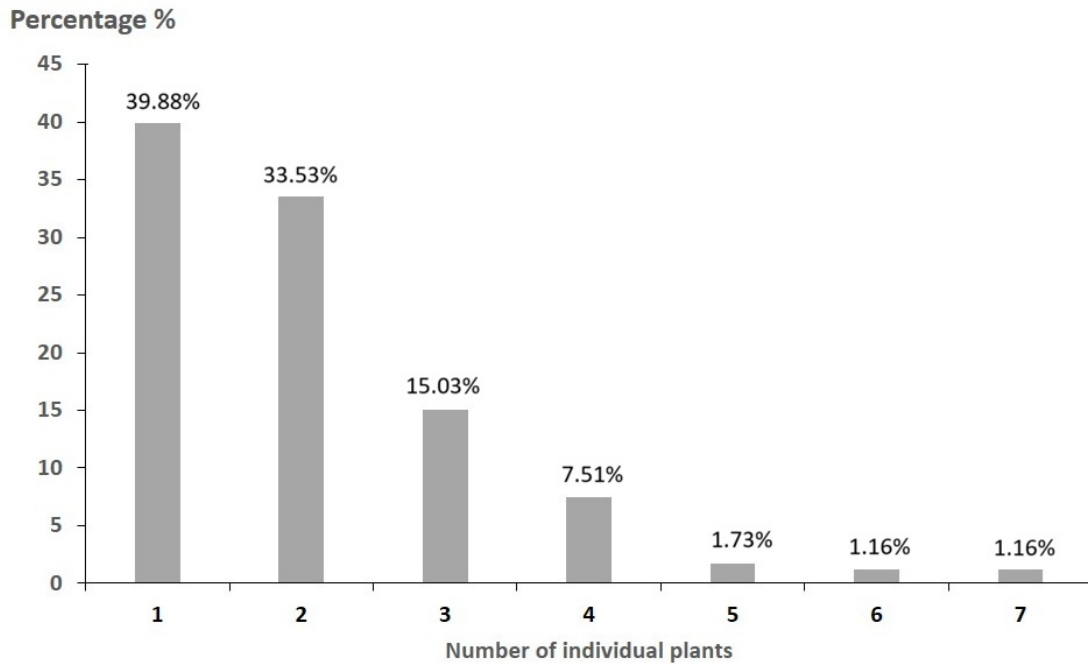


Figure 3. Distribution of the number of individual MAP species reported per participants.

The ethnobotanical inventory documented 17 plant species belonging to seven botanical families (Table 10). Among them, Lamiaceae was the most abundant family with eleven species, while each of the remaining families was represented by only one species. Family Importance Value revealed that the Asteraceae was the most prominent family with an FIV of 0.462, followed by Verbenaceae (FIV=0.151), and Lamiaceae (FIV=0.091). However, the other families showed low FIV, reflecting their limited use with green tea in our study area (Fig. 4).

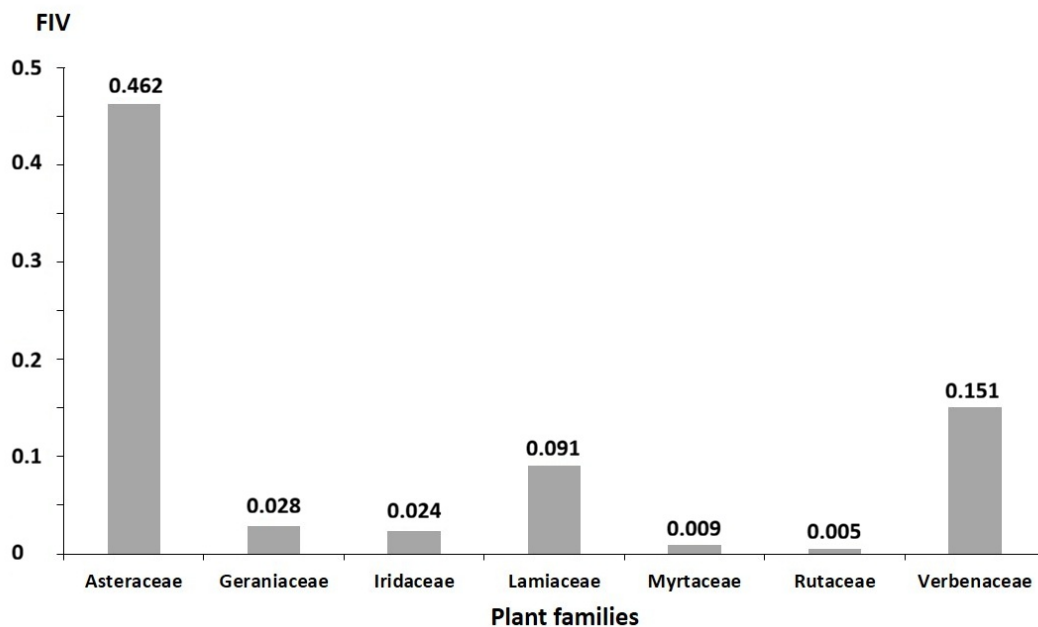


Figure 4. Family Importance Value (FIV) of the families of MAPs used individually with green tea.

Regarding the origin of the used plants, respondents reported the use of both spontaneous and cultivated plants, while some of consumers indicated no knowledge about their origin (Table 10). In addition, they obtain MAPs from different sources, mainly from street vendors, marketplaces, herbalists, cooperatives, home gardens and direct harvesting from nature. These data indicate the diversity and availability of MAPs in the study area. Moreover, it seems that many respondents cultivate MAPs near their homes to benefit from an organic source and avoid purchasing plants from unknown sources, and thus

avoid the negative impact of pesticides on their health. These findings also revealed a noticeable diversity in terms of use frequency, mainly dominated by a seasonal consumption, as well as high rate of daily use of these MAPs. A significant number of participants (71 out of 356 citations) reported that they use MAPs for medicinal purposes against a wide range of health disorders. Indeed, 10 species out of the 17 cited MAPs are used for at least one (*i.e.*, *Mentha suaveolens*) to more than ten therapeutic cases (*Origanum compactum*) (Table 10).

At the specific level, *Mentha spicata* was revealed as the most frequently used species, with 129 citation and an RFC of 0.609, followed by *Artemisia absinthium*, with 98 citations and an RFC of 0.462 (Table 10). These high citation numbers and RFC values reflect their cultural importance and strong integration in green tea preparation, as well as their availability in the study area. Both *M. spicata* and *A. absinthium* are cultivated species, and their use was dominantly based on aerial parts, mainly leaves and stems. Generally, they are added as fresh herbs and rarely in a dry state. Moreover, their consumption showed a marked seasonal pattern. *Mentha spicata* is mainly preferred during warm periods, particularly in spring and summer, due to its refreshing properties (Zhang *et al.* 2025), while, *A. absinthium* is generally consumed during colder periods, particularly in winter, which may be associated with its perceived warming effect (McMullen *et al.* 2014). In the majority of citations, these both species were principally added to green tea for their flavoring property, while their medicinal use was rarely reported, indicating a predominantly gastronomic rather than therapeutic use. For *M. spicata*, the medicinal use accounted for 6 out of 129 citations and was mainly associated with the management of digestive disorders (*e.g.*, impaired digestion and nausea), nervous disorders notably stress and anxiety, musculoskeletal pain, common cold, and halitosis. For *A. absinthium*, the medicinal use was reported only in 4 out of 98 citations, mainly as an antidiarrheal, for gastrointestinal infections, as well as in the case of fever (Table 10). Although the studies show that *A. absinthium* has potent neuroprotective effects, due to its antioxidant properties, it is also reported to be neurotoxic at high doses (Lachenmeier 2010).

Origanum compactum and *Aloysia citrodora* were ranked in the second place in terms of use frequency, each cited 32 times with an RFC of 0.151. They both reported as the most frequently used species for medicinal purposes, indicating their important role in local phytotherapeutic practices (Table 10). For *O. compactum*, the used parts were leaves and stems in both dried and fresh forms. The species is from both spontaneous and cultivated origins. The medicinal uses of *O. compactum*, in combination with green tea, were diverse, including the management of infection and related pains, such as abdominal, menstrual, uterine, toothache, and headache. It was also used in the case of influenza, common cold and asthma, as well as for digestive, neurological and urogenital disorders (Table 10). Numerous studies have revealed the significant integration of *O. compactum* into phytopharmacological practices in Morocco, which is linked to its known strong biological activities such as antimicrobial, anticancer, and antioxidant, among others, mainly attributed to carvacrol and thymol (Sharifi-Rad *et al.* 2021). *Aloysia citrodora* is a cultivated species, whose leaves represent the only plant part used in both fresh and dried states (Table 10). The reported medicinal use of this species, in combination with green tea, is related to its sedative properties, notably to manage stress, anxiety, insomnia and hypertension. Other consumers also reported its use in the case of headaches, digestive, and cardiovascular disorders. The sedative and cardiovascular effects of this species are widely documented in literature (Haryalchi *et al.* 2023). It is very important to highlight that many participants reported a daily or regular consumption frequency of both *O. compactum* and *A. citrodora* (Table 10). Despite their effectiveness, the side effects that could be induced by their long-term consumption have to be seriously considered.

With 18 citations, *Mentha pulegium* seems to be relatively used with green tea by a significant portion of the study population, with seven participants reporting a medicinal use. The parts used were leaves, stems, and flowers in both dried and fresh forms. The species is mainly employed in the case of respiratory disorders, including the common cold, and cough. However, its richness in pulegone may cause hepatotoxicity effect at high doses and long-term consumption (Voigt *et al.* 2024).

Pelargonium graveolens (6 citations), *Crocus sativus* and *Salvia officinalis* (5 citations each) were rarely reported, although their availability. While, *Mentha x piperita*, *Salvia rosmarinus*, *Thymus spp.*, and *Syzygium aromaticum* cited two times each, and *Lavandula stoechas*, *O. majorana*, *Satureja nepeta*, and *Citrus spp.*, with a single citation each, were very rarely used in tea preparation (Table 10).

Table 10. Ethnobotanical information on individual MAPs used in combination with green tea.

Family	Scientific name	Vernacular name	Citations	RFC	Growth	Sources	Used part	State	Frequency of use					Medicinal use		
									DU	RU	WU	MU	SU	No	Yes	Treated diseases & symptoms
Asteraceae	<i>Artemisia absinthium</i> L.	Chiba	98	0.462	98 C	SV, HG	L. S	F. D	7	6	-	1	84	94	4	Digestive disorders (Antidiarrheal effect, Gastrointestinal infection). Inflammation (Fever, Joint pain)
Geraniaceae	<i>Pelargonium graveolens</i> L'Hér	Aatarcha	6	0.028	6 C	SV, HG	L. S. Fl	F. D	-	1	3	2	-	4	2	Digestive disorders, Menstrual pain, Anxiety, Acne management
Iridaceae	<i>Crocus sativus</i> L.	Zaafan	5	0.024	5 C	Coop, MK	St	D	-	1	1	3	-	3	2	Antioxidant effect, Urogenital disorders
Lamiaceae	<i>Lavandula stoechas</i> L.	Halhal	1	0.005	1 S	HN	L	D	-	-	-	-	1	1	-	-
	<i>Mentha × piperita</i> L.	Mantya	2	0.009	1 C. 1 DK	SV	L. S	F	-	-	-	-	2	2	-	-
	<i>Mentha pulegium</i> L.	Flayou	18	0.085	7 C. 9 S. 2 DK	SV, HG, HN	L. S. Fl	F. D	3	5	7	-	3	11	7	Respiratory disorders, Common cold, Cough, Menstrual pain
	<i>Mentha spicata</i> L.	Naanaa	129	0.609	129 C	SV, HG, MK	L. S	F. D	41	5	4	5	74	123	6	Digestive disorders, Improve digestion, Nausea, Nervous disorders (Stress, Anxiety), Muscle pain, Common cold, Halitosis management
	<i>Mentha suaveolens</i> Ehrh.	Timija	19	0.090	13 C. 2 S. 4 DK	SV, HG, HN	L. S	F. D	5	4	5	3	2	18	1	Anti-inflammatory effect
	<i>Origanum majorana</i> L.	Merdedouch	1	0.005	1 C	SV	L	F	-	1	-	-	-	1	-	-
	<i>Origanum compactum</i> Benth.	Zaatar	32	0.151	7 C. 14 S. 11 DK	SV, HN, Coop, Her	L. S	F. D	10	3	6	13	-	4	28	Pain (Abdominal, Menstrual, Uterine, Toothache, Headache), Respiratory disorders (Influenza, Common cold, Asthma), Nervous disorders and Stress, Digestive disorders (Gastric ulcer), Urogenital disorders
	<i>Salvia officinalis</i> L.	Salmiya	5	0.024	5 C	HG, SV	L	F. D	1	-	1	3	-	2	3	Digestive disorders, Menstrual cycle regulation, Gum bleeding

	<i>Salvia rosmarinus</i> Spenn.	Azir	2	0.009	2 C	HG	L	F. D	-	-	2	-	-	2	-	-
	<i>Satureja nepeta</i> (L.) Kuntze	Manta	1	0.005	1 C	SV	L. S	F	-	1	-	-	-	1	-	-
	<i>Thymus</i> sp.	Zeaitra	2	0.009	2 S	HN, SV	L	F. D	1	-	-	1	1	1	1	Digestive disorders
Myrtaceae	<i>Syzygium aromaticum</i> (L.) Merr. & L.M.Perry	Kranfel	2	0.009	2 C	Her	Sd	D	-	-	2	-	-	2	-	-
Rutaceae	<i>Citrus</i> sp.	Zhar de limon	1	0.005	1 C	HG	Fl	F	-	-	-	-	1	1	-	-
Verbenaceae	<i>Aloysia citrodora</i> Paláu	Louiza	32	0.151	32 C	SV, HG, Her, Coop	L	F. D	5	6	7	8	6	12	20	Nervous disorders (Stress, Anxiety, Insomnia), Headache, Digestive disorders,, Cardiovascular disorders

Legend:

RFC: Relative Frequency of Citation

Growth: C: Cultivated; S: Spontaneous; DK: Don't know**Sources:** MK: Marketplace; Her: Herbalist; Coop: Cooperative; HN: Harvesting from nature; SV: Street vendor; HG: Home garden**Used parts:** L: Leaves; S: Stem; Fl: Flowers; Sd: Seeds; St: Stigma**States:** F: Fresh; D: dried**Frequency of use:** DU: Daily use: 6-7 day or more per week; RU: Regular use: 3-5 day per week; WU: Weekly use: 1-2 day per week; MU: Monthly use: < 4 day per month; SU: Seasonal use: spring, summer, etc.

MAP mixtures added to green tea

The use of MAP mixtures in combination with green tea was reported by 36% of participants, indicating a relatively common practice in the study area (Table 11). The majority of consumers declared using a single type of mixture, while a small proportion reported the use of two or three different mixtures. A total of 93 mixtures were cited by 78 participants. The number of combined plants per preparation ranged between two and nine plant species, with a marked predominance of five and four plant combinations (27.96% and 25.81%, respectively). In contrast, complex mixtures incorporating seven to nine plants were infrequently (together 7.53%) reported. The results showed a great diversity of plant parts used in the preparation of mixtures, with a predominance of the dried form, which could be due to its long-term storage by both vendors and consumers. Regarding consumption patterns, most participants reported weekly, monthly or very rarely use frequency, whereas daily, regular, and seasonal uses were rarely mentioned, indicating irregular rather than habitual practice (Table 11). Additionally, 60% of citations indicated no medicinal use of the mixtures, whereas 40% of citations were associated with therapeutic purposes. The data revealed that the principal source of knowledge regarding mixture preparation was from traditional familial heritage (65%) and herbalists (16%). In contrast, other sources of information, such as healthcare professionals, social media and books were rarely reported, which further confirms the depth and continuity of traditional ethnobotanical practices in the study area.

Table 11. Source, composition, and frequency of use of MAPs cited in mixtures with green tea.

		Number	Percentage %
Green tea preparation with MAP mixtures	No	134	63.68
	Yes	78	36.32
Number of MAP mixtures used per respondent	One mixture	66	84.42
	Two mixtures	9	11.69
	Three mixtures	3	3.90
Source of mixture	MAP mixture prepared by the consumer	78	83.70
	MAP mixture ready-to-use	15	16.30
Number of plants per mixture	Two plants	8	8.60
	Three plants	18	19.35
	Four plants	24	25.81
	Five plants	26	27.96
	Six plants	10	10.75
	Seven plants	4	4.30
	Eight plants	2	2.15
	Nine plants	1	1.08
Use frequency	Daily use (6-7 days per week)	4	4.3
	Regular use (3-5 days per week)	9	9.68
	Weekly use (1-2 days per week)	28	30.11
	Monthly use (1-3 days per month)	24	25.80
	Very rarely (<1 day per month)	21	22.58
	Seasonal use	7	7.53

In contrast to the individual use of MAP species, the analysis of plant mixtures revealed a significant richness at both familial and specific levels, with a total of 13 botanical families and 31 species (Table 12). At the family level, Geraniaceae and Verbenaceae appeared as the most prominent families with FIV of 0.208 and 0.189, respectively, followed by Lamiaceae (FIV=0.093) (Fig. 5). The remaining families were rarely cited with FIV not exceeding 0.031. Despite being ranked third in terms of family importance, Lamiaceae displayed the highest species richness, with 14 species (Table 12). This diversity reflects the frequent use of Lamiaceae taxa in mixture preparation, principally for aroma enhancement, as well as their importance in phytotherapeutic practices.

All 17 plant species reported in the individual use (see Table 12) were also incorporated into plant mixtures. Among these species, some rarely used individually, such as *Salvia officinalis* and *S. rosmarinus*, were frequently involved in mixture preparations (Table 12). However, 14 species were exclusively cited in mixture preparations, suggesting a specific ethnobotanical practice related to plant mixture formulation. Among these species, *Alpinia purpurata* is the only plant that is not classed as an aromatic taxon.

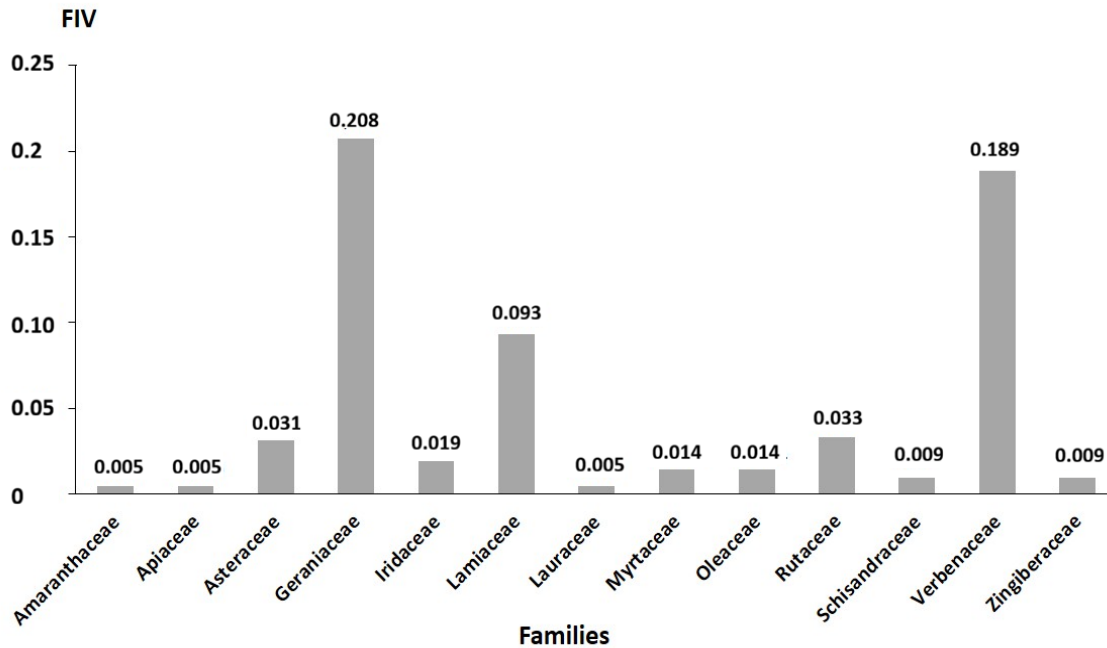


Figure 5. Distribution of family importance value (FIV) among the botanical families reported in the study.

Species of the genus *Mentha* were predominant in mixture preparations, particularly *M. spicata* (59 citations), *M. pulegium* (48 citations), and *M. suaveolens* (44 citations). These species were most often combined with *Pelargonium graveolens* (44 citations), *A. citrodora* (40 citations), *O. compactum* (37 citations), and *S. officinalis* (29 citations) (Table 12). A second group of moderately cited species included *A. absinthium*, *S. rosmarinus*, and *Thymus* spp., each cited 15 times, followed by *Ocimum basilicum* (13 citations), *O. majorana* (10 citations), and *Citrus* spp. (7 citations). The remaining species were occasionally cited, indicating a limited frequency or a specific context of use. The low citation of some species could also be due to the fact that they are uncommon, mainly for cultivated plants that are occasionally sold or are expensive.

This richness in mixtures and in incorporated plants indicates the noticeable importance of this practice in local traditions. In addition, the moderate use of MAP mixtures with green tea indicates a circumstantial specific rather than systematic use. The popularity of self-prepared mixtures reflects an inherited ethnobotanical knowledge reinforced by the availability of MAPs, which is further evidenced by the notable presence of street vendors and herbalists specializing in the sale of MAPs in the study region. Moreover, the dominance of four to five species per mixture suggests balanced preparations.

The strong prevalence of *Mentha* spp. rich in aromatic compounds such as menthol, carvone and pulegone (Oualdi *et al.* 2023; Saba *et al.* 2024), in addition to *P. graveolens* and *A. citrodora* rich in citral and geraniol (Jaradat *et al.* 2022; Majewska *et al.* 2022) compounds indicates that they are mainly used for their aromas and sensory preferences. Moreover, the integration of *O. compactum*, *S. officinalis*, *Thymus* spp. and *A. citrodora*, known for their potent bioactive compounds, contributes to improving (Table 8) the medicinal properties of the mixtures.

This interspecific variability in chemical composition and related biological activities may increase the possibility of plant-plant and plant-green tea interactions, especially in complex or unbalanced multi-plant preparations (Bloch *et al.* 2023). In this context, the regular and long-term use of certain mixtures may cause potential risk effects (Abdel-Aziz *et al.* 2016; Reisi *et al.* 2025). Therefore, urgent investigations are needed to assess the possible chemical interactions, mainly for the most commonly used species, both in individual and multi-plant combinations to guarantee their security profile and to avoid any risk of poisoning or associated side effects.

Table 12. Ethnobotanical data of MAPs used in mixture preparations with green tea.

Family	Scientific name	Vernacular name	Citations	RFC	Growth			Used parts	State
					C	S	DK		
Amaranthaceae	<i>Dysphania ambrosioides</i> (L.) Mosyakin & Clemants	Mkhinza	1	0.005	-	1	-	L	F

Apiaceae	<i>Ammodaucus leucotrichus</i> Coss. & Durieu	Kamoun Essoufi	1	0.005	-	-	1	Sd	D
	<i>Coriandrum sativum</i> L.	Kazbour	1	0.005	1	-	-	Sd	D
Asteraceae	<i>Artemisia absinthium</i> L.	Chiba	15	0.071	15	-	-	L. S	F
	<i>Artemisia herba-alba</i> Asso	Chih	1	0.005	-	1	-	L	D
	<i>Matricaria chamomilla</i> L.	Camomille	4	0.019	2	1	1	L. S. FI	F. D
Geraniaceae	<i>Pelargonium graveolens</i> L'Hér.	Aatarcha	44	0.208	44	-	-	L. S	F. D
Iridaceae	<i>Crocus sativus</i> L.	Zaafan	4	0.019	4	-	-	St	D
Lamiaceae	<i>Mentha × piperita</i> L.	Mantya	1	0.005	1	-	-	L	D
	<i>Lavandula</i> sp.	Lkhzama	2	0.009	-	-	2	FI	D
	<i>Lavandula stoechas</i> L.	Halhal	1	0.005	-	1	-	L	F
	<i>Marrubium vulgare</i> L.	Marrube	1	0.005	-	1	-	L	F
	<i>Mentha pulegium</i> L.	Flayou	48	0.226	32	16	-	L. S	F. D
	<i>Mentha spicata</i> L.	Naânaâ	59	0.278	59	-	-	L. S. FI	F. D
	<i>Mentha suaveolens</i> Ehrh.	Timija	44	0.208	39	4	1	L. S	F. D
	<i>Ocimum basilicum</i> L.	Hbak	13	0.061	12	1	-	L. S. FI	F. D
	<i>Origanum majorana</i> L.	Merdaddouch	10	0.047	10	-	-	L. S. FI	F. D
	<i>Origanum compactum</i> Benth.	Zaatar	37	0.175	12	18	7	L. S. FI	F. D
	<i>Salvia officinalis</i> L.	Salmiya	29	0.137	29	-	-	L	F. D
	<i>Salvia rosmarinus</i> Spenn.	Azir	15	0.071	12	1	2	L. S	F. D
	<i>Satureja nepeta</i> (L.) Kuntze	Manta	1	0.005	1	-	-	L. S	F
	<i>Thymus</i> spp.	Zeitra	15	0.071	3	10	2	L. S. FI	F. D
Lauraceae	<i>Cinnamomum verum</i> J.Presl	Lkarfa	1	0.005	1	-	-	SB	D
Myrtaceae	<i>Syzygium aromaticum</i> (L.) Merr. & L.M.Perry	Kranfel	3	0.014	3	-	-	Sd	D
Oleaceae	<i>Jasminum officinale</i> L.	Yasmine	3	0.014	3	-	-	FI	D
Rutaceae	<i>Citrus</i> spp.	Hamed; Limon	7	0.033	7	-	-	L. FI Fr.P	F
Schisandraceae	<i>Illicium verum</i> Hook.f.	Badiayana	2	0.009	2	-	-	Fr	D
Verbenaceae	<i>Aloysia citrodora</i> Paláu	Louiza	40	0.189	40	-	-	L. S	F. D
Zingiberaceae	<i>Alpinia purpurata</i> (Vieill.) K.Schum.	Khodenjal	1	0.005	-	-	1	R	D
	<i>Elettaria cardamomum</i> (L.) Maton	Kaaklla	2	0.009	2	-	-	Sd	D
	<i>Zingiber officinale</i> Roscoe	Gingembre	3	0.014	3	-	-	R	F. D

Legend

Growth: C: Cultivated; S: Spontaneous; DK: Don't know

Used part: Fr: Fruits; Fr.P: Fruits peels; SB: Stem bark; L: Leaves; S: stem; FI: Flowers; Sd: Seeds; St: Stigma

State: F: Fresh, D: Dried

Conclusion

Green tea consumption is prevalent in many regions worldwide. However, the practices and habit patterns associated with its consumption are still undocumented in Morocco. Taking the Beni Mellal-Khenifra region as a case study, this research filled in this gap through a comprehensive survey of green tea consumption practices, with particular emphasis on the MAPs combined with tea. The present study demonstrates that green tea constitutes an integral component of local dietary habits, which explains the high quantities of green tea imports into Morocco. The diversity observed in its preparation and modes of consumption reflects a deeply rooted ethnobotanical tradition, primarily grounded in cultural heritage rather than scientific evidence. The required information mainly consisted of the nature of MAPs combined with green tea, either individually or in mixture, their frequency of use, their health benefits, and potential side effects. The ethnobotanical inventory revealed considerable botanical richness in both single and mixture plant preparations, as well as their common use in phytotherapy by the local population. Nevertheless, the diversity of incorporated species and the complexity of certain mixtures raise important safety considerations. It would be interesting to extend this survey to other Moroccan regions (e.g., northern, central, and southern) to draw a general picture of how people use MAPs with green tea.

Declarations

Ethics approval and consent to participate: This study did not require official ethical approval, as it did not involve any clinical procedures or vulnerable populations. However, the research followed known ethical norms for ethnobotanical studies. Prior informed consent was obtained verbally from all participants after explaining the aims of the study. Participation was voluntary, and all data obtained were treated with confidentiality and respect for local cultural norms and customs.

Consent for publication: Not applicable

Availability of data and materials: Not applicable

Competing interests: We declare that we have no conflict of interest.

Funding: Not applicable

Author contributions: Conceptualization, methodology, M.B., A.K., M.B.S., Data collection, C.E.H, S.M, B.M., A.K., Writing, M.B., M.B.S., Data analysis, discussion, review and editing, M.B., A.K., S.A, C.E.H., M.S., M.B.S.

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