ISSN 2709–3662 (Print)
ISSN 2709–3670 (Online)
https://doi.org/10.52587/JAF050201
Journal of Agriculture and Food
2024, Volume 5, No.2, pp. 1-18

Stepping towards essential oil extraction technology: Prospects and Challenges for aromatic growers in Northern Punjab, Pakistan

Fouzia Anjum*, Sher Muhammad, Badar Naseem Siddiqui

Abstract

Promoting awareness and knowledge dissemination becomes a powerful tool for propelling both sustainability and profitability in navigating the complexities of contemporary agriculture. The perceived effectiveness and profitability are likely attributed to the high-value crops, particularly essential oils such as eucalyptus oil as lucrative. A sample size of 288 aromatic growers was selected from stratified random sampling in northern Punjab, Pakistan. This study delves into the prospects and challenges impacting farmers' knowledge concerning three distinct essential oil extraction (EOE) practices using ordinal regression analysis. The key findings revealed that the majority of the respondents perceived these practices as cost-effective, profit-driven, productive in terms of crop yield, and motivated towards adoption as statistically significant predictors. Conversely, limited market proximity, negative perception among peers, and scarcity of skilled workforce proved to be significant barriers triggering their perception toward adoption. The application of ordinal regression analysis knowledge provided a thorough understanding of decision-making processes among aromatic growers. This study contributes to the theoretical framework by highlighting the interconnectedness of economic factors and farmers' knowledge, providing a nuanced understanding of the drivers behind EOE practices. Hence, this study underscore the importance of this multi-

[1]Department of Agricultural Sciences, Allama Iqbal Open University, Islamabad, Pakistan;[2]Department of Agricultural Sciences, Allama Iqbal Open University, Islamabad, Pakistan;[3]Department of Agricultural Extension, PMAS-Arid Agriculture University Rawalpindi, Pakistan; *Corresponding author email: fauziaanjum184@gmail.com

faceted approach involving education, policy, and industry participation to promote a sustainable and profitable essential oil sector within the agricultural landscape of the Asiatic region. Therefore, it is recommended to enhance farmer education through targeted training programs, incentivize eco-friendly practices with supportive policies, and foster innovation through public-private partnerships to drive a profitable essential oil sector.

Keywords: Eucalyptus Essential-oil**,** Perceived knowledge, Determinants, barriers, Ordinal regression

Article History: Received: 15 November 2024; Revised: 13 December, 2024; Accepted: 25 December, 2024, Published: 31 December, 2024

Introduction

Essential oils are often considered high-value products (Barbieri & Borsotto, 2018). Cultivating and extracting these oils contribute substantial value to the agricultural yield of farm families (Duarte et al., 2017). This value-addition plays a pivotal role in fostering comprehensive economic growth in rural communities. The global essential oils market is significant, estimated at USD 23.74 billion in 2023, with forecasts predicting it will reach USD 27.82 billion by 2032, representing a compound annual growth rate (CAGR) of 10.55% (Kumar et al., 2024). The cultivation and extraction of essential oils can greatly boost the agricultural income of farm families. The involvement of farm families in the essential oil sector encourages them to diversify their agricultural activities. This can drive risk mitigation because the reliance on a single crop is reduced, opening up avenues for adopting sustainable and profitable farming practices (Ootani et al., 2013).
Farmers engaged in this sector are likely to acquire new skills, thereby enhancing their capacity for sustainable agricultural practices and improving their overall socio-economic standing (Devi et al., 2015). The Food and Agriculture Organization FAO, (2024) emphasizes that income-generating activities like essential oil production can significantly enhance rural livelihoods (Karki, 2020; Khan et al., 2020). Shared resources, knowledge exchange, and collaborative efforts among farm families can contribute to the development of supportive and thriving rural communities. The agriculture sector in Pakistan experienced strong growth in 2023-24, showing an overall increase of 6.25 percent (Pakistan Economic Survey, 2023-24). Research in developing countries emphasizes the need to diversify agricultural practices to boost farm income and foster sustainable development (Delgado & Siamwalla, 2018). Incorporating EOE practices supports this goal, providing farmers with new opportunities for economic growth. Therefore, introducing robust farming knowledge of essential oil extraction (EOE) practices can boost awareness and interest among farming communities. Several prospects and challenges need to be defined in this regard. Numerous key aspects highlight the contribution of the essential oil sector including, income generation, employment opportunities, and value-addition to agriculture (Schmidt, 2020).

Farming and extraction of essential oils, such as eucalyptus and mint oils, offer farm families an additional source of income (Franz & Novak, 2020). These crops frequently yield higher returns than conventional crops, thereby enhancing financial stability and overall economic prosperity. Furthermore, throughout the essential oil

production chain, from cultivation and harvesting to processing and marketing, labor is essential (Bhattacharya, 2016; Ying Li, 2014). This contributes to the improvement of rural livelihoods and the reduction of unemployment. In addition to these factors, understanding others such as market demand, crop selection, technological advancement, education, training, and market linkages, is crucial for devising effective strategies to harness the sector's full potential (Sharmeen et al., 2021). Strong and consistent market demand ensures stable income for farm families. The success of the sector is influenced by the demand for essential oils across diverse industries, including cosmetics, pharmaceuticals, and aromatherapy (Alighiri et al., 2017; Franz & Novak, 2020). The choice of high-value aromatic crops including, eucalyptus and mint, is a pivotal determinant. Hence, factors such as optimum crop selection along with market demand tend to result in high profitability, which contributes to the sector's socio-economic impact (Abere & Adetunji, 2024). Access to modern and efficient extraction technologies enhances productivity and quality, positively impacting the sector's economic contribution (Ghasemy-Piranloo et al., 2022). Providing education and training programs for farmers on the finest practices in cultivation, harvesting, and extraction techniques enhances their skills. This, in turn, contributes to increased productivity and economic benefits (Riaz et al., 2021). Establishing strong linkages between farmers and markets, both domestic and international, facilitates the efficient distribution and sale of essential oils (Bolouri et al., 2022). Access to broader markets can significantly impact the income of farm families.

In contrast, addressing different barriers that hinder the adoption of improved practices, is necessary. Limited technical knowledge and awareness about modern cultivation and extraction practices can hinder the success of advanced farming practices (Canwat & Onakuse, 2022). Training programs, educational initiatives, and farmer's participation are crucial for overcoming this barrier. The limited access to markets, especially for smallholders, can restrict the sector's potential. Addressing infrastructure challenges and improving market linkages are essential to overcome this hurdle (Sen & Ganguly, 2017). Limited availability of suitable farmland and resources for cultivation can be a challenge, especially in resource-constrained regions. Sustainable farming practices such as EOE practices and resource management are essential to address this challenge (Mahcene et al., 2020; Merad et al., 2021). Likewise, high initial investment requirements for modern equipment and technology may pose financial challenges for farmers particularly smallholders (Johnson, 2013; Montanari, 2012). Hence, the essential oil sector's contribution to the socio-economic development of farm families is multifaceted, encompassing economic, social, and environmental dimensions (Choudhary et al., 2018). Its impact goes beyond individual households, influencing their overall well-being and prosperity. By overcoming these challenges and leveraging favorable factors, the essential oil sector can play a more significant role in fostering the socio-economic development of farm families.

The primary research questions of this study are as follows: What are the key economic factors driving the adoption of essential oil extraction (EOE) practices among aromatic growers in northern Punjab, Pakistan? What are the main barriers preventing the adoption of EOE practices in this region?

In developing countries, meager literature is available that highlight the importance of essential oil extraction (EOE) practices in uplifting the well-being of farmers. Less emphasis is placed on how the combination of socioeconomic, personal, and

farming variables, linked to perceived knowledge, influences the implementation of EOE practices at the farm levels. In the existing literature, the majority of studies tend to assess components separately, such as education, income, labor, and extension service. This study aims to analyze the existing associations among factors and barriers and explore how they affect and impede the application of these practices within peasant families in northern Punjab, Pakistan. This study is the first in the region; hence, it offers valuable insights for governmental and professional entities including, agricultural extension personnel. These insights can guide decision-making processes related to the formulation of initiatives, emphasizing strategies that recalibrate the existing agricultural development model.

Area of study

This study was conducted in the northern region of Punjab, Pakistan, which is located between latitude 33º 10′ to 33º 15′ N, and longitude east 73º 15′ to 73º -20′ E (figure 1). This is an extensive rain-fed region in Pakistan, encompassing an area of 1.8 million hectares (Shaheen, 2016). The region is composed of four main districts: Attock, Rawalpindi, Chakwal, and Jhelum. The climate falls within the continental subtropical category, characterized by hot summers and relatively cold winters, and is situated in a semiarid to sub-humid climate zone. In December, temperatures average 9°C, peaking at 31°C in June. Annual rainfall ranges from 400 mm in the plains to 1710 mm in the mountains, with two-thirds occurring during the June–September monsoon (Hussain et al., 2021).

Population and sampling size determination

This study employed a participatory characterization survey to evaluate the perceived knowledge of small-scale farmers about EOE practices in Northern Punjab, Pakistan. A list of registered eucalyptus crop growers was obtained from the Punjab Forest Department, which served as the sampling framework. A total of 1,155 growers were collectively engaged in cultivating aromatic crops in Northern Punjab. Hence, the surveys were taken from a sample size of 288 aromatic crop growers. For the surveys, respondents were selected randomly using simple random sampling in the study area (Table 1). The survey was conducted between August and September, 2023. It consisted of 03 distinct EOE practices, providing comprehensive information on numerous determinants and barriers that influence and trigger perceived knowledge on practices. It further incorporated close-ended questions regarding the growers' perceptions of EOE practices toward adoption.

$$\text{Sample size (n)} = \frac{(z^2 * p*q * N)}{(N-1)* e^2 + (z^2 * p*q)}$$

Where,

z= 1.96 (for alpha = 5%), e = 0.05 (for five-point Likert scale (95% confidence interval), p= 0.5, q= 1-p = 0.5

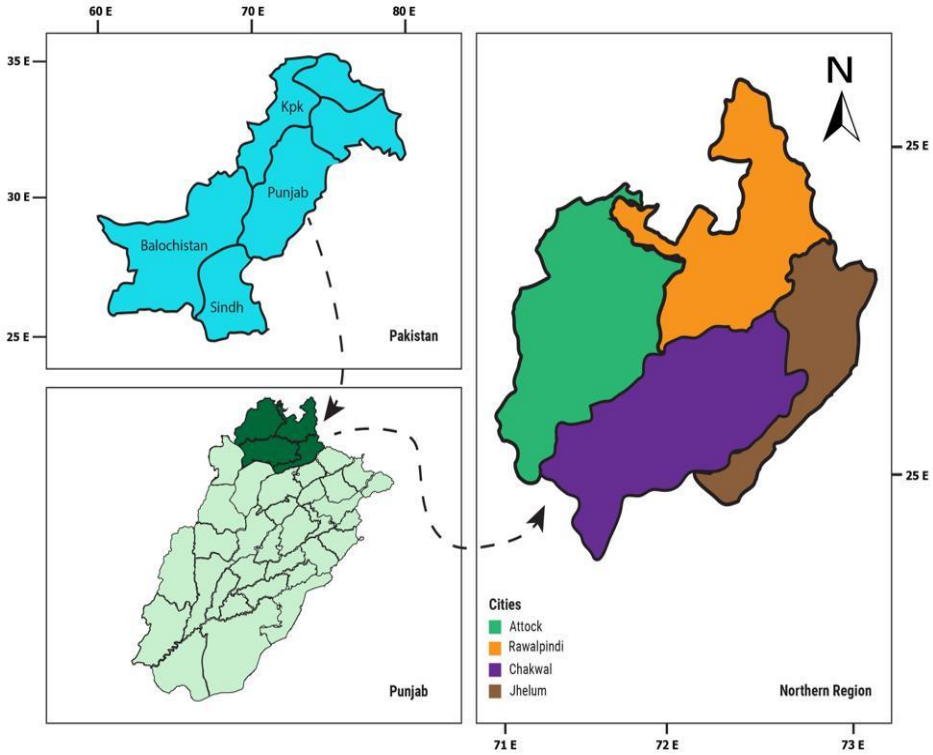

Figure 1. Map of the study area

Data analysis

Descriptive statistics were developed from the collected values following the information gathering process. After completing the socioeconomic characterization stage, codes were allocated, and the data were added into a database. Detailed description of the recommended EOE practices along with key variables of the study is presented in Table 2. Initially, a correlation was run to evaluate the associations between the determinants and barriers affecting the knowledge level of the selected growers. Subsequently, a multicollinearity analysis was performed to examining the degree of correlation among independent variables in a regression model. It helps to assess the potential presence of high correlations, which can impact the reliability and interpretability of the model's coefficients. Finally, ordinal logistic regression was employed to analyze the relationship between the dependent variable (knowledge level) with the ordered categories as low, medium, and high and independent (factors and barriers) variables. Ordinal regression analysis was chosen for this study due to its suitability for the ordinal nature of the dependent variable—farmers' perceptions of essential oil extraction (EOE) practices—ranked as "low," "moderate," and "high." Unlike linear regression, which assumes equal intervals, ordinal regression preserves the rank structure, ensuring accurate modeling.

Additionally, it identifies significant predictors and their impact on adoption decisions, aligning with the study's objective to understand factors influencing farmers' perceptions

Results

Socio-economic profile of the respondents

Demographic data provides insights into how social and economic factors, such as farm size, resource allocation, and usage, affect the farming community. Most growers in the study areas are aged 41-50, with eucalyptus cultivation being the primary source of income in the region. Analysis shows that most households earn between PKR 61,000 to 120,000 per season (Figures 2 & 3), with income levels significantly shaping attitudes towards new technology adoption. Additionally, 45% of households have only primary education, limiting knowledge of sustainable practices (Figure 4). Majority of the respondents have had higher farming experience (48%) falling under the category of 11-20 years of farming experience (Figure 5). Experience is another key factor, with more experienced farmers typically better positioned to adopt improved practices and share knowledge, enhancing their socio-economic status.

Correlation beteween the selected variables of the study

The results revealed a statistically significant moderate correlation between the determinants such as lowering the cost of input and boost awareness (X_7, and X_2) (0.217), followed by a cost-effective approach and heightening interest (X_8, and X_3) (0.194), openness to the practice and convenient practice (X_{11}, and X_1) (0.191), willingness to adopt it and amplify awareness level (X_{11}, and X_2) (0.186), and improvement in interest and minimze farm cost (X_8, and X_6) (0.163), respectively (Figure 6). On the contrary, a moderate positive correlation

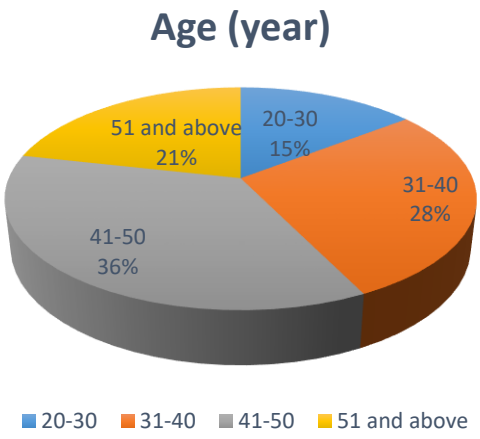

Figure 2. Age (year) of the respondents

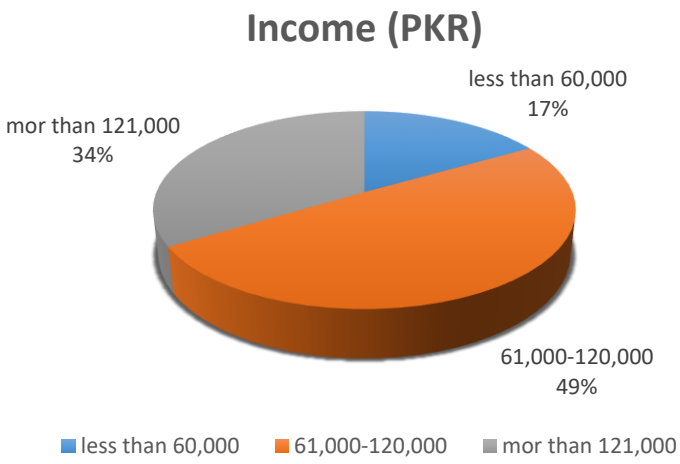

Figure 3. Income (PKR) of the respondents

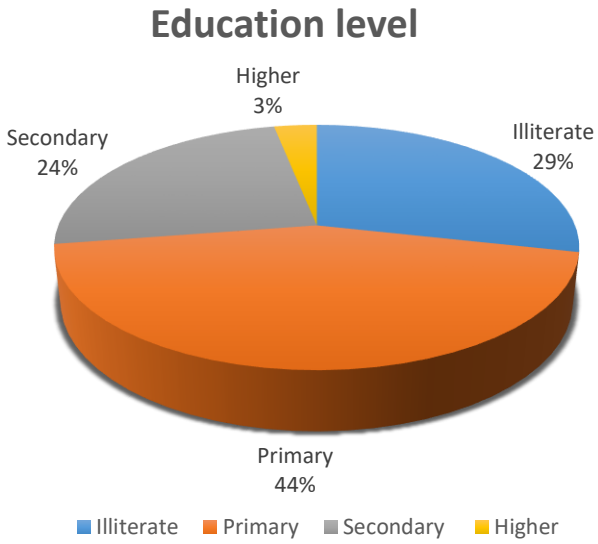

Figure 4. Education (level) of the respondents

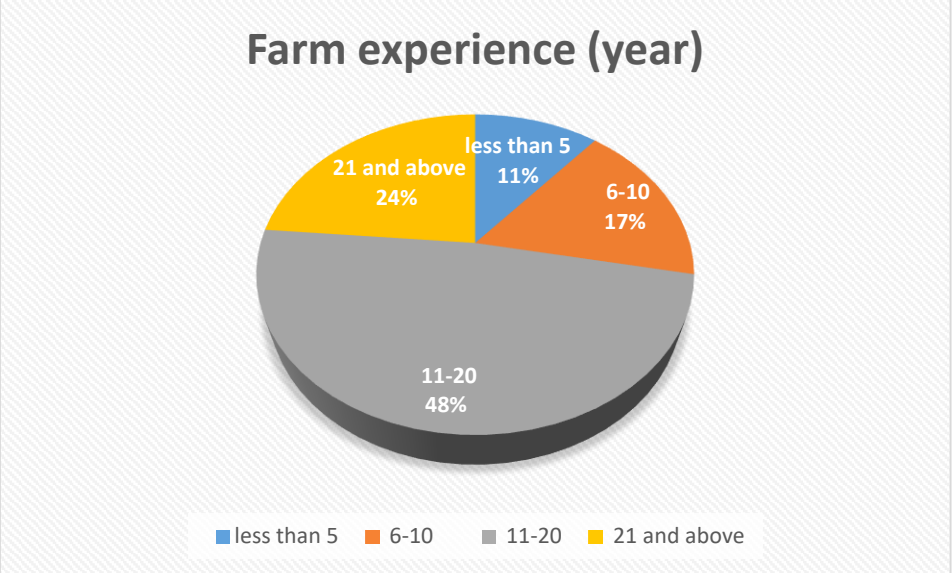

Figure 5. Farm experience (year) of the respondents

was found between the variables highlighting barriers such as shortage of inputs and complex distillation process (X_{19}, and X_{17}) (0.373), limited market proximity and disinterest (X_{21}, and X_{13}) (0.286), deficit in skilled personnel and disinterest (X_{16}, and X_{13}) (0.223), intricate distillation handling and unawareness (X_{17}, and X_{14}) (0.216), reduced output and lack of inputs (X_{22}, and X_{19}) (0.188), reduced output and dearth of awareness (X_{22}, and X_{14}) (0.169), reduced output and challenging to produce oil (X_{22}, and X_{20}) (0.157), and minimal output and substantial startup cost (X_{22} and X_{23}) (0.136) (Figure 7).

Test of multicollinearity

Multicollinearity refers to a statistical issue encountered in regression analysis where two or more predictor variables in a model are highly correlated, making it difficult to differentiate their individual effects on the response variable (Daoud, 2017). Hence, it indicates a strong linear relationship among the predictor variables. Before conducting regression modeling, a multicollinearity test was performed to evaluate notable inter-correlations among the independent variables.

The Appendix findings identified 23 independent variables influencing respondents' knowledge levels. Multicollinearity was assessed using VIF, with no issues detected (all VIF < 0.5). The model showed significance ($p = 0.000$, adjusted $R^2 = 0.279$), with key predictors including profit-driven approach (X10), market proximity (X21), and input costs (X7) significant at 0.001, followed by interest (X3), cost-effectiveness (X8), awareness (X2), apathy (X13), and crop yield improvement (X5) at 0.01. The model's estimates are reliable (Shrestha, 2020). It can be safely concluded that the estimates derived from this model are positive.

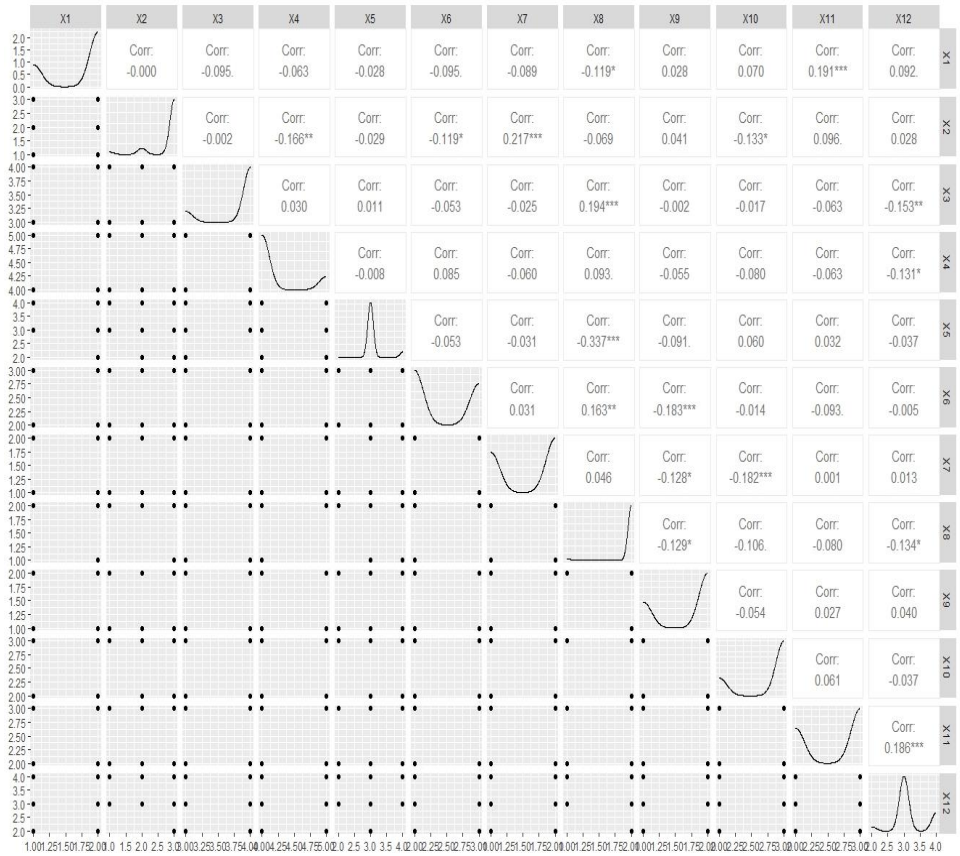

Figure 6. Number of determinants' correlation with each other using a package 'Cor plot' in R-statistics '*** = Sig at 0.001% , '** = Sig at 0.01%, '* = Sig at 0.5%

Determinants (X_1 = Easy access to practice, X_2 = Improved awreness, X_3 = Improved interest level, X_4 = Skill improvement, X_5 = Improved crop yield, X_6 = Minimum farm costs, X_7 = Minimum input cost , X_8 = Cost-effective approach, X_9 = Positive feedback from peers , X_{10} = Profit-driven, X_{11} = Openess to practice, X_{12} = household labor

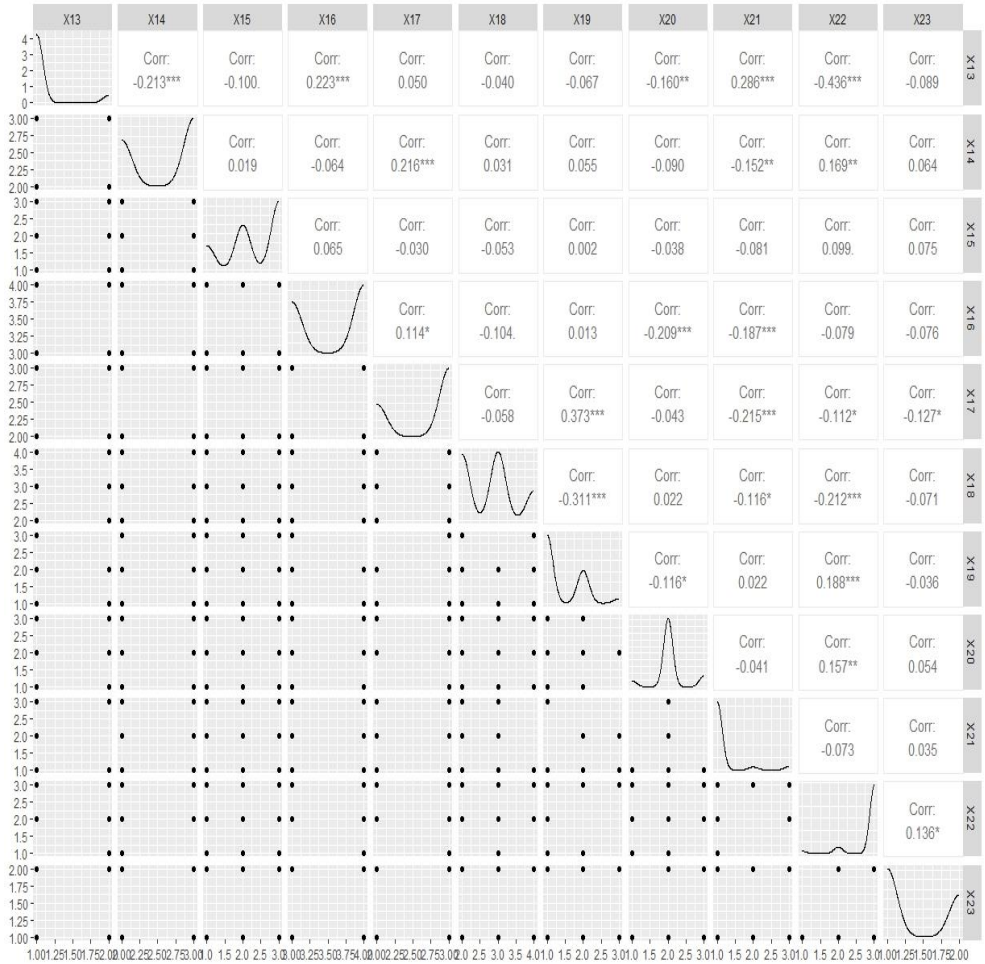

Figure 7. Number of barriers' correlation with each other using a package 'Cor plot' in R-statistics

'*** = Sig at 0.001% , '** = Sig at 0.01%, '* = Sig at 0.5%

Barriers (X_{13} = Apathy, X_{14} = Lack of awreness, X_{15} = lack of proficiency in technology, X_{16} = Lack of skilled workforce, X_{17} = Complex distillation process, X_{18} = Unfavorable feedback among peers, X_{19} = Shortage of inputs, X_{20} = Difficult to produce byproduct, X_{21} = Limited market access, X_{22} = Reduced output, X_{23} = Substantial startup cost)

Ordinal Regression model

To address multicollinearity in the data on factors influencing eucalyptus growers' knowledge of recommended practices, an ordinal regression model was used to identify the key variables predicting the adoption of the three EOE practices. Growers' knowledge levels were categorized from low to high based on the information they received about EOE practices. This analysis, using proportional odds logistic regression,

assessed the relationship between significant factors and barriers (predictor variables) and their contribution to growers' knowledge and adoption (outcome variable) for each practice, measured on a rated scale (Kekkonen et al., 2023).

Ordinal regression for 1st practice (horticultural prerequisites for essential oil extraction)

Table 3 shows the most significant factors influencing adoption of the 1st EOE practice, with "cost-effective" (X8), "profit-driven approach" (X10), "crop yield increase" (X5), "awareness level" (X2), and "positive peer feedback" (X9) all significant at 0.1% ($p = 0.000$). "Easy access to practice" (X12) is significant at 0.5% ($p = 0.028$). Coefficient estimates suggest individuals who perceived the practice as cost-effective, income-generating, and yield-enhancing were 8.705, 3.615, 3.056, and 2.469 times more likely to have higher adoption knowledge. Barriers like peer feedback, production difficulty, and limited market access reduce adoption knowledge, with odds decreasing by 0.782, 0.337, and 0.265 times, respectively.

Test of parallel lines

Moreover, test of parallel lines indicates that the odds of predictor falling into the categories on the dependent variable remain consistent across the categories.

Ordinal regression for 2nd practice (essential oil extraction through steam distillation)

For the second practice, key determinants influencing knowledge were increased interest (X3) ($p = 0.000$), openness to the practice (X11) (0.003), crop yield improvement (X5) (0.031), and reduced farm costs (X6) (0.042) at 0.1 and 0.5% significance.

The coefficient estimates predicted that the likelihood of higher adoption knowledge was 3.462 times greater with increased awareness, 2.046 with greater willingness, 1.964 with improved yield, and 1.519 with reduced input costs, compared to their peers. In addition, the prediction indicates that the odds of possessing a knowledge level inclined towards adopting the EOE practice are 0.629 and 0.512 times lowered when growers perceive barriers such as unfavorable feedback from peers, shortage of input resources, and lack of interest in triggering the adoption of the EOE practice.

Test of parallel lines

Moreover, the test of parallel lines reveals that the odds of predictors falling into the categories on the dependent variable are consistent across the various categories.

Ordinal regression for 3rd practice (Positive outcomes of employing EOE interventions over conventional aromatic farming

Ordinal logistic regression identified significant factors and barriers influencing respondents' perceptions of adopting essential oil interventions over conventional farming (Table 5). Key determinants were reduced input costs (X7), cost-effectiveness (X8), and positive peer feedback (X9) ($p = 0.000$). Crop yield (X5), income (X10), and awareness (X2) were significant at 0.01 and 0.5%. The coefficient estimates predicted that individuals perceiving EOE practices as reducing costs, improving yields, increasing income, and raising awareness were 16.676, 7.501, 3.673, 2.382, and 1.477 times likelier to have higher adoption knowledge. Whereas**,** barriers like lack of skilled labour and unfavourable peer feedback lowered the odds of adopting EOE practices by 0.695 and 0.592 times, respectively.

Test of parallel lines

The test of parallel lines confirms consistent predictor odds across all dependent variable categories.

Discussions

Demographic data provides insights into how social and economic factors, such as farm size, resource allocation, and usage, affect the farming community. Age is one of the notable factors affecting farmers' perception towards adoption. Older farmers generally have a deeper understanding of farming risks and challenges, aligning with Rigg et al. (2020), who note that age influences risk-related barriers in agricultural expansion. Tey et al. (2017) found that higher-income and educated farmers are more likely to adopt sustainable practices. Furthermore, Alemayehu and Melka (2022) argue that lower education levels restrict farmers' ability to explore new farming methods, particularly in eucalyptus cultivation. Likewise, experience is another key factor with more experienced farmers typically better positioned to adopt improved practices and share knowledge, enhancing their socio-economic status (Šūmane et al., 2018).

The study's findings highlight the economic factors that encourage farmers to adopt EOE practices and the obstacles that limit their widespread implementation. Among these, the high profitability of essential oil crops like eucalyptus, which are a key cash crop in the region, stands out. Experienced farmers, particularly older ones, view these practices as both cost-effective and productive, reflecting the study's conclusion that profitability and increased crop yields are critical predictors of adoption. This emphasizes the influence of factors such as income levels, farm size, and market access on farmers' willingness to invest in EOE practices. The study also reveals that higher-income farmers are more inclined to adopt these methods, corroborating the findings of Tey et al. (2017) which link income and education to the uptake of sustainable agricultural technologies. A possible explanation for the significant link between "awareness improvement" and reduced input costs suggests that increased awareness helps farmers optimize minor crop cultivation, boosting output with minimal input. This aligns with (Steen et al., 2016) who found that minor crops improve profitability. Additionally, producers of medicinal and aromatic crops tend to be more productive than cereal growers (Singh et al., 2023). Similarly, the cost-effective approach is linked to knowledge improvement, as farmers recognize the long-term profitability of essential oil production, despite the initial investment in the steam distillation unit.

The second and third important determinants are cost-effective and a profit-orientated approach, as respondents viewed the practices as profitable due to the high value of crops, especially essential oils like eucalyptus, mint, and lemon, which have strong market demand. The results are also in line with Chauhan et al. (2009) who reported that the improved mint variety's essential oil yields higher market prices, boosting farmers' income in India, though prices vary by region due to agro-climatic conditions. Additionally, factors like increased income and crop yields positively influenced growers' attitudes toward adoption. The study model shows that overall willingness to accept the practices is a statistically significant variable. Receptivity, in this context, can be characterized as the willingness to accept. It encompasses a grower's motivation or readiness to embrace innovation, technology, or specific practices (Barham et al., 2015). It also involves individuals' beliefs and attitudes, which influence their behavior in accepting or rejecting practices. Ayanoglu et al. (2005); Zekri et al. (2019) found that individuals showed openness to EOE and drying methods. A strong correlation existed between growers' belief in technology stewardship and participation in training,

influencing adoption (Norton & Alwang, 2020). Hence, farmers with negative attitudes, self-doubt, or low receptivity are less likely to adopt sustainable practices.

This study explores perceived barriers affecting farmers' knowledge and perceptions of recommended practices. The study identifies limited market proximity as a significant barrier to the adoption of EOE practices. This limitation restricts information exchange, reduces returns on technology, and hampers communication and collaboration in agriculture (Asfaw et al., 2012). The rapid growth of essential oils in the market can be attributed to their biological characteristics and commercial significance. In 2018, the global demand for essential oils reached 226.8 kilotons, with an anticipated increase of 8.6% by the year 2025 (Sharmeen et al., 2021). In Pakistan, over 300 industries depend on unprocessed materials, including essential oils imported from Western or European countries, with expenditures on essential oils, perfumes, and isolates exceeding Rs. 1526 million (Raut & Karuppayil, 2014). Punjab, with favorable agro-climatic conditions for essential oil-bearing plants, has significant marketing potential. Punjab, benefiting from favorable agro-climatic conditions for essential oil crops, has considerable marketing opportunities. However, the lack of local market access, particularly in northern Punjab, poses challenges for small to medium-scale farmers. Despite major cities like Lahore, Faisalabad, Rawalpindi, and Islamabad hosting numerous outlets, the distance to these markets hinders adoption. Companies like Qarshi Private Limited and Sayyed Pharmaceutical Industries also face this challenge. Enhancing local marketing infrastructure is essential to support broader adoption of EOE practices. Furthermore, studies by Constance and Choi (2010); Soltani et al. (2014) indicate that a lack of marketing infrastructure often deters smallholders from adopting new practices. Farmers located closer to input and output markets are more inclined to adopt these practices, whereas those in remote areas face challenges that adversely affect their adoption decisions.

The shortage of skilled labor and negative peer opinions were key barriers to adoption. Skilled labor boosts adoption by enhancing knowledge and confidence, while its absence leads to failure, income concerns, and marketing challenges, particularly for small landholders (Ngwira et al., 2014). Pothwar growers, with moderate family sizes, perceive the shortage of technical labor as a barrier to adoption, as it can reduce their knowledge. Asfaw et al. (2012); Suvedi et al. (2017) reported that a larger household size facilitates the adoption of technologies by providing access to a substantial workforce. Additionally, it enables the generation of additional income through the involvement of surplus labor in off-farm activities (Astatike & Gazuma, 2019).

Conclusions and suggesstions

Empowering farmers with information on efficient cultivation methods enhances their success and strengthens the agricultural community's resilience. The study highlights the importance of willingness to adopt EOE practices, emphasizing the role of beliefs, training participation, and the integration of progressive farming methods. Addressing barriers like limited market access and negative peer perceptions is crucial to improving knowledge dissemination and fostering a positive perception, increasing the likelihood of successful adoption of EOE practices. The scarcity of skilled labor and social perceptions

significantly impact growers' willingness to adopt new practices. Emphasizing the economic benefits and expanding on-farm training programs aligned with technology stewardship are essential. Strategies to address barriers include improving market access, targeted education, and mentorship to enhance skills, build confidence, and counter negative perceptions.

Future research can explore the factors influencing farmers' adoption behavior, incorporating both individual and contextual elements. Comparative studies across regions can reveal regional differences in opportunities and barriers, helping tailor adoption strategies. Longitudinal studies tracking changes in attitudes and practices can provide deeper insights, while comparing EOE practices with conventional farming methods can offer practical guidance for farmers considering a shift.

Conflict of interest

The Authors declare that there is no conflict of interest.

Authors' Contribution Statements

FA executed the original research, write up the draft, and conduct formal analysis, SM conceived the idea and supervised the work, whereas, BNS reviewed and edited the final draft.

Acknowledgment

The authors express gratitude for the moral support extended by the surveyed respondents, appreciating their time and the valuable information that contributed to the completion of this study.

Disclosure statement

No potential conflict of interest was reported by the author(s).

References

Abere, B. O., & Adetunji, C. O. (2024). Chapter 22 - Socioeconomic factors and major setbacks involved in the application of essential oil in food systems: what we need to do. In C. O. Adetunji & J. Sharifi-Rad (Eds.), *Applications of Essential Oils in the Food Industry* (Vol. 1, pp. 255-262). Academic Press. https://doi.org/https://doi.org/10.1016/B978-0-323-98340-2.00014-6

Alemayehu, A., & Melka, Y. (2022). Small scale eucalyptus cultivation and its socioeconomic impacts in Ethiopia: A review of practices and conditions. *Trees, Forests and People*, *8*, 100269. https://doi.org/https://doi.org/10.1016/j.tfp.2022.100269

Alighiri, D., Eden, W., Supardi, K., & Purwinarko, A. (2017). *Potential development essential oil production of central java, Indonesia* The 3rd International Conference on Mathematics, Science and Education., Indonesia.

Asfaw, S., Shiferaw, B., Simtowe, F., & Lipper, L. (2012). Impact of modern agricultural technologies on smallholder welfare: Evidence from Tanzania and Ethiopia. *Food Policy*, *37*(3), 283-295. https://doi.org/https://doi.org/10.1016/j.foodpol.2012.02.013

Astatike, A. A., & Gazuma, E. G. (2019). The impact of off-farm activities on rural household income in Wolaita Zone, Southern Ethiopia. *Journal of World Economic Research*, *8*(1), 8-16. https://doi.org/10.11648/j.jwer.20190801.12

Ayanoglu, F., Arslan, M., & Hatay, A. (2005). Effects of harvesting stages, harvesting hours and drying methods on essential oil. *International Journal of Botany*, *1*(2), 138-142.

Barbieri, C., & Borsotto, P. (2018). Essential oils: market and legislation. In H. El-Shemy (Ed.), *Potential of essential oils* (Vol. 1, pp. 107-127). BoD – Books on Demand.

Barham, B. L., Chavas, J. P., Fitz, D., Ríos-Salas, V., & Schechter, L. (2015). Risk, learning, and technology adoption. *Agricultural Economics*, *46*(1), 11-24. https://doi.org/https://doi.org/10.1111/agec.12123

Bhattacharya, S. (2016). Cultivation of essential oils. In *Essential oils in food preservation, flavor and safety*. (Vol. 1, pp. 19-29). Elsevier. https://doi.org/https://doi.org/10.1016/B978-0-12-416641-7.00003-1

Bolouri, P., Salami, R., Kouhi, S., Kordi, M., Asgari Lajayer, B., Hadian, J., & Astatkie, T. (2022). Applications of essential oils and plant extracts in different industries. *Molecules*, *27*(24), 8999. https://doi.org/https://doi.org/10.3390/molecules27248999

Canwat, V., & Onakuse, S. (2022). Organic agriculture: A fountain of alternative innovations for social, economic, and environmental challenges of conventional agriculture in a developing country context. *Cleaner and Circular Bioeconomy*, *3*, 100025. https://doi.org/https://doi.org/10.1016/j.clcb.2022.100025

Chauhan, R., Kaul, M., Shahi, A., Kumar, A., Ram, G., & Tawa, A. (2009). Chemical composition of essential oils in Mentha spicata L. accession [IIIM (J) 26] from North-West Himalayan region, India. *Industrial Crops and Products*, *29*(2-3), 654-656. https://doi.org/https://doi.org/10.1016/j.indcrop.2008.12.003

Choudhary, H., Badal, P., Singh, V., & Maurya, A. (2018). Accessing the socio-economic grade of menthol growers in India: Shifting from traditional farming to income based farming. *Medicinal Plants-International Journal of Phytomedicines and Related Industries*, *10*(4), 340-247. https://doi.org/10.5958/0975-6892.2018.00049.7

Constance, D. H., & Choi, J. Y. (2010). Overcoming the barriers to organic adoption in the United States: A look at pragmatic conventional producers in Texas. *Sustainability*, *2*(1), 163-188. https://doi.org/https://doi.org/10.3390/su2010163

Daoud, J. I. (2017). Multicollinearity and regression analysis. Journal of Physics: Conference Series,

Delgado, C. L., & Siamwalla, A. (2018). Rural economy and farm income diversification in developing countries. In *Food Security, Diversification and Resource Management: Refocusing the Role of Agriculture?* (pp. 126-143). Routledge.

Devi, M. P., Chakrabarty, S., Ghosh, S., & Bhowmick, N. (2015). *Essential oil: its economic aspect, extraction, importance, uses, hazards and quality* (01 ed.). Springer New Delhi. https://doi.org/https://doi.org/10.1007/978-81-322-2262-0

Duarte, M., Duarte, R., Rodrigues, R., & Rodrigues, M. (2017). *Essential oils and their characteristics*. https://doi.org/https://doi.org/10.1002/9781119149392.ch1

Franz, C., & Novak, J. (2020). Sources of essential oils. In G. B. K. Husnu Can Baser (Ed.), *Handbook of essential oils* (3rd ed., Vol. 1, pp. 41-83). CRC Press. https://doi.org/https://doi.org/10.1201/9781351246460

Ghasemy-Piranloo, F., Kavousi, F., & Kazemi-Abharian, M. (2022). Comparison for the production of essential oil by conventional, novel and biotechnology methods.

Journal of Essential Oil Research, *34*(5), 455-478. https://doi.org/https://doi.org/10.1080/10412905.2022.2120557

Hussain, F., Nabi, G., & Wu, R.-S. (2021). Spatiotemporal rainfall distribution of soan river basin, pothwar region, Pakistan. *Advances in Meteorology*, pp. 1-24. https://doi.org/https://doi.org/10.1155/2021/6656732

Johnson, C. (2013). *Sustainability Assessment of an Essential Oil Distillation Unit in Nepal.* Universität Hohenheim].

Karki, M. B. (2020). Harnessing the potential of medicinal, aromatic and non-timber forest products for improving the livelihoods of pastoralists and farmers in Himalayan mountains. *Conservation and utilization of threatened medicinal plants*, 93-106. https://doi.org/10.1007/978-3-030-39793-7_4

Kekkonen, A., Pesor, R., & Täks, M. (2023). Stepping towards the Green Transition: Challenges and Opportunities of Estonian Companies. *Sustainability.*, *15*(5), 4172. https://doi.org/https://doi.org/10.3390/su15054172

Khan, N., Fahad, S., Naushad, M., & Faisal, S. (2020). Analysis of Livelihood in the World and Its Impact on World Economy. *Available at SSRN 3717265*.

Kumar, A., Sharma, N., Kumar, A., Kumar, D., Jnanesha, A. C., Gupta, A. K., Chanotiya, C. S., Bisht, D., & Lal, R. K. (2024). Differential responses of genotype × environment interaction on Agronomic interventions affect the yield and quality of essential oil of interspecific basil hybrid of Ocimum basilicum L. × Ocimum kilimandscharicum. *Ecological Genetics and Genomics*, *30*, 100217. https://doi.org/https://doi.org/10.1016/j.egg.2024.100217

Mahcene, Z., Mahcene, Z., Bireche, K., & Serdouk, F. (2020). Socioeconomic valorization and development of a bio-fungicide from essential oils of four Algerian aromatic and medicinal plants: Artemisia herba alba Asso, Mentha pulegium L, Rosmarinus officinalis L and Ocimum basilicum L. *Asian Journal of Reserach and Chemistry*, *13*(6), 473-484. https://doi.org/https://dx.doi.org/10.17582/journal.pjar/2021/34.2.381.392

Merad, N., Andreu, V., Chaib, S., de Carvalho Augusto, R., Duval, D., Bertrand, C., Boumghar, Y., Pichette, A., & Djabou, N. (2021). Essential oils from two Apiaceae species as potential agents in organic crops protection. *Antibiotics*, *10*(6), 636. https://doi.org/https://doi.org/10.3390/antibiotics10060636

Montanari, B. (2012). *A critical analysis of the introduction of essential oil distillation in the High Atlas of Morocco with reference to the role of gendered traditional knowledge* University of Kent]. United Kingdom.

Ngwira, A., Johnsen, F. H., Aune, J. B., Mekuria, M., & Thierfelder, C. (2014). Adoption and extent of conservation agriculture practices among smallholder farmers in Malawi. *Journal of Soil and Water Conservation*, *69*(2), 107-119. https://doi.org/https://doi.org/10.2489/jswc.69.2.107

Norton, G. W., & Alwang, J. (2020). Changes in agricultural extension and implications for farmer adoption of new practices. *Applied Economic Perspectives and Policy*, *42*(1), 8-20. https://doi.org/https://doi.org/10.1002/aepp.13008

Ootani, M. A., Aguiar, R. W., Ramos, A. C. C., Brito, D. R., Silva, J. B. d., & Cajazeira, J. P. (2013). Use of essential oils in agriculture. *Journal of Biotechnology and*

Biodiversity, *4*(2), 162-174. https://doi.org/https://doi.org/10.20873/jbb.uft.cemaf.v4n2.ootani

Raut, J. S., & Karuppayil, S. M. (2014). A status review on the medicinal properties of essential oils. *Industrial Crops and Products*, *62*, 250-264. https://doi.org/https://doi.org/10.1016/j.indcrop.2014.05.055

Riaz, U., Iqbal, S., Sohail, M., Samreen, T., Ashraf, M., Akmal, F., Siddiqui, A., Ahmad, I., Naveed, M., & Khan, N. (2021). A comprehensive review on emerging importance and economical potential of medicinal and aromatic plants (MAPs) in current scenario. *Pakistan Journal of Agricultural Research*, *34*(2), 381-392. https://doi.org/https://dx.doi.org/10.17582/journal.pjar/2021/34.2.381.392

Rigg, J., Phongsiri, M., Promphakping, B., Salamanca, A., & Sripun, M. (2020). Who will tend the farm? Interrogating the ageing Asian farmer. *The Journal of Peasant Studies*, *47*(2), 306-325. https://doi.org/10.1080/03066150.2019.1572605

Schmidt, E. (2020). Production of essential oils. In G. B. K. Husnu Can Baser (Ed.), *Handbook of essential oils.* (3rd ed., Vol. 1, pp. 125-160). CRC Press. https://doi.org/https://doi.org/10.1201/9781351246460

Sen, S., & Ganguly, S. (2017). Opportunities, barriers and issues with renewable energy development–A discussion. *Renewable and Sustainable Energy Reviews*, *69*, 1170-1181. https://doi.org/https://doi.org/10.1016/j.rser.2016.09.137

Shaheen, A. (2016). Characterization of eroded lands of Pothwar plateau, Punjab, Pakistan. *Sarhad Journal of Agriculture*, *32*(3), 192-201. https://doi.org/http://dx.doi.org/10.17582/journal.sja/2016.32.3.192.201

Sharmeen, J. B., Mahomoodally, F. M., Zengin, G., & Maggi, F. (2021). Essential oils as natural sources of fragrance compounds for cosmetics and cosmeceuticals. *Molecules*, *26*(3), 666. https://doi.org/https://doi.org/10.3390/molecules26030666

Shrestha, N. (2020). Detecting multicollinearity in regression analysis. *American Journal of Applied Mathematics and Statistics*, *8*(2), 39-42. https://doi.org/10.12691/ajams-8-2-1

Singh, P. A., Bajwa, N., Sharma, L., & Baldi, A. (2023). Farm-level medicinal plants production and economic analysis in the Indian state of Punjab. *Journal of Applied Research on Medicinal and Aromatic Plants*, *34*, 100486. https://doi.org/https://doi.org/10.1016/j.jarmap.2023.100486

Soltani, S., Azadi, H., Mahmoudi, H., & Witlox, F. (2014). Organic agriculture in Iran: Farmers' barriers to and factors influencing adoption. *Renewable Agriculture and Food Systems*, *29*(2), 126-134. https://doi.org/https://doi.org/10.1017/S1742170513000069

Steen, J., Ahmad, S., Verreynne, M.-L., Battese, G., Burki, A., Khan, M. A., Hussain, A., Jabbar, A., & Akmal, N. (2016). *Final Report for ADP/2015/004: farmers' capabilities, productivity and profitability: a case study of smallholders in selected agro zones in Pakistan*. ACIAR.

Šūmane, S., Kunda, I., Knickel, K., Strauss, A., Tisenkopfs, T., Rios, I. d. I., Rivera, M., Chebach, T., & Ashkenazy, A. (2018). Local and farmers' knowledge matters! How integrating informal and formal knowledge enhances sustainable and

resilient agriculture. *Journal of Rural Studies*, *59*, 232-241. https://doi.org/https://doi.org/10.1016/j.jrurstud.2017.01.020

Suvedi, M., Ghimire, R., & Kaplowitz, M. (2017). Farmers' participation in extension programs and technology adoption in rural Nepal: a logistic regression analysis. *The Journal of Agricultural Education and Extension*, *23*(4), 351-371. https://doi.org/https://doi.org/10.1080/1389224X.2017.1323653

Tey, Y. S., Li, E., Bruwer, J., Abdullah, A. M., Brindal, M., Radam, A., Ismail, M. M., & Darham, S. (2017). FACTORS INFLUENCING THE ADOPTION OF SUSTAINABLE AGRICULTURAL PRACTICES IN DEVELOPING COUNTRIES: A REVIEW. *Environmental Engineering & Management Journal (EEMJ)*, *16*(2). https://doi.org/10.30638/eemj.2017.034

Ying Li, A.-S. F.-T., Farid Chemat. (2014). Essential oils: From conventional to green extraction. In *Essential oils as reagents in Green Chemistry* (1st ed., Vol. 1, pp. 9-20). Springer Cham. https://doi.org/https://doi.org/10.1007/978-3-319-08449-7

Zekri, N., Elazzouzi, H., El Makhoukhi, F., Alaoui El Belghiti, M., & Zair, T. (2019). Drying effect on yields and chemical composition of essential oils extracted from the Moroccan Mentha spicata (L.) aerial parts. *Journal of Essential Oil Bearing Plants*, *22*(3), 789-798. https://doi.org/https://doi.org/10.1080/0972060X.2019.1632746

Citation

Anjum, F., Muhammad S., Siddiqui, B.N. (2024). Stepping towards essential oil extraction technology: Prospects and Challenges for aromatic growers in Northern Punjab, Pakistan. *Journal of Agriculture and Food*, *5*(2), 1–18.