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in

Marchetti M. (ed.), Parma C. (ed.), Hamouche Z. (ed.)
OliveCulture Pakistan: Building a Sustainable, Climate-Smart and Competitive Value Chain

Bari : CIHEAM
Options Méditerranéennes : Série B. Etudes et Recherches ;n. 78

2026
pages 113-127

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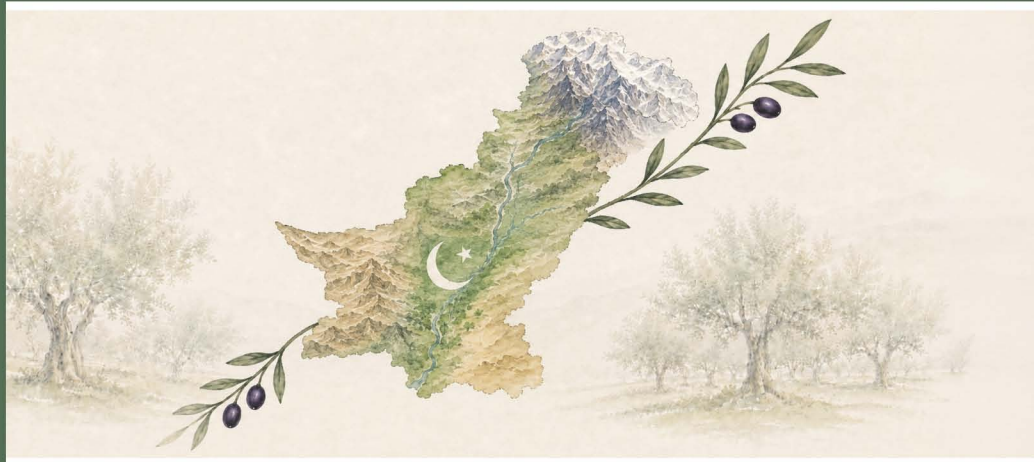

OPTIONS méditerranéennes

SERIES B: Studies and Research
2026 - Number 78

CIHEAM

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OPTIONS
méditerranéennes
Head of publication: Teodoro Miano

2026 | Series B: Studies and Research | Number 78

Centre International de Hautes Etudes Agronomiques Méditerranéennes
International Centre for Advanced Mediterranean Agronomic Studies

Selection of olive cultivars and their potential by province*

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Abstract. The expansion of olive cultivation in Pakistan has emphasized the importance of selecting olive cultivars adapted to the country's diverse agroclimatic conditions to ensure sustainable productivity, economic profitability, and high-quality olive oil production. Pakistan presents a wide range of environmental conditions, particularly across Balochistan, Khyber Pakhtunkhwa, and Punjab, where variations in temperature, rainfall, altitude, humidity, and soil characteristics strongly influence varietal performance and adaptability. The evaluation of olive cultivars under local conditions has enabled the identification of varieties with stable productivity, suitable phenology, tolerance to abiotic and biotic stresses, and desirable oil and fruit quality characteristics. Factors such as cultivar acclimatization, orchard suitability, and cross-pollination requirements, are essential for improving fruit set and ensuring economically viable yields. The study also emphasizes the importance of integrating agronomic, morphological, and productive traits into varietal selection strategies tailored to regional climatic conditions. In addition, the development of climate-suitable varietal zoning and provincial recommendations represents an important step toward strengthening the olive value chain and supporting the long-term sustainability and growth of the olive sector in Pakistan.

Keywords. Cultivar selection – Agroclimatic zones – Olive phenology – Sustainable production.

Sélection des cultivars d'olivier et de leur potentiel par province

Résumé. *Le développement rapide du secteur oléicole au Pakistan nécessite une sélection rigoureuse des cultivars d'olivier capables de s'adapter aux diverses conditions agroclimatiques du pays afin d'assurer une production durable, une rentabilité économique et une huile d'olive de haute qualité. Le Pakistan présente une grande diversité de conditions environnementales, notamment dans les provinces du Baloutchistan, du Khyber Pakhtunkhwa et du Pendjab, où les variations de température, de précipitations, d'altitude, d'humidité et de caractéristiques des sols influencent fortement les performances et l'adaptabilité des variétés. L'évaluation des cultivars dans les conditions locales a permis d'identifier des variétés présentant une productivité stable, une phénologie adaptée, une tolérance aux stress biotiques et abiotiques, ainsi que des caractéristiques qualitatives favorables pour l'huile et les fruits. Une attention particulière est accordée à l'acclimatation variétale, à l'aptitude des vergers et aux exigences de pollinisation croisée, éléments essentiels pour améliorer la nouaison et garantir des rendements économiquement viables. L'étude souligne également l'importance d'intégrer les caractéristiques agronomiques, morphologiques et productives dans des stratégies de sélection variétale adaptées aux conditions climatiques régionales. Enfin, l'élaboration d'un zonage variétal adapté au climat et de recommandations provinciales constitue une étape importante pour renforcer la chaîne de valeur oléicole et soutenir le développement durable du secteur oléicole au Pakistan.*

Mots-clés. *Sélection variétale – Zones agroclimatiques – Phénologie de l'olivier – Production durable.*

*This chapter represents an updated version of a document previously published within the framework of the project. https://doi.org/10.48259/bc1962t

I – Introduction

Olive cultivation has gained increasing importance in Pakistan as a strategic agricultural sector with strong potential to reduce edible oil imports, enhance rural livelihoods, and utilize marginal lands effectively. The country's diverse agro-climatic zones, particularly in rainfed and semi-arid regions, provide favorable conditions for olive production. Over the past decades, significant efforts have been made to introduce, adapt, and expand olive cultivation, transforming it from an experimental crop into an emerging commercial industry.

Indeed, the olive was introduced in parts of Dera Ismail Khan (Now in present-day Khyber Pakhtunkhwa (KP)) in 1866, and efforts have been made for long to grow olive for domestic and agronomic purposes. The first attempt was by Mr. Henderson, who imported 100 European olive plants and planted them in Rawalpindi. During 1907-1910, the program was restarted with the help of an Italian expert who established a small saplings orchard at Soon Valley, Garhi Dopatta, and Chattar in 1907. Plantations were also established at Khari Murat in the Attock District, Sakesar, and Rakh Chandia in 1910. All these plantations were handed over to the Agriculture Department in 1927 and eventually ended up with the Forest Department in 1935. The plantation was also done at the Agriculture Research Institute Tarnab Peshawar KP in 1912. In 1935 some of the saplings were imported from Palestine, the USA, and Italy. In 1950-1952, olive plants were again imported from Syria, Egypt, and Turkey and planted in Rawalpindi and Faisalabad region. In 1960 five thousand plants were procured from Italy and were planted at different locations of Pakistan.

The Pakistan Oilseed Developments Board (PODB) started work on olives in the year 2000 and adopted a two-pronged approach for the promotion of olive cultivation in the country (i) conversion of wild olives into bearing species by top working, and (ii) establishment of new plantation. A five-year project (2000-2004) "*Accelerated Promotion of Olive in NWFP/KP and Potohar*" was initiated. Another five-year duration project (2005-2009) "*New Plantation of Olive in NWFP/KP, Potohar and Balochistan and maintenance of Orchards Established by PODB*" was initiated.

Since then, experiments have been conducted in a haphazard manner, which has not resulted in either increasing the area or production of olives, and the yield was too low to be of any commercial importance.

The real development and commercialization of the olive sector in Pakistan began in 2012 through an olive promotion project funded under the Pakistan–Italy Debt Swap Agreement (PIDSA). Building on this initiative, the Government of Pakistan launched a flagship olive cultivation project in 2014. As a result, nearly 5 million olive plants have now been cultivated across the country. In parallel, a dedicated olive value chain has gradually emerged, including olive oil extraction units, table olive processing facilities, and olive certification laboratories, all of which continue to develop and expand.

The cultivated plants include mainly 21 different varieties**,** namely**,** Arbequina, Arbosana, Coratina, Koroneiki, Earlik, Gemlik, Frantoio, Picual, Ottobratica, Leccino, Pendolino, Chemlali, Ascolana, Manzanilla, Sevillano, Oliana, Chetoui, Souri, Nabali, Nocellara, and Hojiblanca, grown across the country (suitable areas) mainly in marginal and undulated land.

However, detailed studies on the acclimatization suitability and economic potential of specific olive varieties were previously missing. To address this gap, Italian experts conducted

comprehensive technical and agronomic evaluations of the phenological performance of olive varieties cultivated in Pakistan. Based on these assessments, Pakistani olive-growing areas were classified into five varietal zones according to microclimatic suitability, productive performance, and vegetative response. The classification also considered the origin and purpose of the varieties (oil or table olives), morphological traits (tree vigor, growth habit, canopy density, and fruit characteristics), as well as bio-agronomic and productive attributes, including tolerance to abiotic and biotic stresses, productivity under good agricultural practices (GAP), planting distance, and management practices. These evaluations established an important foundation for future olive research and for the production of premium-quality extra virgin olive oil in Pakistan. In addition, this chapter presents a holistic agronomic approach aimed at assisting farmers in selecting high- and stable-yielding cultivars to maximize economic returns.

Accordingly, the main objectives of this study were: (i) to identify olive varieties suitable for different agroclimatic conditions; (ii) to select high- and consistent-yielding cultivars capable of ensuring both the quantity and quality of extra virgin olive oil production in the country; and (iii) to identify pest- and disease-resistant varieties adapted to their respective climatic conditions for sustainable cultivation.

II – Methodological considerations and limitations

The selection of olive varieties across different provinces is based on data collected over a three-year period, complemented by observations of varietal performance and adaptation to diverse climatic zones over the past four decades. These observations have been supported by the active involvement of both technical experts and farmers, whose practical experience has contributed significantly to understanding varietal behavior under local conditions.

The study has identified distinct patterns in the performance of olive varieties across various macro-zones, allowing for the recommendation of cultivars that are well acclimatized and capable of producing economically viable yields under prevailing environmental conditions. This approach ensures that only those varieties demonstrating both adaptability and productive potential are suggested for cultivation within each specific zone.

However, the list of recommended varieties should not be considered exhaustive. Additional cultivars with suitable characteristics may further enhance varietal selection, particularly when evaluated under specific microclimatic conditions. It is important to note that each province encompasses diverse microclimates, which may influence varietal performance and suitability.

Furthermore, the study highlights important concerns regarding the certification and traceability of olive varieties. In several cases, plant material and established plantations could not be reliably identified as belonging to a single variety. Since morphological characterization alone may not provide definitive identification, it is recommended that such assessments be complemented with genetic analysis to ensure accuracy.

III – Cross-pollination

Following the identification and selection of suitable olive varieties for different agro-climatic zones, it is essential to consider the biological factors that influence their productivity. Among these, pollination plays a critical role in determining fruit set and, ultimately, economic yield. In

olive cultivation, understanding cross-pollination dynamics is particularly important for orchard design and varietal planning.

The viability and sustainability of the olive industry depend on achieving an economic yield of fruit for both oil production and table olives. Despite the abundance of flowers produced by olive trees, only a small proportion successfully develop into fruits (Di Marco *et al.,* 1990; Martin, 1990; Ghrisi *et al.,* 1999; Cuevas *et al.,* 2001), with typically only about 1-2% reaching maturity (Martin, 1990). This low fruit-to-flower ratio is influenced by several factors, including the proportion of male to hermaphroditic flowers, climatic conditions during fruit set, and compatibility relationships among cultivars (Dal Pero Bertini, 1960).

Most olive cultivars are self-incompatible, meaning that self-pollination is often insufficient for effective fertilization. Therefore, the presence of compatible cultivars within the same orchard is essential. In addition, some cultivars exhibit cross-incompatibility, where pollen from certain varieties cannot fertilize others. For this reason, growers must carefully consider cross-compatibility when designing orchards to maximize fruit set and yield, particularly in isolated plantations where pollen sources are limited. It is generally recommended to plant a mixture of compatible varieties to enhance pollination efficiency.

Although olive pollen can be dispersed by wind over long distances, sometimes up to hundreds of kilometers, this is more effective in traditional olive-growing regions with high tree density. In contrast, in countries like Pakistan, where olive cultivation is still expanding and tree density remains relatively low, it is strongly recommended to plant different cultivars together within the same orchard to ensure adequate pollination.

Olive cultivars can also be classified into compatibility groups (*e.g.,* G1 and G2), where combinations between varieties from different groups tend to result in higher fruit set. Furthermore, the role of wild olive populations as potential pollen donors should be investigated, particularly regarding their compatibility with cultivated varieties.

Olive trees produce both hermaphroditic (fruit-bearing) and staminate (male) flowers, the latter serving exclusively as pollen donors. Each flower can produce up to 200,000 pollen grains, reflecting the species' adaptation to wind pollination. For successful fertilization, it is essential that sufficient quantities of compatible pollen are available during the flowering period. This depends largely on the synchronization of bloom among compatible cultivars. While trees of the same cultivar tend to flower simultaneously under similar environmental conditions (Dal Pero Bertini, 1960), bloom timing and duration can vary between cultivars and across years (Griggs *et al.,* 1975; Ghrisi *et al.,* 1999), with climatic conditions playing a key role in determining the length of the flowering period (Lavee *et al.,* 2002).

IV – Pakistan ATLAS of climate suitable varietal map per province

Figure 1 represents a graphical orientation for the main olive cultivars (commonly named varieties) suggested for the main three olive-suited provinces of Pakistan. The selection is based on observations from different adaptability trials in each province considered and observed throughout the years for their stability, behavior, and performances. Nonethless, this is a non-exhaustive list of other possible cultivars/varieties that could be considered in future adaptability trials.

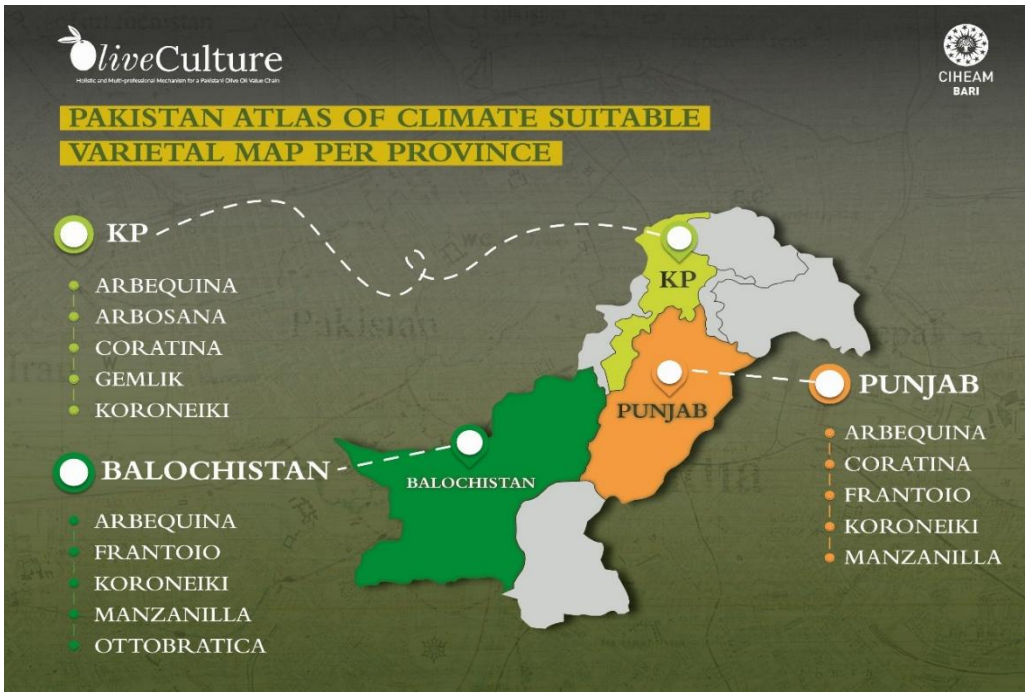

Figure 1. Pakistan ATLAS of climate suitable varietal map per province.

V – Selection of best-yielding olive varieties divided by provinces

The following tables (1-8) present a comprehensive selection of best-yielding olive varieties specifically adapted to Balochistan, Khyber Pakhtunkhwa (KP), and Punjab provinces of Pakistan. Each variety includes detailed morphological characteristics, regional phenology, oil content, and bio-agronomic traits to support optimal cultivar selection for commercial oil production under local climatic conditions.

Table 1. Comprehensive profile of Arbequina olive cultivar under Pakistani conditions.

Arbequina			
Origin		Spain	
Suitable regions		Balochistan, Khyber Pakhtunkhwa, Punjab	
Area of suitability		Cold and hot	
Purpose		Oil (not suitable for table olives due to small size and large pit)	
Morphological characteristics			
Vigor		Weak (small to medium-sized tree, 3-5m height at maturity, slower growth, less branching)	
Growth habit		Spreading (outward branching)	
Canopy density		Medium (allows light penetration and airflow for healthy fruit and disease reduction)	
Fruit characteristics			
Fruit weight		Small (1-2g)	
Shape and color		Oval, dark purple to black when ripe	
Oil content (% of fresh weight)			
Region		**Cold area**	**Hot area**
Balochistan		16%	15%
Khyber Pakhtunkhwa		14%	12%
Punjab		13%	-
Phenology by region			
Balochistan	**Stage**	**Timing**	
	Start of vegetative growth (Bud bursting)	Late March	
	Full bloom	Late April	
	Fruit turning (Veraison)	End of September	
	Time of harvest	Mid-November to early December (best oil: end Oct-Nov)	
Khyber Pakhtunkhwa	**Stage**	**Timing**	
	Start of vegetative growth (Bud bursting)	Early March	
	Full bloom	April	
	Fruit turning (Veraison)	Mid-September	
	Time to harvest	October-November (best oil: end October-November)	
Punjab	**Stage**	**Timing**	
	Start of Vegetative Growth (Bud Bursting)	Late February	
	Full Bloom	Late March	
	Fruit Turning (Veraison)	Early September	
	Time of harvest	October-November	
Bio-agronomic and productive characteristics			
Sensitivity to biotic stress		Medium resistance to verticillium wilt	
Sensitivity to abiotic stress		Resistant to cold; tolerant to salinity	
Productivity (with GAP)		High and constant; early bearing; early harvest for quality oil	
Planting distance		6x4m (18x12ft)	
Production characteristics		Light, smooth oil; intense fruity fragrance; deep green color; high oleic acid; medium polyphenols	

Table 2. Comprehensive profile of Arbosana olive cultivar under Pakistani conditions.

Arbosana	
Origin	Spain
Suitable regions	Khyber Pakhtunkhwa
Area of suitability	Hot
Purpose	Oil (good characteristics for quantity and quality)
Morphological characteristics	
Vigor	Weak (small to medium-sized tree, 4m height at maturity)
Growth habit	Open-upright (branches grow vertically)
Canopy density	Medium (balanced shade and sunlight penetration)
Fruit characteristics	
Fruit weight	Small to medium
Shape and color	Oval-shaped with smooth skin; green when young, reddish-purple to black when ripe
Oil content (% of fresh weight)	15%
Phenology (Khyber Pakhtunkhwa)	
Stage	**Timing**
Start of vegetative growth (Bud bursting)	February-March
Full bloom	March-April
Fruit turning (Veraison)	October
Time of harvest	November
Bio-agronomic and productive characteristics	
Sensitivity to biotic stress	Sensitive to olive mites, Verticillium wilt, olive knot, Olive Psyllids
Sensitivity to abiotic stress	Sensitive to cold climates
Productivity (with GAP)	High and constant
Planting distance	6x4m (18x12ft)
Production characteristics	Intense green fruity aroma, pungent; blended into other oils; medium level of polyphenols

Table 3. Comprehensive profile of Coratina olive cultivar under Pakistani conditions.

Coratina			
Origin		Italy	
Suitable regions		Khyber Pakhtunkhwa - Punjab	
Area of suitability		Cold and hot	
Purpose		Oil (highly esteemed for olive oil production)	
Morphological characteristics			
Vigor		Strong (medium to large-sized tree, 5-7m height at maturity, robust growth and branching)	
Growth habit		Spreading (upright and outward-branching)	
Canopy density		Dense (protects fruit from sunburn, promotes uniform ripening)	
Fruit characteristics			
Fruit weight		Medium-large	
Shape and color		Elongated, cylindrical; green when young, purple or black when ripe; smooth skin	
Oil content (% of fresh weight)			
Region		**Cold area**	**Hot area**
Khyber Pakhtunkhwa		16%	14%
Punjab		12-14%	-
Phenology by region			
	Stage	**Timing**	
Khyber Pakhtunkhwa	Start of vegetative growth (Bud bursting)	March	
	Full bloom	Late March to early April	
	Fruit turning (Veraison)	October-November	
	Time to harvest	November (mid or end-November)	
	Stage	**Timing**	
Punjab	Start of Vegetative Growth (Bud Bursting)	February-March	
	Full Bloom	March-April	
	Fruit Turning (Veraison)	October	
	Time of harvest	November (early to mid-November)	
Bio-Agronomic and productive characteristics			
Sensitivity to biotic stress		Susceptible to olive peacock spot and wood rot	
Sensitivity to abiotic stress		Particularly tolerant of cold	
Productivity (with GAP)		High and constant	
Planting distance		6-7x6m (18-21x18ft)	
Production characteristics		Good organoleptic characteristics; green with golden reflection; rich in polyphenols; very high fruity, powerful flavor with intense spicy notes	

Table 4. Comprehensive profile of Frantoio olive cultivar under Pakistani conditions.

Frantoio			
Origin		Italy	
Suitable regions		Balochistan - Punjab	
Area of suitability		Hot	
Purpose		Oil (highly esteemed for olive oil production)	
Morphological characteristics			
Vigor		Strong (medium sized tree, 4-6m height at maturity)	
Growth habit		Spreading (upright and outward branching)	
Canopy density		Medium dense (provides good coverage of the fruit, allows adequate light penetration and airflow)	
Fruit characteristics			
Fruit weight		Medium	
Shape and color		Elliptical to ovoid; Green, turning purple to black when fully ripe	
Oil content (% of fresh weight)			
Region		**Cold area**	**Hot area**
Balochistan		-	16-18%
Punjab		-	12%
Phenology by region			
Balochistan	**Stage**	**Timing**	
	Start of vegetative growth (Bud bursting)	Late March	
	Full bloom	Late April	
	Fruit turning (Veraison)	October-November	
	Time to harvest	November-December	
Punjab	**Stage**	**Timing**	
	Start of Vegetative Growth (Bud Bursting)	February-March	
	Full Bloom	March-April	
	Fruit Turning (Veraison)	October	
	Time of harvest	October-November	
Bio-agronomic and productive characteristics			
Sensitivity to biotic stress		Susceptible olive knot, medium resistant to verticillium wilt	
Sensitivity to abiotic stress		Quite sensitive to cold and Frost	
Productivity (with GAP)		High and constant	
Planting distance		6-7x6m (18-21x18ft)	
Production characteristics		Rich, fruity flavor balanced by an aromatic, grassy nose, olive oil is dark green color, higher than average polyphenol value	

Table 5. Comprehensive profile of Gemlik olive cultivar under Pakistani conditions.

Gemlik	
Origin	Turkey
Suitable regions	Khyber Pakhtunkhwa
Area of suitability	Cold
Purpose	Dual (olive oil and table olives)
Morphological characteristics	
Vigor	Medium
Growth habit	Spreading (branches grow horizontally, wide and sprawling appearance)
Canopy density	Dense (thick and packed foliage, ample shade and coverage)
Fruit characteristics	
Fruit weight	Large
Shape and color	Elongated oval to cylindrical; Reddish-purple to dark purple; sometimes greenish black
Oil content (% of fresh weight)	14%
Phenology (Khyber Pakhtunkhwa)	
Stage	**Timing**
Start of vegetative growth (Bud bursting)	March
Full bloom	March-April
Fruit turning (Veraison)	October
Time of harvest	November
Bio-agronomic and productive characteristics	
Sensitivity to biotic stress	Sensitive to verticillium wilt, olive knot, and olive psyllids
Sensitivity to abiotic stress	Resistant to cold climate
Productivity (with GAP)	High and constant
Planting distance	6x5m (18x15ft)
Production characteristics	Used for both table and oil purposes, it tastes very intensive and burns with the high polyphenol

Table 6. Comprehensive profile of Koroneiki olive cultivar under Pakistani conditions.

Koroneiki			
Origin		Greece	
Suitable regions		Balochistan, Khyber Pakhtunkhwa, Punjab	
Area of suitability		Hot	
Purpose		Oil (known for high oil content)	
Morphological characteristics			
Vigor		Medium-strong (small to medium-sized tree, 3-4 m height at maturity)	
Growth habit		Spreading (robust growth a vigorous branching)	
Canopy density		Sparse (good coverage, protects fruits from sunburn)	
Fruit characteristics			
Fruit weight		Small	
Shape and color		Oval, dark purple to black when ripe	
Oil content (% of fresh weight)			
Region		**Cold area**	**Hot area**
Balochistan		-	16-18%
Khyber Pakhtunkhwa		-	14%
Punjab		-	10-12%
Phenology by region			
	Stage	**Timing**	
Balochistan	Start of vegetative growth (Bud bursting)	April	
	Full bloom	Late April	
	Fruit turning (Veraison)	October-November	
	Time of harvest	Mid-November to early December (best oil: end October-November)	
	Stage	**Timing**	
Khyber Pakhtunkhwa	Start of vegetative growth (Bud bursting)	March	
	Full bloom	April	
	Fruit turning (Veraison)	October-November	
	Time to harvest	Mid to end November	
	Stage	**Timing**	
Punjab	Start of Vegetative Growth (Bud Bursting)	Late February	
	Full Bloom	Late March	
	Fruit Turning (Veraison)	October	
	Time of harvest	November	
Bio-agronomic and productive characteristics			
Sensitivity to biotic stress		Resistant to olive leaf spot, Sensitive to olive knot	
Sensitivity to abiotic stress		Resistant to drought but does not tolerate cold	
Productivity (with GAP)		High and constant	
Planting distance		6x5m (18x15ft)	
Production characteristics		Very high level of polyphenols, green color, a fruity and delicate flavor, very strong aroma, rich in precious organoleptic substance	

Table 7. Comprehensive profile of Manzanilla olive cultivar under Pakistani conditions.

Manzanilla			
Origin		Spain	
Suitable regions		Balochistan - Punjab	
Area of suitability		Cold and hot	
Purpose		Dual (olive oil and table olives)	
Morphological characteristics			
Vigor		Weak medium (medium sized tree, 4-7m height at maturity)	
Growth habit		Spreading (open canopy, good sunlight penetration)	
Canopy density		Medium (decent coverage of the fruit branches)	
Fruit characteristics			
Fruit weight		Small	
Shape and color		Elliptical to ovoid; Green, turning purple to black when fully ripe	
Oil content (% of fresh weight)			
Region		**Cold area**	**Hot area**
Balochistan		16%	14%
Punjab		-	10%
Phenology by region			
	Stage	**Timing**	
Balochistan	Start of vegetative growth (Bud bursting)	Late March	
	Full bloom	April	
	Fruit turning (Veraison)	September	
	Time to harvest	October	
	Stage	**Timing**	
Punjab	Start of Vegetative Growth (Bud Bursting)	Early March	
	Full Bloom	April	
	Fruit Turning (Veraison)	August	
	Time of harvest	September	
Bio-agronomic and productive characteristics			
Sensitivity to biotic stress		Very sensitive to verticillium wilt, sensitive to anthracnose and olive knot	
Sensitivity to abiotic stress		Tolerant to cold and drought	
Productivity (with GAP)		High and alternate	
Planting distance		6x4m (18x12ft)	
Production characteristics		Used for both table and oil purposes, low amount of polyphenols medium fruit size, with deep green color, sweet taste, slight bitterness and some spicy presence in the throat	

Table 8. Comprehensive profile of Ottobratica olive cultivar under Pakistani conditions.

Ottobratica	
Origin	Italy
Suitable regions	Balochistan
Area of suitability	Cold
Purpose	Oil (one of the finest olive oils)
Morphological characteristics	
Vigor	Strong
Growth habit	Erect (branches grow vertically)
Canopy density	Dense (packed foliage, extensive coverage)
Fruit characteristics	
Fruit weight	Small
Shape and color	Elongated oval to cylindrical; Reddish-purple to dark purple; sometimes greenish black
Oil content (% of fresh weight)	18-20%
Phenology (Balochistan)	
Stage	**Timing**
Start of vegetative growth (Bud bursting)	Late March
Full bloom	Late April
Fruit turning (Veraison)	October-November
Time of harvest	November-December
Bio-Agronomic and Productive Characteristics	
Sensitivity to biotic stress	Tolerant to olive knot and leaf spot
Sensitivity to abiotic stress	Resistance to drought, humidity, and strong temperature change
Productivity (with GAP)	High and alternate
Planting distance	6-7x6m (18-21x18ft)
Production characteristics	Oil is yellow in color with greenish nuances, characterized by bitterness and vegetable scent flavors and naturally rich in polyphenols.

VI – Conclusions and future perspectives

Overall, the present study provides a valuable foundation for guiding olive cultivation in Pakistan. It offers scientifically grounded recommendations on the selection of olive cultivars best suited to the agroclimatic conditions of key provinces, including Balochistan, Khyber Pakhtunkhwa, and Punjab.

By aligning cultivar selection with regional climatic conditions, a critical constraint in the sector has been addressed, namely, the mismatch between olive varieties and local environments. This approach supports improved productivity, better adaptation, and enhanced resilience of olive plantations. Furthermore, the study highlights the economic potential of olive cultivation, emphasizing both oil production and table olive processing as key components for strengthening the value chain. The optimized selection and management of olive varieties can therefore contribute significantly to the long-term sustainability, profitability, and expansion of Pakistan's olive sector, while supporting broader agricultural development goals.

- **Balochistan**

Olive cultivation presents an opportunity for agricultural development in the province of Balochistan. Situated in the arid and semi-arid regions of the country, the province boasts agroecology and agroclimatic conditions that favor the cultivation of *Olea europaea*. Particularly in the areas north of Quetta, including Zhob, Killa Saifullah, Loralai, and surrounding areas, the conditions align favorably for the growth and flourishing of olive orchards.

Balochistan's terrain and varying altitudes contribute to diverse microclimates, providing suitable niches for olive cultivation. The region experiences a predominantly dry climate with low precipitation, which is conducive to olive cultivation, as the tree thrives in well-drained soils and can withstand periods of drought. Additionally, winter-summer day and night temperature fluctuations characteristic of the Balochistan climate further support the necessary chilling hours needed for optimal flowering of the olive tree.

Balochistan can be divided into two distinct areas: the area north of Quetta experiences colder winters and mild summers. The region south of Quetta is characterized by a warmer climate with hot summers and milder winters. By harnessing the adaptability of olive trees to the province's agroecology and agroclimatic suitable conditions, Balochistan will greatly benefit, economically and environmentally, from the establishment of thriving olive orchards.

Moreover, as a drought-tolerant crop, olives can be a valuable addition to Balochistan's agricultural portfolio, offering resilience in the face of water scarcity and climatic variability. The province may contain additional suitable areas for olive cultivation due to favorable soil and climatic conditions; however, thorough site assessment, soil analysis, and appropriate management practices are essential to ensure the successful establishment and sustainable productivity of olive orchards in the region.

- **Khyber Pakhtunkhwa**

Khyber Pakhtunkhwa (KP) exhibits diverse agroclimatic conditions across its variable topography, ranging from plains to mountains, which supports a wide range of agronomic and horticultural crops including olives. Geographically, the province is divided into two zones, the northern zone, and the southern zone. The region features distinct and particular climatic zones: arid southern areas with hot summers with temperature exceeding 40°C and mild winters having temperature regime from 15 to 25°C, characterized by low humidity conducive to olive cultivation. Central regions experience semi-arid conditions with hot summers, cool winters, and moderate rainfall, necessitating good drainage for successful olive farming. Northern areas offer mild summers, cold winters, and less humidity providing suitable conditions for certain olive varieties.

KP's agroecology includes plains, valleys, foothills, and high-altitude areas, each presenting specific advantages and considerations for olive cultivation. Factors such as temperature, optimal rainfall (between 400-600 mm annually with good drainage), and humidity levels (preferably low to moderate to minimize diseases) significantly influence olive farming practices in the region. Given this climatic diversity, conducting scientific studies to identify appropriate olive varieties and determine optimal cultural practices tailored for each location. The region experiences a Mediterranean-like climate with hot, dry summers and mild, wet winters, which are ideal conditions for olive trees. The well-drained soils and abundant sunlight further support the growth

and productivity of olives. Additionally, the elevation variations allow for the cultivation of different recommended olive varieties, enhancing the overall yield and quality of the produce.

- **Punjab**

The climate of Punjab for olive plantations is characterized by higher humidity and seasonal monsoon rains. The province experiences hot summers and relatively mild winters. The area receives most of its rainfall during the monsoon season (July to September), which can be both a boon and a challenge for olive cultivation. The monsoon provides necessary water for olive trees, especially during dry spells, potentially reducing the need for supplementary irrigation. However, excessive rainfall can lead to waterlogging, root rot, and other waterborne diseases, while high humidity levels can promote fungal infections like anthracnose on olive fruit and other pests. It can affect olive cultivation if not managed properly. The olive varieties recommended for cultivation can tolerate higher humidity levels and occasional periods of heavy rainfall. The climate may also present unique challenges in terms of pest and disease management for olive cultivation. With appropriate management practices, olive farming can thrive in Punjab's diverse climatic conditions.

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