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Impact of Climate Change on *Pistacia khinjuk* as a Medicinal Plant in Egypt and Saudi Arabia

Nehal S. Al-Alfy[1], Abdel Raouf M. Moustafa[1]*, Modhi O Alotaibi[2] and Samira R Mansour[1]

1 Botany Department, Faculty of Science, Suez Canal University, Ismailia, Egypt

2 Biology Department, Faculty of Science, Princess Nora bent Abdul-Rahman University, Riyadh, Saudi Arabia

***Corresponding author:** Moustafa ARM

raoufmoustafa2@hotmail.com

Botany Department, Faculty of Science, Suez Canal University, Ismailia, Egypt.

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Abstract

The following review on the effect of climate change documented on the St. Catherine, southern Sinai in Egypt and on wadi Dissah South west of Tabuk in Saudi Arabia where *Pistacia khinjuk* is mostly found. *Pistacia khinjuk* is a tree or shrub that mainly occupies high altitudes. It is known to have both economic and medicinal importance. It was found that the leaves of *Pistacia khinjuk* grown in Egypt are rich in monoterpene hydrocarbons as well as monoterpene alcohols. It has antibacterial, antifungal, antioxidant, and wound healing properties, in addition to its hepatoprotective effect. *Pistacia khinjuk* is widely spread across temperate and tropical Asia. It prefers high altitudes and can tolerate harsh conditions of drought.

Pistacia khinjuk is native to Egypt in North Africa, temperate Asia and India. It is listed in Egypt as an endangered species due to facing lots of natural and human induced threats such as aridity and over-collection. In Egypt *P. khinjuk* is endemic to Serbal mountain (2070m.a.s. l), characterized by low temperature and relatively high precipitation due to the high elevation, while in KSA, Wadi Dissah has a very similar climate, mountain peaks there at 2400 m, above sea level and Jebel al Lawz (800-1,300m)where *P. khinjuk* is found exclusively. In this review, we suggest a tight conservation plan to this unique medicinal plant in Egypt.

Keywords: Serbal mountain; Saint catherine protectorate; Biodiversity loss; Endangered species; Conservation

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Introduction

Climate change is one of the most pressing environmental problems that the world is currently facing. Recent climatological studies found that the global surface air temperature increased from 1850 to 2005 by 0.76ºC and the linear warming trend over the last 50 years is determined by 0.13ºC per decade. Egypt is one of the countries expecting to face damaging effects due to climate change, and potentially facing "catastrophic" consequences in sea level rise (SLR), water scarcity, agriculture and food insufficiency, loss of biodiversity and habitats and new pressures on human health and national economy. Likewise, climate change is a serious challenge to the Kingdom of Saudi Arabia, which is under tremendous pressure as a result of the hyper aridity of the climate, severe shortage in water resources, rapidly growing population and reliance on fossil fuels, the latter of which is viewed globally as major source of GHGE. There is a general warming all over KSA which varies from a minimum of 0.15°C to a maximum of 0.75°C, with an average of 0.40°C. The pattern exhibits a clear systematic distribution with stronger warming tendencies over the interior part of the country and an area of weaker warming along the western and eastern coasts. As for precipitation trends, there are vast areas of rainfall deficits covering all northern parts of the Kingdom (as low as -40%) and the eastern slopes of the Asir mountains (-14% in Abha) [1-8].

Pistacia, genus *of* nine species of aromatic trees and shrubs in the cashew family (Anacardiaceae). Members of the genus can be deciduous or evergreen and commonly feature compound leaves that are alternately arranged along the stems. The plants are dioecious, the flowers are typically small with five petals and the fruit is an asymmetrical drupe. The plants grow well in warm semiarid regions, and many can tolerate poor soils. They are widely distributed at elevations ranging from 700 to 2000 m on hills and mid-height mountains. Besides, grow mainly in hot, dry

climates, such as in Western Asia, Asia Minor, Southern Europe, Northern Africa, and California. Its fruits (kernels) are used as edible nuts, for making a coffee-like drink, and as a source of oil and coloring.

Pistacia khinjuk has a great economic importance; the essential oils of some *Pistacia* plants contain variety of components with different therapeutic effects. The resin of this plant has been used as an indigestion, tonic, toothache and astringent in Bakhtiari folk medicine. The plant is known as Khenjuk or Kelkhong in Persian.

In Egypt, there are hundreds of *Pistacia* trees on Serbal and Tarbush Mountains in Saint Catharine south Sinai where it is endangered due to the increased aridity. Similarly, in KSA, *Pistacia khinjuk* is found mainly on top of Jebel Lawz in Wadi Disseh south west of Tabuk. This review aims at assessing the impact of climate change on the region of Egypt and Arabian Peninsula, predicting the extent of plant vulnerability taking into consideration that *Pistacia khinjuk* is highly resistant to unfavorable environmental and soil conditions specially drought and osmotic stresses [9-20].

Morphology

Pistacia khinjuk is a resinous dioecious tree or shrub, it has an exstipulated alternative pinnate leaves, flowers are unisexual and have no petals, distributed in axillary panicles or racemes, they have one bract, two bracteoles and 1-2 perianth segments, all forming a 5-field perianth, stamens are 3-5(-7) around the disc, pistil is either absent or rudimentary while the ovary is sessile, one-celled with one ovule, besides, the style is short, stigmas are capitated, meanwhile the fruit is one-seeded drupe, that produces compressed seed, lastly, the testa has no membrane. Two varieties of *Pistacia khinjuk* occur in Egypt, *var. glabra* schweinf and *var. microphylla* boiss [21-25].

Chemical Composition of Essential Oil of *Pistacia khinjuk*

Several phytochemical studies on *Pistacia* genus have discovered a diverse secondary metabolite in addition to high level of vitamins and minerals. Exudate gums of the tree contain resins and volatile oil and pinenes, sabinene, and limonene are the main component of its oil. Picci et al. studied the chemical composition of the essential oil of *Pistacia* reveals the presence of several main compounds: myrcene (19-25%), α-pinene (16%), terpinen-4-ol (22%). While, De Pooter et al., have studied the essential oils from the leaves of three *Pistacia* species grown in Egypt, including *Pistacia khinjuk,* they revealed that it is rich in monoterpene hydrocarbons and monoterpene alcohols were detected in *P. khinjuk* by 16% percent, however, no sesquiterpene alcohols were detected. Furthermore, Pirbalouti and Aghaee, studied the chemical composition of essential oil of *Pistacia khinjuk* Stocks grown in Bakhtiari Zagross Mountains in Iran, identifying 95 compounds of them which are mainly constituted of Phellandrene (52.33%) and α-pinene (15.27%). Phellandrene is the name for a pair of organic compounds that have a similar molecular structure and similar chemical properties. Alpha Phellandrene and beta phellandrene are cyclic monoterpenes and are double-bond isomers. The phellandrenes are used in fragrances because of their pleasing aromas. In contrast Mirian et al., proved that α-pinene was the major constituent of resins [26-29].

Medical Importance of *Pistacia khinjuk*

Medicinal plant nowadays is commonly used in the treatment of different diseases. In addition to the effectiveness of medicinal plant and its low cost it has a long-term impact on peoples' health instead of side effect of chemically manufactured medicines. *P. khinjuk* is a widely-distributed plant belongs to the family *Anacardiacea*. Several studies have been done to extract of different parts of *P. khinjuk* that showed different therapeutic characteristic.

Tartan et al. showed significant antibacterial and antifungal effects of chloroform, ethyl acetate, ethyl alcohol and diethyl ether extracts obtained from the leaves of *P. khinjuk*. Furthermore, Tohidi et al. revealed that *P. khinjuk* has antibacterial activity against three strains of bacteria (*Escherichia coli*, *Staphylococcus aureus* and *Staphylococcus epidermidis*) and has a wound healing property.

It was mentioned also in a study by Tahvilian et al. that essential oils of *P. khinjuk*, γ-terpinene, β-Pinene and α-Terpinolene have strong levels of antifungal activity against *Candida albicans*. Besides, it was proven that *P. khinjuk* essential oil had a potential to be applied as an antifungal agent.

In addition to its antibacterial, antifungal and wound healing properties Dizaye, indicated that the aqueous extract of *Pistacia khinjuk* showed significant protection against the increase of liver enzymes, indicating the protection of hepatic cells against both carbon tetrachloride and acetaminophen induced liver damage in rats. Probable mechanism of action may be due to the antioxidant effect of aqueous extract of *P. khinjuk.* Besides, Azadpour et al. proved that *P. khinjuk* could be used as a natural preservative in food and/or in the pharmaceutical industry.

Hatamnia et al. mentioned that also a phenolic compound of fruit of *P. khinjuk,* (ascorbic acid, gallic acid, rutin, caffeic acid, ferulic acid and sinapic acid) responsible for the powerful antioxidant effect. Also reported that among different parts of the fruit, hull extract showed highest antioxidant activities. On the other hand, between 35 and 40% of the raw kernel consists of protein, in which the hydrophilic amino acids predominate (e.g. glutamic and aspartic acids. Finally, most recent researches proved that *Pistacia khinjuk* resin extracts α-pinene and β-pinene have cytotoxic and antiangiogenic effects against cancer cells than normal ones [27-38].

Geographical Distribution

P. khinjuk is widespread across temperate and tropical Asia and its population is suspected to be stable **(Figure 1)**. In Iran this species is wide ranging, occurring through the Makran Zone, Zagros Mountains and the Sanandaj-Sirjan Zone, however subpopulations are also noted to be disjunctive, which suggests that current populations are the remnants of a former, more widely distributed, continuous population; the species is almost

Figure 1 Global distribution of *Pistacia khinjuk*.

absent from the Alborz Mountains. In Syria this species occurs in the Kalamoun Mountains in the northeast, specifically on the Abdel-Aziz Mountain. In Turkey this species is widely distributed across the region of southeastern Anatolia, while in Pakistan it is commonly found in Baluchistan, Khyber, Chitral, Gilgit and in the Indus river gorge from Kohistan district in Skardu valley. The same authors emphasized that populations in Pakistan have previously suffered a decline from high rates of deforestation in the north, and so are now limited to high places that are inaccessible to humans and goats, and in Iraq this species is widely distributed in the Kurdistan region. Meanwhile in KSA, in northern higaz, and the southern fringe of Harrat as Rahah northwestern Saudi Arabia.

Habitat

Pistacia khinjuk is spread in places where the altitude is 700-2000 m. it grows in regions, which have 100-600 mm of rain annually and annual temperature regime of 10-25°C. *P. khinjuk* is able to distribute in all regions which shows that it has less sensitivity against heat, height, and amount of rain, dryness and other hard conditions of the surrounding environment. It is the best species to be cultivated in different climates and regions. Therefore *P. khinjuk* is advised as the best species to be used as rootstocks in plan form or in hybrid.

P. khinjuk is commonly found growing on rock soils, which seem to be very unsuitable sites for trees. The period from the end of August to the end of September appears to be the most appropriate season for the collection of seeds. In some areas (2060 m a.s.l.), nuts have been reported to fall in late September and early October. Since nuts are too small and indehiscent, the potential value of this species is to be rootstocks for *P. Vera* [35-42].

In Egypt, there are hundreds of *Pistacia khinjuk* trees in Serbal Mountain (2070m.a.s. l) which lie in the middle of south Sinai close to the Gulf of Suez that is a typical, diked granite range mainly dissected by rugged boulder-strewn canyons which are mainly granitic with some metamorphic rocks at the mountain foot and alluvial deposits in low elevated wadies. It includes many wadies (e.g. wadi Aleiat, Wadi Rem), gorges (e.g. shaqq Sha'arani), ponds of surface water, spring (Ain Gohaier, Ain El-lousa) and small plains (like Farsh El-lousa) and terraces (Hagar El-bardeia). it is restricted to Serbal and dominates slopes and gorges habitat forming forest-like vegetation. In the high elevation (1600-1700 m.a.s.l.) and in wide range of exposure degree (40° north eastern to 150° south western) and slope degree (12° to 20°). *Pistacia khinjuk* characterized by low water holding capacity mean percent (11.9%) while the other parameters (organic matter percent, electric conductivity, silt and clay percent, total sand percent, gravels percent and hygroscopic moisture) are moderate in its range **Figure 2**.

In KSA, *P. khinjuk* is confined to the Saharo-Sindian Regional Zone Northern Hijaz, Northwest region of Saudi Arabia is administratively part of the Tabuk Province. It is located within 27° 30′ to 29° 30′ N latitudes and 34° 29′ to 36° 45′ E longitudes **(Figure 3)**. Traditionally, this region is known as Midyan (Midian or Madyan) and is bounded by the Hisma plateau from the east and by the Gulf of Aqaba and the Red Sea from the west. It should be mentioned that the Midyan region characterizes by its diversity of cultural heritage, history, and natural landscape. *P. khinjuk* is found wadi dissah located in the Midyan region on top of Jebel Lawz, Jebel Dibbagh, Jebel Radhwa, Jebel shada and the southern fringe of Harrat as Rahah northwestern Saudi Arabia in the form of tall shrublands above 800m a. s. l. in addition, Jabal Al-Lawz (28.6523° N 35.3317° E is the most famous habitat of *P. khinjuk* in the region [39-46].

Climate

South Sinai is characterized by an arid to extremely arid climate with long hot rainless summer and mild winter. Hoewever, due to the wide range of altitude, there is a wide range of variation in air temperature. Meanwhile, Abd El-Wahab described Saint Catherine to be the coolest area in Sinai and Egypt as a whole due to its high elevation. According to Cedare Lake Venture the

Figure 2 Distribution of *Pistacia khinjuk* in South Sinai, Egypt.

summers are long, warm, arid, and clear and the winters are very cold, dry, and mostly clear. Over the course of the year, the temperature typically varies from -2°C to 27°C and is rarely below -5°C or above 29°C. Precipitation occurs mostly in winter. The climate is influenced by the Mediterranean and by the orographic impact of the high elevation of the mountains in southern Sinai. The tropical influence is prominent along the Gulf of Suez and the Gulf of Aqaba.

Similarly, the Midyan region north east of KSA has almost a similar climate since the topography has a very strong influence on the meteorology of the Arabian Peninsula (the book). The climate of the region is characterized by hot dry summer and relatively cold winter. Precipitation mainly occurs irregularly during the fall, winter, and spring seasons. There are no precise rainfall data for the Midyan region. Therefore, measurements from the neighboring areas may give a general idea of the average annual rainfall in the region. The average annual rainfall at Shuwaq (27.40° N 36.50° E) is at 47 mm, at Duba (27.35° N 35.70° E) 23 mm, at Tabuk (28.35° N 36.52° E) 31 mm, and at Aqaba, Jordon 39 mm [42-49].

Hydrogeology

In Sinai, there are three indigenous water sources; rainfall, surface and ground water. Therefore, the water resources in South Sinai resulted from rainfall, springs, and ground water supplies. Hammad stated that the amount of ground water in Sinai decreases southward (25 mm/year). The main water bearing formations in South Sinai include: the basement complex, the Nubian sandstones exposed on the surface overlying the basement rock, the limestones of Mesozoic and Tertiary, the Miocene formation, the coastal sandstone, the alluvial deposits

Figure 3 Distribution of Pistacia khinjuk in Northeast KSA.

(Quaternary) that occupy the alluvial plains, which are parallel to the Gulf of Suez and the Gulf of Aqaba. Basement complex which is composed of highly fissured igneous and metamorphic rocks occupies the southern part of Sinai. As these rocks are highly elevated, their water forms a considerable pressure feeding the northern water bearing formations.

On the other hand, in KSA, Geologically, the western part of the Midyan region contains Proterozoic stratiform and intrusive basement rocks of the Arabian Shield which in some places overlaid by Mesozoic and Cenozoic sedimentary rocks, whereas the eastern part is composed of Paleozoic sandstones of the Hisma plateau. While hydrogeologically is formed of several basins of Wadi al Hamdah basin, Wadi Tayyib Ism basin, and Wadi Ad Disah basin that contain natural springs. Ad Disah is an agricultural village located at 27.60447° N 36.42781°E. This village exists at the confluence of three major canyons in the region. The Wadi Qaraqir and the Wadi Ghamrah are the main branches in the Wadi Ad Disah basin which drain a sandstone area of Jabal Qaraqir. The canyons in lower reaches of Wadi Qaraqir and middle the reaches of Wadi Ghamrah contain springs. The canyon floor in lower reaches of Wadi Qaraqir is filled with alluvial sediments composing mainly of sand and fine gravels, whereas the canyon floor in middle the reaches of Wadi Ghamrah is filled with coarse gravels, pebbles, and boulders. The canyon floor in lower reaches of Wadi Qaraqir is narrow and mainly occupied by stream channels and sandbars. It is vegetated with relatively dense wetland plants, namely Phragmites and Typha. water qualities of springs in the Wadi Ad Disah basin are very good, where it ranges between 420 and 730 µmohs/cm with small temporal changes [44-51].

Precipitation and snow

Most of the precipitation in St. Catherine occurs during autumn, winter, and spring. Considerable precipitation occurs as a result of convective rains which are very local in extent and irregular in occurrence. The number of convective rains per season is unpredictable. Flash floods due to heavy rainfall may occur. The maximum amount of rainfall for one day was 76.2 mm in November 1937. Precipitation may occur as snow on the high peaks of southern Sinai Mountains, and winter snow lasting two to four weeks has been observed on the northern slopes of Mountain Catherine. More than one snowfall may occur during some years while during others it may be absent. Precipitation which falls as rain in the valleys of southern Sinai may occur as hail on the high peaks. Water derived from melting snow or hail is more likely to infiltrate the desert soil because of its low rate of percolation. Zohary suggested that some of the higher mountains receive an annual precipitation of not less than 300 mm due to snow fall and orographic precipitation. Danin mentioned that the range of mean rainfall is 70 to 100 mm. Issar & Gilad mentioned that the study area receives approximately 50 mm of precipitation, partly as snow. Abd El-Wahab calculated the mean rainfall of 22 years as about 44.2 mm. Ghodief showed that St. Catherine area receives about 60 mm which is the greatest mean all over southern Sinai [46-51].

In dry years the isohyets shift to the north and west, while in wet years they shift to the south and east. During the period from 1979 to 1992, the mean annual rainfall in Saint Catherine area was 42.59 mm. According to Cedar Lake Ventures, the day in 2017 with the most precipitation observations was Jan 3th. The month with the most precipitation observations was January with 2% while the least month was July with 0% precipitation [49-56].

On the Saudi side we're lacking detailed information about precipitation, however, the precipitation rates of the surrounding the Myidyan region is ranging between 23 to 47 mm. per year which is less than the Egyptian side.

Discussion

Global climate change has already large effects on populations and distributions of species across the globe and the shifting distributions and abundances of species will have significant consequences on the future of biodiversity. On the past 100 years, the Earth temperature has increased by approximately 0.6°C with two periods of warming, between 1910 and 1945 and from 1976 onwards. The rate of warming during the last century has been approximately greater than at any other time during the last 1,000 years.

According to IPCC 2001, the extent of snow cover has been shrunk by about 10 % since the 1960s. in addition to the decrease in Northern Hemisphere spring and summer sea-ice extent by about 10 to 15% since the 1950s. There are increases in cloud cover over mid- to high latitude land areas by about 2% in the last century, like wise a reduction in the frequency of extreme low temperature with smaller increase in the extreme of elevated temperature since 1950s. Moreover, the intensity of drought in some regions such as Asia and Africa have been increased in the recent decades. It was mentioned by that Precipitation in Serbal Mountain is characterized by scantiness, Seasonality, and inconsistency and it occur mainly in winter from October to April. According to recorded data, Serbal Mountain receives about 70 to 100 mm annual precipitation as rain and snow. And the monthly mean temperature varies between 6.8°C in January to 26.1°C in August. The relative humidity is higher in winter than in summer.

In agreement with Moustafa et al. and Abd El-wahab et al. Serbal Mountain is characterized by more rich and unique flora than any other mountain in the upper Sinai massif. The flora of Serbal Mountain represents about 28% of the flora of south Sinai recorded by Danin and El-Hadidi, and about 44% of the flora of St. Catherine Protectorate recorded by Moustafa et al. More than 57% of the medicinal plant species in south Sinai, and 14% of the threatened species in Sinai Peninsulaare represented in Serbal mountain. Thirty-six species of the flora of Serbal Mountain are considered as characteristic species, including *Pistacia khinjuk, Acacia tortilis* subsp, *raddiana* and *colutea isteria*. They cover most of the area and dominate many of plant communities. The number is more than that of other mountains of the upper Sinai massif including saint Catherine Mountain.

Studies have shown that Egypt's climate has changed greatly over the last 10,000 years, changing gradually from a wet climate (rainfall was more than 300 mm/year) to a more arid climate (less than 50 mm/year). Analyses of data for temperature and rainfall from 1970 to 2014 show a clear tendency towards decreasing rainfall and increasing average temperatures. This trend caused severe droughts for many years that were suddenly interrupted by high and unpredictable rainfall that fluctuated heavily in space and time. If this tendency continues, the population dynamics of many plant and animal species will be negatively affected, with many of them being important for local inhabitants. Conservation efforts should be directed to conserve the biological and natural resources and to keep pace with this environmental change. A limited number of studies have been undertaken to assess the impact of climate change on endangered medicinal plant species. This may be due to the fact that the availability of biodiversity data records of Egyptian flora is few and not well organized.

Only few studies have dealt with the conservation of *Pistacia khinjuk*, although it's a very economically and medicinally important plant. Ecologically, according to IUCN *P. khinjuk* conservation status is least concern. However, according to Abdelwahab et al. that carried out a study on medicinal plant in Saint Catherine Protectorate, *P. khinjuk* in Egypt is endangered. Abdelwahab et al. have suggested that *P. khinjuk* population in Serbal, Ain el-louza facing lots of threats such as aridity which considered to be the first and main natural threat facing *P. khinjuk*. Also, they mentioned the human-induced threats which plays a very aggressive role on this plant by many ways such as over-cutting for fuel, over-collection, overgrazing, tourism, urbanization, feral donkeys and solid wastes due to urbanization and tourism activities. Consequently, we must collect full data about *P. khinjuk* in Egypt, such as preferred habitat, spatial

distribution, abundance, and population size, collection methods, parts of the plant used in medical manufacturing, uses, and threats. Molecular diversity of *P. khinjuk* in Egypt needs to be studied for further understanding of its genetic diversity and hence it's resistant to different environmental conditions to aid in the conservation process.

Furthermore, *P. Khinjuk* in Serbal Mountain is exposed to over-grazing and over- cutting, hence, we suggest constructing a detailed conservation plan for *P. khinjuk* in Serbal Mountain such as establishing a protected area or enclosures around the plant, creating gene banks, identifying the most appropriate cultivation methods for *P. khinjuk* and encourage local people to propagate them, beside studying the seed bank. In addition, we must make abroad-scale grazing management plan to *Pistacia khinjuk* trees, a long-term monitoring plan that involves indigenous people and governmental environmental authorities as well as, increasing the awareness of the public about *P. khinjuk* current status in Egypt to decrease human-impact on it and clarify how much it is important to be protected. Also inform the organizations which are responsible for plant conservation about *P. khinjuk* to set legislations that could prevent cutting and selling of it and finally, Insert *P. khinjuk* in endangered plant species manual in Saint Catherine Protected area.

Natural ecosystems identified as being at risk in relation to climate change in Saudi Arabia including mountain forests and woodlands, wadis, wetlands, coastal areas, etc. Anticipated negative impact of climate change on range and forest lands over the next 50-100 years in Saudi Arabia include: increase in the frequency and changes in the patterns of natural disturbances, such as drought, sand storms, fire, floods, leading to increased die- back and die-off in forests and woodlands, spread of diseases, change in species composition and richness, drop in productivity a decrease in biodiversity. The Midyan region is an important natural ecosystem that is famous for high recreational and touristic activities in Saudi Arabia, its slightly affected by drought stresses as its rich with wadi systems, springs and ground water which all run off towards the gulf of Aqaba Red Sea, however compared to Egypt it has less precipitation amount per year.

Conclusion

In conclusion, *Pistacia khinjuk* is a unique plant that can only be found in specific parts of Asia, the high drought and osmotic stress tolerance of *Pistacia khinjuk* is the major key of how it will tolerate more aridity due to climate change along with its high-altitude preference which provides more moisture, precipitation rates and moderate temperatures. Its uniqueness emerges from the different chemical constituents, economic importance and high-altitude preference which is limited to the Saint Catherine region in Egypt. Being endangered, it's highly critical to consider preserving *Pistacia khinjuk* population as rare Egyptian natural heritage. While in KSA its restricted to the north most parts of Higaz mountains, more investigations are recommended for *P. khinjuk.*

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