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THE INFLUENCE OF INTERANNUAL CLIMATE VARIATION ON THE PHENOLOGY OF SOME WILD FRUIT SPECIES AND THEIR RELATION WITH AVIFAUNA

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Abstract

This paper aimed to investigate the influence of interannual climate variation on the phenology of some wild fruit species and their relationship with avifauna. For this study, wild fruit species such as blackthorn, red and black hawthorn, dog rose, European crab apple, wild pear, elder, dewberry, and some bird species such as white and black stork, common cuckoo, Eurasian hoopoe, barn swallow, and European bee-eater were monitored. The observations were carried out in an ecosystem from the southern part of Oltenia, Romania, during the period 2019-2021. From the three years of study, 2021 stood out with an extension of the spring season, which influenced both plant phenology and the behaviour of bird species. It turns out that the presence of wild fruit species is essential in terms of the provided ecosystem services from an ecological and ecosystem balance point of view.

Key words: *BBCH, birds, phenology, spring, wild fruits.*

INTRODUCTION

Phenology is the time and duration of recurrent biological events under the influence of climatic factors, such as bud breaking, flowering (Yang et al., 2020), fruit ripening. Early bud breaking influences the length of the species vegetation season and their life cycle is under the impact of rising temperatures (Doi & Katano, 2008). There are currently numerous studies on the effects of climate change on ecosystems and implicitly on biodiversity (Pereira et al., 2010; Bellard et al., 2012; Garcia et al., 2014; Urban et al., 2016). The influence of human activities is increasingly evident on the climate (Trenberth, 2018) with repercussions on flora and fauna, reducing or increasing the growth stages of vegetation or birds' migration patterns. The simplest way to observe the influence of climate change on biodiversity is to track the phenology of plant species and the migration of birds (Walther et al., 2002). Phenological growth stages (BBCH) are considered as indicators used in detecting the influence of climate change on ecosystems, offering the possibility to quantify data based on visual observations (Ahas & Aasa, 2006). Spring phenology represents the beginning of the vegetation season of the species and it is the most sensitive to climate change (Yu et al., 2010) being prone to sudden changes in temperature that can have an unfavourable impact on their growth and development (Larue et al., 2021). According to Badeck et al. (2004) and Linkosalo et al. (2006) temperature is the main factor of biological developmental processes. One of the unfavourable consequences that can affect fruit species is a high temperature followed by late frosts and rime (Vitasse et al., 2018), thus affecting buds or flowers (Eccel et al., 2009; Djaman et al., 2021). Another consequence as a result of climate change is the gap of spring phenophases by prolonging some growth stages, respectively budding, flowering, due to much too low temperatures and frequent rainfall. This can be seen in the case of rainy and cold springs that increase the spring growing stages. According to Koleček et al. (2020) in migratory birds, to high temperatures led to their arrival at nesting areas much earlier and thus to the extension of the breeding season. At the same time, the impact of climatic factors on the life cycle of birds also depends on the local and regional characteristics of the area (Zalakevicius et al., 2006), the abundance of food, the presence of nesting sites or how the breeding habitat provides protection against predators. Chuine (2010) mentions phenology as being an adaptive trait specific to each plant species with a high degree of variability. The timing of key life events (phenology) migration, breeding, and nesting are timed every spring to coincide with the peak availability of critical food sources in a delicate synchronization that occurs across large latitudinal gradients and diverse habitats. According to El Yaacoubi et al. (2014), most weather stations in Europe, East Asia and Alaska recorded a significant increase in maximum and minimum annual temperature, especially during winter and spring. As stated by Vitasse et al. (2018) nowadays, the emphasis is more on species resistance to drought than on the relationship between spring phenology and late frosts. These climatic accidents can have undesirable effects on species productivity (Djaman et al., 2021). Species in temperate forests are most vulnerable to frost when the leaves appear (Vitasse et al., 2018). Researches from Estonia suggest that spring has progressed while winter has decreased (Ahas & Aasa, 2006). Chuine et al. (2016) mention a start of the growing season 2.3 days earlier per decade in the last 40 years in the temperate zone of Europe due to climate change. Shifts in phenology are important for conservation actions and the seasonality of species for recreational activities (Badeck et al., 2004). According to Rumeu et al. (2020) understanding how species interact and drive ecological processes across space is crucial given the current scenario of world-wide habitat fragmentation. The simplest method of investigating climate change is *in situ* observations by field trips and records of data corresponding to the onset of vegetation phenophases. The purpose of this paper is to provide additional information on the influence of interannual climate variation on phenology of some wild fruit species and their relation to avifauna, from the southern part of Oltenia region, Romania.

MATERIALS AND METHODS

Materials

In terms of descriptive research, wild fruit species from Bratovoeşti area (44°05'N 23°53'E), Dolj county, southern part of Oltenia region, Romania, were analysed in terms of triggering spring phenophases (on an area of approximately 15 km^2). Eight wild fruit species, blackthorn/sloe - *Prunus spinosa* (L.), hawthorn - *Crataegus monogyna* (L.) Jacq., black hawthorn - *Crataegus pentagyna* (L.) Waldst. et Kit., dog rose - *Rosa canina* (L.), European crab apple - *Malus sylvestris* (L.) Mill., European wild pear - *Pyrus pyraster* (L.) Burgsd., Elder - *Sambucus nigra* (L.) and dewberry - *Rubus caesius* (L.) were observed over 3 years period (2019-2020-2021) for data collection corresponding to the onset of the main spring phenophases. These particularly wild fruit species were chosen because of their importance in terms of ecosystem services that they provide (source of food for birds and animals; shelter; support for several categories of organisms such as insects, butterflies; horticultural importance in terms of breeding programs, medicinal and therapeutic importance due to their content in bioactive compounds useful for human health, cultural services in terms of recreational purposes). Six species of long-distance migratory birds from sub-Saharan Africa (white stork - *Ciconia ciconia*; black stork - *Ciconia nigra*; common cuckoo - *Cuculus canorus*; Eurasian hoopoe - *Upupa epops*; barn swallow - *Hirundo rustica* and European bee-eater - *Merops apiaster*) nesting in the study area, were observed during the three years period in order to mark their date of arrival. Nests of other present species were identified and monitored over the three years of the study to collect data regarding those that chose the studied wild fruit species as a support in building nests.

Climatic data

From the climatic point of view, the analysed ecosystem is situated in the type of continental climate, with annual precipitations of 500 mm (most frequent at the beginning of summer) and a temperature amplitude of over 25˚C (Cojoacă & Niculescu, 2018).

In terms of climatic data (meteocraiova.ro), the average monthly temperature and the total amount of monthly precipitations were used as a comparison between the studied years (2019-2020-2021). The weather station from where the data was acquired is situated at 25 km from the site, being the closest.

Methods

Exploratory research was conducted via field trips made at intervals of 2 to 3 days to observe the development of the principal growth stages and identification keys according to the BBCH scale (bud breaking BBCH 07; full flowering BBCH 65; end of flowering/all petals fallen BBCH 69). The data calendar corresponding to each phenophase was recorded and the number of days between January 1^{st} to the main spring phenophase was calculated. For the species *M. sylvestris*, *P. pyraster*, *C. monogyna*, *C. pentagyna*, *R. caesius* and *P. spinosa* the phenological growth stages and identification keys described by Meier (2001) were used, for *R. canina* the growth stages described by Meier et al. (2009) were applied and for *S. nigra* the growth stages described by Atkinson & Atkinson (2002) were adapted. The same individuals from each wild fruit species were observed each year, so that the obtained data can be conclusive. The studied bird species were observed around their nesting sites in order to register the calendar date of arrival. These particularly species were chosen because of their ease of observation (both visually and after the sounds made, in the case of the common cuckoo and the hoopoe).

Statistical analysis

All data regarding the number of days starting January 1^{st} to the main growth stage (bud break, full flowering, end of flowering) was processed in Microsoft Excel.

RESULTS AND DISCUSSIONS

Tracking phenological landmarks is a simple and easy to apply method, often used in both flora and fauna monitoring. It provides accurate and useful data on how climate affects the development of each organism and thus the ecosystem. Spring phenology is considered to be the most prone to temperature fluctuations but also to precipitation with negative effects on the growth and development of plant species but also on the dynamics of bird migration patterns.

Following the obtained data, the year 2021 was noted as the earliest in terms of bud bursting (Figure 1) for *M. sylvestris*, *P. pyraster*, *C. monogyna*, *R. canina*, *S. nigra*, *P. spinosa* but also the longest in all studied wild fruit species by prolonging the spring phenology (bud break – all petals fallen).

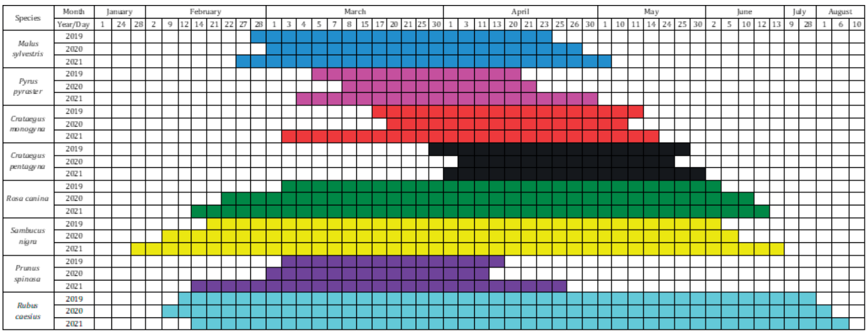

Figure 1. Wild fruit species phenogram of bud breaking - end of flowering (all petals fallen)

Following the analysis of meteorological data (Figure 2), January 2021 was the warmest with an average temperature of 3.77°C compared with 2019 with -3.39°C, and 2020 with 2.96°C. February 2021 was the coldest with a monthly average temperature of 5.2°C, compared with 5.36°C in 2019 and 7.5°C in 2020. These data can explain the phenomenon of faster vegetation entry and at the same time analysing the other data for March and April, 2019 was found to be the warmest with a monthly average of 11.72°C compared to the same month (March) of 2020 (average monthly temperature of 9.61°C) and 2021 (with an average of 7.33°C). April recorded the highest average monthly value in 2020 (14.25°C) followed by 2019 (13.67°C) and 2021 (11.41°C). The last month of spring, May had the highest monthly average temperature in 2021 with 18.61°C, followed by 2020 with 18.58°C, while 2019 had an average monthly temperature of 17.05°C. The monthly average temperature correlated with the monthly total rainfall (Figure 3) offer a better picture on the influence of cold/warm temperatures to the development of spring vegetation season.

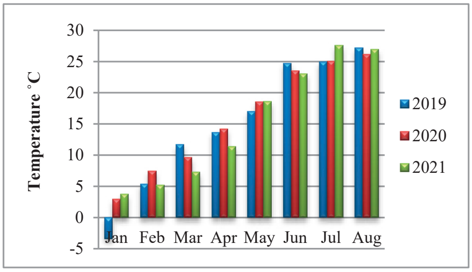

Figure 2. Monthly average temperature over the 3 years of study (°C)

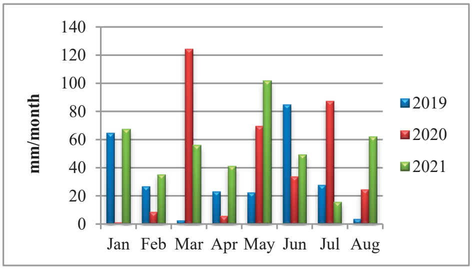

Figure 3. Quantity of monthly total rainfall over the 3 years of study (mm)

The months of January, February, May and June had the highest amount of rainfall in 2021 compared to 2020 and 2019, this could be a possible explanation of the extension of the spring vegetation season. Taking as a landmark the number of days from January 1st to bud breaking, the order in which this phenophase occurred in the identified species was: *S. nigra* > *R. caesius* > *R. canina* > *P. spinosa* > *M. sylvestris* > *P. pyraster* > *C. monogyna* > *C. pentagyna*. According to the study of Cosmulescu et al. (2021) the highest coefficient of variation was obtained at elder followed by blackthorn, dog rose and red hawthorn which indicates a medium to high degree of variability for this phenological growth stage (BBCH 07). Considering the same landmark (number of days from January 1st) to full flowering (BBCH 65), the order in which this phenophase occurred in the identified species was: *P. spinosa* > *P. pyraster* > *M. sylvestris* > *C. monogyna* > *C. pentagyna* > *R. canina* > *S. nigra* > *R. caesius*. Regarding the number of days from January 1st to end of flowering (BBCH 69) the order in which this phenophase occurred in the identified species was: *P. spinosa* > *P. pyraster* > *M. sylvestri*s > *C. monogyna* > *C. pentagyna* > *S. nigra* > *R. canina* > *R. caesius*. Based on this data it can be concluded that elder gives the starting of vegetation season, and black hawthorn is the last of the studied species to bud break (about two weeks later after red hawthorn). The timing between the spring phenology and the arrival of studied migratory birds can be found in Table 1. Another important factor for bird species regarding the development of wild fruit species is the plant habit, growing characteristics (presence of thorns, twigs shape and length), which provides shelter from predators, or climatic factors. Species that were observed nesting in studied wild fruit species were: Eurasian collared dove (*Streptopelia decaocto*) in elder, the long-tailed tit (*Aegithalos caudatus*) in dog rose, Red-backed Shrike (*Lanius collurio*) in blackthorn, hawthorn and wild pear, Eurasian Blackbird (*Turdus merula*) in European crab apple. This is mainly due to the growth characteristics of wild fruit species that provide protection against external factors.

According to Vander Mijnsbrugge et al. (2015) the bud breaking phenophase is the one that influences the length of the growing season, flowering and reproduction. Following the obtained data, there are significant differences from one year to another in terms of time of vegetation season starting on wild fruit species with the prolongation of the spring season (bud break – end of flowering/all petals fallen). It is found that the order in which the bud break took place was maintained, but the period of development changed, in connection with environmental factors and location.

Table 1. Date of arrival of long distance migratory bird species and the main BBCH phenophases at the studied wild fruit species

Species	First seen on site	Wild fruit species BBCH phenophases
Ciconia ciconia (White stork)	2019 Mar 17	Pink bud stage at *M. sylvestris;* first leaves fully expanded at *P. pyraster;* bud break at *C. monogyna* and *R. caesius;* full leaves at *S. nigra;*
	2020 Mar 10	First leaves fully expanded at *M. sylvestris*; bud break at *P. pyraster* and *R. caesius*; first leaves fully expanded at *R.canina*; full leaves at *S. nigra;*
	2021 Mar 13	Bud break at *M. sylvestris, P. pyraster, C. monogyna, R, caesius, R. canina;*
Ciconia nigra (Black stork)	2019 Mar 17	Pink bud stage at *M. sylvestris;* first leaves fully expanded at *P. pyraster;* bud break at *C. monogyna;* full leaves at *S. nigra;*
	2020 Mar 14	Visible flower buds at *M. sylvestris*; bud-breaking at *P. pyraster;*
	2021 Mar 28	Visible flower buds at *M.* sylvestris and *C. monogyna*; pink bud stage at *P. pyraster*; bud burst at *P. spinosa*; first leaves at *R.canina;*
Cuculus canorus (Common cuckoo)	2019 Apr 16	Flower buds at *C. pentagyna* and *C. monogyna;* flowers fading at *M. sylvestris* and *P. pyraster*; flower buds at *S. nigra;*
	2020 Apr 14	Flowers fading at *M. sylvestris* and *P. pyraster*; first flowers at *C. monogyna*; flower buds at *C. pentagyna*; all petals fallen at *P. spinosa*; flower buds at *S. nigra;*
	2021 Apr 03	Pink bud stage at *M. sylvestris* and P. *pyraster*; first flowers at *P. spinosa*; flower buds at *S. nigra* and *C. monogyna*; bud break at *C. pentagyna;*
Upupa epops (Eurasian hoopoe)	2019 Mar 24	First flowers at *M. sylvestris*; flower buds at *P. pyraster*; bud break at *C. monogyna*; first flowers at *P. spinosa*; first leaves at *R. canina*; flower buds at *S. nigra;*
	2020 Apr 11	Full flowering at *M. sylvestris*; flowers fading at *P. pyraster*; pink bud stage at *C. monogyna*; leaves unfolding at *C. pentagyna*; end of flowering at *P. spinosa*; flower buds at *S. nigra;*
	2021 Mar 27	Leaves fully expanded to flower buds at *M. sylvestris*; pink bud stage at *P. pyraster*; flower buds at *C. monogyna*; bud burst at *P. spinosa*; first leaves at *R.canina;*
Hirundo rustica (Barn swallow)	2019 Mar 20	Pink bud stage at *M. sylvestris*; leaves fully expanded to flower buds at *P.pyraster*; bud break at *C. monogyna*; bud burst at *P. spinosa*; first leaves at *R. canina* and *R. caesius;*
	2020 Mar 17	Flower buds at *M. sylvestris*; first leaves unfolding at *P. pyraster*; bud break at *C. monogyna*; bud burst at *P. spinosa*; first leaves fully expanded at *R.caesius;*
	2021 Apr 08	Pink bud stage at *M. sylvestris*; pink bud stage to first flowers at *P. pyraster*; flower buds at *C. monogyna*; bud break at *C. pentagyna*; flowering at *P. spinosa*; flower buds at *S. nigra*
Merops apiaster (European bee-eater)	2019 May 05	Full flowering to flowers fading at *C. monogyna*; pink bud stage at *C. pentagyna*; bud burst at *R. canina*; flower buds at *S. nigra;*
	2020 Apr 26	Full flowering at *C. monogyna*; flower buds at *C. pentagyna* and *S. nigra*; end of flowering at *M. sylvestris*; bud burst at *R.canina;*
	2021 May 01	End of flowering at *M. sylvestris* and P. pyraster; first flowers at *C. monogyna*; flower buds at *C. pentagyna* and *R. canina* and *S. nigra.*

Triggering these changes depends on climatic factors (Forrest, 2016) of the area (temperature, photoperiod). According to Grime et al. (1988) bud break of *S. nigra* may occur earlier due to high temperatures in winter, while Atkinson & Atkinson (2002) refer to leaves emergence in February-March and flowers in May-June as reference periods, consistent with the data obtained in this study. The differences between the two species of the same genus (*Crataegus*) are significant in terms of bud breaking in 2019 occurred 13 days apart, in 2020 at 14 days and in 2021 at a difference of 29 days. According to Fichtner & Wissemann (2021), bud break at *C. monogyna* takes place in mid-March to April, depending on altitude and location, while the "end of the flowering" takes place from April to June. Dönmez (2004) mentions that hawthorn has a period of 1-2 weeks with flowers present, and *C. pentagyna* blooms later than *C. monogyna*, which confirms the results obtained in this study. The results obtained within the *P. spinosa* species are consistent with those obtained by Cosmulescu & Căluşaru (2020) in the study from Gura Văii, Oltenia region. Worrell et al. (2019) remarks the flowering of crab apple in mid-late May in Scotland, much later than the data obtained in this paper (April), which supports the influence of environmental conditions and location on phenology. Šebek (2019) analysed *P. pyraster* regarding the moments of onset of the main phenophases (flowering, fruit ripening) in Montenegro, and the results obtained are consistent with those of this paper (the beginning of the flowering period took place between 7th of April and 9th of May). Another relevant study mentions the red hawthorn blooming around 13th of May (SD:8.4 days), the dog rose around 8th of June (SD:6.2 days) and elder around 4th of June (SD:6.7 days) according to the study conducted by Tooke & Battey (2010) in temperate zones. A later starting of the growing season is preferable so that the species are not affected by late frosts or rime which can have serious repercussions on fruit productivity and quality. At the same time wild fruit species should trigger their starting of vegetation season prior to arrival of the migrating birds or at least upon their arrival, this way they can benefit through the interactions established between species. Foliage and flowers attract insects, pollinators, represent a source of food for larvae and these in turn represent the food source for insectivorous birds (hoopoes, swallows, cuckoos, bee-eaters). Storks feed on a wide range of animals (lizards, snakes, amphibians, small birds, insects, fish, invertebrates), including mice (in many cases they tend to have nests at the base of hawthorn or dog rose) and also, they feed on large insects which can be found on leaves or flowers of wild fruits trees. Migratory birds arrive in different decades of spring months, some arrive earlier (storks, barn swallows, Eurasian hoopoes) while others arrive later (common cuckoo and European bee-eater) in accordance with their own breeding strategy (for example the cuckoo returns to the breeding grounds before the host species in order to lay eggs in the nest of a single host species). Upon arrival, the birds must procure their food in order to recover after the long journey. This means that the insects must have already emerged and started their activity, and the wild fruit trees must have started growing season The arrival of migratory species at breeding sites is different, because the distance travelled from one point to another is different, the birds needing rest and food at different points along the crossed routes. The white stork arrived in Lithuania between March 30th and April 8th, 1961-2000 in a study by Vaitkuvienė et al. (2015) who mention temperature as an important factor in this landmark. Ptaszyk et al. (2002) confirm the arrival of white storks between March 11th and April 1st in western Poland, and in Slovakia between March 12th and May 15th (Gordo et al., 2013). The study conducted by Bozó & Csörgő (2020), mentions the arrival in the period 2005 - 2019 in south-eastern Hungary and western Romania of the species *U. epops* between 19th of March to 6th of April, *C. ciconia* between 13th of March to 5th of April, *H. rustica* between 20th of March to 5th of April and *C. canorus* between 3rd to 28th of April, results in accordance with those obtained in this paper for the species mentioned in the south-western part of Romania. Scientists mention the arrival of white storks in Southern Oltenia as being generally between 20-25th of March. The species are insectivorous with different trophic niche. Common cuckoos eat different types of insects, including hairy caterpillars which are not eaten by many other birds. European bee-eaters' diet mostly consists of bees, but also includes dragonflies. Barn swallow is a specialized aerial feeder and the diet of the Eurasian hoopoe is mostly composed of insects, but also of small reptiles, frogs and even plant matter. According to ornitodata (pasaridinromânia.sor.ro) the Red-backed Shrike is the most widespread species of Shrike in Romania, and its diet consists mainly in insects, small vertebrates, but also fruits especially before beginning of migration. The long-tailed tit feeds on small invertebrates, but also seeds, buds and fruits (hawthorn, rosehips especially during winter season) as observed during their monitoring. Other present and abundant species that use among others, also fruits and seeds to their diet are blue tits (*Cyanistes caeruleus*), great tits (*Parus major*), Eurasian bullfinch (*Pyrrhula pyrrhula*), chaffinch (*Fringilla coelebs*), European robin (*Erithacus rubecula*), common starling (*Sturnus vulgaris*), European greenfinch (*Chloris chloris*), European Goldfinch (*Carduelis carduelis*), Eurasian golden oriole (*Oriolus oriolus*), green woodpecker (*Picus viridis*) and corn bunting (*Miliaria calandra*). By consuming wild fruits, they contribute to seed dispersal, and so to genetic variability based on the observations made, each year new individuals are spreading and creating new microhabitats, thus maintaining a constant food availability during autumn migration (Gallinat et al., 2020) and cold winter months (in some cases observations were made to fruit species bearing until April, such as rosehips, hawthorn and in some spare cases blackthorns). Lázaro et al. (2005) studied the wild fruit species seed dispersal in northern Europe, and correlates the bird's diet with the formations of "bird-made fruit orchards" (*Sambucus nigra* and *Crataegus monogyna* being the first two most spread species from the studied ones). Also, Rumeu et al. (2020) mention in their study on frugivore species their trophic and spatial role in seed dispersal networks so that they have the ability to shape vegetation structure and maintain landscape connectivity. Existing research suggests phenological or phenometric determinations as a useful tool for addressing changes due to fluctuations in environmental conditions regarding the time and extent of phenological stages (Romo-Leon et al., 2016). Phenological maps can be used successfully in illustrating and interpreting data on the onset, progress and duration of the species vegetation season (Jochner et al., 2011) taking into account the main growth stages (BBCH). The dynamics of phenological processes is determined by complex interactions between genetic and environmental factors (Ruml & Vulić, 2005). The wild fruit species and avifauna are crucial for the provided ecosystem services maintaining balance, stability and functionality.

CONCLUSIONS

Although the temperature is according to researchers the determining factor in phenology, other abiotic factors can also be correlated with the moments of triggering each phenophase. The observations and results obtained in this research confirm the existence of variations in spring phenology from one year to another at the studied species and also the existence of favourable relationships between wild fruit species and avifauna. The presence of wild fruit species is essential in terms of the provided ecosystem services from an ecological and ecosystems balance point of view. Further studies will be carried out to be able to draw some conclusions over a longer period of time regarding the development of the main spring phenological stages on the analysed wild fruit species.

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