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RESEARCH ARTICLE

Effect of altitude on the morpho-phenological parameters of *Juglans regia* L. from different sites of Kashmir Himalaya.

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Abstract

The present study was carried out in different areas of Kashmir Himalaya. Quantitative analyses of *Juglans regia* were done for the following parameters viz., distribution, morphology, population density and phenology. Present research finding revealed that Srinagar has highest population density followed by Badgam, Baramulla, Shopian, and least were found in Anantnag and Ganderbal. The morphological parameters showed a significant variation between different populations. Its sap normally begins to flow in late February while leaves begin to expand at the beginning of March. Flowering starts at the beginning of March and ends in the month of April. Leaf fall starts at the beginning of September and continues till November..

INTRODUCTION

Walnut, botanically known as *Juglans regia* L. belongs to genus *Juglans* (family-Juglandaceae), is represented by about 7 to 45 species depending on the taxonomic study (Dode 1906, Lee 1935, Smolyaninova 1936, Sczepotiev 1957, Manning 1978, Komanich 1982, Whittemore and Stone 1997, Tsurcanu 2004, Aradhya *et al.*, 2007). In certain hilly region, it is named as 'Akhor', 'Kror' or 'Akhrot'. In the Chenab valley, it is called as Than-Than, khor-ka or Darga. In Kashmir, it is known as Dun and Starga in Ladakh. The genus is distributed primarily across the temperate and subtropical regions of the Northern Hemisphere (eastern and western Asia, Eastern Europe, eastern and western North America, and the West Indies), with several species also found in Central America and along the Andes Mountains in western South America (Smolyaninova 1936, McGranahan and Leslie 1991, Stanford *et al.*, 2000). It flourishes well in the temperate belts at altitude of 900 to 3550 meters. Two *Juglans species* are native to regions of the former USSR. These include the Persian (English) walnut of commerce, *Juglans regia* L. (synonyms: *Juglans duclouxiana* Dode, *Juglans fallax* Dode, *Juglans kamaonia* [C. DC.] Dode, *Juglans orientis* Dode, *Juglans sinensis* [C. DC.] Dode), which can be found in Central Asia and the Caucasus region, and *Juglans mandshurica* Maxim, which can be found in the Russian Far East. The Central Asian geographic area includes Uzbekistan, Tajikistan, Turkmenistan, Kyrgyzstan, and part of Kazakhstan (Fig. 1) Sokolov (1952) and represents a large and diverse region that is believed to be a center of origin and diversity of *J. regia* (Vavilov 1931 and 1951, Smolyaninova 1936, Sczepotiev 1957, Zapryagaeva 1964, Zhukovsky 1971, Kolov 1984, Sczepotiev 1985, Komanich 1989, Leslie and McGranahan 1998, Mamadjanov 2006a).

Although Vavilov (1931, 1951) considered Central Asia one of the primary centers of diversity of *J. regia*, the history and origin of the walnut forests in Europe and Asia has been the subject of debate. The species has been documented growing in east and south Asia (China, Tibet, Nepal, Pakistan, and India), Central Asia (Kyrgyzstan, Uzbekistan, Tajikistan), Iran, the Balkans, northern Turkey, the southern Caspian region, the Caucasus, Azerbaijan, and Turkey (McGranahan and Leslie 1991 and 2009, Zohary and Hopf 2004). However, the range of the

species is believed to have been substantially expanded as a result of human introduction and cultivation (De Candolle 1889, Carrión and Sanchez-Gomez 1992, Fornari *et al.*, 1999).

Persian walnut is a species of great importance across Central Asia where nuts are harvested from wild stands, backyard gardens, and commercial orchards that vary considerably in their size and degree of management. Nuts are collected for home consumption, sale at local roadside stands and markets, and for shipping to cities. Walnut trees are further utilized for their high-quality timber to make a wide array of products. The leaves, bark, and other plant parts are used for medicinal remedies, and trees are grown and maintained for soil conservation purposes Mamadjanov (2006b).

Walnuts are large, monoecious trees with wide, dense crowns that can reach heights of 15–35 m. Older trees may have trunk diameters upwards of 1.5–2.5 m (Shalit 1951, Gursky 1932). Walnut trees have large, well-developed, deep root systems that impart significant drought and stress tolerance. At an age of 50–70 years the main roots can reach 6–7 m deep and up to 12 m laterally (Fig. 2). Young trees have slightly furrowed, light-grey bark, while older trees have bark that is darker-grey and strongly furrowed.

The male flowers are arranged in catkins that are borne laterally on one-year-old stems, and pistillate flowers borne terminally or laterally (newer cultivars) on current season's stem. Although walnuts are genetically self-fruitful they exhibit the phenomenon of dichogamy, being either protandrous or protogynous depending upon the cultivar. Hence, walnuts are mostly cross-pollinated by wind Polito (1998). Patch budding and whip grafting during the vegetative season are commonly regarded as the conventional propagation techniques of walnut (Reil *et al.,* 1998). Several researchers agree that these methods result in limited and varying success under uncontrolled field conditions (Karadeniz 2005, Erdogan 2006). At present, walnut is cultivated commercially throughout Southern Europe, Northern Africa, Eastern Asia, USA and Western South America. World production of walnut was around 1.5 × 106 t in 2008 (FAO, 2008). China is the leading world producer, followed by the USA, Iran, Turkey, Ukraine, Romania, France and India, but production in other countries such as Chile and Argentina has increased rapidly in recent years (Martinez *et al.,* 2010).

The walnut is regarded as highly valuable by an increasingly health conscious world due to various health benefits including a great source of vitamin E, minerals, proteins, flavonoids, sterols, pectic substances, phenolic acids and omega-3 fatty acids as well as the ability to lower the level of cholesterol in human bodies (Savage *et al.,* 2001). The high protein and oil contents of the kernels have make this fruit indispensable for human nutrition. Therefore, the walnut is classified as a strategic species for human nutrition and is included in the FAO list of priority plants Gandev (2007). The nutritional contents differs from one cultivar to another which can be influenced by genotype, cultivar, different ecology and different soil (Caglarirmak 2003, Crews *et al.,* 2005, Martinez *et al.,* 2010, Muradoglu *et al.,* 2010).

Phenological adaptations allow utilization of specific resources, which exhibit temporal periodicity and may lead to temporal separation of species (Connel 1964 *et al.,*). This has been viewed as a mechanism of niche separation and evolution of other new adaptations (Muller, *et al.,* 1978). Each phenophase is scheduled to occur at a certain temperature range, above and below which it is replaced by other phenophases. In Himalaya very few studies have been made pertaining to the Phenology of trees (Semalty *et al.,* 1996). Keeping in view the aforesaid facts, this study has been designed to understand distribution, population density, phenological attributes, and the morphometric analysis in *J. regia* L. at different altitudes of Kashmir Himalaya.

MATERIAL AND METHODS

Field surveys and Exploration

An extensive exploration of different Kashmir Himalayan habitats was carried out to identify specific areas across different geological conditions covering a wide range of habitats. Among various populations six sites were selected for further studies on the basis of following criteria: Accessibility of the site, Habitat structure and Plant density. The salient features of the selected sites are depicted in Table 1.

Species morphology and phenotypic variability

Various populations were analyzed for plant structure, plant height, leaf number and dimensions, seed size and weight. Both qualitative and quantitative parameters were studied on the basis of morphological features given by Nath (1996). 50 plants were selected for the current study at each study site in order to study phenotypic variability and species morphology by following proper procedure.

Population density

Population density was recorded by lying 30 x 30 m^2 quadrants and number of plants per quadrant was noted to calculate population density. (Singhal *et al.,* 1986).

Phenology

Studies on initiation and duration of various phenological events viz. vegetative phase, (Initiation and duration of vegetative phase), sexual phase (initiation and duration of bud formation, seed development) and senescence in natural population was carried out. Randomly selected healthy individual plants (15 plants at each study site) marked with aluminium tags were monitored during the growing season of years, 2010 and 2011.

RESULTS AND DISCUSSION

Fig 1: Map of Central Asia.

Fig 2: Root system of a walnut tree

Table1: Salient features of some selected sites.

Location	Altitude (m asl)	Latitude and longitude	Habitat	Threat factor
Gund, Ganderbal	2250	34°12'54.18"N 74°46'18.35"E	Moist open slope	Habitat destruction and construction of Roads.

Shopian	2057	33°43'30.99"N 74°49'39.72"E	Moist open field	Deforestation
Anantnag	1700	33°43'57.24"N 75° 9'37.28"E	Sunny open field	Habitat destruction and construction of Roads.
Badgam	1609	33°56'5.48"N 74°38'24.15"E	Moist open field	Deforestation
Baramulla	1593	34°12'41.31"N 74°20'38.03"E	Moist Open slopy field	Construction of buildings, Factories and houses
Srinagar	1580	34° 5'1.17"N 74°47'50.52"E	Sunny Open fields	Construction of buildings, Factories and houses.

During the present investigation the species was found sporadically distributed in the mountain ranges of Kashmir Himalaya thriving best in moist shady slopes ranging in an altitude of 1500-3000 m asl. The species was mainly found in Anantnag, Badgam, Baramulla, Gund Ganderbal, Handwara, Kulgam, Kupwara, Pulwama, Shopian and Srinagar (Fig 3). Out of these; following sites viz Srinagar, Baramulla, Badgam, Gund Ganderbal, Anantnag and Shopian (Fig. 4) were selected for the present investigation. The characteristics of the selected sites are summarized in Table 1.

Fig 3: Map shows the distribution.

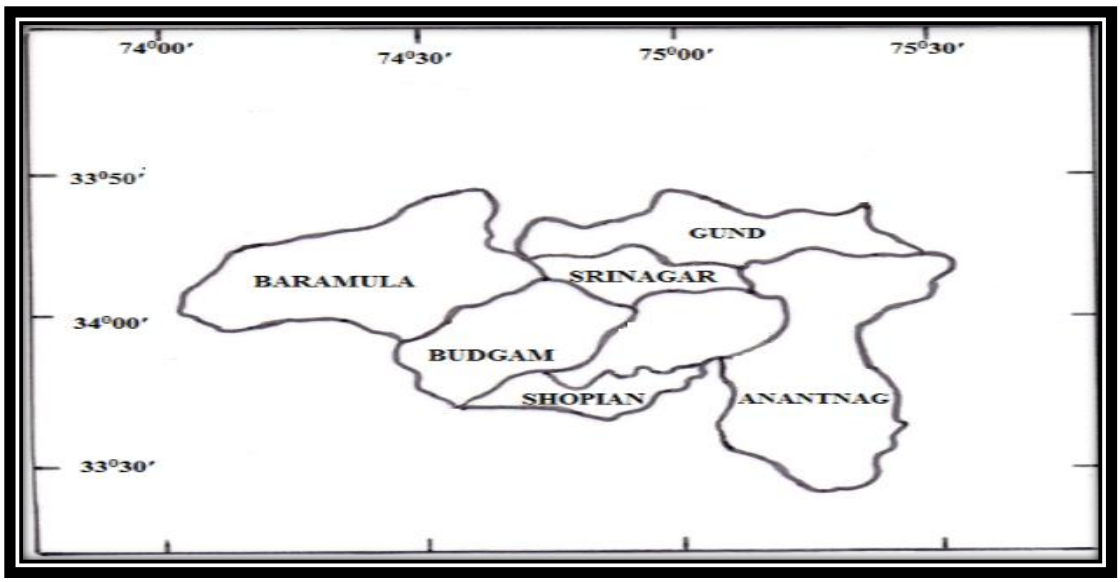


Fig 4: Map showing selected sites.

Data compiled on population density reveals that Shopian (11.23 ± 5.3) has highest population density followed by Gund Ganderbal and Anantnag (10.9 ± 8.6, 10 ± 4.2), Badgam (6 ± 1.7), Baramulla (4 ± 2.6), and least were found in Srinagar (3.4 ± 3.5). It is evident from Table 2 and Fig.5 that highest plant circumference (2.71 ± 0.8 m) were recorded in Shopian, followed by Baramulla (2.56 ± 1.3 m), Gund Ganderbal (2.47 ± 1.3 m), Srinagar (2.41 ± 1.2 m), Badgam (2.21 ±1.2 m) and least were recorded in Anantnag (2.1 ± 1.1 m). Maximum first leaflet length (19.4 ± 4.8 cm) was recorded in Baramulla followed by Gund Ganderbal (18.4 ± 2.3 cm), Shopian (17.5 ±4.8 cm), Anantnag (16.9 ± 2.3 cm), Srinagar (16.7 ± 5.2 cm) and Badgam (8.3 ± 1.5 cm). Maximum first leaflet breadth (10.4± 2.2cm) were recorded in Baramulla followed by Shopian (9.3 ± 1.7 cm), Gund Ganderbal and Srinagar (8.8 ± 1.5 cm, 8.4 ± 1.8cm) and minimum breadth were recorded in Anantnag (7.9 ± 1.7 cm) and Badgam (4.2 ±1.1 cm). Mean distance between leaflets were recorded as 10.5 ± 1.51 cm, 8.6±1.68 cm, 6.5±1.36 cm, 6.2± 1.99 cm, 6.1±1.35 cm and 5.74±1.41 cm in Badgam, Shopian, Srinagar, Gund Ganderbal, Baramulla and Anantnag respectively. Maximum fruit diameter with exocarp were recorded in Shopian (5.9 ± 0.87cm) followed by Gund Ganderbal (5.6 ±0.85 cm), Srinagar (5.2 ± 0.98 cm), Badgam (4.4 ± 0.42 cm) and least was recorded in Anantnag (3.9 ± 0.65 cm) and Baramulla (3.9 ± 0.37 cm) and maximum fruit diameter without exocarp were recorded in Shopian (4.9 ± 0.9 cm) followed by Gund Ganderbal (4.5±0.9 cm), Badgam (3.2±0.3 cm) and least were recorded in Baramulla (2.9±0.3 cm), Srinagar (2.9 ± 0.4 cm) and Anantnag (2.9±0.7 cm). Maximum fruit weight with exocarp were recorded in Srinagar (22.2 ± 2.8 gm) followed by Shopian (21.6 ± 2.4 gm), Gund Ganderbal (21.4 ± 2.6gm), Badgam (20.5 ± 3.3gm) and least were recorded in Anantnag (19.9 ± 2.5 gm) followed by Baramulla (19.2 ± 3.6 gm) and maximum fruit weight without exocarp were recorded in Srinagar (14.8 ±2.9 gm) followed by Badgam (14.2 ±2.3 gm), Anantnag (12.6±2.7gm), Baramulla (12.5±3.1 gm), Shopian (12.2 ±3.3 gm) and least were recorded in Gund Ganderbal (11.7 ± 3.4 gm).

Table 2: Variation in different morphological parameters.

Traits	Gund Ganderbal 2250m	Shopian 2057m	Anantnag 1700m	Badgam 1609m	Baramulla 1593m	Srinagar 1580m	df	f	p
Population density	10.9 ± 8.6*	11.23± 5.3	10 ± 4.2	6 ± 1.7	4 ± 2.6	3.4 ± 3.5	5	16.14	0.00
Circumference (m)	2.47 ± 1.3	2.7 ± 0.8	2.04 ± 1.1	2.21±1.2	2.56 ± 1.3	2.41 ±1.2	5	1.39	0.228

First Leaflet length (cm)	18.4 ± 2.3	17.5 ±4.8	16.9 ± 2.3	8.3 ± 1.5	19.4 ± 4.8	16.7 ± 5.2	5	33.62	0.00
First Leaflet breadth (cm)	8.8 ± 1.5	9.3 ± 1.7	7.8 ± 1.7	4.2 ±1.1	10.9 ± 2.2	8.4 ± 1.8	5	53.39	0.00
Second Leaflet length (cm)	16.4 ± 2.6	13.3 ±3.0	14.1 ± 2.1	6.9 ± 0.9	16.8 ± 3.5	12.8 ± 2.9	5	54.28	0.00
Second Leaflet breadth (cm)	6.2 ± 1.6	6.6 ± 1.2	5.8 ± 1.53	3.2 ±0.5	7.6 ± 1.6	6.3 ± 0.9	5	38.72	0.00
Third Leaflet length (cm)	12.1 ± 3.3	10.3 ±3.8	10.9 ± 2.3	5.7 ± 1.1	11.8 ± 4.9	9.7 ± 3.7	5	13.93	0.00
Third Leaflet breadth (cm)	4.8 ± 1.1	5.5 ± 1.8	4.9 ± 1.2	2.8 ± 0.4	5.6 ± 1.7	4.9 ± 1.4	5	17.27	0.00
Fourth Leaflet length(cm)	9.2±3.7	9.6 ± 5.1	7.2±1.6	4.5±1.5	8.4±3.8	9.2±5.2	5	7.63	0.00
Fourth Leaflet breadth (cm)	3.7±1.2	4.6 ± 1.5	3.9±1.2	2.4 ± 0.5	4.6±1.5	4.3±1.5	5	12.76	0.00
Fifth Leaflet length (cm)	10.2±1.8	5.1 ± 1.32	7.2±1.7	3.5±0.5	3.1±0.4	5.1±1.4	5	120.31	0.00
Fifth Leaflet breadth (cm)	4.9±1.1	2.9 ± 0.89	3.9±1.2	1.9±0.2	2.6±0.7	3±0.7	5	42.65	0.00
Distance between leaflets (cm)	6.2± 1.99	8.6± 1.68	5.7± 1.41	10.5± 1.51	6.1± 1.35	6.5± 1.36	5	43.24	0.00
Total leaf length (cm)	22.2±4.2	22.2 ±3.2	20.7± 3.46	20.3±5.6	20.3± 5.57	21.9± 2.62	5	2.87	0.00
Fruit diameter with exocarp (cm)	5.6 ±0.85	5.9 ± 0.87	3.9 ± 0.65	4.4 ± 0.42	3.9 ± 0.37	5.2 ± 0.98	5	44.26	0.00
Fruit diameter without exocarp (cm)	4.5±0.9	4.9 ± 0.9	2.9±0.7	3.2±0.3	2.9±0.3	2.9 ± 0.4	5	57.09	0.00
Fruit weight with Exocarp (gm)	21.4 ± 2.6	21.6 ± 2.4	19.9 ± 2.5	20.5 ± 3.3	19.2 ± 3.6	22.2 ± 2.8	5	4.55	0.00
Fruit weight without Exocarp (gm)	11.7±3.4	12.2 ±3.3	12.6±2.7	14.2±2.3	12.5±3.1	14.8±2.9	5	5.07	0.00

*** Mean±SD**

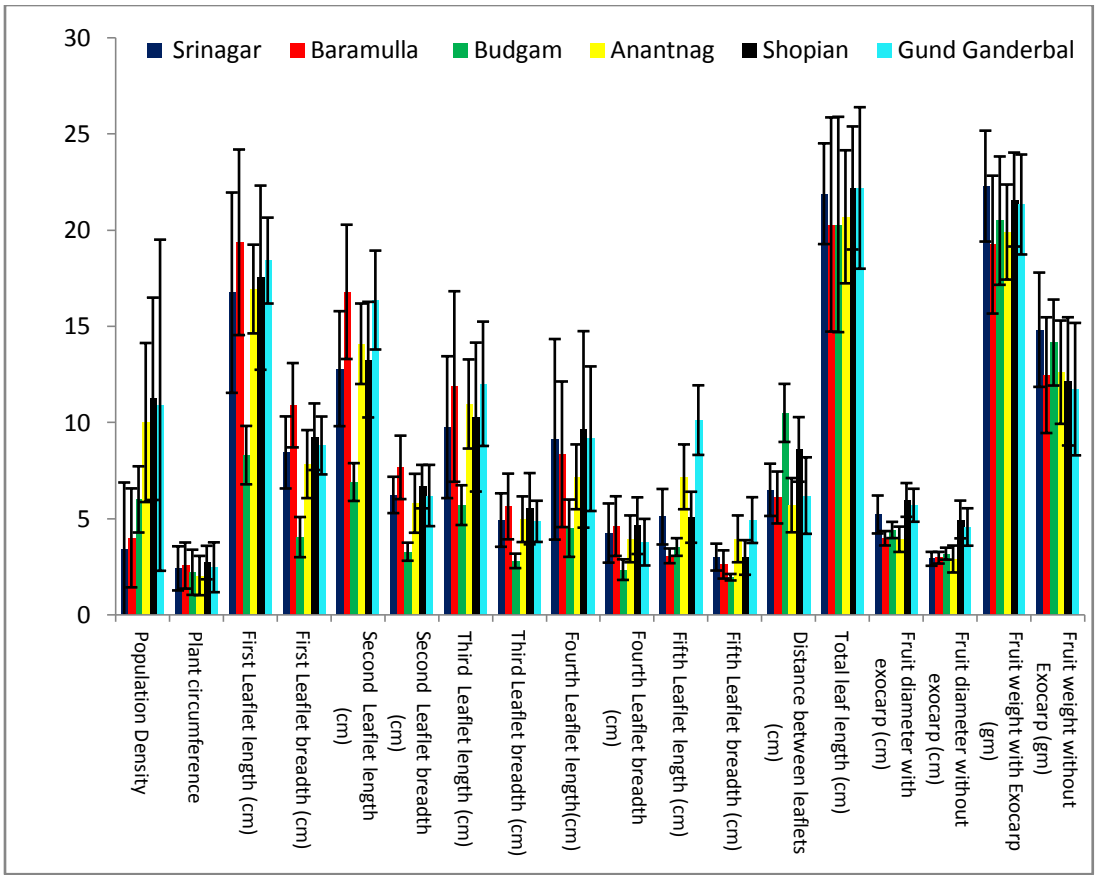


Fig. 5: Graphical representation of variation in different parameters.

During the present study it was observed that there is a positive correlation between total leaf length and fruit diameter with exocarp (Fig 6). Also a positive correlation between total leaf length and fruit weight with exocarp (Fig 7).

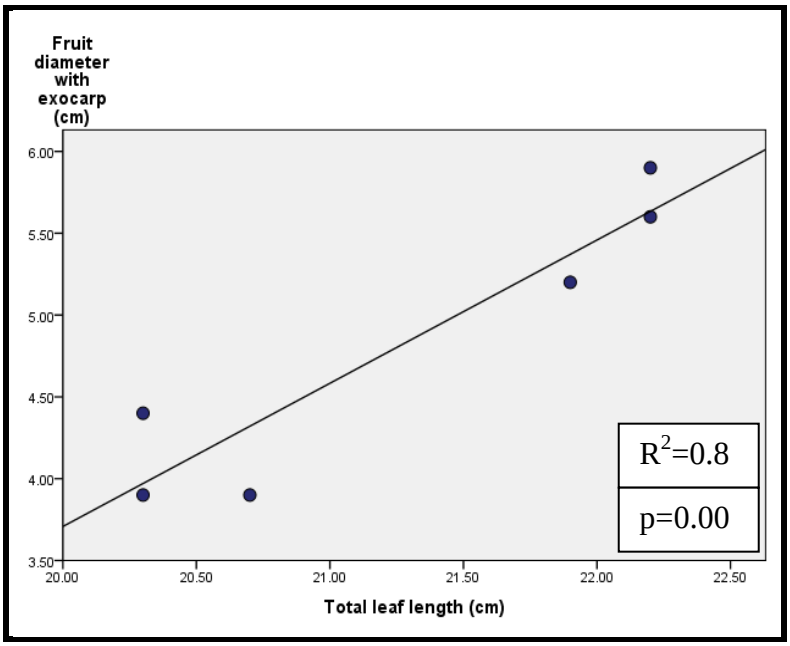


Fig. 6: Regression analysis between total leaf length and fruit diameter with exocarp.

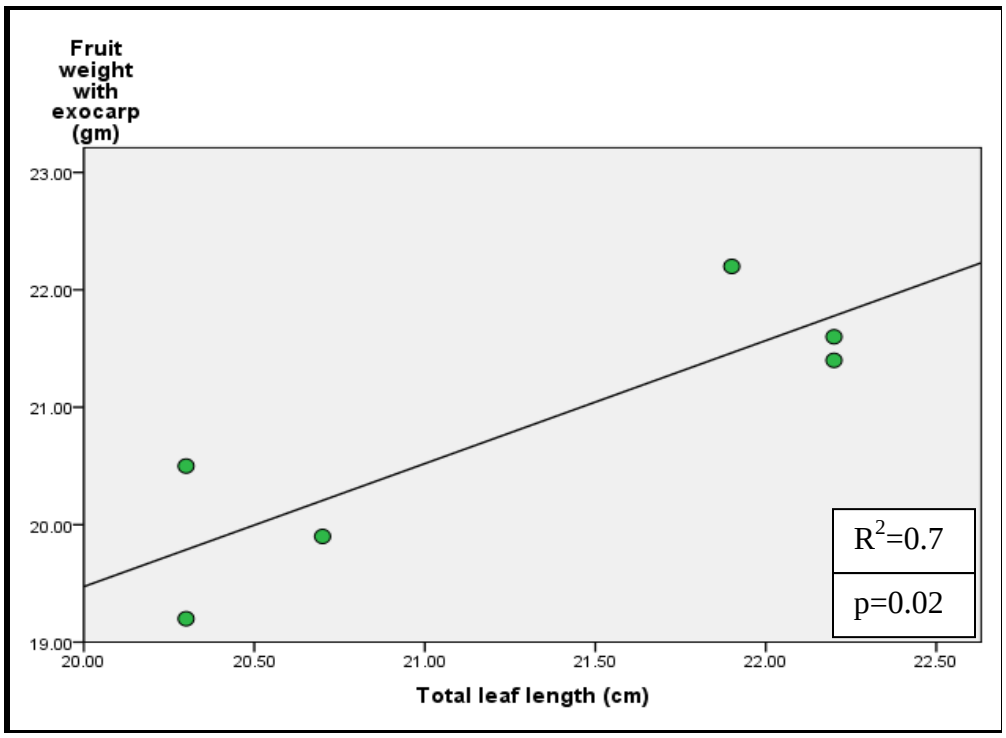


Fig. 7: Regression analysis between total leaf length and fruit weight with exocarp.

PCA (Principal Component Analysis) of morphological characteristics of *J. regia* across selected study sites is shown in Fig. 8. During the present study it was observed that there is a positive correlation between Srinagar and Gund Ganderbal populations and also between Baramulla and Shopian populations. It was also observed that there is a negative correlation among Srinagar and Gund Ganderbal populations with Budgam population. From PCA it is evident that maximum morphological traits favoured Srinagar and Gund Ganderbal populations and Badgam population was favorable for least of the traits. Thus, the habitat of Srinagar and Gund Ganderbal proved comparatively better for the growth of *J. regia*.

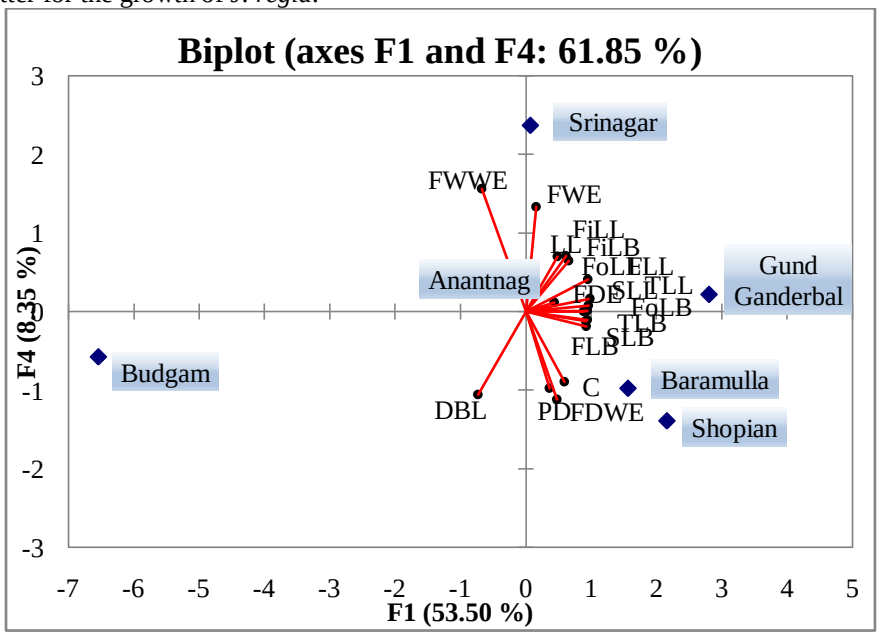
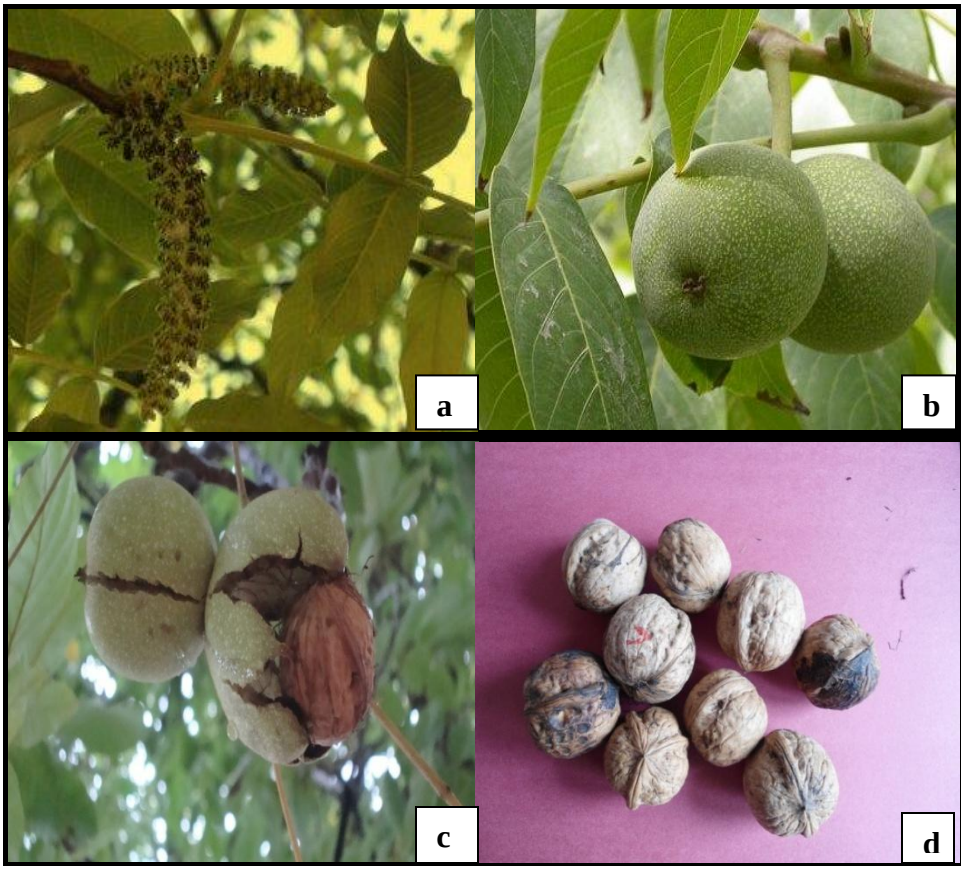


Fig. 8: PCA of morphological characteristics of *J. regia* across selected study sites

PD- Population density; C- Plant circumference; FLL- First leaflet length (cm); FLB- First leaflet breadth (cm); SLL- Second leaflet length (cm); SLB- Second leaflet breadth (cm); TLL- Third leaflet length (cm); TLB- Third leaflet breadth (cm); FoLL- Fourth leaflet length(cm); FoLB- Fourth leaflet breadth (cm); FiLL- Fifth leaflet length (cm); FiLB- Fifth leaflet breadth (cm); DBL- Distance between leaflets (cm); LL- Total leaf length (cm); FDE- Fruit diameter with exocarp (cm); FDWE- Fruit diameter without exocarp (cm); FWE- Fruit weight with exocarp (gm); FWWE- Fruit weight without exocarp (gm).

In order to understand the phenology of *J. regia*, the phenological calendar studies for different growth parameters were monitored from sprouting up to the senescence (Fig. 9). The altitude and eco edaphic conditions seem to play an important role in the phenological behavior of the species. This phenological behaviour of the species was monitored in all the six selected populations distributed in varied habitats of Kashmir Himalaya. There were marked phenological shifts in timing of different phenophases along the altitudinal gradient (Table 3 and Fig. 10). The phenological events studied include initiation and duration of vegetative phase, sexual phase (initiation and duration of bud formation, seed development) and senescence.

After chilling months of winter which lasts from December to February, the plant starts flowering in the 1st week of April and continue till 3rd week of June. As the plant is wind pollinated it enters flowering phase prior to vegetative phase. The reproductive phase of the species is followed by a vegetative phase. Leaf start unfolding in the 3rd week of April and continue till 2nd week of June. After the process of pollen transfer to the stigmas is complete, the initiation of seed development starts from 4th week of May and continues up to 3rd week of August. As and when seeds matures the plant begin to disperse its seed and it begins from the 3rd week of August to the 2nd week of September. After the seed maturation, the species shows a highly asynchronous senescence. It starts in 4th week of August and lasts up to 1st week of December. Thus the species exhibits a life span of 251 -257 days from flowering to senescence (Fig. 11).



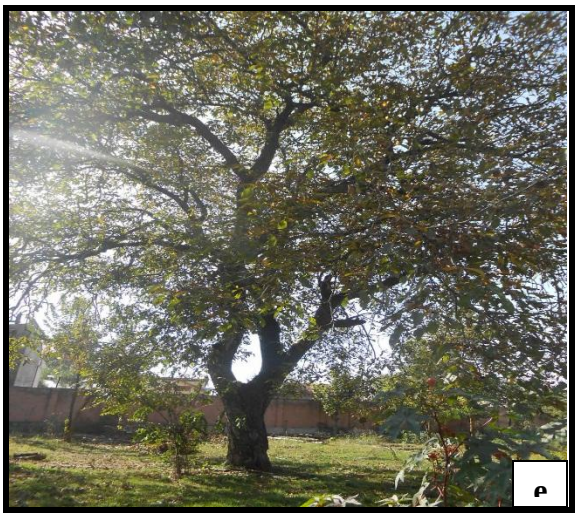


Fig. 9: (a) Flower; (b) Immature fruit; (c) Fruit dispersal ;(d) Fruits; (e) Senescence.

Table 3: The phenological behavior of selected populations.

Phenophase		Population					
		Srinagar 1580m	**Baramulla 1593m**	**Badgam 1609m**	**Anantnag 1700m**	**Shopian 2057m**	**Gund Ganderbal 2250m**
Flowering	**I**	4(1)*	4(2)	4(2)	4(1)	5(1)	5(1)
	C	5(3)	5(3)	5(4)	6(1)	6(3)	6(2)
	D	45 days	42 days	44 days	39 days	41 days	43days
Leaf Initiation	**I**	4(3)	4(3)	4(3)	5(2)	5(3)	5(2)
	C	5(4)	5(4)	5(4)	6(1)	6(2)	6(1)
	D	37 days	36 days	37 days	26 days	25 days	26 days
Fruiting	**I**	5(4)	5(4)	5(4)	5(4)	6(1)	6(1)
	C	8(3)	8(2)	8(2)	8(2)	8(3)	8(3)
	D	80 days	76 days	78 days	77 days	73 days	78 days
Fruit Dispersal	**I**	8(4)	8(3)	8(3)	8(3)	8(4)	8(4)
	C	9(1)	8(4)	8(4)	9(1)	9(2)	9(2)
	D	9 days	9 days	9days	13 days	16 days	17 days
Senescence	**I**	8(4)	8(4)	8(4)	8(4)	8(4)	9(1)
	C	11(3)	11(4)	11(4)	11(4)	12(1)	12(1)
	D	80 days	84 days	85 days	86 days	91 days	93 days

Duration		251 days	247 days	253 days	241 days	246 days	257 days

I- Initiation of phase; C- Completion of phase; D- Total number of days of a particular phase

*-Digit outside parenthesis is the month and inside the week

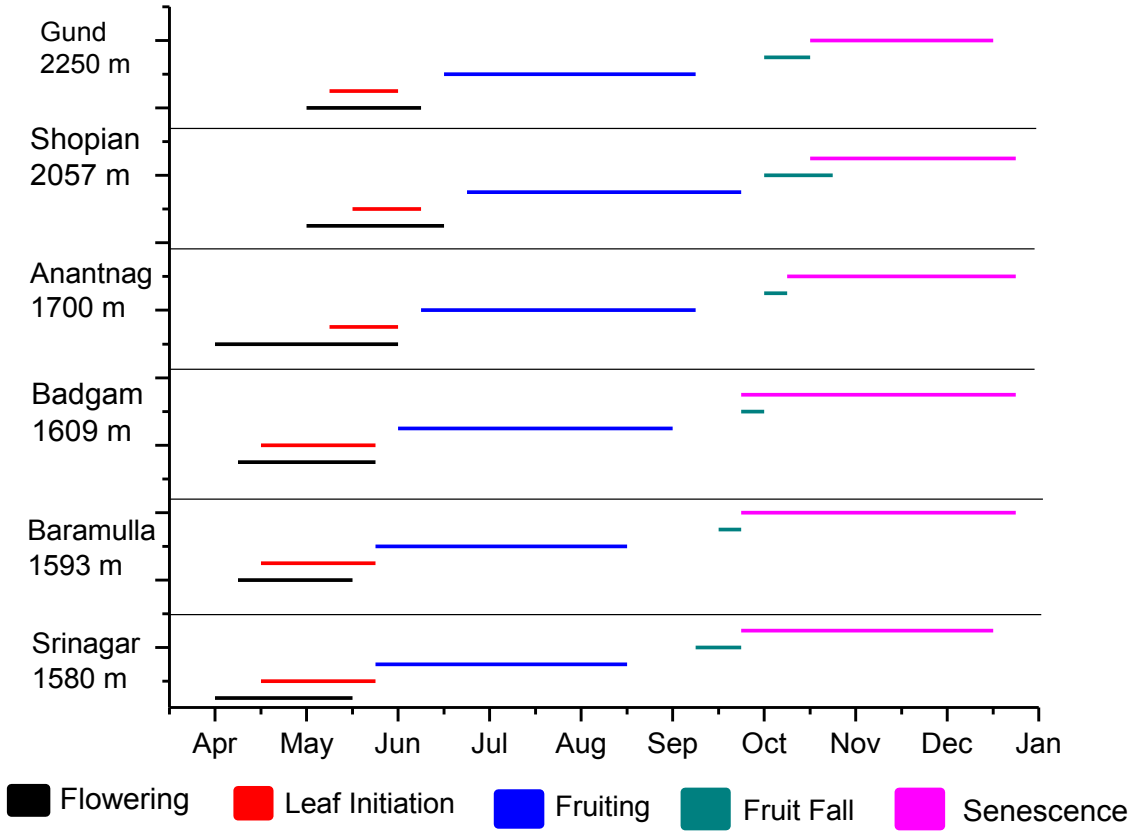


Fig. 10: Phenogram showing phenological behavior of selected populations of *J. regia*.

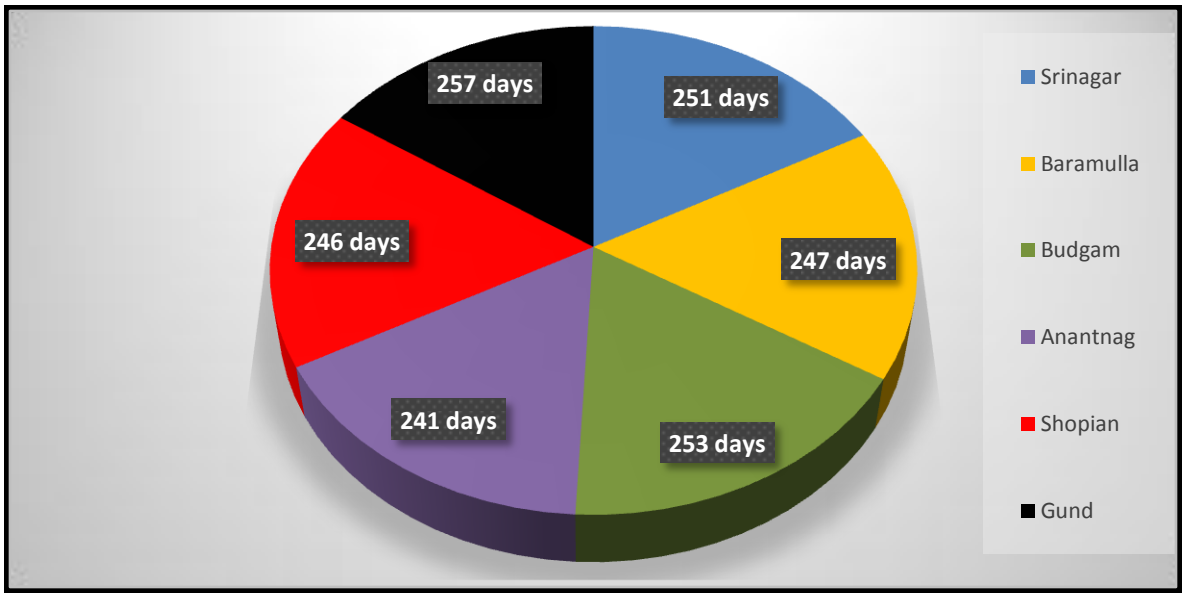


Fig. 11: Duration of aerial parts in *J. regia*

CONCLUSION

Adaptation of plants to the local climate is an important factor that determines the variation in the phenological timing and flower structure (Krammer, 1995; Manzal and Sparks 2006; Franks *et al.*, 2007). During the present study it was observed that plant has a wide range of distribution throughout the Kashmir valley. As per the population density of the species is concerned, it was observed to be highest in Shopian and least in Srinagar. The phenological episodes showed a little variation between different populations and the maximum duration of different phenophases were observed in Gund Ganderbal population (257 days) and least in Anantnag (241 days). The morphological parameters showed a significant variation between different populations. The circumference of the species were recorded highest in the Shopian and least in Anantnag. Moreover significant variation was also observed in fruit diameter with and without exocarp and fruit weight with and without exocarp between different populations. From PCA, it is evident that maximum morphological traits favoured Srinagar and Gund Ganderbal populations and Badgam population was favourable for least of the traits. No study till date has been carried out to compare the total leaf length with fruit diameter (with exocarp) and total leaf length with fruit weight (with exocarp) of the selected species. Our regression analysis showed a significant correlation and predicts that leaf length has direct impact on the fruit diameter and fruit weight of the highly prized plant species.

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