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Fruit maturation and germination in *Ficus auriculata* Lour. A Lesser known multipurpose tree species in Kumaun Himalayan Region

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ABSTRACT

Globally there are 750 species of Ficus belonging to the family Moraceae. *Ficus auriculata* Lour locally known as Timul, commonly occurs throughout the hills especially in Chir-Pine dominated forests up to1700m from the foothills. The study focused on fruit maturity timing and seed germination of *F. auriculata.* Absence of seedlings and saplings of *F. auriculata* was a conspicuous feature across all studied sites. Fruit production peaked in the month of June - July, while the male fruit crop peaked 2-3 months before female fruit production. Across all the sites fruit size between first to last collection varied between 246.45±3.76 and 2063.21±7.38 mm^2 and seed size ranged between 0.42±0.03 and 2.02± 0.12 mm^2. The maximum germination varied between 82.60±1.05 and 86.11±0.77 % when fruit moisture content was between 36.67 and 40.50 % and seed moisture content was 33.34 and 37.84 %.

Key words : *Fruit, Fruit maturation, Seed germination, Moisture content*

Introduction

Ficus (Moraceae) is one of the largest plant genera, with more than 750 described species distributed worldwide. The fruits of *Ficus* are considered to be key plant resources in tropical rainforests due to their rich and continuous production, providing food for frugivorus (especially birds) when the availability of other fruits is less (Pothasin *et al.,* 2014). The pollination of fruits by specific wasps is arguably the most widely known example of mutualism relationship between trees and their pollinators (Machado *et al.,* 2001).

Ficus auriculata (syn *Ficus roxburghii*) is a wild edible fruit belonging to the family Moraceae, commonly known as timul, timla, is a medium- sized tree up to 20 m tall, becoming shortly buttressed. The species occur throughout the hills especially in Chir- Pine dominated forest of Uttarakhand, some north eastern states and Pakistan to South China up to an elevation of 1700m from the foothills (Osmaston, 1927; Troup, 1921; Pandey *et al.,* 2018; Chaudhary *et al*., 2012). The fruit is pinkish or red at maturity. The leaves are used as a fodder during the winter season and liked by cattle and also used as plates by stitching 3-4 leaves together for taking food during special occasions commonly in villages (Parmar and Kaushal, 1982).

The regeneration of the Ficus tree species is highly variable under natural conditions. The indicator of poor regeneration in a forest is scarcity of seedlings and saplings. Regeneration of species, survival and growth of seedling depend upon biotic and abiotic factors like human disturbance, cattle

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browsing and trampling by cattle. Regeneration of the wild edible species is poor in natural habitat mainly due to heavy biotic pressure on them (Sundariyal and Sundariyal, 2001).

Seed maturation in many tree species is often attained by noticeable changes in size, colour, taste, odour and texture of the fruit and seeds. In some species when seeds reach maximum dry weight, seed maturity is achieved. On the other hand in other species maximum seed quality is reached sometime after reaching maximum dry weight (Singh *et al.*, 2010). Germination of Ficus species is mainly through seeds and vegetative means. Seeds of Ficus species require sunlight to germinate and a constant humidity is also essential for germination (Chen *et al.*, 2013). The fruit is edible, eaten raw and used as vegetable also. As fruits are eaten raw the fruits are collected before maturation resulting in low availability of seeds. It is problematic situation for future multiplication of species. Due to global warming induced climate irregularities the fruit/seed maturation times may shift in several species, further threating natural regeneration. Hence determination of exact time of fruit/seed maturation and studying the possible indicators of maturity is important for any plantation programme. In this paper, we have studied timing of fruit/seed maturation and germination of *F. auriculata*. There is a paucity of information on these aspects of *F. auriculata*.

Materials and Methods

Study Site: The study areas lies between 29'30º N latitude and 79'20º E longitude. The study was conducted during two consecutive years 2017 and 2018. After a thorough survey 3 sites were selected between 1400~1700m, altitude on southeast and southwest aspect. *Grewia optiva, Litsia umbrosa, Q. leucotrichophora, Aesculus indica* and *Pinus roxburghii* were common associate species across all the sites. The climate of study sites is subtropical monsoon type with high temperatures towards lower elevations and lower temperatures towards high elevation. Rainfall is governed by southwest monsoon, the average rainfall ranges from 2000~2200mm (Shah, 2005). Annual rainfall was 1679.31~1570.34 mm during 2017-2018 of which nearly 85% occured during the monsoon period (June to Sep). In both the years June was the warmest month of the year and January the coldest month, with temperature varied between 9 and 25 ºC (world weather online).

Tree Characteristics: Ten male and female trees each were marked at each site. Tree height, crown cover and circumference at breast height (1.37 m) was measured for each marked tree in all the sites with the help of ravi multimeter and measuring tape, respectively (Mittal *et al.*, 2017). Across all the sites the mean height of selected female trees of *F. auriculata* varied between 7.00±1.00 and 15.04±1.21 m, mean circumference ranged between 0.48±0.24 and 0.82±0.08 m and mean crown cover of trees across all the sites ranged between 6.84±1.31 and 10.15±4.26 m² (Table 2). In male trees the mean height varied between 5.33± 1.20 and 14.67± 2.33 mean circumference ranged between 0.51±0.01 and 1.17±0.23 m and mean crown cover ranged between 7.34±1.75 and 16.23±5.35 m².

Regeneration Status: For studying the regeneration status of the species 10 quadrats each of 10×10 meter were placed across all the sites. The density of trees, saplings and seedlings were calculated following Malik and Bhatt, 2016.

Maturity Indices: Fruit collection was started from the first week of June up to the availability of fruits from marked trees for all three sites. Fruits were collected at 1 week intervals and were collected directly from the marked tree. Fruits of all trees at one collection date were mixed and a composite sample was made. Fruits were manually de-pulped to extract seeds. From the composite sample three replicates of 25 fruits/seeds were taken for determine different morphological character of fruits/seeds

Table 1. Description of study sites of ***F. auriculata*.**

Sites	Altitude	Lat. Long.	Aspects	Associated species
S1	1475	29º21'N,79º 26'E	South east	*Grewia optiva, Litsia umbrosa, Quercus leucotrichophora, Pinus roxburghii*
S2	1568	29º22'N,79º 29'E	South west	*Grewia optiva, Quercus leucotrichophora, Pinus roxburghii and Litsia umbrosa*
S3	1704	30º29'N, 79º13'E	South east	*Grewia optiva, Pinus roxburghii, Litsia umbrosa* and *Aesculus indica*

(colour, size, fresh weight). Fruit and seed weight (100 fruits/seeds) was measured using electronic balance (Model No. PGB 301 accuracy + 0.001mg Wensar), fruit and seed size (25 fruits/seeds) was expressed in mm² (length and width) was estimated using digital vernier calliper (Model No. CD-6" accuracy + 0.02 mm Mitutoyo Co.). Moisture content percentage was calculated for each collection using three replicates of fruit/seed (25) each, and estimated on fresh weight basis by drying at 103± 2° C for 16± 1 hr. and then the sample were reweighted following ISTA, 1981 and Tamta and Tewari, 2018.

For germination 4 replicates of 100 seeds were kept at the top of germinator paper in petri-dishes at room temperature. Germination was recorded when the radical began to appear and monitored for 40 days. Seed germination percentage was calculated following Shah and Tewari, 2016.

$$GP\ (\%) = \frac{\text{Total germinated seeds}}{\text{Total seeds tested}} \times 100$$

The data was statically analysed using Analysis of variance (ANOVA) to determine difference in fruit/seed characteristics, moisture content and germination (Snedecor and Cochran, 1967).

Results

Regeneration Status: Across all the sites the tree density of *F. auriculata* ranged between 22 and 122 indi/ha. Seedlings and saplings of *F. auriculata* were completely absent in all the sites. The total tree density varied between 176 and 410 indi/ha with 12.36 and 26.17 m²/ha TBA across all the sites.

Fruit/ Seed Characteristics

Across all the sites the fruit colour was green at first collection during third week of June and gradually turned to red at final collection during last week of July (Table 3). The fruit size during the first collection ranged between 246.45±3.76 (S2) and 511.86±10.57 mm² (S3). With each collection the fruit size increased and during final collection ranged between 1763.42±16.14 mm² (S2) and 2063.21 ± 7.38 mm² (S3). Across all the sites the fruits of S3 were largest in size. At first collection the weight of 100 fruits varied between 1488.17±19.63 (S3) and 1509.00±24.57 g (S2) and at final collection reached to 3386.50±28.63 (S1) and 4217.84±105.31 g (S3). Across all the sites the fruit of S3 were heavier in weight. At first collection the number of fruits per 100 g was 5.50±0.33 (S3) and 6.17±0.33 (S2) and by the time of final collection declined to 1.00±0.00 (S1) and 1.17± 0.17(S2), (S3) (Table 3). During first collection the fruit moisture content ranged between 75.34±1.75 (S3) and 80.67±1.43(S1)% and declined to 36.67±1.93(S3) and 40.50± 3.22(S1)% during last collection (Table 3).

The seeds were immature inside the fruit at first collection. The mean seed size during second collection was 0.42±0.03 (S3). With each collection the seed size increased and during final collection ranged between 1.35± 0.16 (S1) and 2.02±0.12 mm² (S2). Across all the sites the seed of S2 were biggest in size. At second collection the weight of 100 seed was 0.07±0.01 (S3) and 0.11±0.02 g (S1) and by the time of final collection had increased to 0.43±0.02 (S2) and 1.10±0.01 g (S3). Across all the site the seeds of S3 were heavier in weight. The number of seeds within fruits ranged between 217500±4.06 (S1) and 233800.17±3.13 (S2) at final collection (Table 3). During second collection the seed moisture content ranged between 68.34±0.73 (S2) and 77.67±0.61% (S3) and then declined to 33.34±1.38 (S3) and 37.84±2.19 % (S1) during last collection (Table 3).

ANOVA showed that fruit size, weight of 100 fruit, number of fruits per 100 g and fruit moisture content varied significantly across dates of collection ($P < 0.05$). Whereas, seed size, weight of 100 seeds, number of fruits per 100 g and seed moisture content varied significantly across sites and dates of collection ($P<0.05$) The interaction between site×date and year× site × date was also significant for number of seeds per 100 g and germination.

Germination: In all the three sites no germination took place in the first collection. The germination started from the second collection and ranged be-

Table 2. Tree Characteristics Average tree height (m), Circumference (m), Crown cover (m²) and Density of *F. auriculata*.

Sites	Height (m)	Circumference (m)	Crown cover (m²)	Density(indi/ha)
S1	9.00±1.53	0.73±0.03	10.15±4.26	122
S2	7.00±1.00	0.48±0.24	9.69±1.43	44
S3	15.04±1.21	0.82±0.08	6.84±1.31	22

Table 3. Changes in physical fruit and seed characteristics and germination in *F. auriculata* across different collection dates (Abbreviation – Im = Seeds were immature inside the fruit, G = Green, YG = Yellowish green, PO = Pinkish orange, R = Red)

Site	Collection	Fruit characteristics					Seed characteristics				
	date	Fruit colour	Fruit Size(mm^2)	Weight of 100 fruits (g)	Number of fruit in 100g	Moisture Content (%)	Seed Size (mm^2)	Weight of 100 seeds (g)	Number of seeds in 100 (g)	Moisture content (%)	Germination (%)
S1	19-06-2018	G	330.25±17.49	1507.50±13.08	6.00±0.50	80.67±1.43	Im	Im	Im	Im	Im
	26-06-2018	G	1090.76±38.93	1653.67±20.28	4.83±0.50	77.84±1.92	0.42±0.04	0.11±0.02	121100.34±1.66	77.00±0.77	4.88±0.02
	03-07-2018	G	1405.32±9.19	2082.00±42.55	3.67±0.17	70.50±1.89	0.49±0.09	0.14±0.00	125400.67±2.06	70.50±0.58	20.77±0.79
	10-07-2018	YG	1528.57±19.09	2544.00±71.25	3.17±0.33	64.67±1.77	0.78±0.05	0.23±0.06	128300.84±1.77	61.00±1.48	40.97±0.51
	17-07-2018	YG	1578.80±8.42	2719.67±59.18	2.50±0.33	60.84±1.21	1.05±0.14	0.34±0.05	130100.34±2.09	54.67±1.33	63.60±0.75
	24-07-2018	PO	1678.68±14.54	3374.84±30.02	1.83±0.33	48.17±2.50	1.14±0.09	0.40±0.03	197200.83±2.30	47.34±1.51	74.08±0.58
	31-07-2018	R	1766.14±10.12	3386.50±28.63	1.00±0.00	40.50±3.22	1.35±0.16	0.52±0.02	217500.00±4.06	37.84±2.19	86.11±0.77
S2	19-06-2018	G	246.45±3.76	1509.00±24.57	6.17±0.33	75.84±1.31	Im	Im	Im	Im	Im
	26-06-2018	G	1142.37±4.82	1614.67±11.25	5.17±0.33	66.17±0.73	0.42±0.06	0.09±0.00	102400.00±4.05	68.34±0.73	11.52±0.35
	03-07-2018	G	1372.79±8.99	1936.34±3.40	4.50±0.33	58.00±2.05	0.50±0.04	0.17±0.01	121100.34±3.50	62.83±1.50	25.82±0.74
	10-07-2018	YG	1419.20±1.95	2289.67±10.95	3.34±0.17	54.00±1.15	1.07±0.09	0.20±0.04	124400.17±6.63	58.84±1.02	38.61±0.76
	17-07-2018	YG	1499.90±3.75	2690.50±13.50	2.17±0.33	49.84±0.73	1.19±0.17	0.30±0.03	198100.50±1.33	52.83±1.32	75.27±1.04
	24-07-2018	PO	1646.97±28.76	3296.67±115.06	1.83±0.33	43.00±1.17	1.37±0.07	0.39±0.02	232100.50±2.03	44.33±1.17	77.26±0.82
	31-07-2018	R	1763.42±16.14	3462.83±23.78	1.17±0.17	38.00±1.61	2.02±0.12	0.43±0.02	233800.17±3.13	36.34±2.02	85.54±0.32
S3	19-06-2018	G	511.86±10.57	1488.17±19.63	5.50±0.33	75.34±1.75	Im	Im	Im	Im	Im
	26-06-2018	G	1049.28±15.38	1636.17±11.63	5.00±0.33	60.84±2.33	0.42±0.03	0.07±0.01	121400.67±4.16	77.67±0.61	3.74±0.17
	03-07-2018	G	1174.86±12.43	1752.67±33.42	4.00±0.33	54.50±2.09	0.54±0.04	0.22±0.04	123400.00±2.37	64.50±2.48	25.15±0.72
	10-07-2018	YG	1329.12±3.56	1835.50±7.50	3.00±0.33	48.00±1.73	0.92±0.02	0.32±0.04	124000.50±1.20	54.17±2.26	43.86±0.53
	17-07-2018	YG	1438.72±15.24	2309.17±39.80	2.00±0.00	47.00±1.17	1.20±0.08	0.37±0.01	128600.33±2.76	47.50±1.95	69.41±1.35
	24-07-2018	PO	1641.00±27.19	3280.67±91.12	1.67±0.33	42.67±1.04	1.35±0.08	0.42±0.02	232200.17±1.93	42.34±1.70	78.01±0.76
	31-07-2018	R	2063.21±7.38	4217.84±105.31	1.17±0.17	36.67±1.93	1.66±0.22	1.10±0.01	232600.17±3.83	33.34±1.38	82.60±1.05

tween 3.74± 1.38 (S3) and 11.52 ± 0.35% (S2). The germination increased with each collection, maximum germination occurred in seed of final collection. Maximum germination ranged between 82.60± 1.05 (S3) and 86.11±0.77 % (S1). Maximum germination occurred when fruit moisture content was between 36.67± 1.93 and 40.50±3.22 % and seed moisture content was between 33.44 ±1.38 and 37.84±2.19 % (Table 3). ANOVA showed germination varied significantly, across sites and dates ($P<0.05$). The interaction between year×site, year ×date, site × date and year×site×date ($P< 0.05$) were also significant. The seed size ($r = 0.83$; $P<0.01$), weight of fruit ($r = 0.86$; $P<0.01$), fruit size ($r = 0.80$; $P<0.01$), were positively correlated with germination. Weight of seeds ($r =0.13$; $P<0.01$), moisture content (fruit) ($r = 0.83$; $P< 0.01$) and moisture content (seed) ($r = 0.86$; $P<0.01$) were negatively correlated with germination across all the sites.

Discussion

Ficus auriculata is a well-known multipurpose tree species of Central Himalayan region. Like other wild edible species regeneration of *F. auriculata* is effected due to high biotic pressure and is poor under natural condition. In the present study seedlings and saplings of the species were completely absent. In wild edible plants availability of mature seed is always been a big problem as all accessible locations are searched by the village dwellers. The poor natural regeneration of Ficus species indicates that the seed sources are

depleted through harvesting of mature and immature fruits. Poor regeneration in *Ficus exasperata* and *Ficus mucuo* has also been reported in Degeya forests (Omeja *et al.,* 2004; Malik and Bhatt, 2016). To synchronized artificial regeneration of such important multipurpose species exact knowledge of maturity time is essential to avoid the collection of immature and non-viable seeds (Willan, 1985). Seed collectors have long been aware that most mature and immature fruits and seeds can be distinguished in a number of ways eg. Colour difference, increased firmness or brittleness, decreased moisture content and specific gravity or by change in physical dimensions (Edward, 1980; Shah, 2005). Collection of fruits and seeds are greatly helped by reliable guidelines of maturity like colour, moisture content etc. that allow the earliest possible collection (Bonner, 1988). Colour change is always considered a reliable indicator of maturity in many species In *F. auriculata* colour change from green to red was a good indicator of maturity. Colour changes has also been recommended as a ripeness indicator in *Myrica esculenta* (Shah *et al.,* 2010) *Prunus cerasoides* (Tewari *et al.,* 2011) and in the *Bauhinia retusa* (Upadhyay *et al.,* 2006) other important wild edible species. In *Pyracantha crenulata* also colour change of fruit from dark green to pinkish orange is also an indicator of maturity (Shah *et al.,* 2006). Besides colour decline in fresh weight moisture content percent from maturing seeds in closely related to seed maturity (Pandit *et al.,* 2002). In *F. auriculata* decline in moisture content also appears another good indicator of seed maturity. Across all the sites maximum germination (ranged between 82.60 ± 1.05% and 86.11 ± 0.77%) occurred when fruit moisture content was between 36.67 and 40.50% and seed moisture content ranged from 33.34 and 37.84%. Fruit and seed moisture content has also been used as a reliable maturity indicators by many researchers (Shah *et al.,* 2010; Tewari *et al.,* 2011; Upadhyay *et al.,* 2006; Pandit *et al.,* 2002; Maideen *et al.,* 1990; Grover *et al.,* 1963).

F. auriculata fruits/seeds attained maturity in the last week of July or in rainy season which is similar to other species of Ficus like *Ficus fulva, Ficus variegate, Ficus hispida, Ficus oligodon* and *F. semicordata* which produced the main seed crop in the beginning of rainy season, the optimal period for germination and seedling establishment (Blakesley *et al.,* 2002, Kuaraksa *et al.,* 2012). Edwards (1969) could not find any relationship between physical parameters and maturity but in *F. auriculata* significant positive correlation was present between fruit size, seed size, weight of fruit, weight of seed and germination. Tewari *et al.,* 2011 and Shah *et al.,* 2010 has also reported significant correlation between physical parameters and germination in *Prunus cerasoides* and *Myrica esculenta*. From this study it becomes evident that colour change from green to red, fruit moisture content ranging between 36 and 40% and seed moisture content varying between 33 and 37% are best indicator of maturity in *F. auriculata*. The best appropriate time for fruit collection is in the last week of July.

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