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Timing of phenological events and fruit ripening in *Ficus palmata* forssk. In the Mid Himalayan Region

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ABSTRACT

Ficus palmata Forssk. is commonly growing wild in the Himalayan region of the family *Moraceae*. A study was undertaken at the Kumaun Himalaya region to evaluate the regeneration, phenology, maturity indices, and nutrition status of *F. palmata*. The density of *F. palmata* across the sites ranged between 22 and 122 ind/ha. Seedlings were completely absent in all the study sites. However, saplings were present in low numbers. The seeds were minute, and germination was high ranging between 84.68 ± 2.42 and 95.33 ± 1.64% while the seed moisture content was between 36.33 ± 0.88 and 42.33 ± 0.88% across all the sites. Flowering and fruiting occurred twice a year from March-May to October-December. Only the seeds produced during summer season (April–May) were viable. It is facing high anthropogenic pressure and poor regeneration. There is an urgent need for conservation and large-scale plantation programs. Assessment of the exact time of fruit/seed maturation using physical indicators can help collect viable seeds for regeneration and multiplication of the species. The study could highlight that this species is facing severe regeneration problems. Fruit/seed maturation can disturb its synchronization with the monsoon rains when maximum germination occurs. Study developed baseline data on phenological events for future referencing on the impact of climate change on this species.

1. INTRODUCTION

The genus *Ficus* universally known as fig, belongs to the family *Moraceae* [1] and is one of the largest plant genera, with more than 750 species distributed worldwide [2-4]. In India, 115 species of *Ficus* are distributed throughout the country, and the maximum diversity of the species lies in the North-East region [5]. *Ficus* species have a diversity of habitations; few are hemi epiphytes, large woody climbers, and trees and shrubs. Most of the *Ficus* species are good fodder sources. A large number of vertebrates depend for food on *Ficus* species [6].

Ficus palmata Forssk. is a multiuse tree that belongs to *Moraceae* family, found growing wild in the Himalayan region, native of North-Western India and Rajasthan regions, Garhwal and Kumaun region, Uttarakhand, Nepal up to 1550 m above the sea level. *F. palmata* occasionally occurs in the forest but grows well around the villages, fields, and wastelands. *F. palmata* is a deciduous tree with minor unisexual flowers and deep violet to black fruit inside which numerous, round, and very small seeds are found. The whole fruit and the seeds can be eaten either in the immature stage by cooking as a vegetable or after maturing as fruit. It is one of the top edible wild fruits with medicinal and nutritional properties [7,8].

Several studies show the importance of *F. palmata* in treating several diseases [9] but very few on its regeneration status, phenological events, fruit/seed maturity, and germination. Shifting in the timing of fruit seed maturation time can severely impact the regeneration of this species. There appear to be no baseline data to compare the changes in the timing of phenological events of this important species coupled with regeneration information.

Ficus species are wild edible species, and the dependency for food on different species of *Ficus* is very high. In the Himalayan mountains, regeneration of the fodder/edible fruit species is a significant problem. Regeneration of the species, survival, and growth of seedlings depend upon human disturbance, trampling by cattle, and cattle browsing [10]. The successful regeneration of forest species is characterized by a sufficient population of saplings, seedlings, and adults [11].

We studied the regeneration status of fruit/seed-related traits, the timing of fruit/seed maturation, and germination, which is critically needed to develop baseline data to fully comprehend the impact of climate change on this struggling species. (1) In view of the importance of this species-poor regeneration and scanty information on seed/fruit maturity indices, the present study was planned to document the most suitable

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time for fruit/seed collection and determines the effect of different collection dates on fruit/seed characters and germination essential for its multiplication. (2) Timing of major phenological events was carried out to determine the impact of climatic change compared to previous studies. (3) Nutrient analysis of leaves and fruits was done to determine the suitability of the leaves/fruits of the species as fodder so that large-scale plantations of the species can be undertaken to meet the needs of green fodder during the lean summer months in the hill areas.

2. MATERIALS AND METHODS

2.1. Study Site

The study areas are located between 29' 22" N latitude and 79' 38" E longitude. The research was carried out over 2 years (2017 and 2018). Three sites (S1, S2 and S3) were selected between 1136 m~1704 msl. altitude on northeast and northwest aspect [Table 1]. The associated species were *Ficus nemoralis* Vern., *Quercus leucotrichophora* A. Camus, *Ficus roxburghii* Wall., *Grewia optiva* Drumm., *Pinus roxburghii* Sarg., *Aesculus indica* Wall., *Cupressus torulosa* D. Don ex Lamb., *Prunus cerasoides* D. Don., *Pyrus pashia* Buch. and *Cedrus deodara* Rox. were found as main associates. The texture of the soil was sandy clay loam across all the three sites. The climate of the study sites is subtropical monsoon with high temperatures towards lower elevation and lower temperatures towards high elevation. Rainfall is governed by the southwest monsoon; annual rainfall was 1337.50~1536.40 mm (approx.) during the study period, of which 90% occurred from mid-June to mid-September. In both years, May was the warmest month of the year and December the coldest month, with temperatures ranging from 2.89°C to 25.9°C (Source: S. M. R. A. G. I. C. Tallital, Nainital).

2.2. Regeneration Status

For calculating the regeneration of the species 10 quadrats each of 10 × 10 m were placed across all the sites [12]. Density of trees, saplings, and seedlings was estimated following [13].

2.3. Phenology

The phenophases were observed from bud formation to fruit/seed formation. During the field visit, the phenophases were recorded for selected species. To record observation of different phenological events, 05 superior individuals were marked and frequent field visits were made [14]. Phenological records were collected from the last week of March 2017 to the 2nd week of January 2018.

2.4. Maturity Indices

The species produced flowers/fruits twice in the year, Mar-May and Oct-Dec. However, only the data for the period between March and May has been presented. As the fruits from October to December produced non-viable seeds which failed to germinate. Fruit collection was started from the 2nd week of April up to the availability of fruits from marked trees for all three sites at week intervals. Fruits were collected at 1-week intervals directly from the selected trees. Fruits from all trees were combined at one collection date to create a composite sample. Fruits were manually de-pulped to extract seeds. Three replicates of 25 fruits/seeds were taken from the composite sample to determine the different morphological characters of fruits/seeds (size, color, and fresh weight). Fruit and seed weight (100 fruits/seeds) was measured by electronic balance (Model No. PGB 301 accuracy + 0.001 mg Wensar), and fruit and seed size (25 fruits/seeds) were expressed in mm² (length and width) was estimated using (Model No. CD-6" accuracy + 0.02 mm Mitutoyo Co.) digital Vernier caliper. Moisture content% was estimated based on three replicates of fruits and seeds (25) each and assessed on a fresh weight basis by drying at 103 ± 2°C for 16 ± 1 h and then the samples were reweighted according to [15,16]. For germination four replicates of hundred seeds were kept at the top of germination paper in petri-dishes at room temperature. The appearance of the first radicle germination was considered to have started and was studied for 40 days, following [17], the seed germination% was calculated.

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

The data were analyzed using analysis of variance [18].

2.5. Viability

For viability retention seeds of *F. palmata* collected at maturity were stored under two conditions in airtight plastic containers placed at room temperature (during day18–26°C and night 3–13°C) and refrigerator (1 and 3°C) [1]. The viability was checked by germinating 3 replicates of 100 seeds every 30 days up to the time seeds germinated (in both year-1 and year-2) [19].

2.6. Nutritive Value

The protein content of leaf/fruit was determined with the help of [20]. Ash was prepared at 550°C in a muffle furnace. Calcium was determined by the volumetric method. Phosphorous was determined by the molybdenum blue method [21,22].

3. RESULTS

3.1. Regeneration Status

The tree density of *F. palmata* ranged between 22 and 122 ind/ha across all the studied sites. Seedlings were completely absent in all the study sites. Saplings were present in all selected sites except site 1 but the density was low. The total tree density of the site varied between 297 and 554 ind/ha with 1.91 and 26.2 m^2/ha^{-1} TBA across all the sites.

3.2. Phenology

The leaf initiation in *F. palmata* started in the 3rd week of March and was complete by the 3rd week of April. Flowering and fruiting occurred 2 times a year 1st-time, fruits were visible between the 3rd week of March and the 3rd week of May, and a 2nd time between the 3rd week of October and the 2nd week of December. Seed dispersal also occurred 2 times in a year, and the period of seed dispersal in both seasons was short. The leaf fall started in the 1st week of December and was completed by the 1st week of January [Figure 1].

Table 1: Details of selected sites of *Ficus palmata*.

S. No.	Site name	Aspect	Elevation (msl.)	Coordinates	Density (ind/ha)
1	Site1 (bhumiyadhar) (nainital district)	North west	1704	N 30°29'70" E 79°13'15"	66
2	Site 2 (gethiya) (nainital district)	North east	1136	N 29°22'10" E 79°30'28"	78
3	Site 3 (katyari) (almora district)	North east	1530	N 29°35'29" E 79°38'30"	122

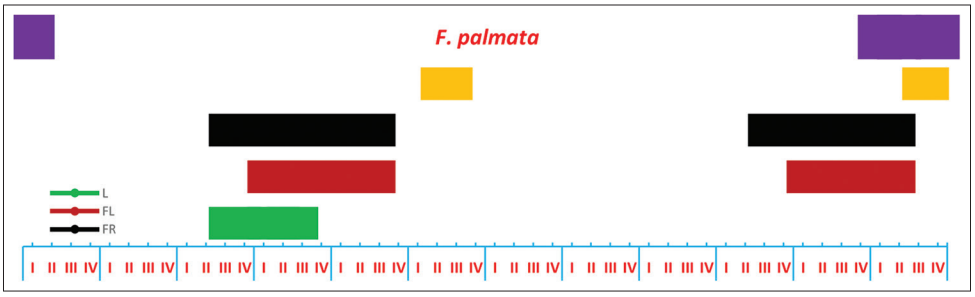

Figure 1: Phenological events of *Ficus palmata* (I-IV) weeks of each month I= week 1, II week 2, III = week 3, IV = week 4. L= Leafing; FL = Flowering; FR= Fruiting; SD= Seed dispersal; LF= Leaf fall.

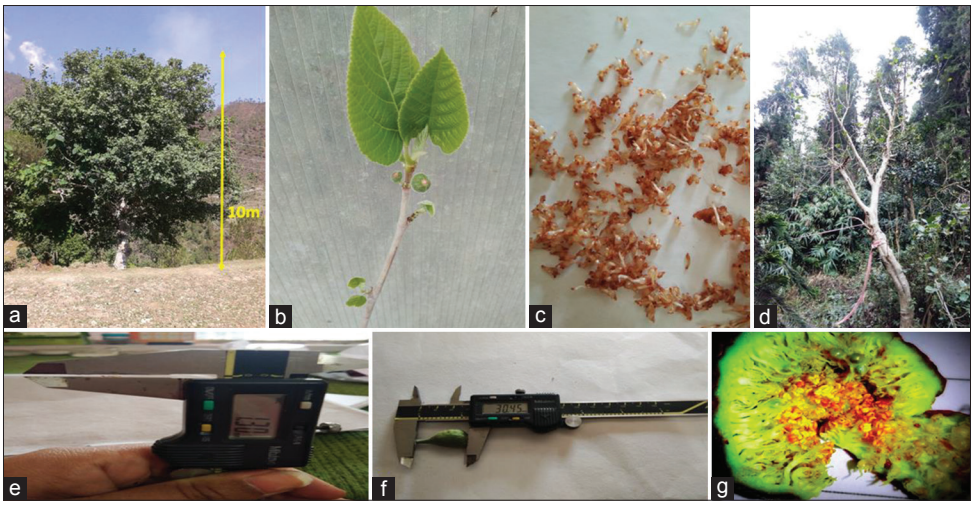

Figure 2: (a) A tree (10 m), (b) leaf initiation, (c), (e) seed (1.30), (d) leaf fall and seeds of *Ficus palmata,* (f) fruiting (30.45) (g) flowering.

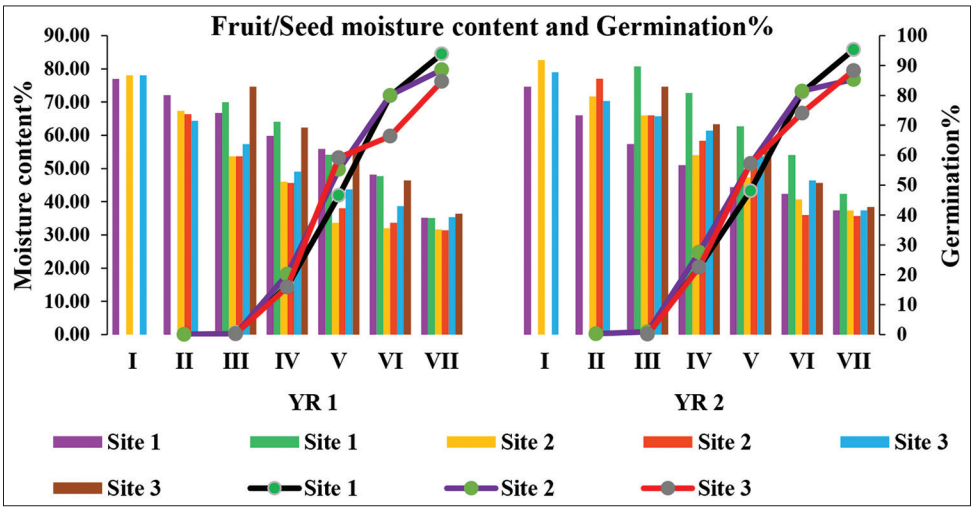

Figure 3: Fruit/Seed Moisture content% and Germination% of *Ficus palmata.* (SMC denotes Seed Moisture Content, FMC: Fruit Moisture Content and GER: Germination).

3.3. Fruit/Seed Characteristics

The color of the fruit in the first collection was light green in the 2nd week of April. The fruit turned dark purple at the final collection last May week [Table 2]. From initial to final collection, the fruit size ranged between 103.13 ± 5.37 (S1) and 502.26 ± 1.53 (S3) mm^2 across all the sites. The seeds during the first two collections were extremely soft and immature. The mean seed size during the third collection ranged between 0.60 ± 0.03 (S2) and 1.06 ± 0.05 (S2) mm^2 across all the sites.

In both the years, the fruit size between initial to the final collection was 103.13 ± 5.37 and 409.52 ± 5.27mm^2 throughout collection change in fruit size was 306.39 mm^2, and the seed size between initial to the final collection was 0.81 ± 0.04 and 3.00 ± 0.04 throughout

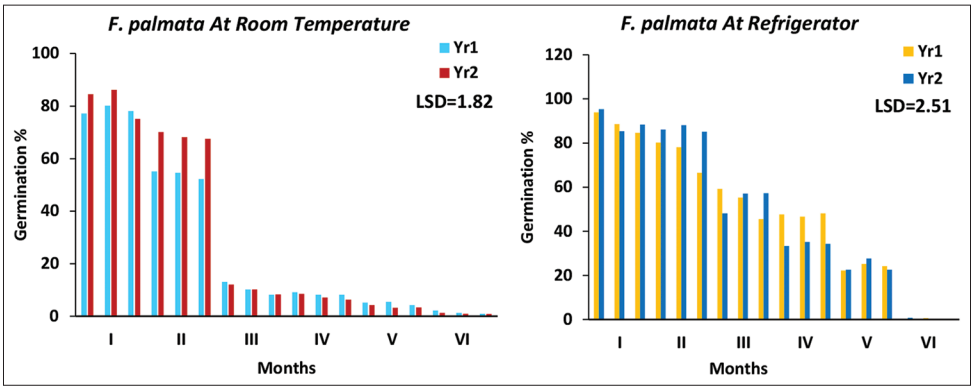

Figure 4: Germination% at room temperature and refrigerator of *Ficus palmata.*

Table 2: Variation in physical parameters of fruits of *Ficus palmata* over the collection period in Yr-1 (2017) and Yr-2 (2018) for site 1, site 2, and site 3.

Sites	DOC	CLR	Yr-1			Yr-2		
			Fruit size mm²	Weight of 100 fruits (g)	No. of fruits in 100 g	Fruit size mm²	Weight of 100 fruits (g)	No. of fruits in 100 g
Site 1	11 April	LG	103.13±5.37	43.30±0.85	280.0±5.77	106.68±0.88	43.41±0.83	260.00±5.77
	18 April	LG	140.37±2.46	61.50±0.31	220.00±5.77	141.70±6.04	44.46±0.47	270.00±8.82
	25 April	DG	155.55±6.48	115.83±1.53	121.67±1.67	152.58±1.21	61.63±0.34	173.33±8.82
	02 May	P	221.47±8.96	136.97±8.82	91.67±6.01	201.20±5.70	113.90±3.51	83.33±3.33
	09 May	P	255.10±2.05	155.83±3.09	77.33±1.20	227.99±7.24	148.34±2.20	57.67±0.88
	16 May	DP	386.45±1.23	156.40±2.48	73.67±2.03	373.15±2.22	158.07±4.17	53.33±3.33
	23 May	DP	409.52±5.27	157.17±1.97	67.33±1.20	397.38±1.76	160.34±0.74	43.33±3.33
Site 2	11 April	LG	112.56±4.10	31.40±2.43	323.33±3.33	111.78±1.48	31.67±2.66	313.33±6.67
	18 April	LG	174.90±6.60	96.67±2.40	213.33±3.33	134.55±4.22	43.87±0.41	243.33±3.33
	25 April	DG	199.76±7.61	107.33±4.37	121.00±0.58	194.37±9.96	95.37±4.68	113.33±6.67
	02 May	P	263.20±1.17	137.53±6.87	97.00±1.53	200.43±9.56	109.93±0.29	93.33±3.33
	09 May	P	301.77±5.01	163.63±0.43	84.67±2.40	220.55±2.62	121.25±4.69	90.00±5.77
	16 May	DP	322.00±6.47	167.70±0.15	76.33±2.19	312.33±3.13	158.30±1.67	53.33±3.33
	23 May	DP	413.47±9.84	169.53±7.35	69.67±0.33	412.34±5.61	160.23±3.58	53.33±3.33
Site 3	11 April	LG	111.21±7.25	31.73±2.60	320.00±5.77	106.41±4.07	31.37±2.63	306.67±6.67
	18 April	LG	118.97±9.16	43.07±0.09	256.67±3.33	110.20±4.18	42.73±0.32	246.67±3.33
	25 April	DG	211.15±2.36	95.47±3.09	125.00±2.89	204.40±9.71	92.23±4.53	133.33±3.33
	02 May	P	213.22±6.41	114.07±3.34	123.67±1.86	216.34±2.75	115.33±2.47	113.33±3.33
	09 May	P	217.67±8.10	141.27±0.07	122.00±2.00	232.91±3.94	143.23±0.41	93.33±3.33
	16 May	DP	342.16±5.23	151.27±0.07	70.00±0.00	321.85±3.64	152.83±1.50	53.33±3.33
	23 May	DP	502.26±1.53	162.30±2.55	63.67±1.86	414.80±3.61	161.17±4.90	50.00±0.58

DOC: Denotes date of collection, CLR: Color, DG: Dark green, LG: Light green, P: Purple, DP: Dark purple.

collection change in seed size was 2.19 mm² at (S1). The fruit size between initial to the final collection was 111.78 ± 1.48 and 413.47 ± 9.84 mm² over the period of collection change in fruit size was 301.69 mm², and seed size between initial to the final collection was 0.60 ± 0.03 and 2.79 ± 0.12 over the period of collection change in seed size was 2.19 mm² at (S2). The fruit size between initial to final collection was 106.41 ± 4.07 and 502.26 ± 1.53 mm² over the period of collection change in fruit size was 395.85 mm² and seed size between initial to final collection was 1.00 ± 0.05 and 2.44 ± 0.04 over the period of collection change in seed size was 1.44 mm² at (S3).

At site 1 the weight of 100 fruits between initial to final collection was 43.30 ± 0.85 and 160.34 ± 0.74 g over the period of collection change in fruit weight was 117.04 g and weight of 100 seeds between initial to final collection was 0.07 ± 0.01 and 0.17 ± 0.01 g over the period of collection change in seed weight was 0.1 g. At site 2 the weight of 100 fruits between initial to final collection was 31.40 ± 2.43 and 169.53 ± 7.35 g over the period of collection change in fruit weight was 138.13 g and weight of 100 seeds between initial to final collection was 0.05 ± 0.01 and 0.25 ± 0.01 g over the period of collection change in seed weight was 0.2 g. At site 3 the weight of 100 fruits between initial to final collection was 31.37 ± 2.63 and 162.30 ± 2.55 g over the period of collection change in

Table 3: Variation in physical parameters of seeds of *Ficus palmata* over the collection period in Yr-1 (2017) and Yr-2 (2018) for site 1, site 2, and site 3 (Im=Seeds were immature inside the fruit).

Sites	DOC	CLR	Yr-1			Yr-2		
			Seed size mm²	Weight of 100 seeds (g)	No. of seeds in 100 g	Seed size mm²	Weight of 100 seeds (g)	No. of seeds in 100 g
Site 1	11 April	Im	Im	Im	Im	Im	Im	Im
	18 April	Im	Im	Im	Im	Im	Im	Im
	25 April	OW	0.93±0.07	0.07±0.01	86733.33±2.03	0.81±0.04	0.07±0.02	86900.00±10.12
	02 May	OW	1.00±0.03	0.09±0.01	94500.00±0.58	0.88±0.06	0.09±0.01	94500.00±7.77
	09 May	LB	1.02±0.07	0.10±0.01	95300.00±1.73	0.99±0.10	0.11±0.01	97100.00±10.97
	16 May	B	2.36±0.03	0.13±0.01	98600.00±4.93	2.25±0.07	0.12±0.02	97700.00±12.17
	23 May	B	2.55±0.23	0.16±0.01	210533.33±6.64	3.00±0.04	0.17±0.01	119600.00±12.17
Site 2	11 April	Im	Im	Im	Im	Im	Im	Im
	18 April	OW	0.60±0.03	0.07±0.01	75500.00±6.35	Im	Im	Im
	25 April	OW	1.00±0.01	0.08±0.01	76366.67±9.77	1.06±0.05	0.05±0.01	76066.67±9.94
	02 May	LB	1.07±0.04	0.12±0.01	86566.67±9.53	1.09±0.12	0.07±0.01	81966.67±8.41
	09 May	LB	1.72±0.26	0.16±0.01	95933.33±2.03	1.23±0.11	0.08±0.01	85766.67±11.67
	16 May	B	2.35±0.11	0.18±0.01	97600.00±6.93	1.54±0.18	0.11±0.01	94500.00±11.02
	23 May	B	2.79±0.12	0.25±0.01	98100.00±6.08	2.63±0.08	0.15±0.01	96200.00±14.43
Site 3	11 April	Im	Im	Im	Im	Im	Im	Im
	18 April	Im	Im	Im	Im	Im	Im	Im
	25 April	OW	1.00±0.05	0.17±0.01	85466.67±6.12	1.03±0.03	0.06±0.01	85800.00±10.41
	02 May	OW	1.12±0.11	0.17±0.01	93700.00±5.29	1.15±0.02	0.09±0.01	86133.33±12.72
	09 May	LB	1.44±0.06	0.19±0.01	96400.00±6.35	1.42±0.06	0.12±0.01	94000.00±9.17
	16 May	B	2.44±0.03	0.22±0.02	119600.33±7.54	1.76±0.16	0.14±0.01	96333.33±6.64
	23 May	B	2.44±0.04	0.23±0.01	120133.33±7.86	2.42±0.17	0.17±0.01	210366.67±13.20

DOC: Denotes date of collection, CLR: Color, OW: Off-white, LB: Light brown, B: Brown.

Table 4: Analysis of variance (ANOVA) for different fruit parameters across different collection dates (number), sites, and years of *Ficus palmata*.

Characters	Source	Type III Sum of Square	df	Mean Square	F-Value
Fruit size (mm²)	Year	12354.607	1	12354.607	102.605**
	Site	2033.226	2	1016.613	8.443**
	Date	1623433.472	7	231919.067	1.926**
	Year×site	2644.489	2	1322.245	10.981**
	Year×date	6150.654	6	1025.109	8.514**
	Site×date	35470.172	12	2955.848	24.548**
	Year×site×date	30109.453	12	2509.121	20.838**
Weight of 100 fruits (g)	Year	4475.006	1	4475.006	148.906**
	Site	1512.932	2	756.466	25.171**
	Date	301693.971	7	43099.139	1.434**
	Year×site	2563.155	2	1281.577	42.645**
	Year×date	2814.375	6	469.062	15.608**
	Site×date	3114.919	12	259.577	8.637**
	Year×site×date	4427.374	12	368.948	12.277**
Number of fruits in 100 g	Year	672.071	1	672.071	13.519**
	Site	4499.190	2	2249.595	45.251**
	Date	974341.587	7	139191.655	2.800**
	Year×site	1023.857	2	511.929	10.298**
	Year×date	7636.984	6	1272.831	25.603**
	Site×date	22033.365	12	1836.114	36.934**
	Year×site×date	7441.587	12	620.132	12.474**

NS: Non significant, **Significant at 5% (P<0.05).

Table 5: Analysis of variance (ANOVA) for different seed parameters across different collection dates (number), sites, and years of *Ficus palmata.*

Characters	Source	Type III sum of square	df	Mean square	F-value
Seed size (mm^2)	Year	0.477	1	0.477	18.193**
	Site	0.179	2	0.090	3.420NS
	Date	108.211	7	15.459	589.991**
	Year×site	0.455	2	0.228	8.690**
	Year×date	1.179	6	0.197	7.500**
	Site×date	1.984	12	0.165	6.311**
	Year×site×date	0.873	12	0.073	2.778**
Weight of 100 seeds (g)	Year	0.055	1	0.055	277.648**
	Site	0.023	2	0.012	57.752**
	Date	0.515	7	0.074	369.008**
	Year×site	0.028	2	0.014	69.161**
	Year×date	0.014	6	0.002	11.951**
	Site×date	0.020	12	0.002	8.157**
	Year×site×date	0.021	12	0.002	8.886**
Number of seeds in 100 g	Year	1.172	1	1.172	6.590**
	Site	2.066	2	1.033	5.809**
	Date	2.844	7	4.062	2.284**
	Year×site	3.220	2	1.610	9.052**
	Year×date	2.185	6	3.642	2.048**
	Site×date	2.344	12	1.953	1.098**
	Year×site×date	2.771	12	2.309	1.298**

NS: Non significant, **Significant at 5% (P<0.05).

Table 6: Analysis of variance (ANOVA) for fruit and seed moisture content and germination across different collection dates (number), sites, and years of *Ficus palmata.*

Characters	Source	Type III sum of square	df	Mean square	F-value
Fruit moisture content %	Year	283.470	1	283.470	36.927**
	Site	256.327	2	128.163	16.695**
	Date	26085.043	7	3726.435	485.431**
	Year×site	1273.090	2	636.545	82.921**
	Year×date	39.114	6	6.519	0.849NS
	Site×date	534.109	12	44.509	5.798**
	Year×site×date	429.705	12	35.809	4.665**
Seed moisture content %	Year	283.260	1	283.260	51.038**
	Site	111.274	2	55.637	10.025**
	Date	75637.651	7	10805.379	1.947**
	Year×site	174.383	2	87.191	15.710**
	Year×date	3707.182	6	617.864	111.327**
	Site×date	5763.137	12	480.261	86.534**
	Year×site×date	5539.661	12	461.638	83.178**
Germination %	Year	184.598	1	184.598	18.825**
	Site	633.800	2	316.900	32.317**
	Date	162532.42	7	23218.918	2.368**
	Year×site	1170.638	2	585.319	59.689**
	Year×date	331.275	6	55.213	5.630**
	Site×date	1363.055	12	113.588	11.583**
	Year×site×date	1136.284	12	94.690	9.656**

NS: Non significant, **Significant at 5% (P<0.05).

fruit weight was 130.93 g and weight of 100 seeds between initial to final collection was 0.06 ± 0.01 and 0.23 ± 0.01g over the period of collection change in seed weight was 0.17 g across both the years. Across all the sites and years the largest fruit size was in (S3) Yr-1. Across all the sites and years the heaviest fruit was recorded at (S2) Yr-1 [Tables 2,3]. Across all the sites and years the largest seed size was in (S1) Yr-2. Across all the sites the heaviest seed was recorded at (S2) Yr-1.

Analysis of variance (ANOVA) showed that fruit size, weight of 100 fruits and number of fruits in 100 g varied significantly across years, sites and dates ($P < 0.05$). The interactions between year × site, year × date, site × date, and year × site × date were also significant for fruit size, weight of 100 fruits and number of fruits in 100 g. ANOVA showed that size, weight, and number of seeds in 100 g were significant across years and dates ($P < 0.05$). The interactions between year × site, year × date, site × date and year × site × date were significant for seed size, weight of 100 seeds, and number of seeds ($P < 0.05$) [Tables 4,5].

Germination started from the third collection and varied from 0.09 ± 0.02 to 0.69 ± 0.30%. Germination rate increases with each collection and maximum germination occurred in seed of final collection. Maximum germination ranged between 84.68 ± 2.42 and 95.33 ± 1.64% when seed moisture content was between 36.33 ± 0.88 and 42.33 ± 0.88% [Figure 3].

In both years germination of stored seed at room temperature declined after 3 months 10.42 ± 1.42% and 10.11 ± 1.09% and germination under room temperature decreased drastically after 60 days in both the years. In both years, there was no germination in seed stored in refrigerator after 6 months. The best temperature for storage was 1–3°C in refrigerator [Figure 4].

ANOVA showed that fruit and seed moisture content varied significantly across years, sites and dates ($P < 0.05$). The interaction between site × date, year × site, and year × site × date was significant for moisture content and germination of fruit and seed ($P < 0.05$) [Table 6].

The germination was positively correlated with fruit size ($r = 0.91$; $P < 0.05$) [Figure 5], fruit weight ($r = 0.85$; $P < 0.05$) [Figure 6], and negatively correlated with fruit moisture content ($r = 0.85$; $P < 0.05$) [Figure 7] across all the sites. Similarly, germination was positively correlated with seed size ($r = 0.90$; $P < 0.05$) [Figure 8], seed weight ($r = 0.77$; $P < 0.05$) [Figure 9], and negatively correlated with seed moisture content ($r = 0.85$; $P < 0.05$) [Figure 10].

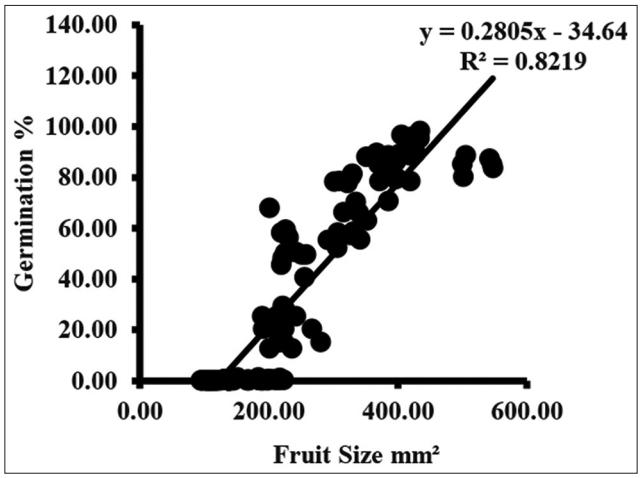

Figure 5: Relationship between fruit size and seed germination for *Ficus palmata.*

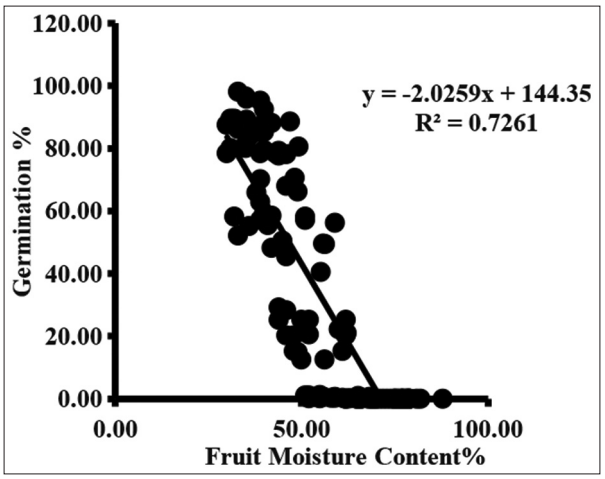

Figure 7: Relatyonship between fruit moisture content% and seed germination for *Ficus palmata.*

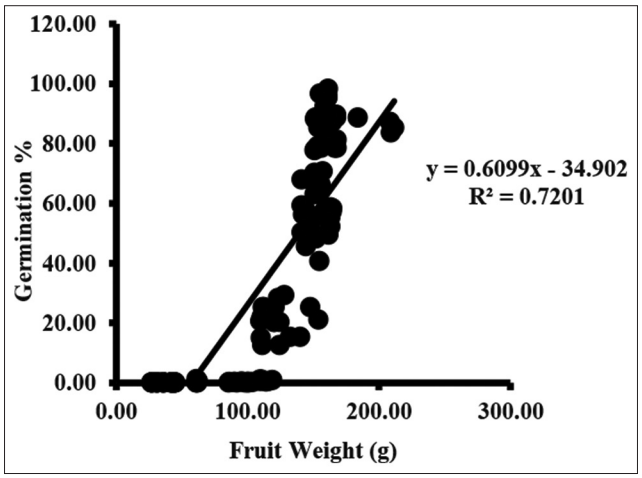

Figure 6: Relatyonship between fruit weight nd seed germination for *Ficus palmata.*

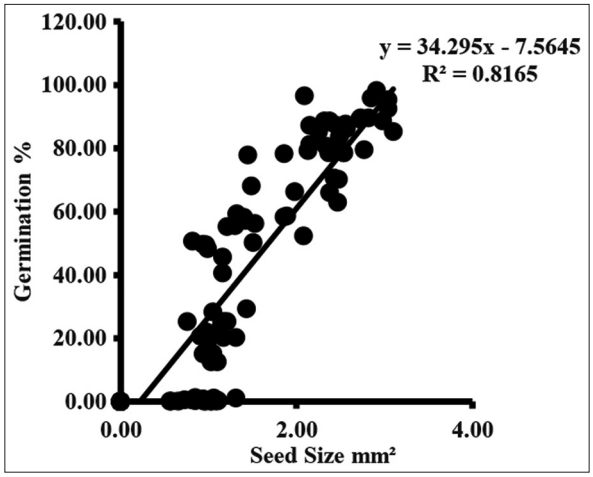

Figure 8: Relatyonship between seed size and seed germination for *Ficus palmata.*

3.4. Nutritional Status

The mean moisture content, protein content, ash content, calcium, and phosphorous% of leaves were 18.30 ± 1.54, 4.41 ± 1.41, 6.44 ± 1.21, 1.02 ± 1.22, and 1.18 ± 1.02%. The mean moisture content, protein content, ash content, calcium, and phosphorous% of fruits was 58.49 ± 4.72, 11.15 ± 0.52, 11.45 ± 1.39, 1.56 ± 1.22, and 1.77 ± 1.26% [Table 7].

4. DISCUSSION

F. palmata is a lesser-known species, and the nutritional value of species is also not very well defined. *Ficus* species produce a large amount of fruit and seed, but the distribution of the selected species in the natural condition is restricted to small pockets. Fruit of *F. palmata* is edible for animals and humans; thus, they are collected extensively before maturation resulting in curtailed dispersal, regeneration, and germination. Very little information is available on the seed germination of the selected species, along with the fruit/seed maturation time. The timing of phenological events, mostly flowering, fruiting, seed fall, etc., is relatively less studied particularly in relation to changing climate.

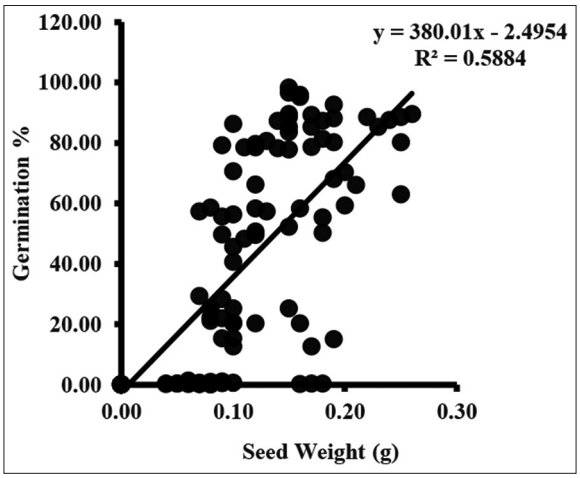

Figure 9: Relatyonship between seed weight and seed germination for *Ficus palmata.*

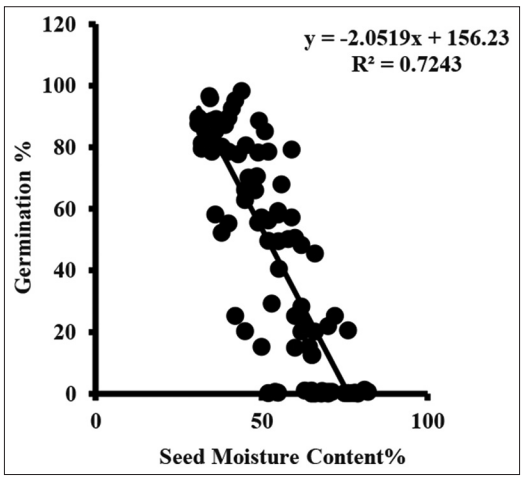

Figure 10: Relatyonship between seed moisture content % and seed germination for *Ficus palmata.*

4.1. Regeneration

Complete absence of seedlings and saplings in a forest indicates no regeneration [10]. Lack of sufficient regeneration is a major problem for mountain forests [23]. In the present study, *F. palmata* showed scattered distribution and low tree density. Seedlings were completely absent in all the studied sites. Saplings were present in all selected sites except site 1 but the density was low (22 to 67 ind/ha). Similarly, Jyotsna *et al*. [24] have reported the absence of seedlings and saplings of *F. roxburghii* in study areas of the Nainital district. Regeneration of species is dependent on internal community processes and exogenic disturbance [25-27]. reported *F. vasta* Forssk. and *F. thonningii* Blume. in not regenerating category. However, in Hazarikhil Wildlife Sanctuary, Bangladesh *F. hispida* Linn. (792 per ha) showed the highest number of seedlings and *F. religiosa* L. 408 seedlings per ha [28]. The absence of anthropogenic pressure appears to be the major cause of good regeneration. In wild edible plants availability of mature seed is always been a big problem. The poor natural regeneration of *Ficus* species indicates that seed sources are depleted through harvesting of immature and mature fruits. However, Malik *et al*. [10] have reported absence of seedlings and low saplings density in *F. roxburghii* in a protected area and its adjoining areas in Western Himalaya.

4.2. Phenology

The phenology of *Ficus* in relation to other forest trees have been less studied. *Ficus* species show various fruiting phenological patterns. The leaf changes can occur seasonally [29]. When we compare the findings of present study on phenological events of *F. palmata* with earlier studies we find that there is a paucity of information and very few studies have been conducted previously. There was very little variation in the timing of seed fall and leaf fall but leaf initiation was delayed by 1 month in comparison to earlier records in the present study. Most of the previous studies have shown flowering time between March and April but in the present study it was delayed by about 1 month and started from April, [7] has reported flowering between May and June. As per the available literature on *F. palmata* fruiting took place in the rainy season (July–August) and only once in a year but in present study fruiting was observed twice a year in March–May and October–December.

4.3. Seed Maturation

Color change is always considered a reliable indicator of maturity. In the present study, the color change of fruit from light green to dark purple in *F. palmata* appeared to be an important indicator of maturity. Diba *et al*.

Table 7: Mean Moisture content%, Protein%, Ash%, Calcium%, and Phosphorous% of leaves and fruits of *Ficus palmata*.

Species	Moisture%	Protein%	Ash%	Calcium%	Phosphorous%
Ficus palmata					
Leaf	18.30±1.54	4.41±1.41	6.44±1.21	1.02±1.22	1.18±1.02
Fruit	58.49±4.72	11.15±0.52	11.45±1.39	1.56±1.22	1.77±1.26

[30] reported the fruit color of *Ficus sur* changed from light yellow to pale brown at maturation. Moisture decline from maturing seeds is closely connected to maturity [31]. Lavania *et al*. [32] reported the moisture content decreased with development of maturity in *Acacia nilotica*. In the present study, maximum germination occurred when seed moisture content was between 35.02 and 42.33% in *F. palmata.* Similarly maximum germination was observed when the moisture content had declined in these species of *Ficus* such as *F. krishnae* and *F. lundellii* [33,34].

In the present study, the correlation between fruit/seed moisture content was negatively correlate with seed germination. Similarly in *Myrica esculenta* [35] found that correlation between seed moisture content and germination was negative. Tewari and Tewari [36] also reported the negative correlation between seed moisture content and germination in *P. cerasoides* in *A. indica* by [37].

4.4. Nutritive Value

During winter animal loose their body weight and milk production drops drastically when animals are mainly provided with fodder tree leaves and rice straw. This problem may be due to deciduous plants and composition and availability of nutrients during moisture stress condition. Protein, phosphorus, and calcium are very important for milk producing animals [38]. *Ficus* species are the main fodder tree species that are lopped during summer season to feed the animals [39]. In the present study, it was observed that value of ash content, protein, and calcium except phosphorous of leaf of *F. palmata* was relatively high compared to other species [40]. However, in *F. polita* ash and protein were higher compared to the present study in *F. palmata.*

5. CONCLUSION

The change in fruit color and range of moisture content of seeds when maximum germination occurs appears to be reliable physical indicators of fruit/seed maturity. However, we know very little about the adaptation traits of tree species about their reproductive phenology and germination behavior. How the species will respond to a warming climate and what will be its effect on its seed traits and on seeds on the ground needs further investigations. Most needed are studies on these lesser known wild tree species to understand the possible effects of climate change on such species that already occur in small pockets with low densities.

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7. AUTHORS' CONTRIBUTIONS

All authors made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; agreed to submit to the current journal; gave final approval of the version to be published; and agreed to be accountable for all aspects of the work. All the authors are eligible to be an author as per the International Committee of Medical Journal Editors (ICMJE) requirements/guidelines.

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9. CONFLICTS OF INTEREST

The authors do not have any conflicts of interest.

10. ETHICAL APPROVALS

This study does not involve experiments on animals or human subjects.

11. DATA AVAILABILITY

Tha data will be provided and made available as per the genuine interest and as per the journal policy.

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