Effect Of Seasonal Variation And Photoperiodism On Flowering Phenology In *Datura Innoxia* Mill.

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Abstract: Plant reproductive biology plays a significant role in conservation of biodiversity, because both in-situ and ex-situ conservation strategies are dependent on a thorough understanding of plant reproductive biology. Traditionally, flowering phenology has been seen as essential to a plant species' reproductive ecology. The field observation of flowering phenology largely highlighted the adaptive significance of flowering at a specific period in comparison to other individuals in the population or other species. Flowering phenology is significant because in this area of plant reproductive biology, we investigate the timing of recurrent biological events in flowers, the factors that influence these events timing with respect to biotic and abiotic forces, and the relationship between these phases in the same or different plant species. To assess the pattern of plant growth and development, phenological observation can be employed. Growth analysis has also been used to explain disparities in growth caused by inherited traits or environmental changes. The pattern of phenological occurrences can be used as a sign of changing climate because it affects how much food we can grow. This makes studying flowering phenology crucial. Temperature, precipitation, humidity and day length all have a direct impact on the phenological pattern of plants and flowers, and they fluctuate over the course of year when there are distinct seasons. In order to improve prediction of species responses to future climate change, phenological thinking can help in formulate generalization with practical application.

Keywords: Phenology, Biodiversity, Conservation, Climate change, in-situ, Population.

Introduction

The majority of plants in the plant kingdom are flowering plants, and they can reproduce both sexually and asexually. Flowering plants are noted for having reproductive organs that are their most distinctive features. The flowering time veryon abiotic conditions, including temperature, soil, humidity, rainfall and day length. Different species of plants bloom at specific times. Flowering phenology is the study of periodic occurrence in a plant's life cycle and how climate and ecological conditions vary seasonally and annually to influence them. Abiotic and biotic elements that are related to the same species or to other species may be the causes that influence the timing of flowering. Despite the fact that flowering phenology has traditionally been thought of as an essential component of a plant species' reproductive ecology, it has been observed in the field that flowering at a particular time is primarily important for adaption in comparison to other individuals in the population (Ollerton A.J.2003). The present study carried out on the *Datura innoxia* Mill. belongs to family Solanaceae,It is native to the South Western United States, Central and South Americaand introduced in Africa, Asia, Australia and Europe. *Datura innoxia*is commonly known as Pricklybur, Indian apple, Lovache, Moonflower, Toloatzin, Toloaxihuitl, Tolguache or Toloache. The name sacred Datura, which is more frequently used to refer to the similarly related *Datura wrightii*, is less frequently used for it. Nearly every civilization in the globe that has come in to contact with Datura species has treasured them as sacred visionary plant. Datura has been used for at least 3,000 years in the southwestern United States and even older in other regions of the world, according to archaeological data. With 9-12 species identified, the genus Datura is extensively distributed throughout the temperate and warmer regions of both the Old and New World. Large trumpet-shaped flowers are a distinguishing feature of Datura species, which are herbaceous spreading annuals or short-lived perennials. The scented flowers, which can be white, yellow, pink, or purple, give birth to a spiny capsule fruit that is filled with numerous seeds. *Datura innoxia* Mill. has also been grown as an ornamental plant all over the world due to its eye-catching big leaves, substantial white blooms and unusual thorny fruit. Although it is a widespread weed that grows everywhere in Rajasthan's climate and blooms most of the year, the plant is now classified as an invasive species in a number of places. As a result, different seasons can be used to study the plant's flowering phenology. The primary determinants of flowering phenology variation are thought to be climatic conditions. The key characteristics of plants that enables them to adapt to environmental changes and progeny reproduction is flowering phenology, which is the beginning of plant reproductive growth and a significant phase of general phenology (Corts-Flores et al., 2017; Konig et al., 2017).By observing biological processesincluding pollination, seed dissemination, seed germination and seeding settling, flowering phenology can reveal the effects of climate change on the fitness and biodiversity of individual plants (Boyle and Bronstein,2012; Davies et al.,2013). In order to increase the success of reproduction, plants have developed a multifaceted strategy. Examples including changes in fruit type and size colour of flower and flowering phenology (Kumar, 2016; Yan Wang et al., 2020).In temperate, tropical and subtropical regions, temperature and photoperiod are widely acknowledged as the primary abiotic stimuli for phenological changes. However, precipitation has also been recognised as a key factor that influences phenology in tropical and subtropical areas, arid regions and the Mediterranean regions. Changes in the flowering period have an impact on the pollination, seed ripening, dispersal and germination processes, as well as the behaviour of many key species.

Due to this, competitive interaction and even niche differentiation may be impacted by flowering time variations (Jianhao Zhang et al. 2018). Based on the foregoing, our attention was drawn to the impact of altering seasonal variation and photoperiodism on the flowering phenology in *Datura innoxia* Mill.

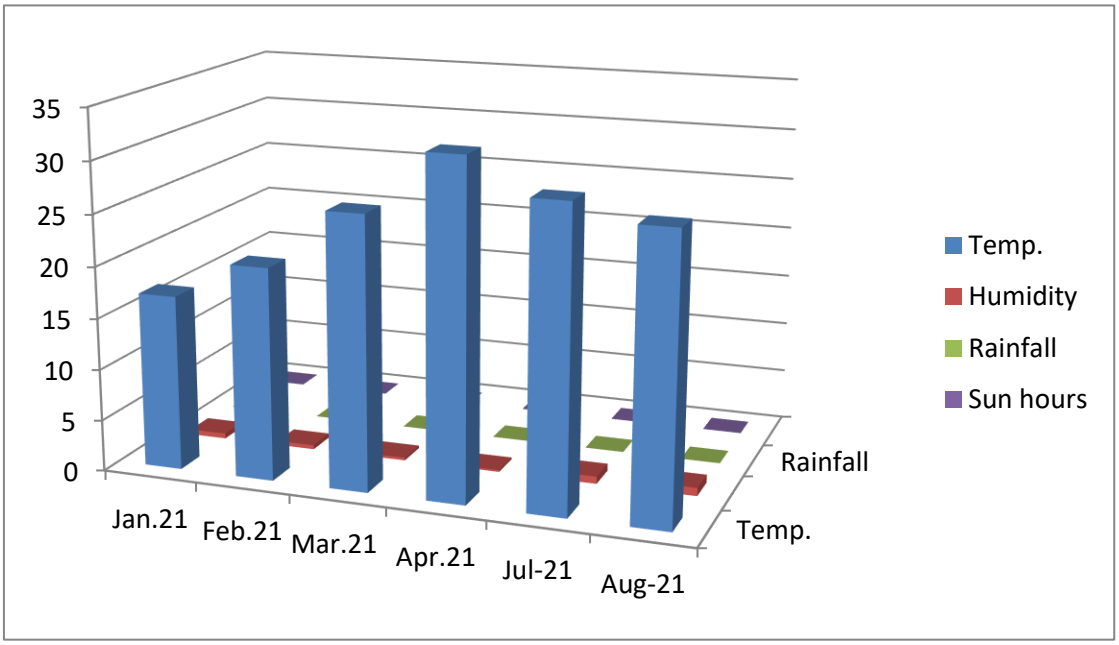
Material and Methods

Study Site- The study was conducted in Kota district of Rajasthan. The city of Kota is located in the Hadoti region, which in the southeast of Rajasthan. On a steeply tableland that is a portion of the Malwa Plateau, Kota district is situated along the banks of Chambal River. District Kota is located between latitudes 24.25° and 25.51° in the north and 75.37°- 77.26° in the east. The range of temperature is 26.7°C (max.) to 12.0°C (min.). The Kota district receives 660.6 mm of rain on average per year. The soil of Kota district is alluvial in origin. Deep to extremely deep soils that range in texture from clayey loam to clay are often devoid of calcareous minerals. The soil might be light brown or dark brown in colour. Daily field observations were taken to obtain flowering phenological data from year 2021 to 2022 during the peak blooming months of January through April and July through August. To collection daily measurements have been made throughout the flowering stage of the initial bud to fully developed flower and fruit. The effect of seasonal variation and photoperiodism on flowering phenology of given species as well as floral morphological characters in peak flowering period have been studied in the climate of Kota district of Rajasthan. The main characteristics of flowering Phenology which have been studied are first flowering date to last flowering date, flowering duration, time taken by a initial bud to fully developed flower, longevity of the flowers. Thestudy was made on 50 samples each in wildly growing population of *Datura innoxia* Mill.

TABLE–1

Average weather conditions of Kota district (Rajasthan) in selected monthsof flowering in year 2021.

Months	Average Temperature (In °C)	Average Humidity	Average Precipitation	Average day length
January2021	17°C	50%	7mm	9:00h
February2021	20.6°C	40%	6mm	10:00h
March 2021	26.4°C	26%	4mm	11:00h
April 2021	32.4°C	18%	4mm	11.00h
July2021	29°C	71%	294mm	10:00h
August 2021	27.4°C	79%	247mm	9:00h

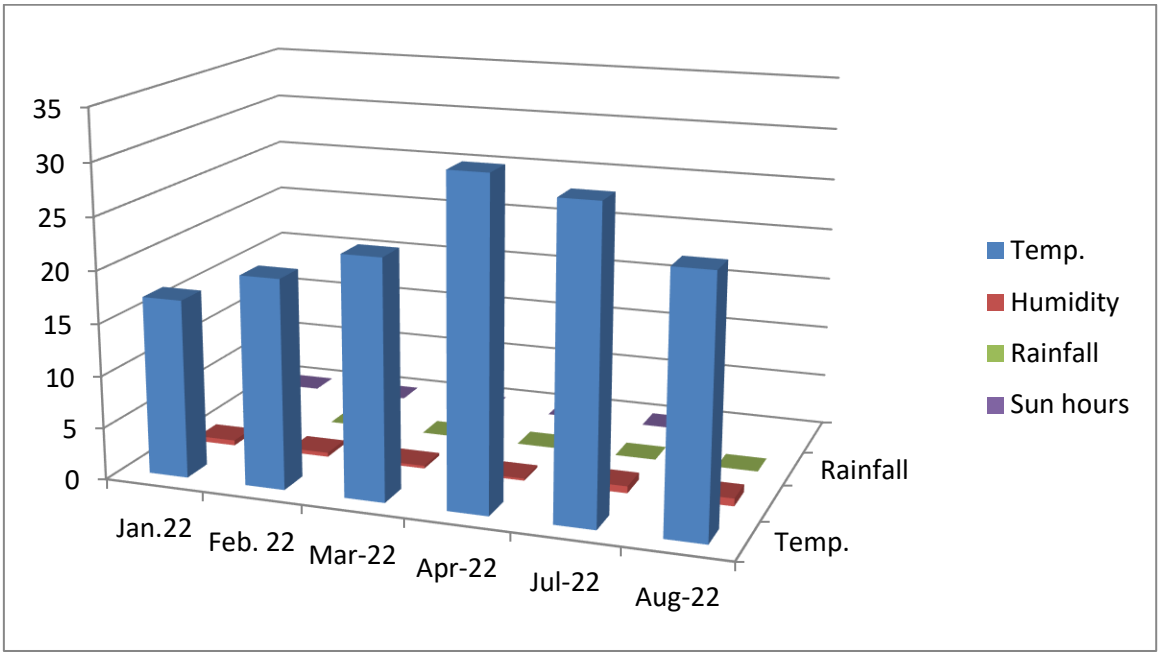


1.1 Graphical representation of average weather conditions in year 2021.

TABLE –2

Average weather conditions of Kota district (Rajasthan) in selected months of flowering in year 2022.

Months	Average Temperature (In °C)	Average Humidity	Average Precipitation	Averageday length
January2022	17.1°C	49%	6mm	9:00h
February2022	20°C	39%	2mm	10:00h
March 2022	22.8°C	26%	4mm	10:00h
April 2022	31°C	20%	4mm	12.7h
July2022	29.3°C	67%	298mm	10.9h
August 2022	24.2°C	74%	276mm	9:00h



1.2 Graphical representation of average weather conditions in year 2022.

Collection of Data

Timing of events is a concern in phenology. Mechanisms in plants control the time of blooming in order to make sure that flower emergence takes place under ideal circumstances. Environmental cues, particularly photoperiod and temperature, allow plants in temperate areas to adapt their flowering cycle to the changing of the seasons. These flower induction cues may also be used to inform the plant when to hibernate. Any attempt to explain how different elements affect the timing of flowering, according to Grainger (1939), would also appear to necessitate a connection between the time when flower bud was first produced and the timing of its emergence. It is well known that many plants produce their flower buds a long time before they blossom. In annuals, flowering appears to be an easy, direct, and time-consuming process where all meristems bloom and the life cycle is finished in a single year.

Observation and Findings

Floral Morphological Characteristics of *Datura innoxia* Mill.

Inflorescence is solitary, bisexual flowers grown in the bifurcations of the branches; peduncleis about 1.5cm long. Average length of calyx is 9.67±0.51cm, narrowly cylindrical, 5-6 lobed; lobes 0.8-1cm long, sometimes incompletely separated. Corolla is white, infundibuliform, with a tube 7.5±0.42cm .long, spreading gradually towards the apex and terminating in 5 small, subulate lobes. Stamens are inserted; anthers 8-10 mm long. Style 10-14 cm long; stigma0.2cm long. Well below anthers. The fruit is a globose or ovoid spiny capsule with numerous slender spines, about 3-5 cm in diameter, deflexed, spiny. Spines are numerous, slender, sharp, all about equal in length, of 14.86cm long; persistent base of calyx 2.5-3 cm long, very prominent. Capsule break irregularly after ripening andrelease brown seeds. Seeds are kidney shaped, compressed, 3.9±0.5 mm long.

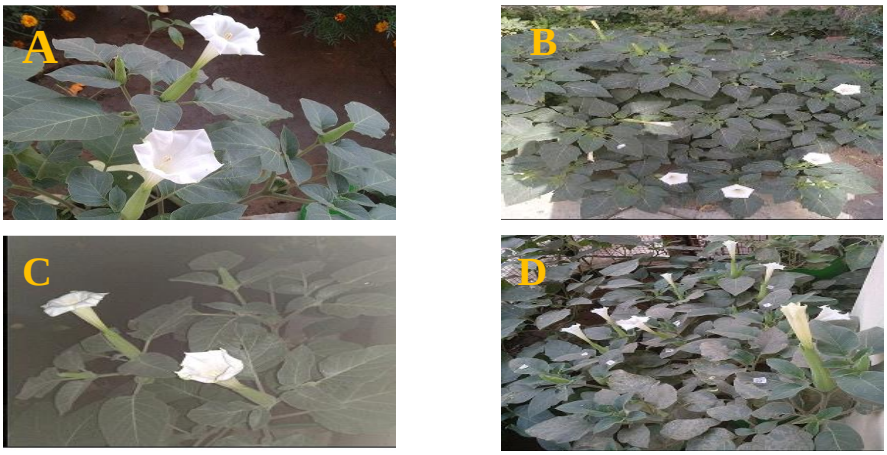


Figure-1

Datura innoxia Mill. Plant at blooming time, flowers at the time of anthesis,mature buds and flowers.

TABLE- 3

Morphological characteristic of the studied *Datura innoxia*Mill.

S. No.	Floral characters	Morphological Nature	S. No.	Floral characters	Morphological Nature
1.	Insertion	In fork of Branches	27.	Anther length	1.21cm.
2.	Number of flower / infl.	Solitory	28.	Anther width	0.2cm.
3.	Pedicel length	1.56cm	29.	Anther colour	Yellowish white
4.	Pedicel indumentums	Densely hairy	30.	Anther indumentums	Sparsely hairy
5.	Arrangement of calyx	Gamosepelous	31.	Ovary shape	Ovate
6.	Calyx length	9.67±0.51cm.	32.	Ovary length	0.5 - 0.8cm
7.	Calyx width	1.5±0.16cm.	33.	Ovary width	0.5cm.
8.	Calyx indumentums	Dense hairy	34.	Number of carpel	2
9.	Calyx colour	Light green	35.	Style length	13.92±1.42cm.
10.	Calyx Teeth Length	.0.8-1cm.	36.	Length of stigma	0.2 cm.
11.	Calyx Teeth shape	Unequal	37.	Stigma width	0.2cm.
12.	Calyx Teeth Number	5-6	38.	Capsule shape	Ovoid/ellipsoid shape
13.	Calyx apex	Acuminate	39.	Capsule length	4.26cm.
14.	Corolla Length	18.58±1.13cm.	40.	Capsule width	2.78cm.
15.	Corolla Width	3.2±0.33cm.	41.	Capsule L/W ratio	1.53cm
16.	Corolla Shape	Infundibuliform	42.	Capsule habit	Curved
17.	Corolla Tube	7.5 ± 0.42cm.	43.	Capsule surface	Spiny
18.	Corolla Funnel	≤ 5cm.	44.	Spine length	0.5 to 1cm.
19.	Corolla lobes length	1.5 -2cm.	45.	Spine numbers	≥ 350
20.	Corolla lobes apex	Cuspidate	46.	Number of valves in capsule	4
21.	Corolla lobes number	5	47.	Peduncle length	1.3-1.5cm.
22.	Corolla colour	White	48.	Seed length	0.25- 0.3cm.
23.	Calyx/Corolla ratio	≤0.5	49.	Seed width	0.2cm.
24.	Stamen number	Generally 5 sometime 6or7	50.	Seed shape	D shape or kidney shape
25.	Filament length	13.63cm.	51.	Mature seed colour	Dark brown
26.	Filament surface	Hairy	52.	Seed ornamentation	Alveolate

Figure 2

A- Mature bud just before the anthesis. B- Stigma protruding from the young bud showing the presence of cross pollination.

Figure 3
A-Elongated stigma shows protogyny stage. B- L.S. of buds and flowers. C- Flowers of *Datura innoxia* having different size. D- L.S. of mature flower.

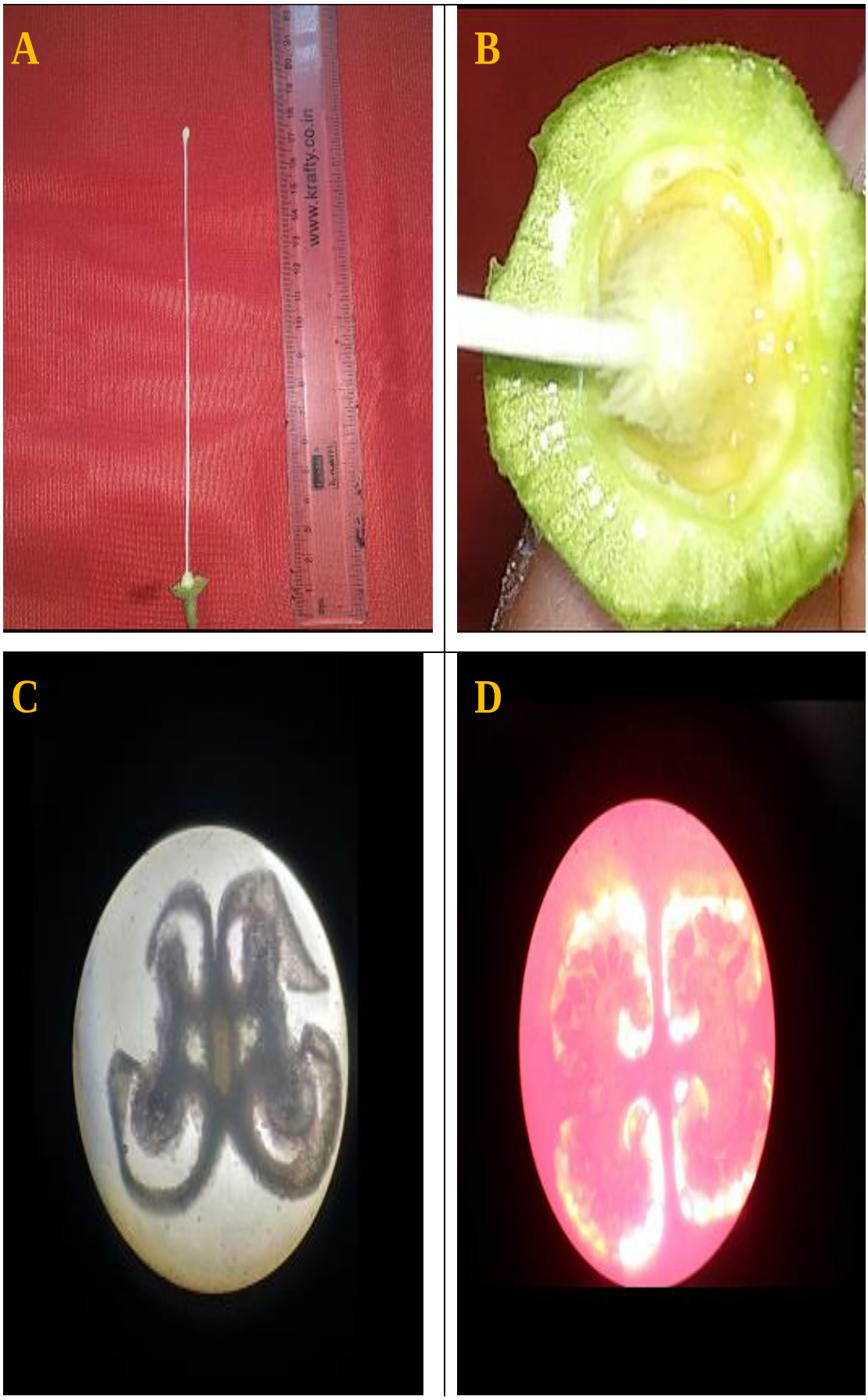


Figure 4
A- Size of mature style. B-5-nactaries surrounding the ovary. C- T.S. of anther. D- T.S. of ovary.

Figure 5

A- T.S. of fruit of *Datura innoxia* Mill. B- Young fruit with persistant calyx. C-Mature fruit after ripening.D- seeds dehiscanced by splitting of capsule.

TABLE-4

Flowering phenological observation in 2021

Month	Sample size	Size of initial bud	Size Of mature flower in cm	Average time of maturation of flower-days	Size of initial fruit	Size of mature fruit in cm	Average time of maturation of fruit-days
Jan.2021	50	.5cm	17.29±0.37	23.76±2	1cm	3.53±0.36	36.12±0.02
Feb.2021	50	.5cm	20.8±0.88	20.54±1.35	1cm	3.55±0.35	25.26±2.92
Mar.2021	50	.5cm	21.04±0.81	18.1±1.43	1cm	3.46±0.34	25.24±2.35
Apr.2021	50	.5cm	15.52±1.32	17.22±2.20	1cm	2.49±0.34	23.4±2.53
July2021	50	.5cm	17.96±0.88	28.2±2.02	1cm	3.57±0.37	35.3±3.76
Aug.2021	50	.5cm	17.34±0.37	22.82±2.30	1cm	3.42±0.35	36.76±2.77

TABLE-5

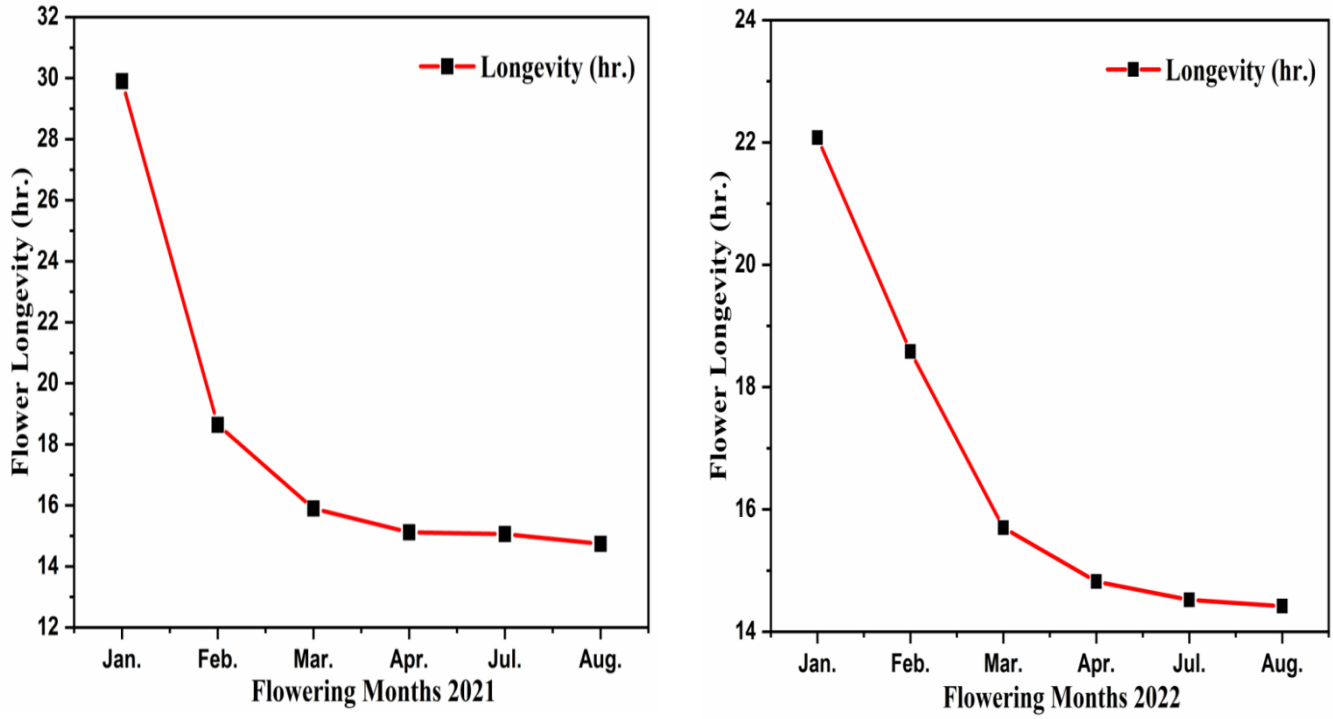
Flowering phenological observation in 2022

Month	Sample size	Size of initial bud	Size of mature bud in cm	Average time of maturation of flower-days	Size of initial fruit	Size of mature fruit in cm	Average time of maturation of fruit-days
Jan.2022	50	.5cm	17.73±0.48	26.18±2.39	1cm	3.41±0.35	37.94±2.42
Feb.2022	50	.5cm	20.76±1.02	21.82±2.21	1cm	3.79±0.26	27.28±1.65
Mar.2022	50	.5cm	21.24±0.77	19.3±2.25	1cm	3.56±0.31	27.1±2.21
Apr.2022	50	.5cm	15.98±1.40	19.12±2.40	1cm	2.84±0.38	25.42±3.05
July2022	50	.5cm	18.04±0.92	25.34±2.83	1cm	3.69±0.33	35.22±3.18
Aug.2022	50	.5cm	17.52±0.40	22.14±0.76	1cm	3.56±0.38	35.64±2.96

TABLE-6

Showings mean value of Flower Longevity in 2021-2022.

Flowering Months	Duration of flower	Flower Longevity in hours	Flowering Months	Duration	Flower Longevity
Jan.2021	7pm-5pm	21.9h±0.91	Jan.2022	7pm-4pm	22.08±1.04h
Feb.2021	7pm-1pm	18.64h±0.59	Feb.2022	7pm-2pm	18.58±0.67h
Mar.2021	7pm-11am	15.9h±0.71	Mar.2022	7pm-10am	15.7h±0.64h
Apr.2021	7pm-10am	15.12h±0.74	Apr.2022	7pm-9pm	14.82±0.69h
July2021	7pm-11am	15.06h±0.71	July2022	7pm-10am	14.52h±0.61h
Aug.2021	7pm-10am	14.74h±0.63	Aug.2022	7pm-9am	14.42h±0.49h



2. Graphical representation of average flower longevity (hr.) in year 2021-22.

Result and Discussion

Floral morphology- *Datura innoxia* is a tuberous-rooted, annual subshrub that typically reaches a height of 76.04±0.13cm. It is evergreen plantthe stems and leaves are covered with short and soft grayish hairs, giving the whole plant a grayish appearance. It has elliptic smooth-edged leaves with pinnate venation. All parts of the plant emit a foul odor similar to rancid peanut butter when crushed or bruised, The flowers of *Datura innoxia* Mill. are solitary terminal and giving a quite pleasant appearance when they bloom at night. Flowers are large in size white coloured, tubular/ trumpet or bell shaped, 17 to 21cm long, perigynous, actinomorphic, pentamerous, bisexual, hermaphrodite and complete. Flowers are bracteate, ebracteolate and calyx is green in colour, gamosepalous 9.67cm±0.51 long. Petals are white in colour and average length in 18.58±1.18 cm. There are 5 hairy stamens withlong filiform filaments attached to corolla at the base.Stamens are epipetalousabout 14.86±1.20cmlong; the anthers are dithecus, tetrasporangiate with average length of 1.21±0.26cm. Anthers dehisce by two longitudinal slits. Dehiscence is facilitated by radially enlarged endothecial walls. The filament of stamen is 13.63±1.42cm long. Anthers are basifixed attached on long filament. The gynoecium is 13.92cm±1.43 long, bicarpillary, syncarpic with a superior 1.0±0.24 cm long ovary having axile placentation. The fruit set is considerably high (100%). Mature fruit is capsulespheroid to ovoid shape, with spiny surface 4.26±0.41cm × 2.78±0.41cm in size, splits by four chambers.In young stage, the fruit is green but it turns to brownish after ripening. The number of fruits per plant at blooming season is 17±2. There are 250-400 ellipsoid-oblong and compressedseeds per fruit which are kidney shaped yellow or brown in colour. According to Hepper et al. *Datura innoxia* is a pubescent perennial which retain 10-12 lobed flowers and has entire or slightly toothed leaf margins. Capsule of *Datura innoxia* borne on a curved stalk, which does not dehisce by regular sized valves (Happer, 1963; Alva, 1973; Chaudhary and Revri, 1983; Weaver and Warwick, 1984; Wells et al., 1986; Chaudhary and Akram, 1987; Boulos and El-Hadidi, 1995).*Datura fastuosa* has nodding capsule which dehisce irregularly, leaves entire and flower are 5-10 lobed. *Datura metal* is similar to *Datura innoxia* in habit, but it is glabrous and has very short spines on capsule. (Herper, 1963; Backer, 1973; Holm et al., 1979; Wells et al., 1986;Robertson, 1989; Trophicos,1998). In *Datura stramonium* flowers are actinomorphic, solitary,axillary in fork of branching stem,pedicel short 2-10 mm long, densely hair,calyx 5 or 6, tubular, light green or purpulish green, corolla 5 or 6 white or violet tubular, infundibular 50-100 mm long, 5 or 6 lobed, stemens 5 or 6, whitish brown or purple, equal 40-60 mm inserted near base of corolla, stigma two lobbed capsule ovoid to ellipsoid, erect, dehisced regularly by 4 valves in basipetal order (Rania, A. Hassan and Wafaa, M. Amer, 2019).

Flowering Phenology- *Datura innoxia* Mill. usually grown as a weed along road sides and dung rich area also germ as an important medicinal and ornamental plant in gardens. It blooms twice in a year from January to April and in July, August. Flowering phenology of *Datura innoxia* is affected by the various climatic factors like temperature, humidity and rainfall, but day length (photoperiod) affect the most. Buds appear in the month of January when temperature is low (average 17°c) and day length is short about 8-9hours. The smallest size of emerging bud is 0.5cm. Floral buds' formation initiated in successive acropetal order at the fork of branch. Flowers opened between 19:00h and 19:30h. At this time the rate of maturation is very low, its takes 23-26days for maturation. Average length of mature flower is about 17.29±0.36 cm. February-March is the appropriate timing for blooming in *Datura innoxia* with optimum temperature and photoperiod and other climatic condition. In this month the average temperature is 20.6°c with 10 hours of photoperiod. The emerging bud maturesin about 20.54±1.35 days and the size of mature flower is 20.8±0.88 cm. As the temperature and day length increase the timing of bud maturation and flower longevity is decrease.In the month of March when the average temperature is 26.4°c, the maturation time of bud is18.1±1.43 days with maximum length of flower 21.4±0.81 cm. April is the last month of flowering, in this month the rate of flowering is very low due to high temperature about 32.4°c and 11-12hours of photoperiod. At this time the size of mature flower is decreased 15.52±1.32cm and the bud maturation time is 17.22±2.21 days. May- June is the timing of fruit maturation and seed dehiscence, mature capsule splits irregularly or by four splitting lines. Seeds are dehisced through the splitting of fruit and spread in soil near the plant. After 20-25 days' seeds germinate and grow up for next season. July-August is the second blooming period in *Datura innoxia* with appropriate climatic conditions, when the flowers emerge in new plants. In the month of July when average temperature is 29°c with 9hours of photoperiod, at this time the size of mature flower is 17.96±0.88cm and timing of maturation is 28.2±2.02 days, size of mature fruit is 3.57±0.38 cm, and time taken to maturation is 35.3±3.76 days. In the month of August average temperature is 27.4°c with 7 hours of photoperiod, at this time the flowering rate becomes decreased &the size of mature flower is 17.34±0.37 cm and the bud maturation time is 22.82±2.30 days. Mature fruit is 3.42±0.35 cm in size with their maturation time of 36.76±2.77 days. After the month of August there is no flowering because it is the timing of fruit maturation and seed dehiscence. After the sufficient time of maturation, the ripe fruits (capsule) split and seeds are dehisced, and ready to emerge new generation for next flowering season. Flowering phenology is one of the important events which strongly influence the reproductive success of a species (Rathcke and Lacey, 1985; Fenner, 1998). Different climatic factors including temperature and humidity play an important role in successful fruiting and seed set (Kevan and Baker, 1983; Hudedamani and Yadav, 2013).

Flower Longevity-Flower longevity is highly variable species to species. It has been recorded frequently in time slots of 1-4 hours depending on the species for several days (Shivanna, 2014; Shivanna and Tandon, 2014).A flower bud took 20 to 26 days to attain maturity. Flowers began to open around 19:00h during night and the process was completed in about 11-12h. Anthers are elongated and bilobed, erect on the day of anthesis. The anther dehiscence takes place day before of anthesis. Second day onwards stamens and petals deflexed more towards outside and stigma became stiffened; petals changed into creamish yellow and started to wither.Rathcke (2003) remarked that longevity of flower is presumed to reflect equilibrium among amplified pollination achievement and the floral maintenance cost. Longevity of flower of a species reveal the ideal time for exposure of flower to extent the maximum achievement for fitness of male as well as female floral organ (Routley and Husband, 2005).In the month of January time of anthesis is 17:00h to 16:00h and flower longevity is 21.9±0.9hours. In February the longevity of flower is 18.64±0.59 hours and duration of process is 19:00h to 14:00h. In March and April flower longevity time became 15.9±0.71hours

and 15.12±0.75 hours respectively. In the next flowering season July the duration of flower longevity is 17:00h to11:00h with 15.06±0.71h. In August longevity of flower is about 14.74±0.63 hours. Primack (1985) also stated that plant species (tropical) often have low floral longevities of only one day, feasibly because of high rates of floral deterioration due to microbial diseases (Shykoff et al., 1996) or may be for predation. In contrast, Blionis and Vokou (2001) observed longer floral durations have frequently been corrected to low pollinator abundance in different localities.

Conclusion

Present study shows the floral morphological characteristics as well as the flowering phenology of *Datura innoxia* Mill. in two different seasons. The findings of study show that, in both flowering periods the pattern of flowering phenology varies slightly due to some climatic factors.The most affecting factors are temperature and photoperiod. *Datura innoxia* is short day plant, the optimum temperature and photoperiod required for blooming are 20-26°c and maximum 10 hours respectively. So the February-March and July-August are the appropriate timing of flowering. In both of season the mature buds of *Datura innoxia* became largest in their size, 21-22cm at the time of anthesis and the maturation time of bud is 15-20days. Besides that, the very high and very low temperature and more than 10hours photoperiod decreased the flowering rate and flower longevity also.

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