Int.J.Curr.Microbiol.App.Sci (2018) *7*(4): 3797-3814

International Journal of Current Microbiology and Applied Sciences
***ISSN: 2319-7706* Volume 7 Number 04 (2018)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2018.704.428

Phenological Growth Stages of Saffron (*Crocus sativus* L.) under Temperate Conditions of Jammu & Kashmir-India

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Keywords

Developmental stages, Weather, Morphological criteria, Phenology, Saffron (*Crocus sativus* L.)

Article Info

Accepted:
30 March 2018
Available Online:
10 April 2018

A B S T R A C T

Phenological studies at different stages of crop growth are important to mitigate the ill effects of climate change to which saffron is very much sensitive and to predict the production system modules involving cultural practices and crop protection systems. Study on phenological growth stages of natural temporal sub-populations of Kashmir saffron (*Crocus sativus* L.) carried over 2 years revealed that the ontogenesis period of saffron with above ground organs is almost similar to period showing no organs above ground. Among ontogenic periods vegetative phase is the longest period (142 days), followed by flower ontogenesis (60 days), dormancy (55 days), reproductive (41 days),bud sprouting phase (36 days) and plant senescence (30 days). Timing of the phenological stage is observed to be closely related to weather parameters particularly air temperatures. Dormant corms show reduced impression of mother corm. No change in the size of the bud (the length of the outermost cataphylls) was observed from the time of corm lifting in early May to late June, some 55 days after leaf senescence. Incubation period of 97 days lead to increase in size of the apex followed by the formation of sprouts with complete flower embedded in whorl of tepals (Gynoecium, stamen, tepals). Initial corm weight has been found responsible for increased number of flowers/spathe, more activation of meristematic regions and greater biomass leading to efficient replacement corm production. The flowering stage starts when the sprout (usually composed of three sheaths) emerges from the soil surface and is influenced by weather parameters. Vegetative stage is most critical as chilling requirement for vernalization is received during 66 days (11th November to 15th February). The period is critical for development of replacement corms which largely depends on efficient translocation of photosynthates from source to sink. Phenological growth stage is completed with plant senescence with production of full mature corms showing impression of mother corms. A staging system for development saffron (*Crocus sativus* L.) that relies on simple, visual, non-destructive criteria was proposed to allow for quick determination of development stage. This system can be used by both farmers and for experimental trials.

Introduction

India has a distinction of being second largest producer of saffron globally after Iran. Most expensive spice appreciated because of its colouring, flavouring and aroma capacity is being called “the red gold” (Poggi, 2009). Saffron produced in India is worldwide known

for its best quality and is recognized to be produced in the state of Jammu and Kashmir (Salwee *et al.,* 2012). Seasonal weather changes are significant in the saffron growing areas areas and saffron plants have been able to develop survival mechanisms coping with adverse conditions derived from higher or lower temperatures as well as extreme drought events (Wareing and Phillips, 1981; Pérez Bueno, 1988).

Vela *et al.,* (2013) laid emphasis on the characterization of the phenological stages for saffron crop production as cultural practices depends largely on importance of certain critical stages of crop growth (Vela *et al.,* 2013).Many reports are available on morphology and annual cycle of saffron plant (Chrun-goo *et al.,* 1983; Botella *et al.,* 2002; Carmona *et al.,* 2006; Poggi, 2009). Nevertheless, there are currently no universally used keys to describe the entire development cycle of this plant.

The study of identifiable changes that occur during the course of plant development occurring due to cell differentiation and organ initiation and are influenced by environmental factors is defined as plant phenology (Hodges, 1991, Meier *et al.,* 2009a). Time interval different stages of morphogenesis (developmental stage) of an organ, is defined as a developmental phase (Streck *et al.,* 2003). An organ can be identified using magnification (hand lens or microscope) or in some cases by the naked eye. Understanding of developmental events including developmental phase, a code (a number, a set of letters or a combination of letters and numbers) and a description (criteria) of each developmental stage followed by their sequencing is an important tool to standardise communication with all those concerned with crop production directly or indirectly (Zadoks *et al.,* 1974; Fehr and Caviness, 1977; Counce *et al.,* 2000).

For several agricultural crops developmental scale has been put forth viz., soybean (Fehr and Caviness, 1977), maize (Hanway, 1966; Ritchie *et al.,* 1993), wheat (Large, 1954; Zadoks *et al.,* 1974) and rice (Counce *et al.,* 2000), and fruit crops such as persimmon tree (Garcia-Carbonell *et al.,* 2002), olive tree (Sánz-Cortés *et al.,* 2002), coffee tree (Morais *et al.,* 2008) and mango tree (Delgado *et al.,* 2011). Some floral crops also have phenological scale such as *Rosa* sp. (Meier *et al.,* 2009b), *Zinnia elegans* (Gonçalves *et al.,* 2008), Saffron (Horacio Lopez-Corcoles *et al.,* 2015) and *Gladiolus* (Schwab *et al.,* 2015). A world-wide Coding system commonly used to integrate phenological studies is based on extended BBCH-scale proposed by Hack *et al.,* (1992). Staging system of Schwab *et al.,* (2015) is easier for end users such as extension agents and growers than a system coded only with numbers such as the Zadoks' scale (Zadoks *et al.,* 1974) and the BBCH system (Meier *et al.,* 2009a). Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir is premier University in India doing research on saffron. Based on this background, the objective of this present investigation was to create a staging system for describing the development of saffron that relies on simple, visual and non-destructive criteria that are easy-to-use.

Materials and Methods

The experimental site has been famous ab-initio by its original name Padampore situated along the banks of river Vatista, which flows down to North-Southward bank-the direction in which the prominent historical places such as Lethpora, Chandhara, Konibal, Dussu, Ladhoo, Shar, Khrew, Wuyan and Balhama are inhabited. Pampore is located at 34°01′N and 74°56′E with an average elevation of 1574 meters, about 25 km south-east of Srinagar in Kashmir. Studies were carried out on the temporal sub population of Saffron

available at Saffron Research Station a constituent Research Station of SKUAST-Kashmir during 2015-16 and 2016-17.

Corms of different weight (>10g, 8-10g, <8g) were uprooted at 15 days interval timing and after removal of protective cataphylls, the shoot apex was examined under trinocular microscope. A further characterization of flower initiation was performed viewing longitudinal sections through the central part of the apex and naked shoot apex was observed after removal of protecting sheath of cataphylls.

A plant development system needs four main features (Counce *et al.,* 2000): (a) dichotomous criteria based on plant morphogenesis (i.e. discrete morphological criteria which are either present or absent) to identify developmental stages and phases; (b) a basis on actual events rather than indications; (c) a wide range of geographical application and (d) visible criteria or markers readily identifiable with a small hand lens (about 10× magnification).

Following the approaches provided by Horacio Lopez-Corcoles (2015) and Schwab *et al.,* (2015) Saffron morphogenesis was divided into six stages: corm dormancy, flower ontogenesis, bud sprouting, reproductive, vegetative and plant senescence. Studies were carried out on ten plants that were randomly sampled when they reached each developmental stage. Package of practices to raise a good crop were followed as per recommendations of SKUAST-Kashmir (Nehvi *et al.,* 2011, 2017). To study impact of weather parameters on saffron morphogenesis meteorological data was recorded from MET observatory Saffron Research Station Pampore. Based on this background, the present investigation was carried to describe the phenological growth and developmental stages of saffron plant.

Results and Discussion

The ontogenesis of Kashmir saffron (*Crocus sativus* L.) spread over 6 developmental stages from 1st May to 25th June (corm dormancy), 26th June to 25th August (flower ontogenesis), 26th August to 20th October (bud sprouting), 1st October to 10th November (Reproductive), 11th November to 30th March (Vegetative) and 1st April to 30th April (Plant senescence) under temperate conditions of Kashmir is presented in Table 1. The ontogenesis period of saffron with above ground organs (183 days). is almost similar to period showing non above ground organs (182 days). However, Molina *et al.,* (2005) reported longer period of saffron without above ground organs. Study revealed that among various ontogenic periods vegetative phase is the longest period (142 days), followed by flower ontogenesis (60 days), dormancy phase (55 days), reproductive (41 days), bud sprouting phase (36 days) and plant senescence (30 days). Timing of the phenological stage is observed to be closely related to weather parameters particularly air temperatures (Minimum and Maximum). Relative Humidity on an average was observed to be uniform over different timings of phenological stages. The earlier rise in temperature from 26.1ºC (dormancy) to 29.3ºC (flower ontogenesis) during summer (26th June to 26th August) accelerates flower initiation. Average air temperature of 27.5ºC with a total precipitation of 418.90 mm/ha (33.70% of total precipitation) favoured shoot and root development. When the average maximum air temperature reaches below 20.0ºC anthesis is favoured under temperate conditions of Kashmir. Similar findings of importance of mean air temperature of 15.0ºC to 17.0ºC for anthesis in saffron have also been reported by Molina *et al.,* (2015). A low average temperature of 11.4ºC accompanied with sub-zero temperatures (-0.33ºC) ensures development of replacement corms through better photosynthetic accumulation resulting

in efficient source sink relationship (Figure 1, Table 2).

Dormancy phase

Corm is a sub soil organ, composed mainly of parenchymatous tissue which stores substances needed for flowering and sprouting. On an average, corms vary in size from 1.5 to 3.9cm in diameter and 1gm to > 20gm in weight and are tunicated with varying shapes from flattened to ovoid or subglobose. The sheath which represents the expanded base of the sheathing leaves (scales) surrounds the corm. The tunic has fine reticulate, or parallel fibers extended upwards around 5cm above the neck of the plant. Apical, subapical and auxillary buds are observed in internodes and are also seen protected by dark reddish scales. 80% of all the buds are located in the upper central part of the corm and can be classified into two groups: buds of a mixed nature that develop vegetative- reproductive sprouts, that is, which can produce leaves and flowers (Apical and sub-apical buds) and leaf producing or axillary buds. As the diameter of the corm increases, the buds tend to group together, so that, majority can be found in one, two or three internodes (Salwee and Nehvi, 2014). Because of the flowering in apical sprout, a depression is found in the central apical area of the corm where floral remains are observed. Average number of sprouts range from 1 to 11 with average number of reproductive sprouts ranging from 0 to 3. During dormancy (Stage 0) saffron corms apparently show neither morphological change nor external growth and the apex looks like a resting bud with protective cataphylls (Figure 2). However, Le Nard and De Hertogh (1993) reported that there do exist internal physiological and morphogenetic changes during dormancy period. Dormant corms show reduced impression of mother corm. No change in the size of the bud (the length of the outermost cataphylls; flower score SO, Figure 1d) was observed from the time of corm lifting in early May to late June, some 55 days after leaf senescence. During this time, the buds made no growth and seemed to be dormant. No flower initials were present in the resting buds). Similar phenology for corm dormancy in gladiolus has also been reported by Schwab *et al.,* (2015). During dormancy saffron corms receive about 28% of total annual precipitation (347.85 mm) accompanied with high relative humidity. Wet weather conditions predispose corms to the infection of *Fusarium species* and *Rhizoctonia solini* if management practices are not followed in time. Saffron fields are subjected to first hoeing during dormancy period prior to 25th June to facilitate aeration of soil. But leaving the soil with wide air spaces triggers the rot infections due to increased soil temperature and humidity and therefore proper soil dressing immediately after first hoeing is advocated to save corms from damage (Nehvi *et al.,* 2017).

Flower ontogenesis

Flower ontogenesis was studied from 26th June to 25th August as also reported by Molina *et al.,* (2004). The numerical scale used for flower differentiation was based on the stages of meristem development as defined by Beyer (1942). The main stages are illustrated in Table 1 and Figure 3. Incubation period of 61 days (26th June to 25th August) at an average day and night temperature of 29.39ºC and 16.5ºC, morning and evening relative humidity of 82.9% and 55.5% associated with a total precipitation of 294.5 mm lead to increase in size of the apex followed by the formation of leaf primordia (flower score, F0.1; Figure 3a). Shortly afterwards the sheathing leaves started to grow at a faster rate than the shoot apex and protecting the growth of the young shoot and the scape. In succession the formation of stamen primordia (flower score, FO.2; Figure 3b), leaf primordia development is at the base of meristem (flower

score FO.3; Figure 3c) and the formation of gynoecium (flower score, FO.4; Figure 3d) were observed. The stamens were observed to be much longer than the leaves, a consequence of the hysteranthy of this species. All the flower parts were already differentiated by the end of August. Results are in confirmation with the studies of Molina *et al.,* (2004) carried under filed conditions of Albacete Spain but contradict for number of days taken and incubation temperature elapsed from the initiation of the leaves to the initiation of gynoecium. Koul and Farooq (1984) reported that although important flower ontogenic process leading to differentiation of floral and vegetative buds take place, nothing is observed externally. During this period, growers prepare the corms for fresh plantation after digging followed by sorting and cleaning to rejuvenate their saffron crop.

Bud sprouting

Flower ontogenesis is followed by bud sprouting (Table 1, Figure 4, 5 and 6). There are four stages within the sprouting phase: BS (Figure 4a, 4d and 4g), BS.1 (Figure 4b, 4e and 4h), BS.2 (Figure 4c) and BS.3 (Figure 4f and 4i). Under temperate conditions of Kashmir all the developmental stages of the sprouting phase occur beneath the soil between 26th August to 30th September (36 days) under average maximum air temperature of 27.5ºC, minimum air temperature of 11.25ºC, morning relative humidity of 84%, evening relative humidity of 52.6% and precipitation of 92.25mm (Figure 1 and Table 2). Sprout initiation from the apical and axillary buds accompanied with fibrous root formation from the corm disc has been observed to be related to initial corm weight. Corms weighing >8g attain a length of 13cm during the sprout incubation period of 36 days (26th August to 30th September) whereas, corms weighing <8g attain a length of 4.6 cm during this period thus would result in delayed initiation of above ground organs. Study on uprooted corms revealed that corms weighing >10g attains a length of 4 cm in 15 days (9th September) which further increases to 12 cm (19th September) and finally reaches to 13 cm by 30th September (Figure 5). Sprouts with an average length of 4 cm recorded fully developed floral parts (Gynoecium, stamens, flower score, BS.1: (Figure 4 e and 4h) and at 13 cm length sprouts recorded complete flower embedded in whorl of tepals (Gynoecium, stamen, tepals, flower score, BS.3: Figure 4f and 4i). Initial corm weight is an indicator of number of floral primordial per spathe (Figure 6). Corms weighing <8g usually develop single sprout which lack any floral primordial due to reduced spathe width of 1.2 cm. (Figure 7cand 7f), 4whereas corms weighing >10g recorded multiple sprouting associated with 3 flowers/spathe with maximum sprout width of 2.7cm (Figure 7a and 7d). Corms weighing 8-10g recorded sprout width of 1.7 cm revealing 1 flower/spathe (Figure 7b and 7e). Study confirmed that increase in sprout width by 41-58% which is directly associated with initial corm weight results in proportionate increase in number of flowers/spathe by 200%. Differences in corm size or seasonal variations have been considered the cause of these differences in transition dates (Negbi, 1999). Flower formation is directly related to corm size (Negbi *et al.,* 1989; De Mastro and Ruta, 1993) and a quantitative relationship between these two parameters was found (Negbi *et al.,* 1989). However, the role of ambient temperatures on flower bud differentiation and subsequent flowering is largely unknown. Plessner *et al.,* (1989) reported the formation of a similar number of flowers in corms forced either under uncontrolled conditions (at around 15ºC) or in a phytotron at a 17/12ºC (day/night) cycle.

Reproductive

Despite its importance, the flowering process in saffron has not been characterised precisely.

The life cycle of saffron is similar in all producing countries, but there are wide differences in the timing of events (Botella *et al.,* 2002). Flowering occurs during autumn (October–November). During the month of October, sprouts are visible above the ground and the sub-soil stem is short. Very fine roots also start to protrude in the form of crown from the third basal internodes, possibly reaching a length of 5 cm. The flowering stage starts when the sprout (usually composed of three sheaths) emerges from the soil surface. Developmental stages are denoted as R stages (Figure 8). Flowering (sprout are visible above ground and saffron flower are within the sheath. Flower score R.1; Figure 8a), blooming (unopened flowers with floral organs enclosed by the tepals. Flower Score R.2; Figure 8 b), anthesis (opened tepals with visible stigma and anthers. Flower Score R.3; Figure 8c) and flower senescence (when the tepals dehydrate and falls on the ground. Flower ScoreR.4; Figure 8d) are major developmental stages (Table 1).

Saffron flowering (emergence of sprouts above ground) is controlled by air temperature. Study confirmed that maximum air temperature of 17.5ºC accompanied with minimum air temperature of 1.8ºC, morning relative humidity of 86.1% and evening relative humidity of 65.5% was ideal for saffron flowering under temperate conditions of Kashmir (Figure 1 and Table 2). Above 20ºC maximum day temperature recorded from 1st October to 20th October inhibited saffron flowering thereby indicating influence of temperature on saffron flowering. However results of reduction in flowering outside the range of 23-27ºC has been reported by Molina *et al.,* (2005). Saffron flowering followed by blooming and anthesis generally starts in the second fortnight of October and lasts up to the first week of November. Flowers emerge in 3-4 flushes with massive emission known as covering in the 2nd flush. Each flush lasts for 2-6 days. Similar reports have been suggested by Dhar and Mir, (1997) and Nehvi *et al.,* (2017). Anthesis phase lasts for 4-6 days after which the saffron flowers record flower senescence. Un-opened flower buds are visible 2-3 days after flowering (Sprout initiation). The purple saffron flowers have three violet sepals and three petals together called tepal. At the bottom, they are joined in the perianth tube. Tepals are violet in color with darker vein. Flowers are erect. The perianth tube serves as a stem between the ovary and the flower. Perianth segments are almost equal, 3-6 cm in length and 1-2.5 cm wide, oblanceolate to ovate. The flower has an underground ovary, a style (5 to 9cm long), dividing at the top into three red trumpet like stigmas (2 to 3cm long) which when dried form the commercial spice- the saffron The flowers of *Crocus* are bisexual. Pistil is central with a tubular ovary with a style. The style is long and pale yellow that is branched to an orange red three-branch stigma. Androecium consists of three distinct stamens three in number and smaller than perianth. Anthers are on top of the filaments. There are three stamens joined to the outer perianth segments but are smaller than perianth. The length of the filament is 10mm and that of the anthers 15 to 20 mm. The anthers are yellow in color and the filament white in colour. However in the apparent groove of the pedicel, the filaments are slightly pigmented and appear light purplish (Salwee *et al.,* 2017). Structural variations for tepal number, tepal shape, tepal colour, flower weight, Stamen number, Pistil length, stigma number and stigma shape are visible immediately after anthesis (opening of flower) and are valued if variations are heritable. Tepals followed by pistil and stamens contribute most to the mass of flowers with an average weight of 326 mg. Once the pistil is separated from the flowers, large quantities of bioresidues composed of tepals and stamens is obtained (301 mg) accounting for 92.14% of the total flower weight.

Table.1 The developmental staging system of saffron

Stage	Period	Phase	Code	Description
0	Ist May to 25th June	Dormancy	S0	saffron corms apparently show neither morphological change nor external growth and the apex looks like a resting bud with protective cataphylls
1	26th June to 25th August	Flower ontogenesis	FO	
	26th June to 14th July		F0.1	Shoot apex has increased in size and leaves differentiated at the flank
	15th July to 25th July		F0.2	Stamen initiate
	26th July to 15th August		F0.3	Base of meristem covered by the developing leaf primordia
	16th August to 25th August		F0.4	Gynoecium formation
2	26th August to 30th September	Bud Sprouting	BS	Sprout Initiation and fibrous root development and Longitudinal section showing floral initials in vascular bundle
	26th August to 9th September		BS.1	Sprout length reaches to 4 cm length and Longitudinal section showing floral parts in the sprout
	10th September to 19th September		BS.2	Sprout length reaches to 12 cm and Longitudinal section showing floral parts in the sprout
	20th September to 30th September		BS.3	Sprout length reaches to 13 cm and Sprout showing complete floral parts embedded in whorl of tepals
3	1st October to 10th November	Reproductive	R	sprout are visible above ground and saffron flower are within the sheath
	1st October to 10th November	Flowering	R.1	Unopened flowers with floral organs enclosed by the tepals
	1st October to 10th November	Blooming	R.2	opened tepals with visible stigma and anthers
	1st October to 10th November	Anthesis	R.3	opened tepals with visible stigma and anthers
	1st October to 10th November	Flower Senescence	R.4	When the tepals dehydrate and falls on the ground
4	11th November to 3oth April	Vegetative	VE	
	11th November to 31st December		VE.1	Leaves from the apicular bud region are first visible above ground and leave grow at 20% of final length
			VE.1	Leaves from the lateral bud region are first visible above ground and leaves grow at 10% of final length
			VE.1.1	Leaves grow at 80% of final length
	Ist January to 15th February		VE.2	Development of corm, lateral bud and terminal bud contractile roots
	16th February to 30th March		VE.3	Formation of replacement corms
			VE.3.1	Leaves grow at 100% of final length
			VE.4	Leaf and corm development completed
5	Ist April to 30th April		VE.5	Leaves show signs of prominent senescence
			VE 5.1	Development of fully mature daughter corms

Table.2 Weather parameters under temperate conditions of Kashmir studied over different phenological stage

Phenologicl Stage	Max Temp(ºC)			Min Temp (ºC)			RH 1(%)			RH 2(%)			Precipitation (mm)		
	2015-16	2016-17	Average	2015-16	2016-17	Average	2015-16	2016-17	Average	2015-16	2016-17	Average	2015-16	2016-17	Total
1st May to 25th June	24.3	27.9	26.1	10.2	11.5	10.8	77.6	76.5	77.0	58.8	49.4	54.1	189.6	67.8	128.7
26th June to 14th July	27.8	31.7	29.7	16	16.5	16.2	78.9	75.6	77.2	60	47.5	53.7	76.7	11.6	44.15
15th July to 25th July	29.2	30.1	29.6	18.1	16.6	17.3	87.5	81.4	84.4	67.2	48.9	58.0	114.5	34.6	74.55
26th July to 5th August	29.5	28.8	29.1	18.2	16.8	17.5	87.1	87	87.0	60.1	56.8	58.4	169.4	62.8	116.1
6th August to 15th August	30.7	26.6	28.6	17.8	16.6	17.2	83.3	85.5	84.4	58.3	53.4	55.8	0	30.8	15.4
16th August to 25th August	29.9	29.4	29.6	15.2	14.1	14.6	79.4	84.3	81.8	50.4	52.9	51.6	82.8	5.8	44.3
26th August to 9th September	27.6	26.2	26.9	11.9	13.4	12.6	83.4	85.2	84.3	50.8	64.3	57.5	4.6	69	36.8
10th September to 30th September	26.2	29.0	27.6	9.5	10.4	9.9	80.2	87.3	83.7	52.9	42.8	47.8	61.8	3.1	32.45
1st October to 20th October	23.5	26.2	24.8	7.1	5.1	6.1	89.1	82.4	85.7	56.4	36	46.2	54.1	6.7	30.4
21st October to 10th November	14.8	21.1	17.9	3.9	-0.3	1.8	87.4	84.9	86.1	68.8	62.2	65.5	3.5	0	1.75
11th November to 31st December	10.9	12.3	11.6	-1.1	-3.0	-2.0	88.9	92.4	90.6	68.5	53.1	60.8	27.4	4.0	15.7
1st January to 15th February	10.3	5.7	8	-2.1	-1.9	-2	91.8	91.5	91.6	59.3	72.7	66	56.8	438.4	247.6
16th February to 30th March	15.6	14	14.8	1.6	4.4	3	86.1	81.2	83.6	53.6	55.2	54.4	224.9	197.9	211.4
1st April to 30th April	18.7	19.9	19.3	6	6.5	6.2	87.6	81.9	84.7	68.9	58.1	63.5	116.8	321.5	219.15

Fig.1 Ontogenesis of Kashmir Saffron viz-a-viz weather parameters averaged over two years

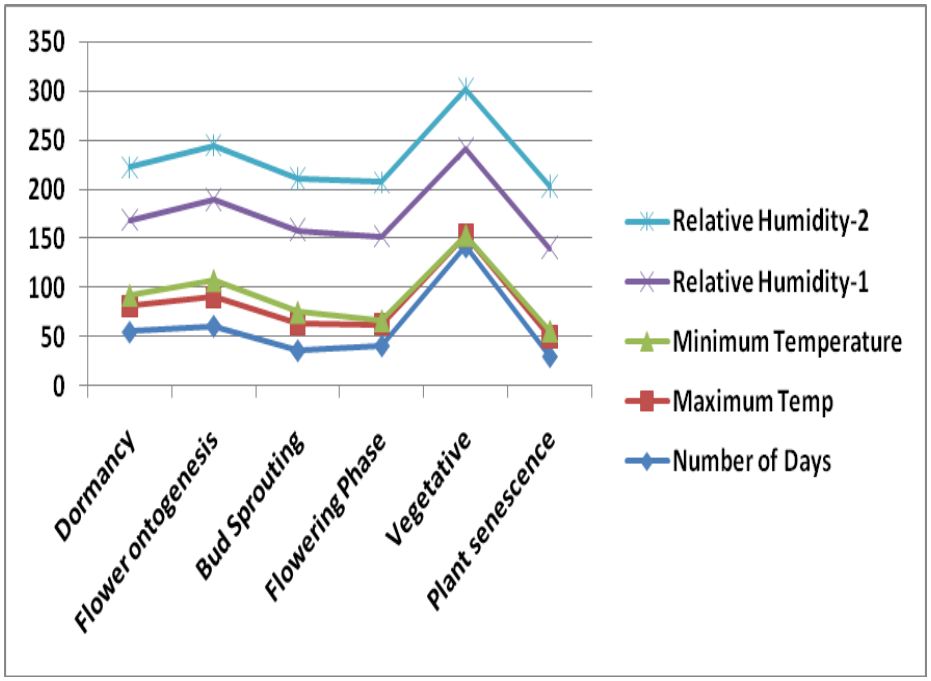

Figure 1

Fig.2 Corm Dormancy Phase (S0). a) Dormant corms with tunic. b) Dormant corm with mother corm residue. c) Naked corm showing dormant meristimatic regions. e) The apex of dormant corm looks like a resting bud with protective cataphylls

Figure 2

Fig.3 Flower Ontogenesis Phase (FO). a) Shoot apex has increased in size and leaves differentiated at the flank (FO.1). b) Stamen initiate (FO.2). c) Base of meristem covered by the developing leaf primordia. The stamens are much longer than the leaves, a consequence of the hysteranthy of this species (FO.3). e) Gynoecium formation (FO.4)

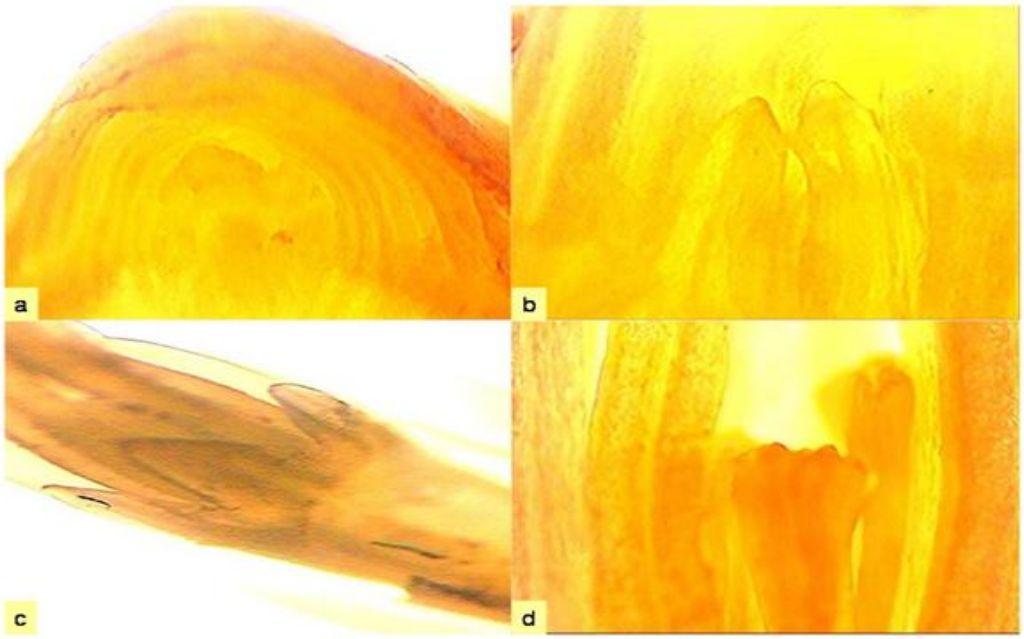

Figure 3

Fig.4 Bud Sprouting (BS). a,) Sprout Initiation and fibrous root development.(BS). b,) Sprout length reaches to 4 cm length (BS.1). c) Sprout length reaches to 12 cm (BS.2).d, g) Longitudinal section showing floral initials in vascular bundle (BS). e, h) Longitudinal section showing floral parts in the sprout.(BS.1).f,i) Sprout length reaches to 13 cm and Longitudinal section showing complete floral parts embedded in whorl of tepals (BS.3)

Figure 4

Fig.5 Impact of corm weight on sprout length over different periods of sprouting

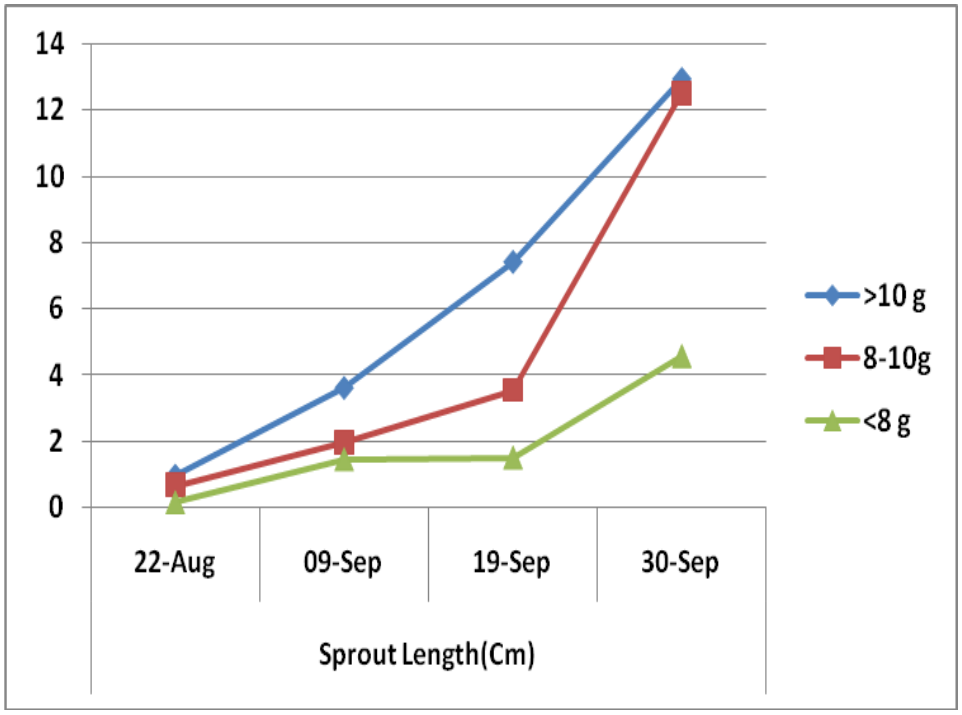

Figure 5

Fig.6 Impact of corm weight on number of flowers/sprout and sprout width

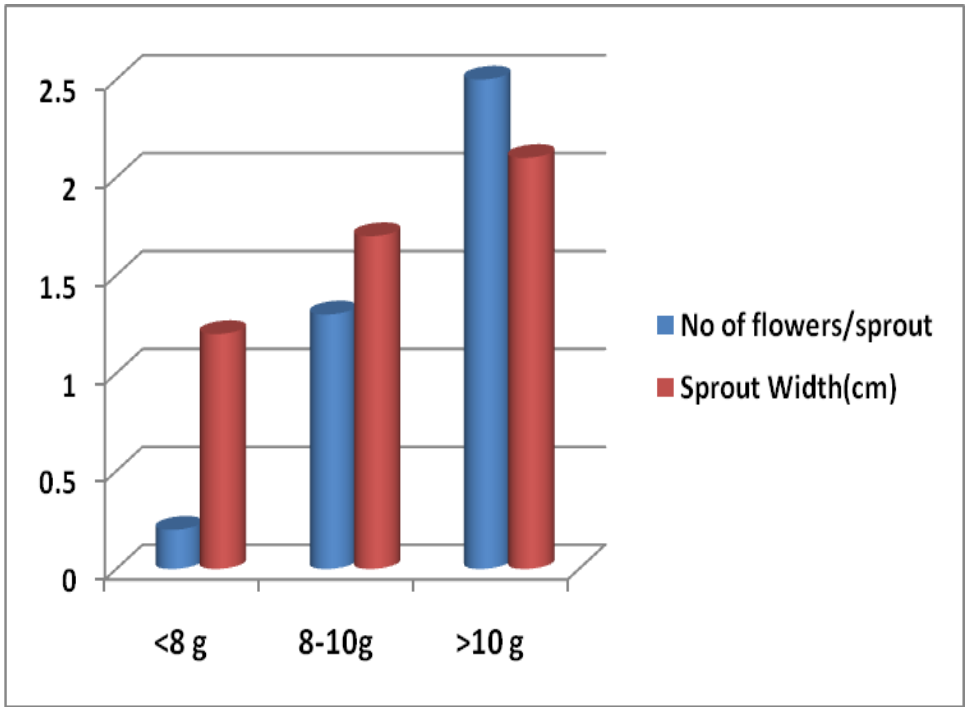

Figure 6

Fig.7 Effect of corm weight on number of flowers/sprout and sprout width (cm) a)>10g Corm weight showing profuse activation from apical and axiullary buds. b) 8-10g corms showing activation from apicular region) <8g corm showing slow sprout growth. d)>10g corms showing 3 flowers/ spathe with 2.7cm sprout width. e) 8-10g corm showing 1 flower/spathe with 2.1cm sprout width f),<8 g corm showing no flowers/spathe with 1.2cm sprout width

Figure 7

Fig.8 Reproductive Phase(R).a) Flowering: Shoots (cataphylls) breaking through soil surface. Flower cataphylls are visible above ground, enveloped by its bracts. Flower cataphylls still closed (R.1). b) blooming (unopened flowers with floral organs enclosed by the tepals. (R.2), c), anthesis (opened teplas with visible stigma and anthers. (R.3), d,) flower senescence. Tepals dehydrate and falls on the ground (R4)

Figure 8

Fig.9 Vegetative phase. (VE). a) Leaves from the lateral bud region are first visible above ground (VE.1). b) Leaves growth at 80% of final length, (VE.1.1), c), Development of corm, lateral bud and terminal bud contractile roots (VE.2), d) Formation of replacement corms. (VE.3). e) Leaves grow at 100% of final length (VE.3.1). f) Leaf and corm Development completed (VE.4)

Figure 9

Fig.10 Effect of corm weight on number of leaves

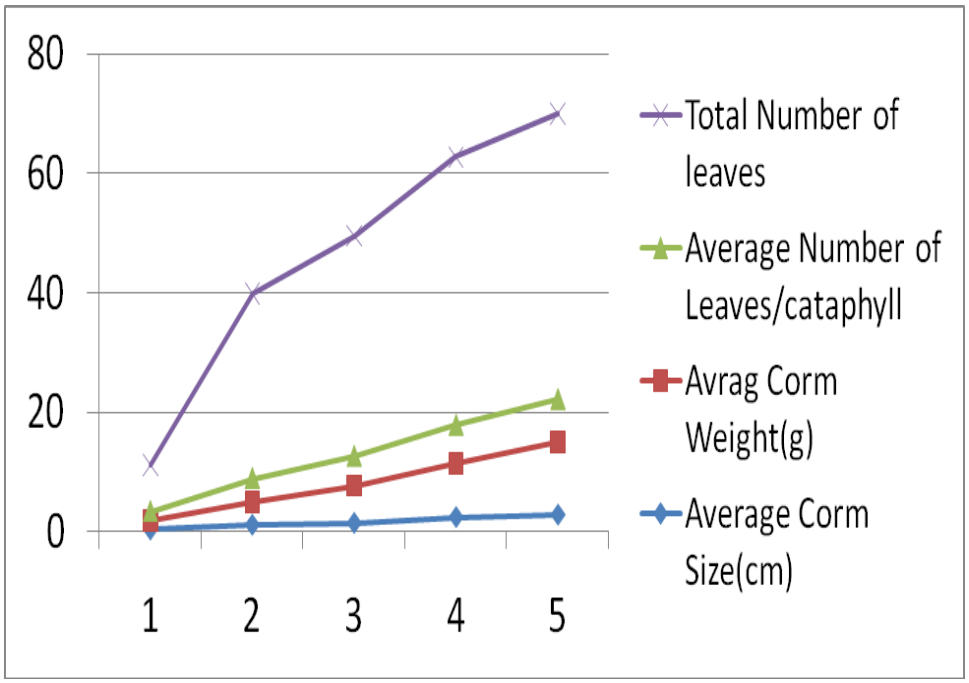

Figure 10

Fig.11 Periodical incremnt in leaf length duribng vegetative phase

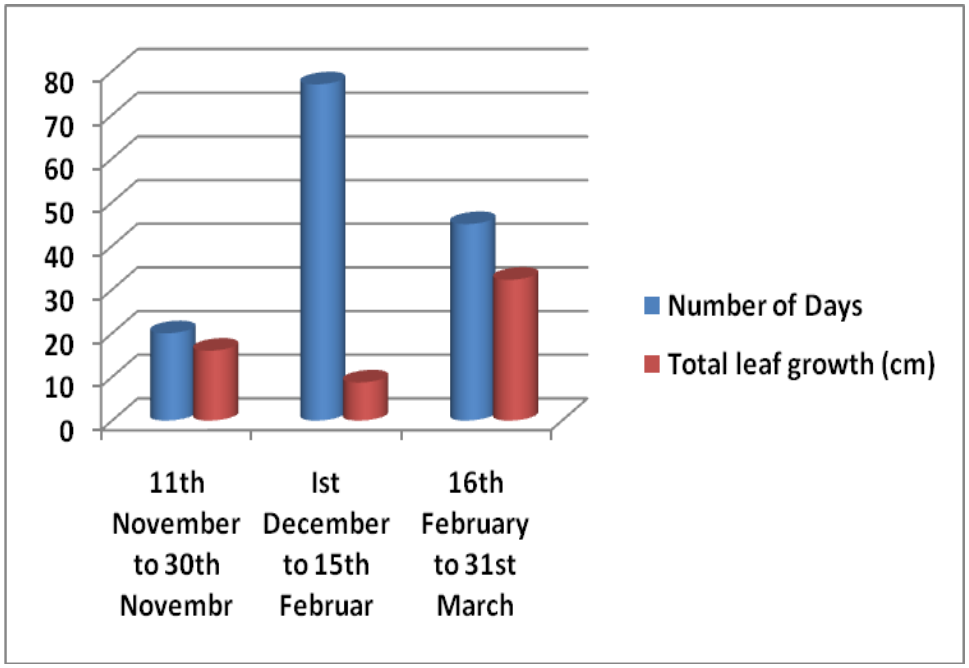

Figure 11

Fig.12 Plant senescence (R). a) Leaves show signs of prominent senescence (VE.5). b) Development of fully mature daughter corms (VE.5.1)

Figure 12

About 1,30000 flowers which weigh over 42.38kg are required in Kashmir to obtain 1 kg of saffron spice taking into account that stigmas lose 75% of their fresh weight during dehydration process followed traditionally in Kashmir. Hence about 39.04 kg of bioresidues are generated in the production of 1 kg of saffron spice.

Vegetative

Vegetative phase is the most important and critical stage of plant phenology as during this the plant receives 1100 chilling hours that is requisite for vernalization. During vegetative phase the crop receives an average maximum temperature of 11.4ºC, average minimum temperature of -0.33ºC, morning relative humidity of 88.6%, average evening relative humidity of 60.4% and precipitation of 474mm (Figure 1and Table 2). Chilling requirement for vernalization is received during 66 days (11th November to 15th February) observing an average minimum temperature of -2ºC associated with a maximum air temperature of 9.8ºC.

Vegetative phase starts when the shoot (usually composed of three sheaths) emerges from the soil surface. Vegetative developmental stages are designated as V stages, beginning at VE (emergence of the sheaths above the ground) and extend until the last leaf is visible (Figure 9). Vegetative phase lasts for 142 days (11th November to 30th March) (Figure 1). There are four stages within the vegetative phase: Flower score VE.1 (Figure 9a), flower score VE.1.1 (Figure 9b), flower score VE.2 (Figure 9c), flower score VE.3 (Figure 9d) Flower score VE.4 (Figure 9e) and flower score VE.5 (Figure 9f). Foliar structures begin to appear from 3-5 tubular tunics of white colour known as cataphylls. Cataphylls protect and strengthen stems in the process of appearance on the surface and protect the corms once formed from dehydration and possible lesion. 5-11 green leaves or monophylls between 1.5 and 2.5 mm wide are found per sprout and are called bristles and can measure up to 50 cm. In saffron, leaves can be synanthous or hysteranthous at flowering time. However if the irrigation is started early leaf appear before flowering transferring the hysteranthous behaviour of saffron into synanthous behaviour. The number of leaves are positively correlated with the size of the corm. The number of leaves is also influenced by the position of the bud on the planted corm (Figure 10). The base of the leaf is expanded forming the upper cap corm tunic. The blades are linear lanceolate. Study revealed that corms weighing 12.2 g with a corm size of 2.9cm recorded maximum number of leaves (48)/plant and maximum number of leaves per cataphyll (7). Similar effect of corm weight for incremental increase in number of leaves was recorded by corms weighing 8.9g, 6.2g, 3.8g and 1.4g revealing 45, 37, 31 and 7.8 number of leaves/plant, respectively (Figure 4). Maximum leaf growth (32.25cm) is observed during 16th February to 30th March (45 days) at an average growth of 0.75cm/day followed by 16 cm achieved @ 0.80cm /day in 20 days (11th November to 30th November). However least growth (8.74cm) is observed in 77 days (1st Decmber to 15th February) observing low temperatures (Figure 11).

During 45 days (1st January to 15th February) corm, lateral bud and terminal bud contractile roots are developed, whereas fibrous contractile roots are developed prior to flowering. In every corm 8-14 fibrous contractile roots are formed. Corm contractile roots are produced from fibrous root rings, but rather originate from the peripheri. About 1-2 contractile roots are produced in every corm, Lateral bud contractile roots originate from the base of lateral buds and continue to grow and become contracted during the

Senescene. About 3-5 lateral bud contractile roots are developed. Terminal bud contractile roots appear in the base of apical bud. First they are seen as small tuberous root and are thicker than the other types. Their number generally varies from 2-3/corm. Corm depth is an important factor for development of contractile roots.

Maryam *et al.*, (2004) also reported similar results. Formation of replacement corms (Recaptuation stage) is another most important stage of vegetative phase. Stage is economically important because formation of replacement corms contribute to important corm attributes viz., multiplication ratio, big corm index and flower raising index. Study revealed that replacement corms (daughter corms) initiate from apical and axillar buds from January followed by development of replacement corm from lateral buds depending upon the initial corm weight. Faster development of replacement corms depends on better source (leaves) and sink (replacement corms) relationship. Better relationship improves big corm index (proportion of bigger corms to the total number of developed corms). Escribano *et al.*, (2000) also reported importance of better source sink relationship

Plant senescence

Plant senescence becomes prominent from Ist week of April when leaves show signs of prominent senescence (Flower Score VE.5; Figure 12a). After 30 days of downward translocation of photosynthates from source into sink fully mature daughter corms are developed with reduced impression of mother corms (Flower Score VE.5.1; Figure 12b). Plant senescence is completed under maximum temperature of 19.3ºC, minimum temperature of 6.2ºC accompanied with morning and evening relative humidity of 84.7% and 63.5%, respectively (Figure 1). Stage is sensitive to corm rot because plant receives about 219.15 mm rainfall during this phase.

Acknowledgement

Authors thankfully acknowledge the financial support provided by Ministry of Agriculture Govt of India under National Saffron Mission Project

References

Botella O, de Juan JA, Muñoz MR, Moya A, López-Córcoles H, 2002. Descripción morfológica y ciclo anual del aza-frán (*Crocus sativus* L.). Cuadernos de Fitopatología 71: 18-28.

Carmona M, Zalacaín A, Alonso G, 2006. El color, sabor yaroma del azafrán especia. Altaban Ediciones, Albacete, Spain

Chrungoo N, Koul KK, Farooq S, 1983. Carbohydrate changes in corms of saffron crocus (*Crocus sativus* L.) during dormancy and sprouting. Trop Plant Sci Res 1 (4): 295-298

De Mastro, G. and Rute, C. 1993. Relative between corm size and saffron (*Crocus sativus* L.) flowering. Acta Horticulturae 344: 512-517.

Dhar, A. K. and Mir, G. M. 1997. Saffron in Kashmir VI. A review of distribution and production. Journal of Herbs, Spices and Medicinal Plants 4: 83-90.

F.A.Nehvi.2011. Good Practices for Saffron Cultivation in Kashmir " A Practical Manual. SKUAST-K Publication

Fehr W.R., Caviness C.E. 1977. Stages of Soybean Development. Ames, IA, USA: Iowa State University of Science and Technology (Special Report, 80).

Garcia-Carbonell S., Yagüe B., Bleiholder H., Meier U., Augusti M. 2002. Phenological growth stages of the persimmon tree (Diospyroskaki). Annals of Applied Biology, 141, 73–76.

Hanway J.J. 1966. Growth stages of corn (*Zea mays* L.). Agronomy Journal, 55, 487–492.

Hodges T. 1991. Introduction. In Predicting Crop Phenology, pp. 1–2. Ed T. Hodges. Boston, MA, USA: CRC Press.

Horacio Lopez-Corcolesm, Antonio Brasa-Ramos, Francisco Montero-García,, Miguel Romero-Valverde and Francisco Montero-Riquelme.2015.Phenological Growth stages of saffron Plant (*Crocus sativus* L.) according to the BBCH Scale. Spanish journal of Agricultural Research 13(3):e09sc01

Koul, K. K. and Farooq.S.1984.Growth and differentiation in the shoot apical meristem of the saffron plant (*Crocus sativus* L) Indian. Bot.Soc.63: 153-160

Large E.C. 1954. Growth stages in cereal – illustration of the Feekes scale. Plant Pathology, 3, 128–129.

Le Nard M, De Hertogh AA, 1993. Bulb growth and development. In: The physiology of flower bulbs; De Hertogh A and Le Nard M (eds), pp: 29-43. Elsevier Science Pub, Amsterdam, The Netherlands.

Meier U, Bleiholder H, Buhr L, Feller C, Hack H, Hess M, Lancashire PD, Schnock U, Stauss R, van den Boom T, Weber E, Zwerger P, 2009. The BBCH system to coding the phenological growth stages of plants – His-tory and publications. Journal Für Kulturpflanzen,z 61:41-52

Meier U., Bleiholder H., Buhr L., Feller C., Hack H., Heß H., Lancashire P.D., Schnock U., Stauß R., Van Den Boom T., Weber E., Zwerger P. 2009a. The BBCH system to coding the phenological growth stages of plants – history and publications. Journal für Kulturpflanzen, 61, 41–52.

Molina RV, Valero M, Navarro Y, Guardiola JL, Garcia-Luis A, 2005. Temperature effects on flower formation in saffron (*Crocus sativus* L.). Scientia Hort 103: 361-379.

Negbi, M. Saffron cultivation: Past, present and future prospects.P.,1-17.In: M. Negbi (ed) Saffron (*Crocus sativus* L) Harwood, Amesterdam 1999

Negbi, M., Dagan, B., Dror, A. and Basker, D. 1989. Growth, flowering, vegetative reproduction and dormancy in the saffron crocus *(Crocus sativus* L.*).* Israel Journal of Botany 38: 95–113.

Nehvi, F.A., Salwee Yasmin, Sabeena Naseer, Shaheena Nagoo, Niyaz Ahmad and Bashir Ahmad Elai. 2017. Good practices for saffron production under high density plantation in Jammu and Kashmir. Published by Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir

Pérez Bueno M, 1988. El azafrán: cultivo-enfermedades rendimientos-industrialización. Mundi Prensa Libros. Madrid, Spain. 155 pp.

Plessner O, Negbi M, Ziv M, Basbe D, 1989. Effects of temperature on the flowering of the saffron crocus (*Crocus sativus* L.): induction of hysteranthy. Isr J Bot 38: 1-7.

Poggi LM, 2009. Problemáticas y nuevas perspectivas tecnológicas para la producción de azafrán. Horticultura Argentina 28: 39-6

Ritchie S.W., Hanway J.J., Benson G.O. 1993. How a Corn Plant Develops. Ames, IA, USA: Iowa State University of Science and Technology, Cooperative Extension Service (Special Report, 48)

Rosa V. Molina, Amparo Garcia-Luis, Virginia Coll, Clra Ferrer, Miguel Valero, Yolnda Navarro and Jose L. Guardiola. 2004. Flower formation in the saffron crocus (*Crocus sativus* L).The role of temperature. Acta Horticulturae 650:39-47

Salwee Yasmin, F. A. Nehvi, J. K. Dhar, Sabina Naseer, Shaheena Nagoo, Gowhar Ali and Asif A. Qureshi. 2017. Saffron Improvement improvised methods. In: Quality and Quantum Improvement in field crops. Edited by C. P. Malik, Shabir Hussain Wani, Himakshi Bhati-Khuswaha and Ritsh Kaur. Publisher: Agrobios (India) Publication.PVT Ltd Jodhpur.PP225-264

Salwee Yasmin, F.A. Nehvi and Shafiq A Wani.2012. Saffron-The Goden Condiment A Review of R and D Interventions. SKUAST-K Publication

Sánz-Cortés F., Martínez-Calvo J., Badenes M.L., Bleiholder H., Hack H., Llácer G., Meier U. 2002. Phenological growth stages of olives trees (*Olea europaea*). Annals of Applied Biology, 140, 151–157Sánz-Cortés F., Martínez-Calvo J., Badenes M.L., Bleiholder H., Hack H., Llácer G., Meier U. 2002. Phenological growth stages of olives trees (*Olea europaea*). Annals of Applied Biology, 140, 151–157.

Schwab, N.T., Streck, N.A., Becker, C.C., Langner, J.A., Uhlmann, L.O and M.R. Ribeiro M B.S. 2015. Phenological scale for the development of Gladiolus. Ann Appl B iol 166: 496–507

Streck N.A., Weiss A., Xue Q., Baezinger P.S. 2003 Incorporating a chronology response function into the prediction of leaf appearance rate in winter wheat. Annals of Botany, 92, 181–190.

Vela P, Salinero C, Sainz MJ, 2013. Phenological growth stages of Camellia japonica. Ann Appl Biol 162: 182-190

Wareing PF, Phillips IDJ, 1981. Growth and differentiation in plants. Pergamon Press, 343 pp

Zadoks JC, Chang TT, Konzak CF, 1974. A decimal code for growth stages of cereals. Weed Res 14: 415-421

How to cite this article:

Salwee Yasmin and Nehvi, F.A. 2018. Phenological Growth Stages of Saffron (*Crocus sativus* L.) under Temperate Conditions of Jammu and Kashmir-India. *Int.J.Curr.Microbiol.App.Sci.* 7(04): 3797-3814. doi: https://doi.org/10.20546/ijcmas.2018.704.428