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Research Article

Study the phenology, growth and reproductive behavior of *Calendula officinalis*

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ABSTRACT
The experiment was conducted to study the phenology, growth, and reproductive behavior of Calendula officinalis under field conditions. Seeds were sown in the first week of December. In phenological studies, vegetative growth was undertaken up to March; flowering (anthesis) initiated simultaneously in the month of February and continued till mid-April; fruiting and seed maturation also occurred simultaneously from mid-April to early May and death/senescence was observed from early May onwards. Growth attributes viz., plant height, basal stem diameter, the number of leaves plant-1, leaf biomass, stem and branches biomass, flowers, and fruits biomass and root biomass studied increased with the advancement of growth stages (vegetative, flowering, and maturity stage) under field conditions. However, the root/ shoot ratio decreased with the advancement of the growth stage. Reproductive behavior such as number of flower heads plant-1, number of seeds head-1, seeds output (numbers per plant), seed yield (g/plant), germination of seeds produced, and reproductive capacity was observed as 51, 40.3, 2055.7, 6.1, 86.67, and 1783.02 at maturity stage in field conditions.
Keywords: *Calendula officinalis, growth, yield parameters, reproductive capacity*

INTRODUCTION
Calendula officinalis L. commonly known as pot marigold in English belongs to the family Asteraceae (Compositae). Its name comes from the Latin word (calend) meaning the first day of each month because this plant has a long flowering period. The plant is native to the Mediterranean zone, the Middle East, and Central Europe. This plant has been grown in European gardens since the 12th century. It is not only a springboard for monasteries and gardens but has an array of uses in drugs, foods, feed, beverages, dye, culinary, cosmetics, perfumery industries, and at ceremonial religious occasions (Kalvatchev et al., 1997), efficient pesticide (Martin, 2005). It is cultivated as an ornamental plant in countries viz., Iran, Palestine, Iraq, Saudi Arabia, Egypt, Libya, Tunisia, Algeria, Morocco, Canary Islands, Southern Spain Turkmenistan, Afghanistan, Pakistan, and Kashmir until its medicinal properties were known (Mozafariyan, 2003). Pot marigold is being grown as a medicinal drug in Germany, Australia, Czech, Austria, Switzerland, Hungary, Egypt, Syria, Eastern Europe, North America, India, etc. (Samsamsharit, 2003). It is an annual herb with simple leaves, bright yellow or orange daisy-like flowers that is used as a decorative plant in the horticultural industry (Duke et al., 2002).
The tincture and sap of its flowers are used locally to hasten the cure of injuries and to reduce swelling. Its sap is also used to reduce the body temperature, cure painful menstruation and cancer. The pot marigold flower has astringent, menstruation, anticonvulsant, energizing, antiseptic nourishing, sophomoric, diuretic, blood thinning and elimination of vomiting effects. It has uses in anemia, kidney problems, grip, mumps, chickenpox, measles, ulcer, jaundice, neurotic problems, acne pimples, skin disease, wounds, snow bites. Its flowers can be used to lower the cholesterol level of the blood or blood pressure because of dilation of surface vessels, relieving stomach ulcers and curing digestive system problems (Mohammad and Kashani, 2012). Research efforts are being made toward the utilization of such areas which have become unsuitable for raising conventional crops due to one or the other reasons that may be used for growing such plants depending upon their suitability to the prevailing environmental conditions. With the diversification of agriculture, medicinal and aromatic plants are gaining importance in the national scenario. The present

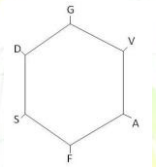
investigation was undertaken to enrich the scientific database regarding the morpho-physiology of *Calendula officinalis* under field conditions.

MATERIALS AND METHODS

The experimental site is situated at 29˚10′ North latitude and 75˚46′ East longitude at an elevation of 215.3 m above the mean sea level. This region has semi-arid climate with severely cold winter and hot dry summer. The average annual rainfall is about 420 mm, bulk of which is mostly received from mid June to mid September. There was no specific pattern of rainfall in winter season during which this investigation was carried out. The seeds were collected from the Botanical Garden, Department of Botany and Plant Physiology, CCS Haryana Agricultural University, Hisar in the month of May. Seeds were sown directly in field, Botanical Garden, CCS Haryana Agricultural University, Hisar.

PHYSIO-CHEMICAL PROPERTIES OF THE SOIL

Parameters	:Soil of field (Botanical Garden)
pH	:8.0
EC $_{1:2}$	:0.20 dSm^{-1}
Organic Carbon:	0.15 %
Available K_2O	: 375 kg/ha
Available P_2O_5	:20 kg/ha
Texture	:Sand



PHENOLOGY :Various life cycle events were expressed diagrammatically as :

G - Germination; V - Vegetative growth;
A -Anthesis; F - Fruiting;
S - Seed maturation; D-Death /senescence

GROWTH BEHAVIOUR **:** Plant height was measured with the help of meter scale from ground level to the tip of the apical shoots or flower of tallest shoot at the vegetative (75 DAS), flowering (105 DAS) and maturity stages (155 DAS). Average plant height was calculated and presented in centimeter (cm). Basal stem diameter was measured with the help of digital vernier caliper at two and half centimeter above the ground level and expressed in millimeter (mm). Numbers of leaves per replication were counted as leaves per plant basis.

Leaves, shoot portion (stem and branches except leaves and flower), flower and fruit portions of plants and roots of the plants were dried in an oven at 60±2˚C till the weight achieved and determined on digital electronic balance, and expressed in gram. Roots were washed thoroughly under running water to remove the adhering soil particles. Root and shoot portions were separated with the help of scissors for root shoot ratio.

REPRODUCTIVE BEHAVIOR: Total number of flowers was counted visually on all the experimental plants to observe number of flowers per plant. Fruiting heads were harvested after maturity and seeds were separated and then counted for number of seeds per head. The average seeds per flower head were multiplied by number of flower heads to calculate total number of seeds per plant. Seed collected at the time of maturity were air dried and germinated in petri dishes on moistened filter paper discs under laboratory conditions in the month of October, per cent seed germination was calculated. The criterion for seed germination was the emergence of radicle. Reproductive capacity was calculated with the help of formula suggested by Salisbury, 1942.

$$\text{Reproductive capacity} = \frac{\text{Av. seed output plant}^{-1} \times \text{Av. \% seed germination}}{100}$$

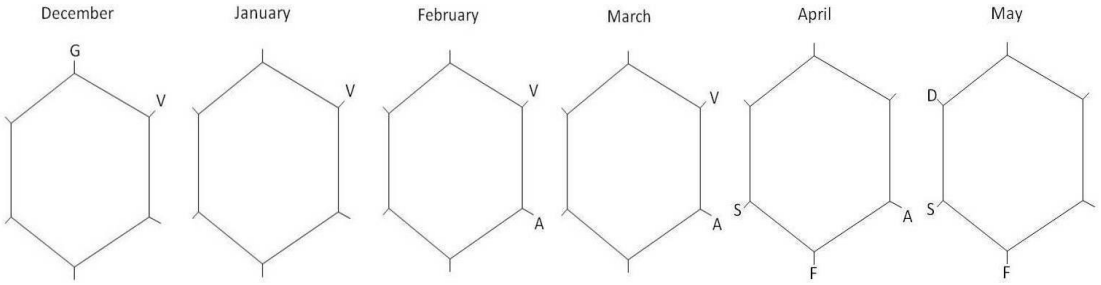
The data was analysed using randomized block design as suggested by Panse and Sukhatme, 1967.

RESULTS AND DISCUSSION

PHENOLOGY**:** The seeds of *Calendula officinalis* were sown in field conditions, germination completed within week, in the first week of December. It was followed by the vegetative growth up to March. The flowering (anthesis) initiated in the month of February and continued till mid April (Fig. 1). Fruiting and seed maturation occurred simultaneously from mid April to early May. Death / senescence was observed from early May onwards.

GROWTH ATTRIBUTES

Plant height of *Calendula officinalis* under field conditions increased with the aging of plants. A significant increase in plant height was recorded up to the flowering stage (Table 1), however, the maximum height of the plants (64.00 cm) was achieved at the maturity stage. The increase in basal diameter, however, was not significant beyond the flowering stage. Maximum basal stem diameter of 13.5 mm was found at the maturity stage. The number of leaves plant-1 increased significantly with the growth of plants and a maximum number of leaves (262.3) was recorded at the maturity stage. Plant height, basal stem diameter, and the number of leaves of calendula increased from vegetative stage to maturity stage increased. These parameters increased due to an increase in shoot biomass, leaf area, root biomass, which ultimately increases the uptake of nutrients and production of photosynthates for the overall growth of the plant. The results are in accordance with Kumar et al., 2006a, Kumar et al., 2006b, Kumar et al., 2007, and Kumar et al., 2014 in the marigold.



G=germination; V=vegetative growth; A=anthesis (flowering); F=fruiting; S=seed maturation; D=death/ senescence

Fig. 1: Phenological study of *Calendula officinalis* under field condition

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An increase in leaf biomass (g plant-1) was recorded with the advancement of the growth stage. The increase in accumulation of food material and photosynthates may increase the growth attributes such as plant height, basal diameter, number of leaves, and leaf biomass. It reached up to 3.93 g plant-1. The increment in leaf biomass, however, was not significant beyond the flowering stage. Stem and branches biomass (g plant-1) continued to increase with the advancement of age and became 8.95 g plant-1 at the maturity stage.

The flower and fruit biomass (g plant-1) also increased from flowering to the maturity stage. It was a maximum (7.16 g plant-1) at the maturity stage. A significant increase in root biomass (g plant-1) was obtained from the vegetative to flowering stage and then reached a maximum (1.75 g plant-1) at the maturity stage. It means an increase in growth parameters directly increases the flower biomass of the plant. The root/ shoot ratio at the vegetative stage was 0.12. It decreased with the advancement of the growth stage. A significant decrease in root/ shoot ratio, however, was recorded up to the flowering stage. The minimum root/ shoot ratio of the plant (0.09) was recorded at the maturity stage. Leaf biomass, stem and branch biomass, flower and fruit biomass, and root biomass increased as the overall growth of the plants increased. The increases in these parameters are inter-correlated with each other. The increase in growth parameters directly proportionate to the increase in growth parameters (Kumar et al., 2007). As the overall growth of the plant enhanced the flowers and fruit biomass will also increase (Kumar et al., 2006b).

Table 1: Growth attributes of *Calendula officinalis* L. under field conditions

Growth parameters	Growth stage (GS) Vegetative Stage	Flowering Stage	Maturity Stage	CD (P≤0.05)
Plant height (cm)	07.83	60.33	64.00	04.93
Basal Stem diameter (mm)	06.33	12.67	13.50	02.16
Number of leaves plant^{-1}	018.0	239.0	262.3	011.5
Leaf biomass (g plant^{-1})	01.21	03.76	03.93	00.81
Stem and branches biomass (g plant^{-1})	00.17	06.29	08.95	00.23
Flowers and fruits biomass (g plant^{-1})	00.00	03.85	07.16	00.42
Root biomass (g plant^{-1})	00.16	01.32	01.75	00.13
Root/ Shoot ratio	00.12	00.10	00.09	0.02

REPRODUCTIVE BEHAVIOUR

The number of flower heads plant^{-1} in *Calendula officinalis* under field conditions significantly increased from 40.33 at the flowering stage to 51.00 at the maturity stage (Table 2).

Number of seeds head^{-1} has been recorded to 40.3±0.9. Seed output was 2055.7±46.8 number plant^{-1}. Seed yield was found to be 6.1±0.3 g plant^{-1}. The germinability of seeds under field conditions was observed to be 86.67± 0.35% [Table 2]. The average reproductive capacity was worked out to be 1783.02± 15.0 %.

Table 2: Reproductive behaviour of *Calendula officinalis* L. under field conditions

Parameters	Flowering stage	Maturity stage	CD (P≤0.05)
Number of flower heads plant^{-1}	40.33	51.00	01.54
Number of seeds head^{-1}	-	40.3±0.9*	-
Seed output (number plant^{-1})	-	2055.7±46.8*	-
Seed yield (g plant^{-1})	-	6.1±0.3*	-
Germination of seeds produced (%)	-	86.67±0.35*	-
Reproductive capacity	-	1783.02±15.0 *	-

* Mean ±Standard Error

CONCLUSION

In plant phenology the vegetative growth stage was overlapped with anthesis, fruiting and seed maturation overlapped with flowering. Death/ senescence was observed from early May onwards. Growth attributes, flowers and fruits biomass (g plant^{-1}) and root biomass (g plant^{-1}) increased with the advancement of growth stage under field conditions. The root/ shoot ratio, however, decreased with the advancement of growth stage. Reproductive behaviour such as number of seeds head^{-1} (40.3±0.9), seeds output (2055.7±46.8 number plant^{-1}), seed yield (6.1±0.3 g plant^{-1}), germination of seeds produced (86.67±0.35%) and reproductive capacity (1783.02±15.0) were performed better under field conditions. Number of flower heads plant^{-1} was increased from flowering (40.33) to maturity stage (51.00).

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