

EFFECT OF VARIOUS CONCENTRATIONS OF PUTRESCINE ON GROWTH, FLOWERING AND SEED YIELD IN CORNFLOWER AND HELICHRYSUM



THESIS SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
Master of Science (Agriculture)
in
Horticulture

Supervisor
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Submitted by
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To,
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Through: The Head, Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, 221005

Sir,

I have great pleasure in forwarding the thesis entitled “**Effect of various concentrations of putrescine on growth, flowering and seed yield in cornflower and helichrysum**” of Ms. Diksha Kumari, I.D. No. 20412HOR006, Enrolment No. 390167 submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science (Agriculture)** in **Horticulture**, Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (U.P.) and placing on record that she has completed the requisite residential requirements as contained in the statutes of the university.

I certify that the work has been carried out solely by **Ms. Diksha Kumari** under my supervision and guidance and her findings and data presented in herein are to the best of my knowledge and belief genuine and original and no part of the work has been submitted for any other degree or distinction.

Thanking you,

FORWARDED

Yours faithfully,

(Anjana Sisodia)
Supervisor

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Date:

Place: Varanasi

(**Diksha Kumari**)

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ABBREVIATIONS

%	Per cent
/	Per
@	at the rate of
°C	Degree celsius
CD	Critical difference
cm	Centimeter
cv.	Cultivar
DAT	Days after transplanting
<i>et al.</i>	(et albeit) and elsewhere
etc.	Etcetera
Fig.	Figure
g	Gram
ha	Hectare
i.e.	(<i>Id et.</i>) That is
m	Meter
mm	millimeter
mmol	milimoles
No.	Number
PAs	Polyamines
Put	Putrescine
Rs.	rupees
SE(d)	Standard error of difference
SE(m)	Standard error of mean
Viz.	(Videlicet) Name1v.

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INTRODUCTION

Flowers play a crucial role in our lives they have been used for generations to express the thoughts and feelings. Studies have shown that flowers impact happiness, help connect people and increase feelings of kindness and compassion. These are powerful nature's gift that lift moods, decrease depression and improve creative performance.

Annuals are commonly known as seasonal as they complete various processes like germination growth, flowering and seed formation in one season and finally wither out (Singh and Sisodia, 2017). Annuals are planted in the winter, summer and rainy season and die in a season or within a year. A wide variation that exists among annuals in form, habit of growth, flower colour, flower size, profuse flowering in short time and their propagation through sexual and asexual methods makes them all-time favourite flowers globally. Annuals without aid of other plants keep the garden full and joyful year round (Singh and Sisodia, 2017).

Winter annuals serve as essential components in any landscape plant (Brown, 2012) with a great number of annuals of various colours. Apart from growing in beds of various size and shapes with one or more annuals they are frequently used as bedding plants, garden plants, in rockery, window sills, cut flowers, loose flowers and herbaceous border in gardens (Love *et al.*, 2009). Hence there is scope of exploiting these annuals as cut flowers for commercial utilization.

Among winter annuals, *Centaurea cyanus* commonly known as cornflower belongs to family Asteraceae native to Europe. It is most commonly used in beds and borders. They are popular for indoor decorations. Free and easy natural cross pollination between various coloured flowers gives rise to mixed coloured flower plant such as white, pink, purple or dilution of these colours (Desai, 1970). Besides this, there are single and double flowering cultivars available in many pure colour

shades, bright blue, maroon, pink red and white are the one which are important (Rao and Prathap, 2006).

Helichrysum bracteatum also known as straw flower or everlasting flower that belongs to family Asteraceae. It comes in many pleasing colours like yellow, orange, pink, deep rose, red wine, magenta, purple or white blooms (Maryam, 2014). *Helichrysum* are produced worldwide as fresh and dried flowers which retains the colour for a longer time. The dwarf cultivars can be used as bedding plants (Sindhu *et al.*, 2020).

Floriculture industries have taken giant steps in export after liberalization. Thus, there is a dynamic shift for sustenance production to commercial production. In India, during the year 2019-20 the area under floriculture production was 305 thousand hectares with a production of 2301 thousand tonnes loose flowers and 762 thousand tonnes cut flowers as per National Horticulture Database (Anonymous, 2020). Whereas, the main challenge of florists in the global flower trading is the quality of cut flowers (Seglie *et al.*, 2012). Annuals when used as cut flowers need special attention to maintain their longevity and bright colours. Plant growth regulators act as either inhibiting or promoting agents to govern the plant growth depending upon the concentration of dose and internal plant characteristics on which these are applied (Singh and Bala, 2020).

Polyamines as plant growth regulators involved in a wide range of growth and development processes, including cell division, embryogenesis, morphogenesis, flowering, fruit emergence, root development, aging delay, membrane stability, active radical's scavenging and tolerance of various stresses (Esna Ashari and Zokaee Khosroshahi, 2008). Polyamines are small ubiquitous molecules that have been involved in nearly all developmental processes, including the stress response (Perez-Adamor *et al.*, 2002). They regulate growth, probably by binding to negatively charged macromolecules (Smith, 1985; Altman and Levin, 1993; Messiaen *et al.*, 1997). Rowland *et al.* (1988) reported that the most common polyamines studied in plants are the diamine putrescine (Put), the triamine spermidine (Spd) and the tetramine spermine (Spm). They also report that polyamines are part of the overall metabolism of nitrogenous compounds. Polyamines (PAs) namely putrescine (Put),

spermine (Spm) and spermidine (Spd) in different plant developmental process (Martin-Tanguy, 2001). They modulate several growth and developmental processes viz., cell division, differentiation, flowering, fruit ripening, embryogenesis, senescence and rhizogenesis (Kakkar and Sawhney, 2002). In all these, PAs have been ascribed various roles such as that of a new class of plant growth regulators, hormonal second messengers and as one of the reserves of carbon and nitrogen at least in cultured tissues (Slocum and Flores, 1991). Polyamines are biologically active compounds involved in various physiological processes. They are cationic molecules, positively charged under intracellular pH, which are essential for plant growth and differentiation, related to aging and senescence and usually involved in plant responses to stress (Friedman *et al.*, 1989). They regulate growth, probably by binding to negatively charged macromolecules (Messiaen *et al.*, 1997). The mechanism of senescence inhibition by PAs may also be related to their possible inhibition of ethylene synthesis (Lee *et al.*, 1997). This property may account for PAs acting as effective scavengers of free radical generated in a number of chemical and in vitro enzymes (Kandil *et al.*, 2011).

It is of paramount importance to enhance the quantitative and qualitative characteristics of these annual flowers because of their demand for as cut flowers in the market. From this perspective, the application of PAs can be an effective way to improve the quantitative and qualitative traits of annual flowers. PAs are a major plant growth regulator playing role in a wide range of biological, physiological and bio-cycles processes such as cell division, vessel differentiation, chromatin performance, protein synthesis, structure integration of nucleic acids, cell membrane dynamic, root initiation, shoot formation, flower induction and evocation, fruit ripening, senescence and embryo formation in tissue culture (Handa and Mattoo, 2010; Wallace, 2009; Abdel Aziz Nahed *et al.*, 2009; Kusano *et al.*, 2008; Martin-Tanguy, 2001; Thomas and Thomas, 2001). Plant growth rate is directly dependent on cell PAs so that when the biosynthesis of these compounds is stopped, plant growth is slowed down or stopped. PAs are necessary to complete cell division in some animal and plant cells. Putrescine (di-amine), spermidine (three-amine) and spermine (tetra-amine) are the most important PAs in the plants (Valero *et al.*, 2002).

Among three most important PA's, exogenous application of Put in many plant species has also been reported that resulted in reduction in loss of chlorophyll and thus delay aging of leaves (Lee *et al.*, 1997). This effect may be related to inhibition of peroxidase activity (Ma *et al.*, 1996). The effects of different concentrations of putrescine on flower characters, total carbohydrates and photosynthetic pigments of *Chrysanthemum* were investigated by Kandil *et al.* (2011). They concluded that all flower characters were significantly increased by foliar application of putrescine at different concentrations (100 ppm, 200 ppm and 300 ppm). Several studies have examined the effect of PAs on the growth and flowering of many plants. These studies showed positive effects of these compounds in an improving vegetative and flowering growth of dahlia (Mahgoub *et al.*, 2011), chrysanthemum (Kandil *et al.*, 2011) and gerbera (Vieira *et al.*, 2017). Previous findings revealed that foliar application of polyamines (putrescine, spermidine and spermine) on roses increased vase life, flower bud diameter and flower bud length compared to the control (Farahi *et al.*, 2013). Pre- and post-harvest application of putrescine on alstroemeria extended vase life and the best results were observed when putrescine was used before and after harvest (Hemmati *et al.*, 2014). The application of putrescine and humic acid in roses showed that putrescine treatment with humic acid increased the vase life of flowers as compared to the control (Dastyaran, 2015). A lot of work done in different crops to improve their vase life with the application of polyamines. But very meagre information is available on the effect of polyamines at field level in ornamental flower crops which are of prime importance in floriculture. Looking towards the significant role of putrescine the present study was carried out to see the **“Effect of various concentrations of putrescine on growth, flowering and seed yield in cornflower and helichrysum”** with the following objectives.

1. To see the effect of various concentrations of putrescine on growth attributes in cornflower and helichrysum.
2. To find out effect of various concentrations of putrescine on flowering and seed yield attributes in cornflower and helichrysum.



REVIEW OF LITERATURE

Plant growth regulators (PGRs) so far have emerged as “magic chemicals” that could increase agricultural production at an unprecedented rate and help in removing and circumventing many of barriers imposed by genetics and environment. PGRs when added in small amount, modify the natural growth regulatory system right from seed germination to senescence in several crop plants. Polyamines are recognized as a new class of plant growth bioregulators (Dantuluri *et al.*, 2008) which has a great influence on many biochemical and physiological processes such as cell division and senescence (Cohen, 1998).

Putrescine: Putrescine oxidase (EC 1.4.3.4), putrescine: oxygen oxidoreductase (deaminating, flavin containing) has been found to form complexes with a variety of amines.



Structure of Putrescine

Considering the importance of putrescine (polyamines) many research work have been carried out to study its effect on various growth, flowering and seed characters in horticultural crops which has been reviewed below. However, till now no such study has been carried out in cornflower and helichrysum.

2.1 Growth characters

Youssef *et al.* (2004) conducted an experiment and reported that foliar application of putrescine on *Matthiola incana* plants significantly promoted plant height, the number of leaves/plant, fresh weight and dry weight of leaves/plant at the vegetative growth stage with best results obtained at 250 mg/L.

Talaat *et al.* (2005) studied the response of periwinkle plants to foliar spray with tryptophan or putrescine and observed that exogenous application of putrescine on periwinkle transplants significantly promoted plant growth at successive developmental stages which included plant height, number of branches, fresh and dry weight of leaves. More pronounced effect was seen in 10^{-3} M putrescine.

El-Quesni *et al.* (2007) observed the effect of putrescine on *Bougainvillea glabra* L. and reported that foliar application of putrescine significantly increased vegetative parameters @ 100 ppm and 200 ppm. The highest values of some characteristics like plant height, number of branches and leaves/plant, stem diameter, fresh and dry weights of stem, leaves and roots were obtained @ 200 ppm putrescine as compared to control plants.

Talaat and Gamal El-Din (2007) carried out an experiment on *Nigella sativa* L. plants and found that foliar application of 5 mM putrescine to *Nigella* plants significantly increased growth parameters like plant height, number of branches, number of leaves, fresh and dry weights of leaves and stems.

Ei-Tohamy *et al.* (2008) carried out an experiment to study growth characters in eggplant and found that application of putrescine gave significant effect on plant height, number of leaves and number of branches with best result obtained at 50 ppm among various putrescine concentration.

Nahed *et al.* (2009) studied the effect of application of putrescine, ascorbic acid and thiamine on vegetative growth in *Gladiolus grandiflorum* L. plants. They observed that foliar application of putrescine significantly increased plant height, number of leaves/plant, fresh and dry weight of leaves/plant treated with 200 ppm compared to control in two consecutive seasons. There was an increment in fresh and dry weight of leaves by 180 % and 207 % respectively over control plants.

Ei- Abagy *et al.* (2010) carried out an experiment on Artichoke (*Cynara scolymus* L.) and found that 50 ppm putrescine concentration showed maximum plant

height and number of leaves/plant, whereas increase in fresh weight of leaves and dry matter % in leaves were observed as compared to control.

El-Quesni *et al.* (2010) carried out a pot experiment to study the effect of foliar spray of inorganic fertilizer (Grow-more) and bioregulator (Putrescine) on vegetative growth in *Syngonium podophyllum* L. plant and found that foliar application of putrescine significantly increased all growth characters *i.e.* plant height, stem diameter, number of leaves, leaf area, fresh and dry weight of roots and leaves at 100 ppm and 200 ppm with highest values obtained at 100 ppm putrescine as compared to control plants. Fresh weight of root and leaves exceeded by 22.41 % and 22.31 % respectively than the control plant.

Amin *et al.* (2011) conducted an experiment with different concentrations of putrescine on onion and reported that foliar application of 100 ppm putrescine significantly increased plant height, number of leaves, fresh weight of leaves, fresh and dry weight of plant and leaf area.

Mahgoub *et al.* (2011) carried out pot experiment to study the effect of foliar application of putrescine and thiamine in addition to untreated plants as control on vegetative growth in *Dahlia pinnata* L. They observed that spraying putrescine and thiamine increased plant height, number of branches, number of leaves, fresh and dry weight of leaves, stem diameter and fresh and dry weight of stem. Plants treated with 150 ppm putrescine gave highest values as compared to control plants.

Nanvakenary *et al.* (2013) studied the effect of putrescine application on vegetative growth parameters like diameter of rosette, number of leaves, leaf area, stomata index and dry weight in African violet (*Saintpaulia ionantha*). Result showed that putrescine @ 75 ppm increased the diameter of leaves, number of leaves, leaf area and dry weight.

Badawy *et al.* (2015) conducted an experiment to study the effect of diatomite, putrescine and alpha-tocopherol on growth of *Antirrhinum majus* L. plants. Data indicated that most criteria of vegetative growth expressed as plant height, number of

branches/plant, number of leaves/plant, leaf area/plant, fresh and dry weight of shoot, root length, fresh and dry weight of root were significantly increased by the application of putrescine as compared with control plants. Foliar application of putrescine at 200 ppm gave the highest increment of vegetative growth characters at the period of 75 DAT.

Kandil *et al.* (2015) evaluated the effect of spraying putrescine, uniconazole and their interaction in addition to the control (distilled water) on vegetative growth of *Salvia splendens* F. plant and observed that foliar application of putrescine significantly increased plant height, number of branches/plant, number of leaves/plant, fresh and dry weights of leaves, fresh and dry weights of stem with best results found at 150 ppm putrescine. For the interaction between the two growth regulators, it was found that the combination between putrescine at 150 ppm and uniconazole at 10 ppm gave the best results in the most of the given characters.

Faraji *et al.* (2015) conducted an experiment to investigate the effect of salicylic acid and putrescine as foliar spray on growth characters of summer savory (*Satureja hortensis* L.) and found that foliar application of putrescine had significant effect ($p < 0.01$) on some vegetative parameters such as dry weight and yield of total aerial shoots, leaves and inflorescences.

Rezvanypour *et al.* (2015) conducted an experiment to study the effects of exogenous polyamines on vegetative growth of *Freesia hybrida* cv. Golden Wave and found that application of putrescine and spermidine as soil drench on inoculated plants significantly increased leaf length and width compared to sole AMF inoculation while foliar application of PAs did not affect leaf parameters nor the leaf number. Results suggest that soil drench application of polyamines, especially putrescine, positively influenced mycorrhizal inoculation and nutrient uptake, which leads to improving growth of mycorrhizal plants in freesia.

Farahi and Jahroomi (2018) performed an experiment with the open soilless culture system in cut rose cv. Dolce Vita and found that putrescine at 2 mM showed highest stem height while 3 mM showed lowest stem fresh weight.

Chokami *et al.* (2019) evaluated the effect of putrescine, spermine and spermidine on basil under salt stress conditions. The results showed that polyamine application significantly influenced plant height as plants treated with 150 mg/l spermine were the tallest. The effect of polyamines on fresh and dry weights of leaf was significant and 150 mg/l spermine + and 50 mM NaCl had maximum fresh weight, whereas lowest was in spermine control treatment with 150 mM NaCl (negative control). The effect of polyamines on fresh and dry weight of shoot and root was also significant.

Kahrobaiyan *et al.* (2019) studied the effects of foliar application of putrescine in ornamental sunflowers (*Helianthus annuus* L. cv. Sunbright Kids) and found that the effect of exogenous application of putrescine (75mg/L and 150 mg/L) in comparison with control, significantly increased number of leaves/plant, leaves fresh and dry weight, leaves area, stem fresh and dry weight, stem diameter at soil surface, plant height, root fresh and dry weight, root area.

Saeed *et al.* (2019) conducted the experiment and found that foliar application of PAs (putrescine and spermidine) led to enhance of vegetative growth in gerbera cv. Great Smoky Mountains. Treatment with 100 mg/L of spermidine gave the best results in terms of number of leaves, leaves area while treatment with 100 mg/L of putrescine gave the best results in terms of percentage of leaves dry material.

Saeed and Taher (2019) studied the effect of foliar spray with putrescine, spermidine in addition to spraying with distilled water as a control treatment and salicylic acid on vegetative growth of ranunculus plants (*Ranunculus asiaticus* L.) cv. Victoria F1, with flowers in orange colour. Treatment with concentration of 200 mg/L of putrescine gave the best results in terms of plant height, percentage of dry matter in leaves.

Yousefi *et al.* (2019) studied the effect of foliar application of polyamines on roses (*Rosa hybrida* cv. Herbert Stevens) and found that among polyamines, putrescine had the greatest effect on root dry weight while spermidine showed the greatest effect on root length and spermine affected root fresh weight most strongly.

Singh and Bala (2020) studied the effect of different anti-senescence compounds like putrescine and benzyl adenine (BA) on growth characters of chrysanthemum cv. Punjab Shyamli and found significant effect in number of branches/plant with best result obtained at 150 ppm among different putrescine concentration.

Rakbar *et al.* (2021) investigated the effects of putrescine and mycorrhizal fungi on gerbera cv. Dune and found that putrescine along with mycorrhizal fungi increased the number of leaves, leaf area, fresh and dry weight of the leaves.

2.2 Flowering characters

El-Quesni *et al.* (2007) reported the effect of putrescine on flowering characters of *Bougainvillea glabra* L. They observed that foliar application of putrescine significantly increased flower numbers, fresh and dry weight of flowers with best results obtained at 200 ppm putrescine concentration.

Nahed *et al.* (2009) studied the effect of application of putrescine, ascorbic acid and thiamine on flowering characters of *Gladiolus grandiflorum* L. plants. They observed that foliar application of putrescine significantly increased the flowering parameters and best results were obtained for spike length, number of florets, fresh and dry weight of florets by application of putrescine at 200 ppm.

Ei- Abagy *et al.* (2010) carried out an experiment on Artichoke (*Cynara scolymus* L.) and found that 50 ppm putrescine concentration showed maximum fresh weight of flowers, number of flowers/plant and flower yield/plant, whereas increase in flower head diameter, flower head length and diameter, thickness, fresh weight and dry matter % in receptacle were observed as compared to control.

Kandil *et al.* (2011) studied the effect of putrescine on flower characters of *Chrysanthemum indicum* plant and reported that spraying putrescine @ 100 ppm, 200 ppm and 300 ppm resulted in early blooming than control plants. The highest values were found with plants which were treated with 200 ppm putrescine. Besides this, pedicel length, length of inflorescence stalk, fresh and dry weight of inflorescence

were also enhanced remarkably. They also observed increased yield of inflorescence @ 200 ppm putrescine giving 147 flowers/plant and 161 flowers/plant for 1st and 2nd season respectively.

Mahgoub *et al.* (2011) carried a pot experiment to study flowering characters of *Dahlia pinnata* L and found that foliar application of 150 ppm putrescine gave the best results for number of flowers/plant, fresh and dry weight of flowers than the untreated ones.

Farahi *et al.* (2012) examined the effect of polyamines on rose plants (*Rosa hybrida* cv. Dolce Vita) in soil-less cultures. Foliar sprays of putrescine, spermidine and spermine were applied which showed significant results in flower stalks length, flower stalks fresh weight, flower buds diameter and flower buds length. The highest and lowest flower stalks length were obtained in nutrient solutions containing 1.5 mM spermidine and in control with 100.66 cm and 71 cm respectively.

Nanvakenary *et al.* (2013) studied the effect of putrescine application on flowering parameters like number of florets and diameter of flowers in African violet (*Saintpaulia ionantha*). Result showed that putrescine @ 75 ppm increased the flower diameter.

Mohammadi *et al.* (2014) studied the effects of salicylic acid and putrescine on cut Gladiolus. The recorded traits included flower diameter, flower petal wilting and percent of floret blossoming. Results showed the effect of different levels of putrescine ($p < 0.01$) and interaction of putrescine and salicylic acid ($p < 0.05$) on flower diameter. Mean comparison indicated that increased level of putrescine upto 300 mg/L which resulted in increase of flower diameter. Interaction of putrescine and salicylic acid had significant effect on floret wilting ($p < 0.01$).

Badawy *et al.* (2015) conducted an experiment to study the effect of diatomite, putrescine and alpha-tocopherol on flowering of *Antirrhinum majus* L. plants. Results showed that number of spikes/plant, spike length, number of flowers, fresh and dry weight of flowers/plant were significantly increased by the application of diatomite,

putrescine and alpha-tocopherol as compared with control plants. Foliar application of putrescine at the concentration of 200 ppm gave the highest increment of flowering characters at the period of 75 days from transplanting.

Kandil *et al.* (2015) evaluated the effect of spraying putrescine, uniconazole and their interaction in addition to the control (distilled water) on flowering characters of *Salvia splendens* F. plant. Foliar application of putrescine significantly increased rachis length, fresh and dry weight of spikes. The best results were found in plants treated with 150 ppm putrescine. For the interaction between the two growth regulators, it was found that the combination between putrescine at 150 ppm and uniconazole at 10 ppm gave the best results in the most of the given characters.

Rezvanypour *et al.* (2015) conducted an experiment to study the effects of exogenous polyamines on reproductive growth of *Freesia hybrida* cv. Golden Wave. Among the three polyamines, putrescine in 0.1 mM concentration was the most effective in enhancing floral stem length and diameter, floral spike length, floret number on main and lateral spikes. Soil drench with 0.1 mM putrescine accelerated flowering by about 17 days. Results suggest that soil drench application of polyamines, especially putrescine, positively influenced mycorrhizal inoculation and nutrient uptake, which leads to improving flowering of mycorrhizal plants in freesia.

Sajjad *et al.* (2015) studied the effect of polyamines (putrescine and spermine) and vitamins (ascorbic acid and thiamine) on gladiolus plants and found that most effective treatment was putrescine @ 1 mM which showed prominent effects on important traits including spike length, spike diameter, florets per spike, first floret diameter and first floret weight in *Gladiolus grandiflorus* L. compared to the control.

Farahi and Jahroomi (2018) performed an experiment with the open soilless culture system in order to improve the quality of cut rose cv. Dolce Vita. Results showed that the combined application of polyamines with calcium sulfate had a significant influence on increasing the parameters such as flower length while maximum flower diameter was observed at 2 mM putrescine concentration.

Kahrobaiyan *et al.* (2019) studied the effects of foliar application of putrescine in ornamental sunflowers (*Helianthus annuus* L. cv. Sunbright Kids) and found that exogenous application of putrescine (75 and 150 mg/L) in comparison with control, significantly increased number of flowers and flower longevity. The results confirmed that foliar application of putrescine (75 mg/L) increased flowers retention.

Saeed *et al.* (2019) conducted the experiment and found that foliar application of PAs (putrescine and spermidine) led to enhancing of flowering qualities in gerbera cv. Great Smoky Mountains. Treatment with 100 mg/L of putrescine gave the best results in terms of number of flowers and flower diameter. Interaction between PAs (putrescine and spermidine) and salicylic acid showed significant improvement in all flowering characters of gerbera. Treatment of 100 mg/L of putrescine combined with 200 mg/L of salicylic acid gave best number of flowers.

Saeed and Taher (2019) studied the effect of foliar spray with putrescine on flowering qualities of ranunculus plants (*Ranunculus asiaticus* L.) cv. Victoria F1, with flowers in orange colour. Treatment with concentration of 200 mg/L of putrescine gave the best results in terms of number of flowers and flower diameter. Interaction between concentrations of polyamines (putrescine and spermidine) and concentrations of salicylic acid showed significant improvement in all qualities of flowering of ranunculus plants. Treatment of 200 mg/L of putrescine and 150 mg/L of salicylic acid excelled in giving best number of flowers.

Yousefi *et al.* (2019) studied the effect of foliar application of polyamines on roses (*Rosa hybrida* cv. Herbert Stevens). The results showed that polyamine concentration of 1 mM had the strongest effect on flower longevity. Polyamine treatments had no significant effect on the number of flowers/plant.

Singh and Bala (2020) studied the effect of different anti-senescence compounds like putrescine and benzyl adenine (BA) on floral characters of chrysanthemum cv. Punjab Shyamli and found significant effect in days to bud appearance, days to colour showing stage, flowering duration, days to flowering and flower diameter.

2.3 Seed characters

Talaat and Gamal El-Din (2007) carried out pot experiment to study the effect of foliar application of putrescine on seed characters of *Nigella sativa* L. plants and found that 5 mM putrescine significantly increased yield parameters like weight of straw, number of fruits/plant, weight of seeds/fruit, weight of seeds/plant. Heat hardening of 50°C for 15 min followed by foliar application of 5 mM putrescine caused the greatest increase in seed yield relative to the control.

Ei-Tohamy *et al.* (2008) carried out an experiment to study the seed characters in eggplant and found that application of putrescine gave significant effect on number of fruits/plant and yield with best result obtained at 50 ppm among various putrescine concentration.

Amin *et al.* (2011) conducted an experiment with different concentrations of putrescine on onion and reported that foliar application of 100 ppm putrescine significantly increased bulb length, bulb diameter and weight as well as yield of onion and quality of bulb also.

Ali *et al.* (2014) conducted an experiment on peach cv. Florida King and found that application of putrescine increased fruit weight, fruit diameter, pulp to stone ratio and yield compared to control.

Faraji *et al.* (2015) conducted an experiment to investigate the effect of salicylic acid and putrescine as foliar spray on seed characters of summer savory (*Satureja hortensis* L.) and found that the essential oil efficiency (2.35 kg/ha) and essential oil yield (76.76%) reached a maximum range in 1.5 mM putrescine.

Rezvanypour *et al.* (2015) conducted an experiment to study the effects of exogenous polyamines on *Freesia hybrida* cv. Golden Wave and found that among the three polyamines, putrescine in 0.1 mM concentration was the most effective in increasing corm and cormlet weight, corm diameter and cormlet number. Results suggest that soil drench application of polyamines, especially putrescine, positively

influenced mycorrhizal inoculation and nutrient uptake, which leads to improving corm production in freesia.

Kahrobaiyan *et al.* (2019) studied the effects of foliar application of putrescine on short-term tolerance against water stress in ornamental sunflowers (*Helianthus annuus* L. cv. Sunbright Kids) and found that the effects of exogenous application of putrescine (75 and 150 mg/L) in comparison with control, significantly increased seeds number/head and seeds weight.



MATERIALS AND METHODS

A field experiment on cornflower and helichrysum was conducted during 2021-22 under agro-climatic condition of Varanasi. The experiment was conducted to study the “Effect of various concentrations of putrescine on growth, flowering and seed yield in cornflower and helichrysum”. The details of experimental materials and methods adopted during the course of investigation are described below.

3.1 Experimental site

The present study was carried out at the Horticulture Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, U.P. from Nov 2021-April 2022. The experimental site lies approximately in the centre of North-Gangetic alluvial plain, on the left bank of river Ganga at a distance of about 10 km away from Varanasi Cantt. Railway Station in the South East direction. Geographically Varanasi city is situated at about 25°10' North latitude 83°03' East longitudes.

3.2 Climatic and weather conditions

The climate of Varanasi is humid subtropical with large variation in temperature between summer and winter. Here winters are associated with foggy nights, whereas, hot and dry winds are common during summers. The normal period of monsoon is from third week of June and lasts up to end of September. The average annual rainfall is about 1110 mm and annual potential evapo-transpiration is about 1552.2 mm. During the experiment maximum temperature ranged from 29.7 °C to 42 °C and minimum was 14 °C to 20.9 °C. Whereas, during the experiment the maximum relative humidity was highest in the month of January (98%) while the lowest relative humidity was highest in the month of April (30%).

Weekly data on various weather parameters prevailing during the experiment was recorded at Meteorological Observatory at Agriculture Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. This is presented in table given below.

Table 3.1: Weekly meteorological data during the period of experimentation 2021-22.

Week No.	Month and Date	Rainfall mm	Temperature °C		R.H. %		Wind Speed km/hr	Sunshine hours	Evaporation mm
			Max	Min	Morn.	Even			
1	Nov 05-11	0.0	29.7	14.0	95	54	0.6	6.7	1.8
2	12-18	0.0	28.5	13.5	96	48	0.4	6.5	1.9
3	19-25	0.0	28.7	12.2	90	40	1.0	7.2	1.8
4	26-02	0.0	26.7	10.6	97	51	0.4	5.4	1.2
5	Dec 03-09	0.0	26.8	12.8	97	54	0.6	4.2	1.2
6	10-16	0.0	24.6	8.6	94	44	0.5	5.4	1.2
7	17-23	0.0	22.3	7.2	91	53	1.1	6.0	1.3
8	24-31	8.6	21.9	10.0	97	72	1.0	3.1	0.8
9	Jan 1-7	1.2	19.2	8.8	98	75	0.9	3.3	0.6
10	8-14	5.4	22.1	11.8	96	74	1.4	1.6	0.9
11	15-21	0.0	18.5	6.7	93	70	1.6	2.2	1.2
12	22-28	49.0	20.0	9.8	94	68	3.1	3.4	1.7
13	29-04	4.3	22.7	8.6	94	61	3.7	7.2	1.9
14	Feb 05-11	0.0	22.6	9.6	94	57	2.9	5.7	2.0
15	12-18	0.0	25.0	7.9	92	47	2.6	9.6	2.7
16	19-25	0.3	26.7	12.3	90	59	3.7	8.7	3.2
17	26-04	0.4	28.6	12.5	95	53	1.9	8.4	2.9
18	March 05-11	0.0	29.7	13.5	89	54	2.4	9.4	3.5
19	12-18	0.0	32.9	16.6	89	53	2.4	8.9	4.1
20	19-25	0.0	36.5	19.3	85	49	2.3	8.7	4.6
21	26-01	0.0	38.0	18.6	79	39	3.1	9.4	5.9
22	April 02-08	0.0	40.2	18.1	76	31	2.6	9.7	6.5
23	09-15	0.0	40.5	21.6	78	33	3.1	9.4	6.2
24	16-22	0.0	40.9	21.9	73	32	3.4	9.8	7.5
25	23-29	0.0	42.0	20.9	65	30	3.8	10.1	8.6

3.3 Experimental material

The experimental material for the experiment was seeds of cornflower and helichrysum. The seeds were maintained at Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, U.P., India.

Experimental details

3.3.1 Experiment no. 1: Influence of putrescine on cornflower.

Crop	:	Cornflower (<i>Centaurea cyanus</i>)
Design of Experiment:		Randomized Block Design
Treatments	:	Control, Putrescine (1.00 mmol, 1.25 mmol, 1.50 mmol, 1.75 mmol, 2.00 mmol, 2.25 mmol, 2.50 mmol, 2.75 mmol and 3.00 mmol).
Replications	:	4
Number of plots	:	40
Plot size	:	2.4 m×2 m
Plant spacing	:	60 cm×50 cm

3.3.2 Experiment no. 2: Influence of putrescine on helichrysum.

Crop	:	Helichrysum (<i>Helichrysum bracteatum</i> Andr.)
Design of Experiment:		Randomized Block Design
Treatments	:	Control, Putrescine (1.00 mmol, 1.25 mmol, 1.50 mmol, 1.75 mmol, 2.00 mmol, 2.25 mmol, 2.50 mmol, 2.75 mmol and 3.00 mmol).
Replications	:	4

Number of plots : 40

Plot size : 2.4 m × 2 m

Plant spacing : 60 cm × 50 cm

3.4 Treatment details

There were total ten treatments including plant growth regulator viz., Putrescine (1.00 mmol, 1.25 mmol, 1.50 mmol, 1.75 mmol, 2.00 mmol, 2.25 mmol, 2.50 mmol, 2.75 mmol and 3.00 mmol) and control.

Table 3.2: Treatment details

S.No.	Name of treatments	Notation
1.	Control	T ₀
2.	Put 1.00 mmol	T ₁
3.	Put 1.25 mmol	T ₂
4.	Put 1.50 mmol	T ₃
5.	Put 1.75 mmol	T ₄
6.	Put 2.00 mmol	T ₅
7.	Put 2.25 mmol	T ₆
8.	Put 2.50 mmol	T ₇
9.	Put 2.75 mmol	T ₈
10.	Put 3.00 mmol	T ₉

Table 3.3: Layout of field

R₁		R₂		R₃		R₄
T₃		T₆		T₂		T₄
T₀		T₇		T₈		T₅
T₉		T₂		T₀		T₁
T₁		T₃		T₅		T₇
T₆		T₉		T₁		T₀
T₄		T₀		T₇		T₃
T₂		T₈		T₄		T₆
T₈		T₅		T₆		T₉
T₇		T₁		T₃		T₈
T₅		T₄		T₉		T₂

3.5 Cultural operations

3.5.1 Field preparation

Field preparation was done by ploughing the field with mould board plough once, followed by leveling and weeding manually. Harrowing was done to break the clods followed by criss-cross ploughing by cultivator, then the field was pulverized by rotavator. The experiment was laid out with the help of measuring tape, rope and bamboo pegs.

3.5.2 Transplanting of seedlings

Cornflower and helichrysum seedlings were transplanted after 25 days of sowing. The seedlings of cornflower and helichrysum were transplanted in experimental field on 29 Nov 2021 and 30 Nov 2021 respectively and immediately light irrigation was given. Seedlings were transplanted in the evening hours with spacing of 50 cm from plant to plant and 60 cm from row to row.

3.5.3 Weeding and Irrigation

Hand weeding was done periodically to keep the field free from the weeds. Manual weeding was done during the entire cropping period at an interval of 15-20 days. Soil was kept moist and frequent irrigation was provided to check moisture stress.

3.5.4 Staking

In helichrysum, staking was done by using 60-75 cm long *sarkanda* sticks, so that the plant do not break or fall down due to winds.

3.5.5 Plant tagging

Representative plants were selected randomly in each plot and tagged for recording of data on various characters.

3.5.6 Plant protection

Aphid and whitefly were major insect infestations seen on the experimental plots of both crops cornflower and helichrysum. To control aphids and whitefly, Rogor (Dimethoate 30% EC) at the rate of 1.5 ml/l was sprayed as per requirement while to control fungal diseases fungicide SAAF (12% Carbendazim + 63% WP Mancozeb) at the rate of 2 g/l was sprayed at regular intervals during the vegetative growth.

3.6 Growth regulator solutions

3.6.1 Preparation of growth regulator solutions

Putrescine 0.088 g was weighed on an electronic balance and dissolved in 1 liter of distilled water to prepare 1.00 mmol solution. Similarly, 1.25 mmol, 1.50 mmol, 1.75 mmol, 2.00 mmol, 2.25 mmol, 2.50 mmol, 2.75 mmol and 3.00 mmol solution were prepared by adding 0.11 g Put, 0.132 g Put, 0.154 g Put, 0.176 g Put, 0.198 g Put, 0.22 g Put, 0.242 g Put and 0.264 g Put in 1 liter of distilled water for each treatment concentration respectively.

3.6.2 Application of growth regulator solutions

With the help of a sprayer, putrescine was sprayed till the runoff stage during the afternoon on the plants. Spraying was undertaken at 20 DAT.

3.7 Observations recorded in cornflower

Different parameters were recorded for cornflower on the basis of growth, flowering and seed production.

3.7.1 Growth parameters

3.7.1.1 Plant height (cm)

The height of the plants was recorded with the help of a meter rod from the base of plant to the tip of the apical shoot at 60 DAT and 90 DAT for each tagged plants in each plot and expressed in centimeters.

3.7.1.2 Plant spread (cm)

It was measured with scale from north-south and east-west direction and their mean was calculated in centimeters at 60 DAT and 90 DAT.

3.7.1.3 Number of primary branches

Total number of primary branches were counted from every tagged plant at 60 DAT and 90 DAT and expressed in numbers.

3.7.1.4 Number of secondary branches

Those branches arising from primary branches are secondary branches and were counted in an individual plant and their average value was recorded at 60 DAT and 90 DAT.

3.7.1.5 Fresh weight of leaf (g)

Five leaves were taken randomly from the individual plant and weighed on a common electric balance. The average was taken and expressed in grams.

3.7.1.6 Dry weight of leaf (g)

Leaf samples were taken in individual plant for fresh weight were dried in hot air oven at 52⁰C for 72 hours *i.e.*, until leaf colour change from green to brown and their weight after drying were taken with the help of common electric balance, which were averaged and expressed in grams.

3.7.1.7 Leaf area (cm²)

Leaf area was recorded from 5 randomly selected plants of each treatment and was then measured by using leaf area meter in cm².

3.7.2 Flowering parameters

3.7.2.1 Days to bud initiation (days)

Number of days were counted from date of transplanting to the date of first visible bud formation and then average was calculated.

3.7.2.2 Pedicel length (cm)

Pedicel length was calculated with the help of scale from the base of flower to the branching or node.

3.7.2.3 Days to bud development (days)

Number of days were counted from date of transplanting to the colour showing stage of first bud.

3.7.2.4 Bud diameter (mm)

Bud diameter of five fully developed bud of an individual plant was calculated using digital vernier calipers and average was computed.

3.7.2.5 Disc diameter (cm)

Disc diameter of five randomly selected flower of an individual plant was calculated using digital vernier calipers and average was computed.

3.7.2.6 Flower diameter (cm)

Flower diameter was measured at the point of maximum breadth using digital vernier calipers of five randomly selected flower of an individual plant and average was computed.

3.7.2.7 Days to flower blooming (days)

Number of days were counted from the date of transplanting to the stage of full flower bloom after attaining flower bud development.

3.7.2.8 Number of flowers/plant

Number of flowers/plant were counted at the time of peak flowering and expressed in numbers.

3.7.2.9 Flower longevity (days)

Flower longevity was calculated from the date of blooming to withering of an individual flower.

3.7.2.10 Days to flower withering (days)

Number of days was counted from the date of transplanting to the stage when flower withers.

3.7.2.11 Fresh weight of flower (g)

Five flowers were randomly selected from each plant and their total weight was recorded on common electric balance in grams.

3.7.2.12 Dry weight of flower (g)

The dry weight of five flowers which were randomly selected from each plant was weighed on a common electric balance after drying the sample in hot air oven till the sample attains a constant weight and it is expressed in grams.

3.7.2.13 Flower yield/m² (g/m²)

The total flowers are harvested at peak flowering stage from all the plants in the plot and then weighed on the common electric balance and is expressed in g/m².

3.7.3 Seed parameters

3.7.3.1 Days to seed maturity (days)

Number of days were counted from date of transplanting to the ripening of seed and expressed in days.

3.7.3.2 Number of seeds/flower

Number of Seeds were counted in an individual flower and expressed in numbers.

3.7.3.3 1000 seed weight (g)

1000 seeds were counted by using seed counter from the seed lot of each plant. Weight of these 1000 seeds was taken in grams.

3.7.3.4 Seed yield/plant (g)

Total number of seeds in a plant were weighed on a common electric balance in grams and yield was calculated per plant.

3.7.3.5 Seed yield/m² (g/m²)

Five flowers were randomly selected from each plant for harvesting of seeds and weighed on a common electric balance in grams and yield was calculated per m².

3.8 Observations recorded in helichrysum

Different parameters were recorded for helichrysum on the basis of growth, flowering and seed production.

3.8.1 Growth parameters

3.8.1.1 Plant height (cm)

The height of the plants was recorded with the help of a meter rod from the base of plant to the tip of the apical shoot at 60 DAT and 90 DAT for each tagged plants in each plot and expressed in centimeters.

3.8.1.2 Plant spread (cm)

It was measured with scale from north-south and east-west direction and their mean was calculated in centimeters at 60 DAT and 90 DAT.

3.8.1.3 Number of primary branches

Total number of primary branches were counted from every tagged plant at 60 DAT and 90 DAT and expressed in numbers.

3.8.1.4 Number of secondary branches

Those branches arising from primary branches are secondary branches and were counted in an individual plant and their average value was recorded at 60 DAT and 90 DAT.

3.8.1.5 Fresh weight of leaf (g)

Five leaves were taken randomly from the individual plant and weighed on a common electric balance. The average was taken and expressed in grams.

3.8.1.6 Dry weight of leaf (g)

Leaf samples were taken in individual plant for fresh weight were dried in hot air oven at 52⁰C for 72 hours *i.e.*, until leaf colour change from green to brown and their weight after drying were taken with the help of common electric balance, which were averaged and expressed in grams.

3.8.1.7 Leaf area (cm²)

Leaf area was recorded from 5 randomly selected plants of each treatment and was then measured by using leaf area meter in cm².

3.8.1.8 Diameter at shoot base (mm)

Shoot base diameter is calculated using digital vernier calipers and expressed in millimeters.

3.8.2 Flowering parameters

3.8.2.1 Days to bud initiation (days)

Number of days were counted from date of transplanting to the date of first visible bud formation.

3.8.2.2 Days to bud development (days)

Number of days were counted from date of transplanting to the colour showing stage of first bud.

3.8.2.3 Bud diameter (mm)

Bud diameter of five fully developed bud of an individual plant was calculated using digital vernier calipers and average was computed.

3.8.2.4 Disc diameter (cm)

Disc diameter of five randomly selected flower of an individual plant was calculated using digital vernier calipers and average was computed.

3.8.2.5 Flower diameter (cm)

Flower diameter was measured at the point of maximum breadth using digital vernier calipers of five randomly selected flower of an individual plant and average was computed.

3.8.2.6 Days to flower blooming (days)

Number of days were counted from the date of transplanting to the stage of full flower bloom after attaining flower bud development.

3.8.2.7 Number of flowers/plant

Number of flowers/plant were counted at the time of peak flowering.

3.8.2.8 Flower longevity (days)

Flower longevity was calculated from the date of blooming to withering of an individual flower.

3.8.2.9 Days to flower withering (days)

Number of days were counted from the date of transplanting to the stage when flower withers.

3.8.2.10 Fresh weight of flower (g)

Five flowers were randomly selected from each plant and their total weight was recorded on common electric balance in grams.

3.8.2.11 Dry weight of flower (g)

The dry weight of five flowers which were randomly selected from each plant was weighed on a common electric balance after drying the sample in hot air oven till the sample attains a constant weight and it is expressed in grams.

3.8.2.12 Flower yield/m² (g/m²)

The total flowers are harvested at peak flowering stage from all the plants in the plot and then weighed on the common electric balance and is expressed in g/m².

3.8.3 Seed parameters

3.8.3.1 Days to seed maturity (days)

Number of days were counted from date of transplanting to the ripening of seed.

3.8.3.2 Number of seeds/flower

Number of Seeds were counted in an individual flower.

3.8.3.3 1000 seed weight (g)

1000 seeds were counted by using seed counter from the seed lot of each plant. Weight of these 1000 seeds was taken in grams.

3.8.3.4 Seed yield/plant (g)

Total number of seeds in a plant was weighed on a common electric balance in grams and yield was calculated per plant.

3.8.3.5 Seed yield/m² (g/m²)

Five flowers were randomly selected from each plant for harvesting of seeds and weighed on a common electric balance in grams and yield was calculated per m².



EXPERIMENTAL FINDINGS

This chapter deals with the findings of the research performed at Horticulture Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India on “Effect of various concentrations of putrescine on growth, flowering and seed yield in cornflower and helichrysum” during 2021-2022.

4.1 Cornflower

4.1.1 Observations recorded on growth characters

4.1.1.1 Plant height (cm)

The data adverting to plant height of various treatments of putrescine is presented in the Table 4.1 and Fig. 4.1. It is perceptible from the data that different concentrations of putrescine significantly influenced the plant height. Plant height varied from 27.03 cm to 42.18 cm at 60 days after transplanting (DAT) while at 90 DAT it varied from 75.50 cm to 95.04 cm. Treatment 2.50 mmol showed maximum plant height (42.18 cm) at 60 DAT which was statistically at par with control (40.36 cm) and significant to 2.25 mmol (37.36 cm), 1.75 mmol (36.36 cm), 2.75 mmol (35.40 cm), 3.00 mmol (34.45 cm), 1.50 mmol (32.90 cm), 2.00 mmol (30.99 cm), 1.00 mmol (28.21 cm), 1.25 mmol (27.03 cm). Similarly, 2.75 mmol showed the maximum plant height (95.04 cm) at 90 DAT which was significant to all other treatments while minimum plant height (75.50 cm) was found at 1.75 mmol.

4.1.1.2 Plant spread (cm)

The result for plant spread as influenced by different treatments of putrescine is represented in the Table 4.1 and Fig. 4.2. Plant spread varied from 36.78 cm to 42.50 cm at 60 DAT and 42.94 cm to 58.39 cm at 90 DAT. At 60 DAT, maximum plant spread (42.50 cm) was obtained at 2.75 mmol which was statistically at par with 1.50 mmol (41.81 cm), 2.25 mmol (41.71 cm), 2.50 mmol (41.57 cm), 3.00 mmol (40.97 cm) and significant to 2.00 mmol (39.60 cm), 1.75 mmol (38.79 cm), 1.25 mmol (38.39 cm), control (37.49 cm), 1.00 mmol (36.78 cm). Similarly, maximum

plant spread (58.39 cm) at 90 DAT was shown by 2.75 mmol which was statistically at par with 2.50 mmol (56.60 cm), 2.00 mmol (53.48 cm), 2.25 mmol (52.33 cm) and significant to 3.00 mmol (49.39 cm), 1.75 mmol (48.22 cm), control (48.11 cm), 1.50 mmol (46.18 cm), 1.25 mmol (46.02 cm), 1.00 mmol (42.94 cm).

4.1.1.3 Number of primary branches

The data on number of primary branches governed by different doses of putrescine is presented in the Table 4.2 and Fig. 4.3. It is clear from the table that number of primary branches varied from 4.58 to 17.99 at 60 DAT and from 24.66 to 36.99 at 90 DAT. Putrescine concentration 2.25 mmol showed maximum number of primary branches (17.99) at 60 DAT which was statistically at par with 2.50 mmol (16.74), control (16.49), 3.00 mmol (14.33 cm) and significant to 1.75 mmol (13.33), 2.75 mmol (12.16), 2.00 mmol (9.49), 1.50 mmol (6.58), 1.00 mmol (4.74), 1.25 mmol (4.58). Putrescine concentration 2.75 mmol showed maximum number of primary branches (36.99) at 90 DAT which was statistically at par with 2.50 mmol (34.66), 2.00 mmol (34.32), 2.25 mmol (31.99) and significant to 1.50 mmol (30.58), 3.00 mmol (29.58), 1.25 mmol (28.74), 1.75 mmol (28.41), control (27.66), 1.00 mmol (24.66).

4.1.1.4 Number of secondary branches

The result pertaining to the number of secondary branches as governed by different concentrations of putrescine is presented in the Table 4.2 and Fig. 4.4. It is noticeable from the data that number of secondary branches varies from 1.00 to 9.83 for 60 DAT and from 113.74 to 176.99 for 90 DAT. At 60 DAT, maximum number of secondary branches (9.83) were found in treatment 2.25 mmol which was statistically at par with 1.75 mmol (9.16) and significant to 2.50 mmol (8.99), 3.00 mmol (6.16), control (5.08), 2.00 mmol (2.33), 2.75 mmol (1.75), 1.25 mmol (1.74), 1.50 mmol (1.08), 1.00 mmol (1.00). Similarly, maximum number of secondary branches (176.99) at 90 DAT were recorded by 2.75 mmol which was statistically at par with 3.00 mmol (175.91), 2.50 mmol (170.66) and significant to 2.00 mmol (153.49), 2.25 mmol (150.99), control (131.41), 1.75 mmol (128.08), 1.50 mmol (124.24), 1.25 mmol (120.58), 1.00 mmol (113.74).

Table 4.1: Effect of various concentrations of putrescine on plant height and plant spread in cornflower

Treatment (mmol)	Plant height at 60 DAT (cm)	Plant height at 90 DAT (cm)	Plant spread at 60 DAT (cm)	Plant spread at 90 DAT (cm)
Control	40.36	83.37	37.49	48.11
1.00	28.21	87.58	36.78	42.94
1.25	27.03	84.57	38.39	46.02
1.50	32.90	88.31	41.81	46.18
1.75	36.36	75.50	38.79	48.22
2.00	30.99	83.03	39.60	53.48
2.25	37.36	85.80	41.71	52.33
2.50	42.18	87.29	41.57	56.60
2.75	35.40	95.04	42.50	58.39
3.00	34.45	89.50	40.97	49.39
C.D. at 5%	2.45	1.35	1.59	7.42

Table 4.2: Effect of various concentrations of putrescine on number of primary and secondary branches in cornflower

Treatment (mmol)	No. of primary branches at 60 DAT	No. of primary branches at 90 DAT	No. of secondary branches at 60 DAT	No. of secondary branches at 90 DAT
Control	16.49	27.66	5.08	131.41
1.00	4.74	24.66	1.00	113.74
1.25	4.58	28.74	1.74	120.58
1.50	6.58	30.58	1.08	124.24
1.75	13.33	28.41	9.16	128.08
2.00	9.49	34.32	2.33	153.49
2.25	17.99	31.99	9.83	150.99
2.50	16.74	34.66	8.99	170.66
2.75	12.16	36.99	1.75	176.99
3.00	14.33	29.58	6.16	175.91
C.D. at 5%	4.62	5.77	0.79	21.65

Fig 4.1: Graphical representation of various concentrations of putrescine on plant height in cornflower

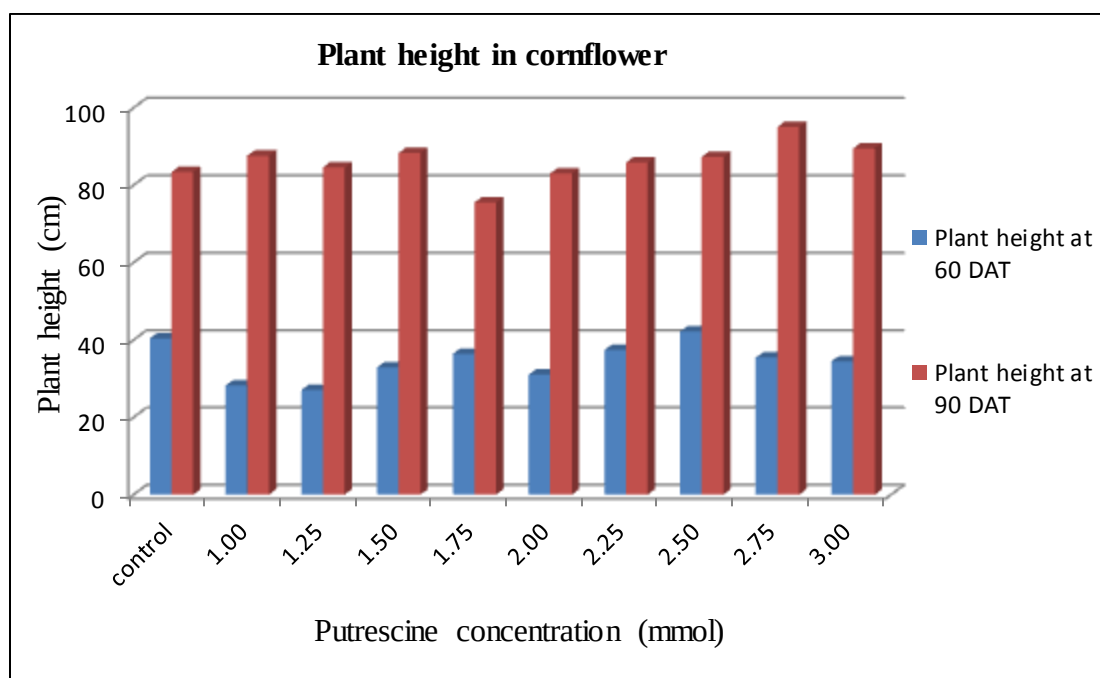


Fig 4.2: Graphical representation of various concentrations of putrescine on plant spread in cornflower

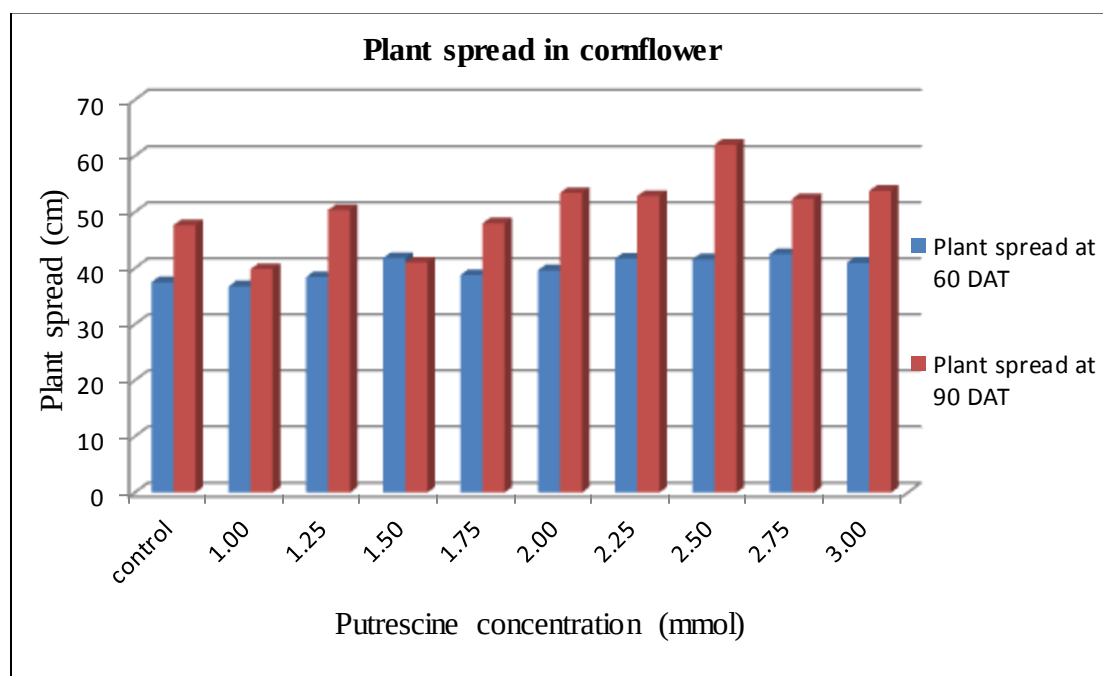


Fig 4.3: Graphical representation of various concentrations of putrescine on number of primary branches in cornflower

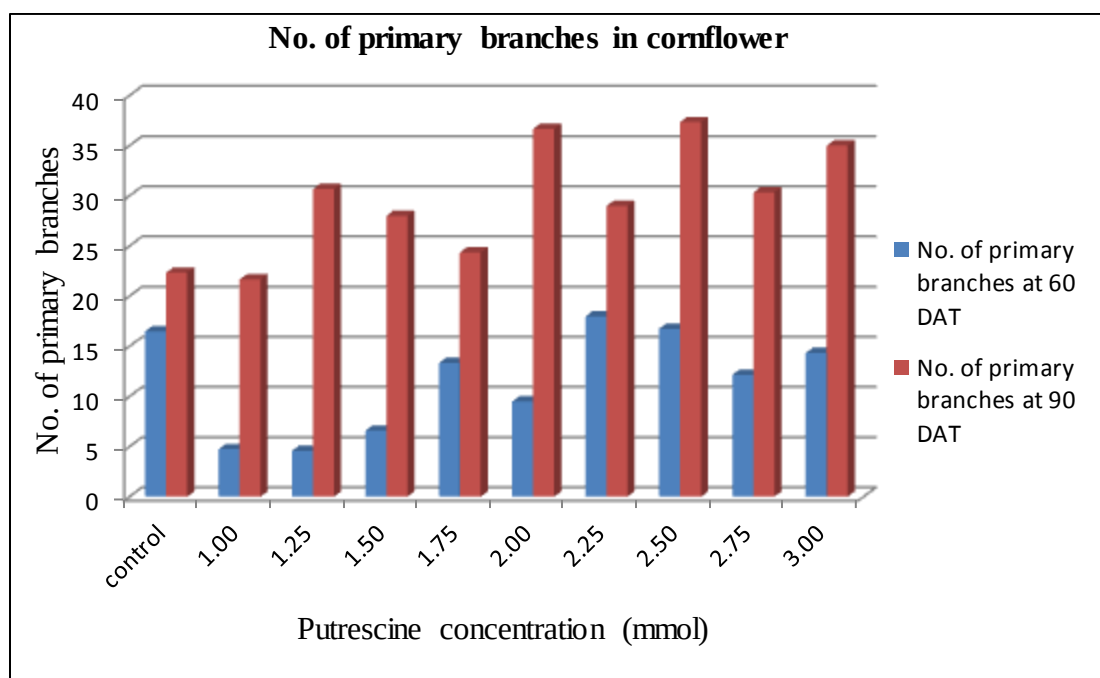
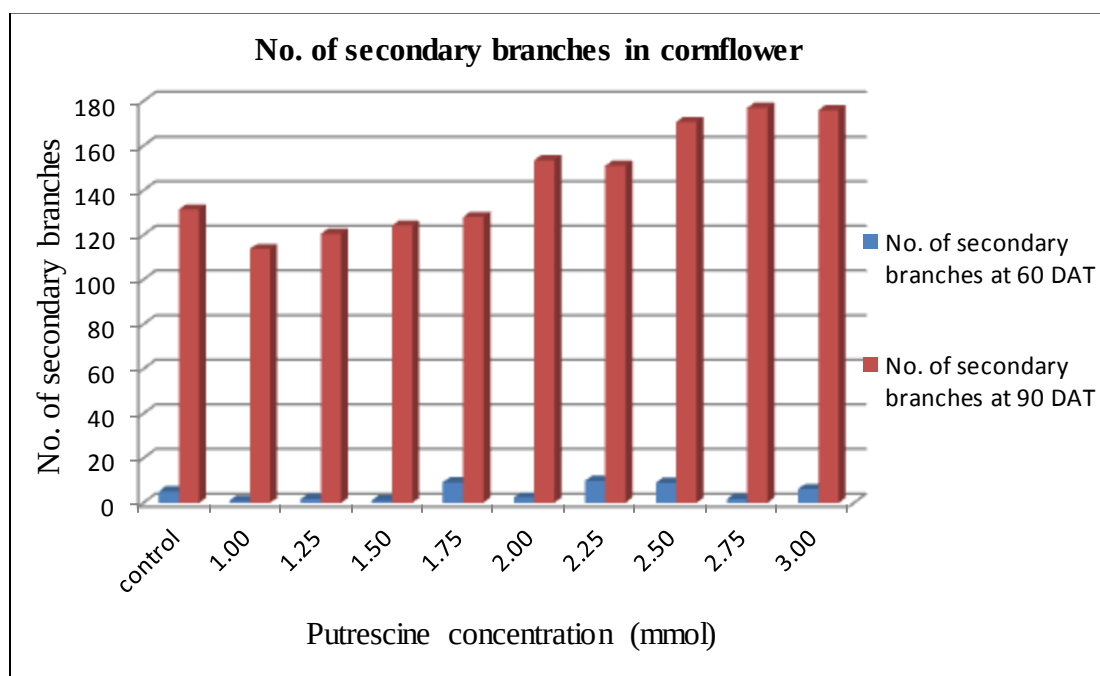


Fig 4.4: Graphical representation of various concentrations of putrescine on number of secondary branches in cornflower



4.1.1.5 Fresh weight of leaf (g)

The results adverting to fresh weight of leaf as influenced by different treatments of putrescine are presented in the Table 4.3 and represented graphically in the Fig. 4.5. The table shows that the fresh weight of leaf differed from 0.15 g to 0.41 g. Maximum fresh weight of leaf (0.41 g) was recorded by 1.00 mmol which was statistically at par with 2.75 mmol (0.39 g) and significant to 3.00 mmol (0.35 g), 1.25 mmol (0.33 g), 1.50 mmol (0.31 g), control (0.27 g), 2.25 mmol (0.26 g), 1.75 mmol (0.22 g), 2.50 mmol (0.18 g), 2.00 mmol (0.15 g).

4.1.1.6 Dry weight of leaf (g)

It is evident from the table (Table 4.3) and Fig. 4.6 that different concentrations of putrescine had a significant influence on dry weight of leaf. It varied from 0.035 g to 0.064 g. Maximum dry weight of leaf (0.064 g) was showed at 1.00 mmol which was statistically at par with both 1.25 and 2.75 mmol (0.061 g) and significant to 3.00 mmol (0.058 g), 1.50 mmol (0.056 g), control (0.050 g), 2.25 mmol (0.045 g), 1.75 mmol (0.044 g), 2.00 mmol (0.039 g), 2.50 mmol (0.035 g).

4.1.1.7 Leaf area (cm²)

The data of leaf area governed by different doses of putrescine is presented in the Table 4.3 and Fig. 4.7. It is clear from the table that the leaf area varied from 6.97 cm² to 14.81 cm². Maximum leaf area (14.81 cm²) was seen in 2.75 mmol concentration which was statistically at par with 1.50 mmol (14.64 cm²), 2.50 mmol (13.30 cm²), 1.00 mmol (11.44cm²), 1.75 mmol (10.55cm²), 1.25 mmol (10.46cm²) and significant to 3.00 mmol (9.44cm²), 2.25 mmol (9.08cm²), 2.00 mmol (8.57cm²), control (6.97 cm²).

Table 4.3: Effect of various concentrations of putrescine on fresh weight of leaf, dry weight of leaf and leaf area in cornflower

Treatment (mmol)	Fresh weight of leaf (g)	Dry weight of leaf (g)	Leaf area (cm²)
Control	0.27	0.050	6.97
1.00	0.41	0.064	11.44
1.25	0.33	0.061	10.46
1.50	0.31	0.056	14.64
1.75	0.22	0.044	10.55
2.00	0.15	0.039	8.57
2.25	0.26	0.045	9.08
2.50	0.18	0.035	13.30
2.75	0.39	0.061	14.81
3.00	0.35	0.058	9.44
C.D. at 5%	0.02	0.004	4.76

Fig 4.5: Graphical representation of various concentrations of putrescine on fresh weight of leaf in cornflower

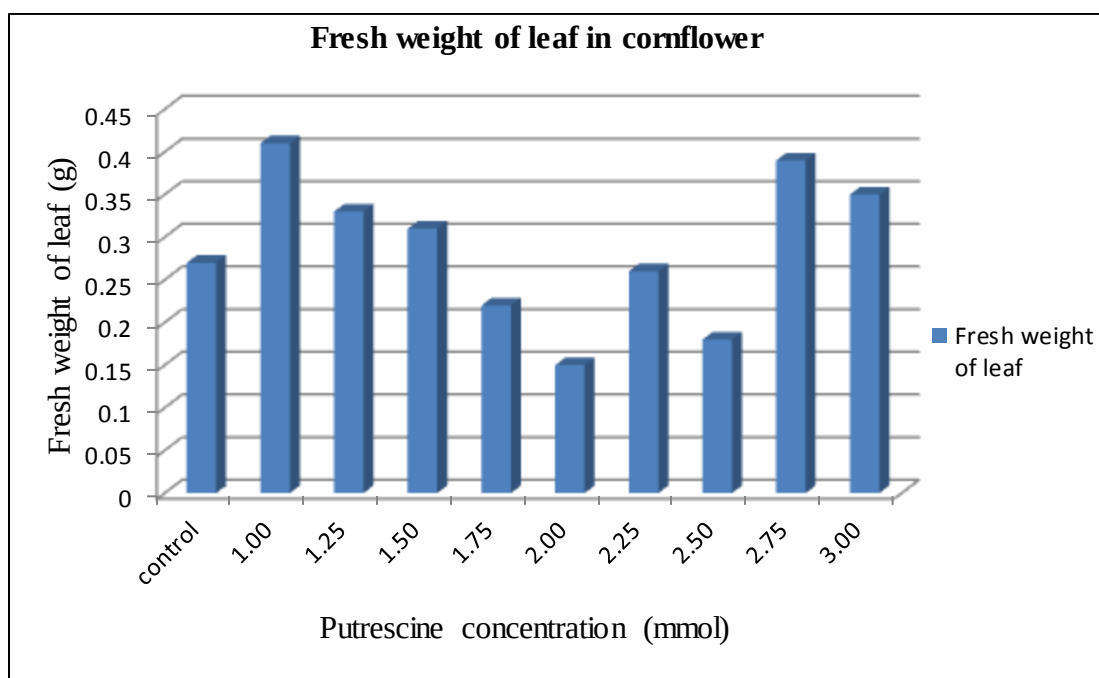


Fig 4.6: Graphical representation of various concentrations of putrescine on dry weight of leaf in cornflower

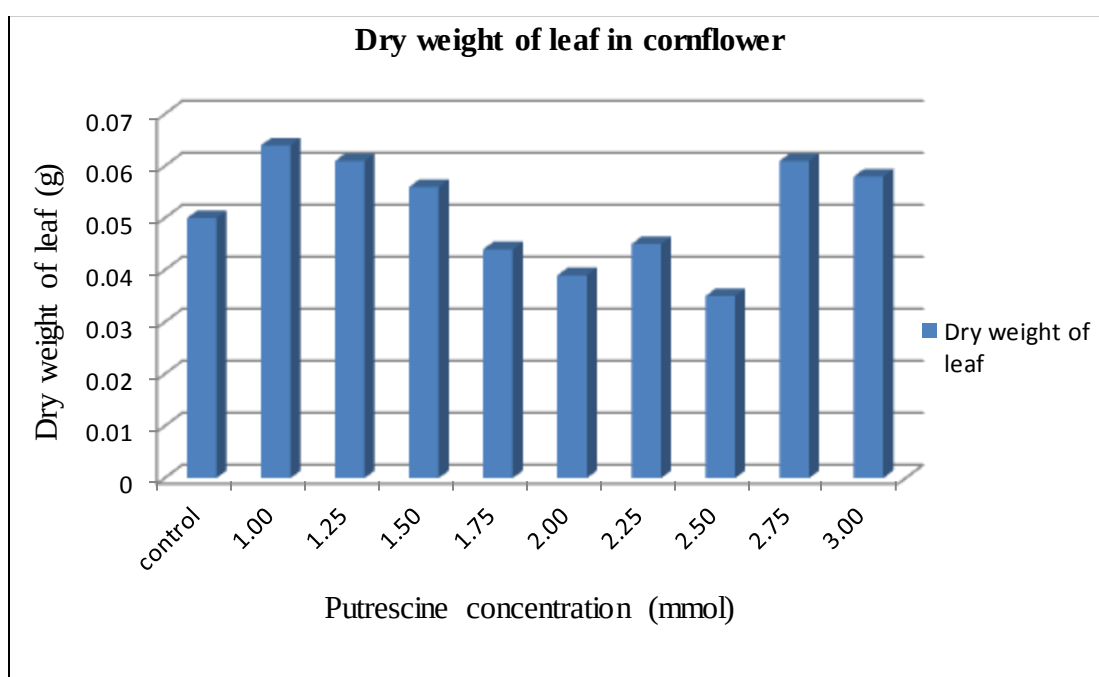
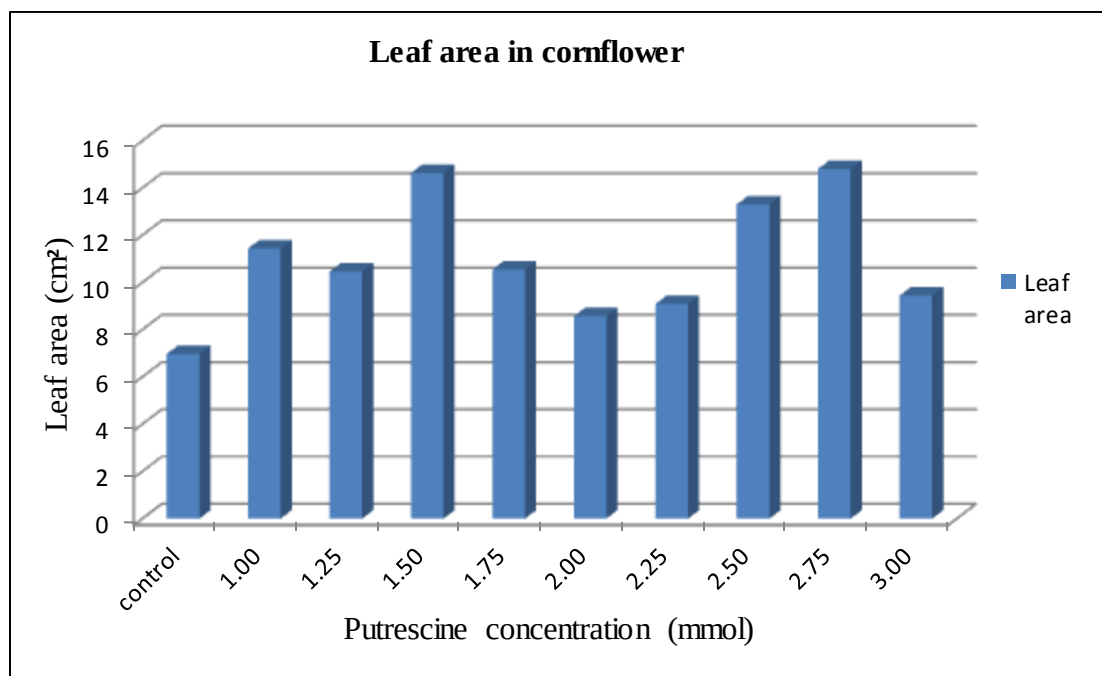


Fig 4.7: **Graphical representation of various concentrations of putrescine on leaf area in cornflower**



4.1.2 Observations recorded on flowering characters

4.1.2.1 Days to bud initiation

The result pertaining to days to bud initiation is represented in Table 4.4 and Fig. 4.8. Different putrescine treatments had significant influence on days to bud initiation. Days to bud initiation varied from 56.99 days to 62.58 days. Earliest bud initiation (56.99 days) was noticed in control which was statistically at par with 2.75 mmol (59.74 days), 3.00 mmol (59.57 days), 1.50 mmol (59.16 days), both 1.75 mmol and 2.25 mmol (57.41 days), 2.50 mmol (57.33 days) and significant to 1.25 mmol (62.58 days), 2.00 mmol (62.41 days), 1.00 mmol (61.91 days). Late bud initiation (62.58 days) was observed at concentration 1.25 mmol.

4.1.2.2 Pedicel length (cm)

The data adverting to pedicel length is presented in Table 4.4 and Fig. 4.9. It varied from 17.51 cm to 24.18 cm. Putrescine @ 2.75 mmol concentration attained significantly maximum pedicel length (24.18 cm) which was statistically at par with 2.25 mmol (22.66 cm), 3.00 mmol (22.19 cm) and significant to 2.50 mmol (21.12 cm), 1.75 mmol (21.09 cm), 1.50 mmol (20.81 cm), 1.25 mmol (19.43 cm), 2.00 mmol (18.83 cm), control (17.91 cm). Whereas, minimum pedicel length (17.51 cm) was attained at 1.00 mmol concentration.

4.1.2.3 Days to bud development

The data presented in Table 4.4 and Fig. 4.10 clearly shown the significant influence of various putrescine treatments on days to bud development and it varied from 74.41 days to 78.66 days. It is evident from the data that earliest bud development (74.41 days) resulted from application of 2.50 mmol which was statistically at par with 2.75 mmol (76.08 days), 3.00 mmol (75.74 days), 1.50 mmol (75.32 days), control (74.91 days), 1.75 mmol (74.83 days), 2.25 mmol (74.66 days) and significant to 2.00 mmol (78.66 days), 1.00 mmol (77.58 days), 1.25 mmol (77.49 days). Whereas, late bud development (78.66 days) was observed in treatment 2.00 mmol.

Table 4.4: Effect of various concentrations of putrescine on days to bud initiation, pedicel length and days to bud development in cornflower

Treatment (mmol)	Days to bud initiation (days)	Pedicel length (cm)	Days to bud development (days)
Control	56.99	17.91	74.91
1.00	61.91	17.51	77.58
1.25	62.58	19.43	77.49
1.50	59.16	20.81	75.32
1.75	57.41	21.09	74.83
2.00	62.41	18.83	78.66
2.25	57.41	22.66	74.66
2.50	57.33	21.12	74.41
2.75	59.74	24.18	76.08
3.00	59.57	22.19	75.74
C.D. at 5%	2.99	2.92	2.73

Fig 4.8: Graphical representation of various concentrations of putrescine on days to bud initiation in cornflower

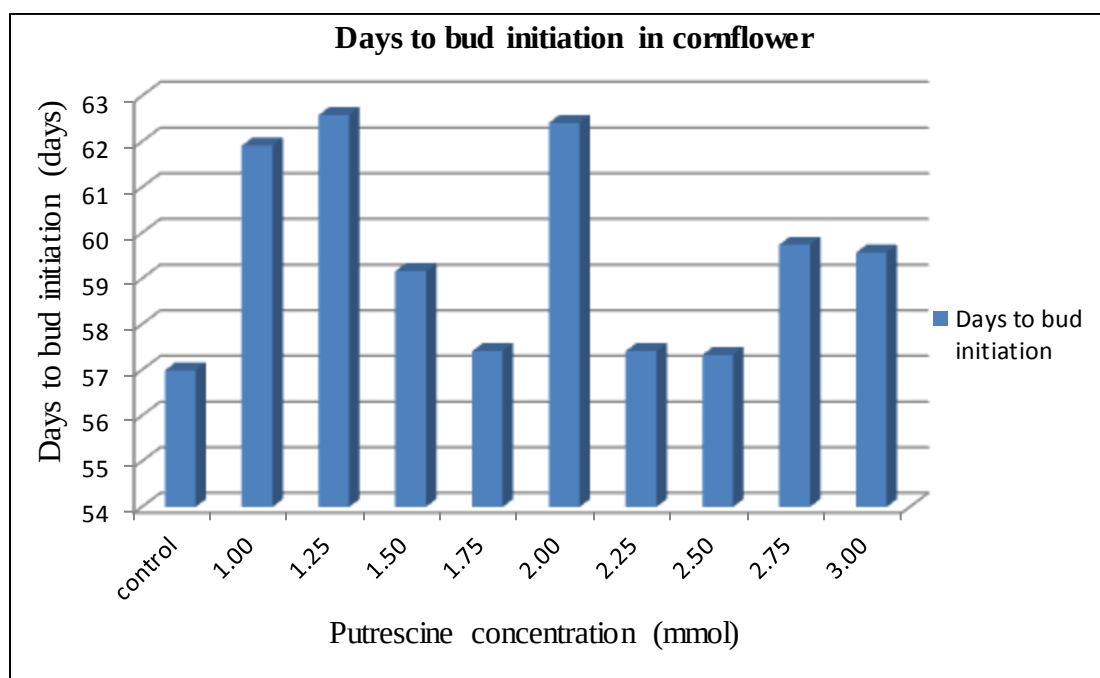


Fig 4.9: Graphical representation of various concentrations of putrescine on pedicel length in cornflower

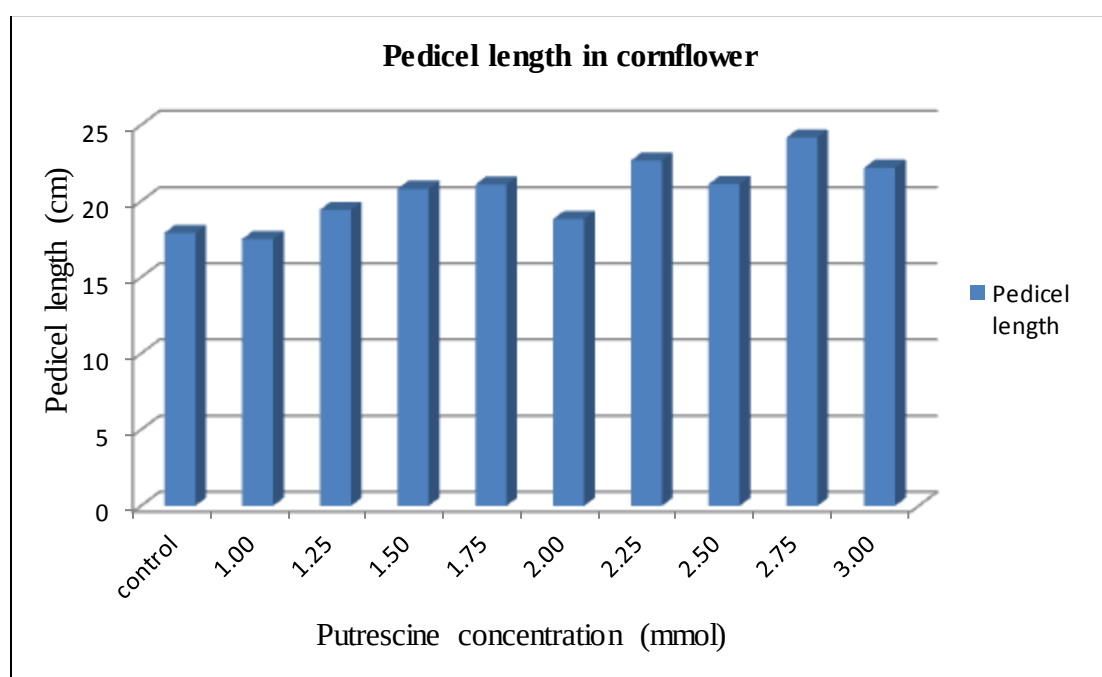
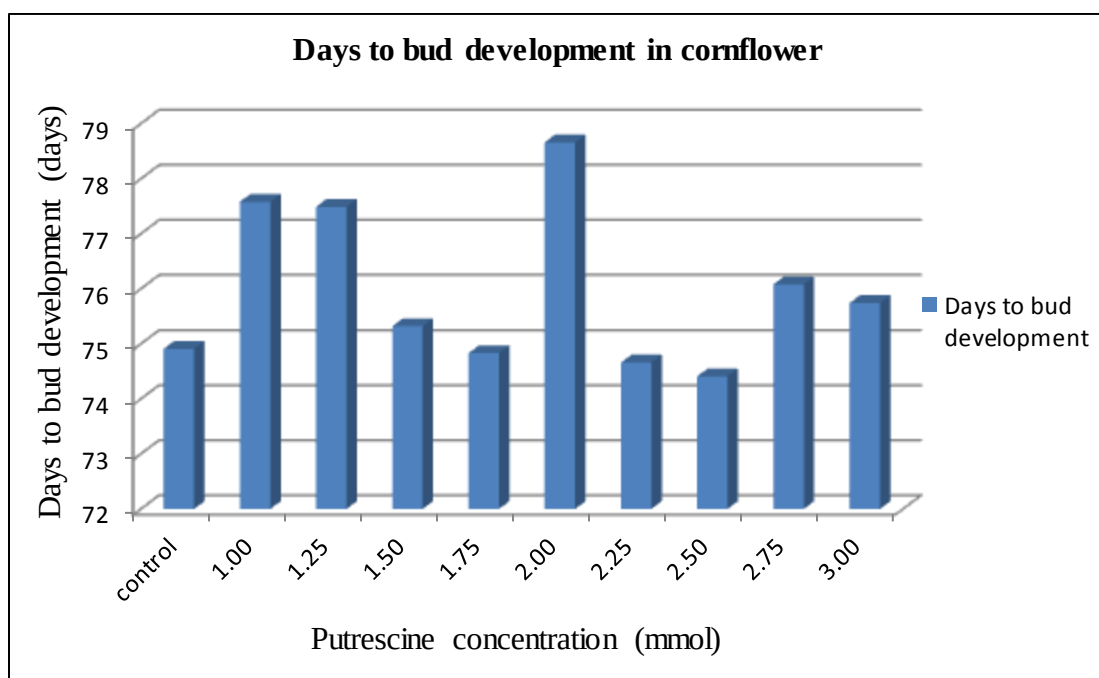


Fig 4.10: Graphical representation of various concentrations of putrescine on days to bud development in cornflower



4.1.2.4 Bud diameter (mm)

Table 4.5 and Fig. 4.11 represents data pertaining to bud diameter. The bud diameter varied from 9.49 mm to 10.69 mm. Maximum bud diameter (10.69 mm) was recorded at 2.50 mmol concentration which was statistically at par with 1.75 mmol (10.57 mm), 2.75 mmol (10.25 mm), 3.00 mmol (10.19 mm) and significant to 2.00 mmol (10.05 mm), 2.25 mmol (9.99 mm), control (9.87 mm), 1.00 mmol (9.86 mm), 1.50 mmol (9.65 mm). Minimum bud diameter (9.49 mm) was noticed in 1.25 mmol concentration of putrescine.

4.1.2.5 Disc diameter (cm)

It is evident from the data Table 4.5 and Fig. 4.12 that different treatments of putrescine significantly influenced the disc diameter. The disc diameter was in the range of 1.80 cm to 2.13 cm. Maximum disc diameter (2.13 cm) was attained by 2.00 mmol concentration which was statistically at par with 1.00 mmol (2.10 cm), 1.25 mmol (2.08 cm), 1.75 mmol (2.05 cm) and significant to 2.25 mmol (1.99 cm), both 1.50 and 2.50 mmol (1.97 cm), 2.75 mmol (1.94 cm), 3.00 mmol (1.85 cm) while minimum (1.80 cm) was attained by control.

4.1.2.6 Flower diameter (cm)

The mean data pertaining to the flower diameter is presented in the Table 4.5 and Fig. 4.13. It varied from 4.36 cm to 4.64 cm. Maximum flower diameter (4.64 cm) was found with 2.00 mmol concentration which was statistically at par with 2.25 mmol (4.62 cm) and significant to both 1.00 mmol and 2.75 mmol (4.51 cm), both 1.25 mmol and 1.75 mmol (4.48 cm), 2.50 mmol (4.45 cm), control (4.43 cm), 1.50 mmol (4.38 cm) while minimum (4.36 cm) was observed at 3.00 mmol concentration.

Table 4.5: Effect of various concentrations of putrescine on bud diameter, disc diameter and flower diameter in cornflower

Treatment (mmol)	Bud diameter (mm)	Disc diameter (cm)	Flower diameter (cm)
Control	9.87	1.80	4.43
1.00	9.86	2.10	4.51
1.25	9.49	2.08	4.48
1.50	9.65	1.97	4.38
1.75	10.57	2.05	4.48
2.00	10.05	2.13	4.64
2.25	9.99	1.99	4.62
2.50	10.69	1.97	4.45
2.75	10.25	1.94	4.51
3.00	10.19	1.85	4.36
C.D. at 5%	0.63	0.10	0.03

Fig 4.11: Graphical representation of various concentrations of putrescine on bud diameter in cornflower

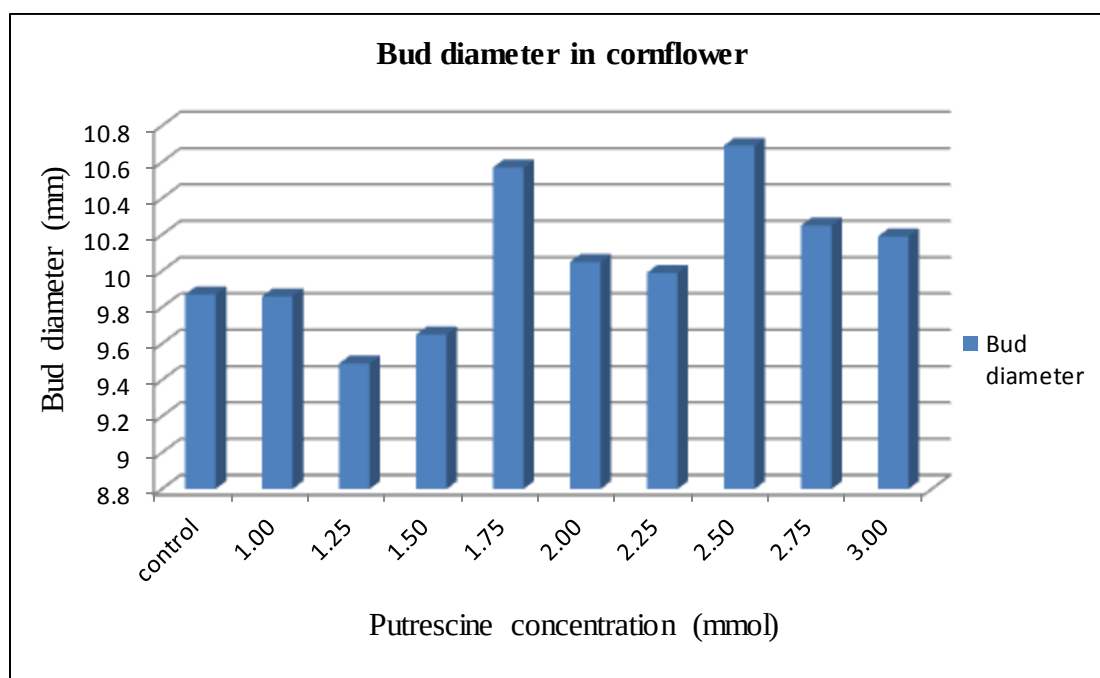


Fig 4.12: Graphical representation of various concentrations of putrescine on disc diameter in cornflower

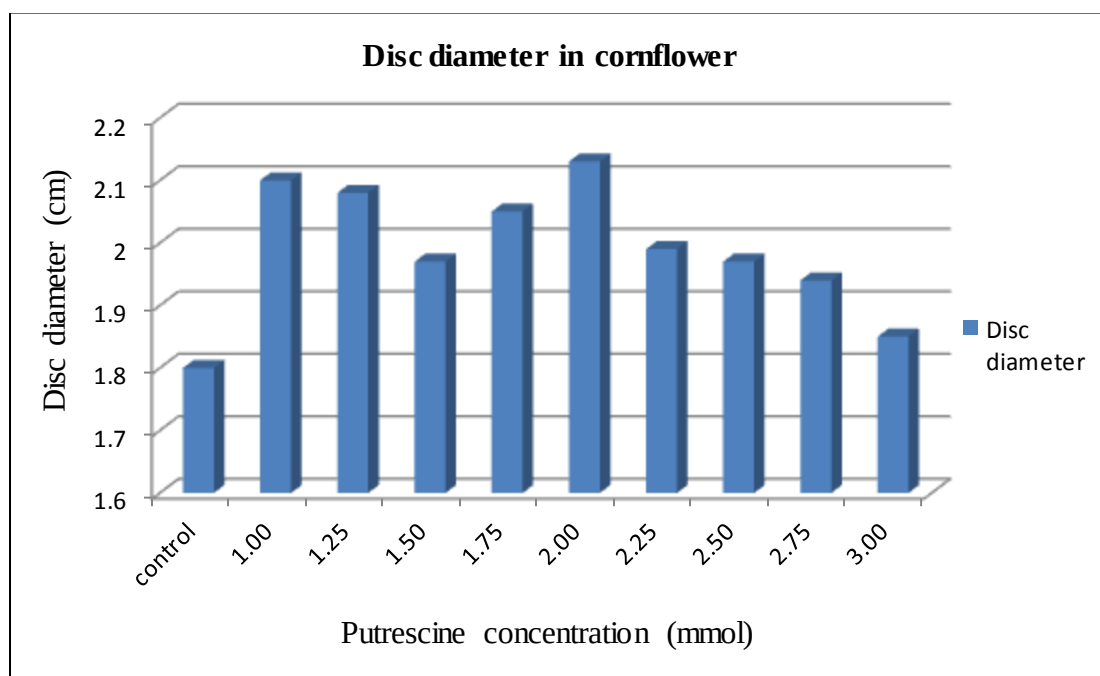
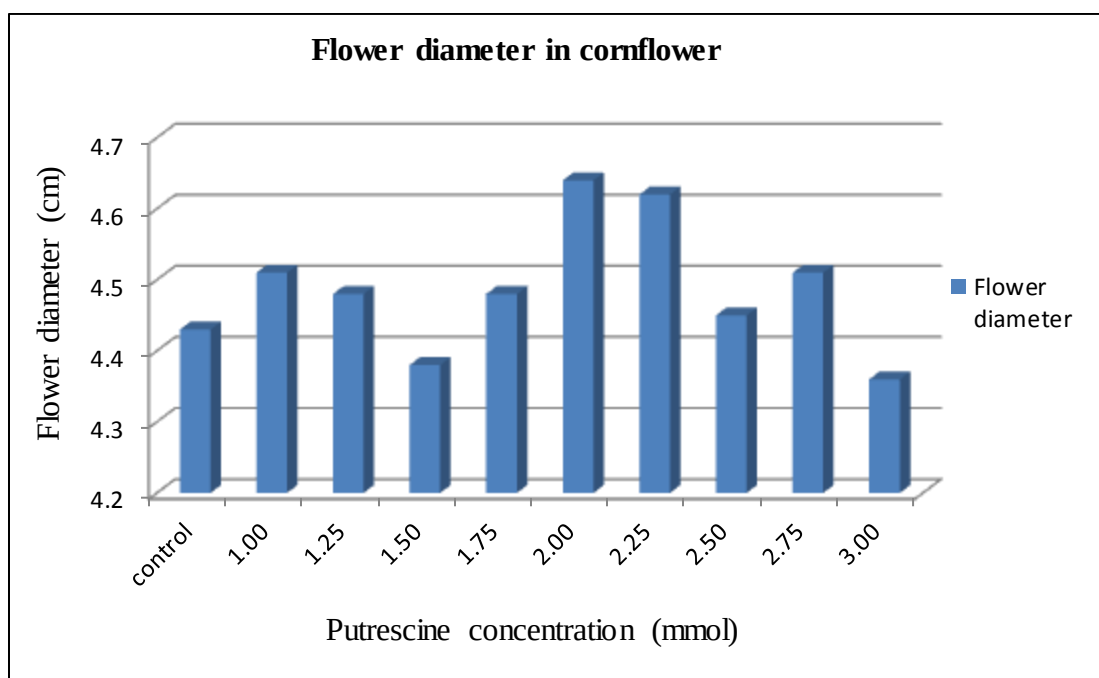


Fig 4.13: Graphical representation of various concentrations of putrescine on flower diameter in cornflower



4.1.2.7 Days to flower blooming

It is evident from the data represented in Table 4.6 and Fig. 4.14 that different concentrations of putrescine had significant influence on days to flower blooming. Days to flower blooming differed significantly from 79.24 days to 82.83 days. It is apparent from the table that earliest flower blooming (79.24 days) was recorded at 2.50 mmol which was statistically at par with 2.75 mmol (80.41 days), both 1.5 mmol and 3.00 mmol (80.08 days), 2.25 mmol (79.66 days), both control and 1.75 mmol (79.49 days) and significant to 2.00 mmol (82.83 days), 1.25 mmol (82.74 days), 1.00 mmol (82.66 days). However, late flower blooming (82.83 days) was reported by treatment 2.00 mmol.

4.1.2.8 Number of flowers/plant

The result pertaining to number of flowers/plant is presented in Table 4.6 and Fig. 4.15. Various concentrations of putrescine had significant effect on number of flowers/plant. It was in the range from 348.24 to 622.24. Maximum number of flowers/plant (622.24) was attained at 2.75 mmol which was statistically at par with 3.00 mmol (567.83), 2.50 mmol (530.99), 2.25 mmol (485.33), 1.50 mmol (467.66) and significant to 2.00 mmol (424.99), control (412.91), 1.25 mmol (403.41), 1.75 mmol (390.58) while, 1.00 mmol recorded minimum number of flowers/plant (348.24).

4.1.2.9 Flower longevity

The data pertaining to flower longevity is presented in Table 4.6 and Fig. 4.16. Flower longevity was greatly influenced by different concentrations of putrescine and was found in the range between 6.74 days to 8.58 days. Maximum flower longevity (8.58 days) was resulted at 2.00 mmol concentration which was statistically at par with 3.00 mmol (8.32 days) and significant to all three 1.50 mmol, 2.25 mmol and 2.75 mmol (7.49 days) concentration together, 2.50 mmol (7.41 days), control (7.24 days), both 1.00 mmol and 1.25 mmol (6.83 days). Minimum flower longevity (6.74 days) was recorded at 1.75 mmol concentration.

Table 4.6: Effect of various concentrations of putrescine on days to flower blooming, number of flowers/plant and flower longevity in cornflower

Treatment (mmol)	Days to flower blooming (days)	No. of flowers/plant	Flower longevity (days)
Control	79.49	412.91	7.24
1.00	82.66	348.24	6.83
1.25	82.74	403.41	6.83
1.50	80.08	467.66	7.49
1.75	79.49	390.58	6.74
2.00	82.83	424.99	8.58
2.25	79.66	485.33	7.49
2.50	79.24	530.99	7.41
2.75	80.41	622.24	7.49
3.00	80.08	567.83	8.32
C.D. at 5%	2.33	166.87	0.98

Fig 4.14: Graphical representation of various concentrations of putrescine on days to flower blooming in cornflower

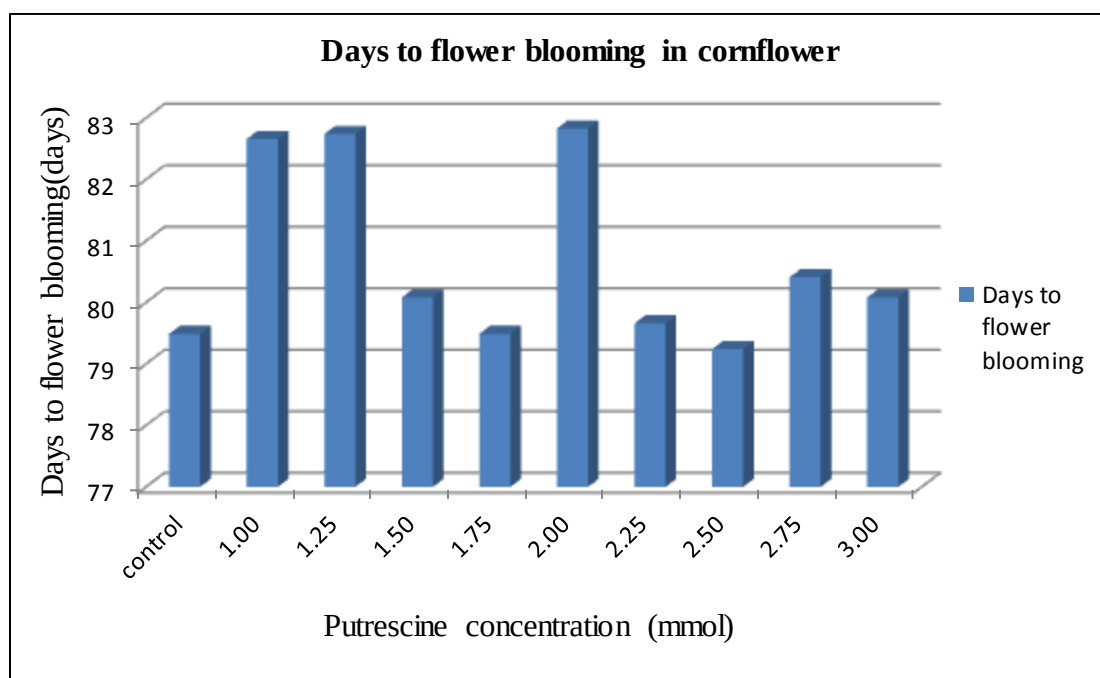


Fig 4.15: Graphical representation of various concentrations of putrescine on number of flowers/plant in cornflower

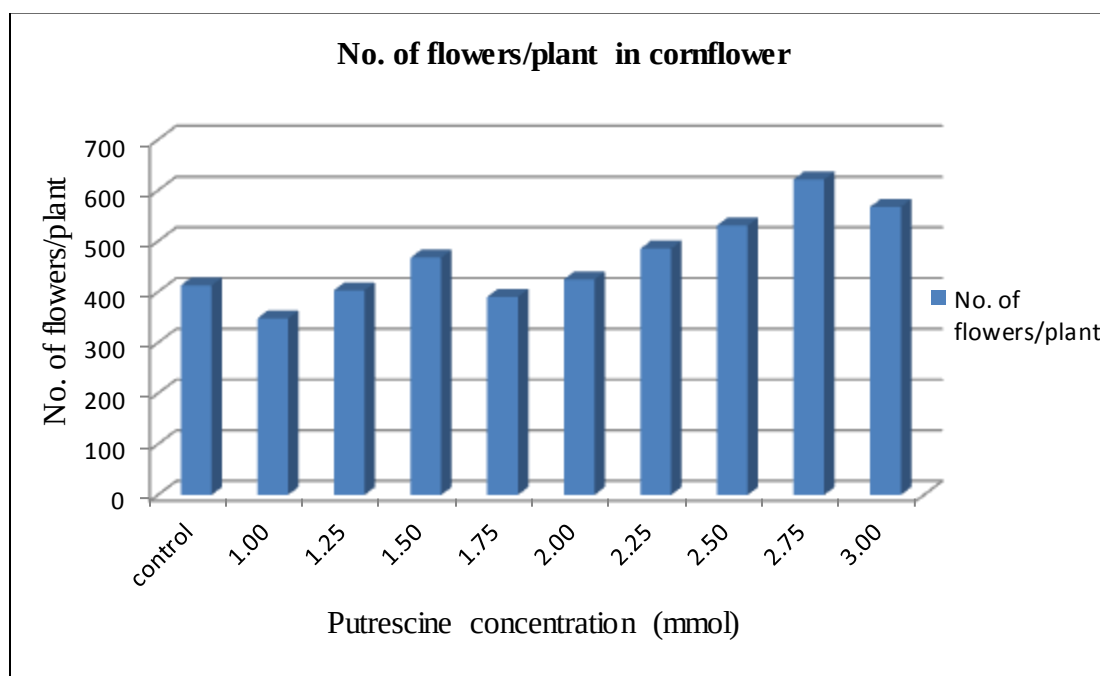
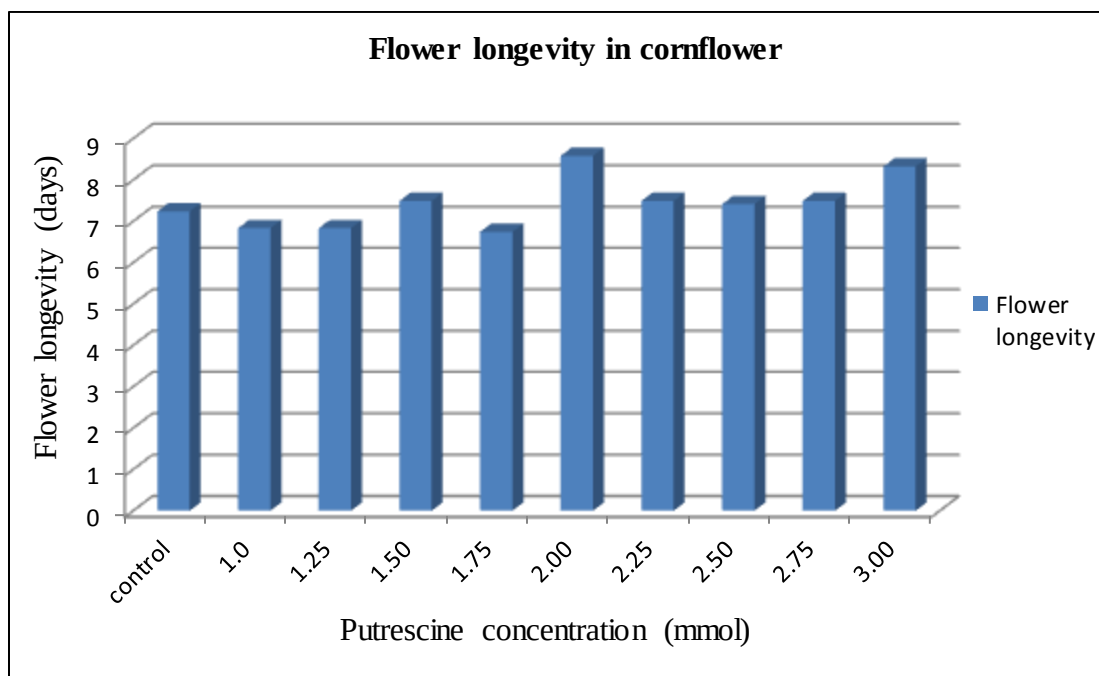


Fig 4.16: Graphical representation of various concentrations of putrescine on flower longevity in cornflower



4.1.2.10 Days to flower withering

The data pertaining to days to flower withering as shown in Table 4.7 and Fig. 4.17 revealed that various concentration of putrescine had significant influence on days to flower withering. It was varied from 86.24 days to 91.41 days. Late flower withering (91.41 days) was found in treatment 2.00 mmol which was found significant to 1.25 mmol (89.58 days), 1.00 mmol (89.49 days), 3.00 mmol (88.41 days), 2.75 mmol (87.91 days), 1.50 mmol (87.58 days), 2.25 mmol (87.16 days), control (86.74 days), 2.50 mmol (86.66 days). Early flower withering (86.24 days) was recorded with 1.75 mmol.

4.1.2.11 Fresh weight of flower (g)

The mean data governing fresh weight of flower is presented in the Table 4.7 and Fig. 4.18. It lies in the range from 0.470 g to 0.525 g. Maximum fresh weight of flower (0.525 g) was observed at 1.25 mmol concentration which was significant to all other treatments. The minimum fresh weight of flower (0.470 g) was reported with control.

4.1.2.12 Dry weight of flower (g)

The result pertaining to dry weight of flower is presented in Table 4.7 and Fig. 4.19. It varied from 0.117 g to 0.138 g. Maximum dry weight of flower (0.138 g) was noticed at 2.75 mmol which was statistically at par with 3.00 mmol (0.136 g) then 1.00 mmol, 1.25 mmol and 2.25 mmol (0.135 g) together and significant to control (0.132 g), 2.50 mmol (0.130 g), both 1.75 mmol and 2.00 mmol (0.127 g). The minimum dry weight of flower (0.117 g) was recorded at 1.50 mmol concentration.

4.1.2.13 Flower yield/m²

The mean data pertaining to flower yield/m² is represented in Table 4.8 and Fig. 4.20. It varied from 594 g/m² to 1053.33 g/m². Maximum flower yield per m² (1053.33g/m²) was attained at 2.75 mmol which was significant to all other treatments. Minimum flower yield/m² (594 g/m²) was recorded with treatment 1.00 mmol.

Table 4.7: **Effect of various concentrations of putrescine on days to flower withering, fresh weight of flower and dry weight of flower in cornflower**

Treatment (mmol)	Days to flower withering (days)	Fresh weight of flower (g)	Dry weight of flower (g)
Control	86.74	0.470	0.132
1.00	89.49	0.515	0.135
1.25	89.58	0.525	0.135
1.50	87.58	0.474	0.117
1.75	86.24	0.502	0.127
2.00	91.41	0.501	0.127
2.25	87.16	0.510	0.135
2.50	86.66	0.500	0.130
2.75	87.91	0.520	0.138
3.00	88.41	0.498	0.136
C.D. at 5%	1.57	0.002	0.003

Table 4.8: **Effect of various concentrations of putrescine on flower yield/m² in cornflower**

Treatment (mmol)	Flower yield/m² (g/m²)
Control	626.63
1.00	594.00
1.25	701.62
1.50	735.44
1.75	675.59
2.00	692.06
2.25	805.98
2.50	879.59
2.75	1053.33
3.00	922.97
C.D. at 5%	4.58

Fig 4.17: Graphical representation of various concentrations of putrescine on days to flower withering in cornflower

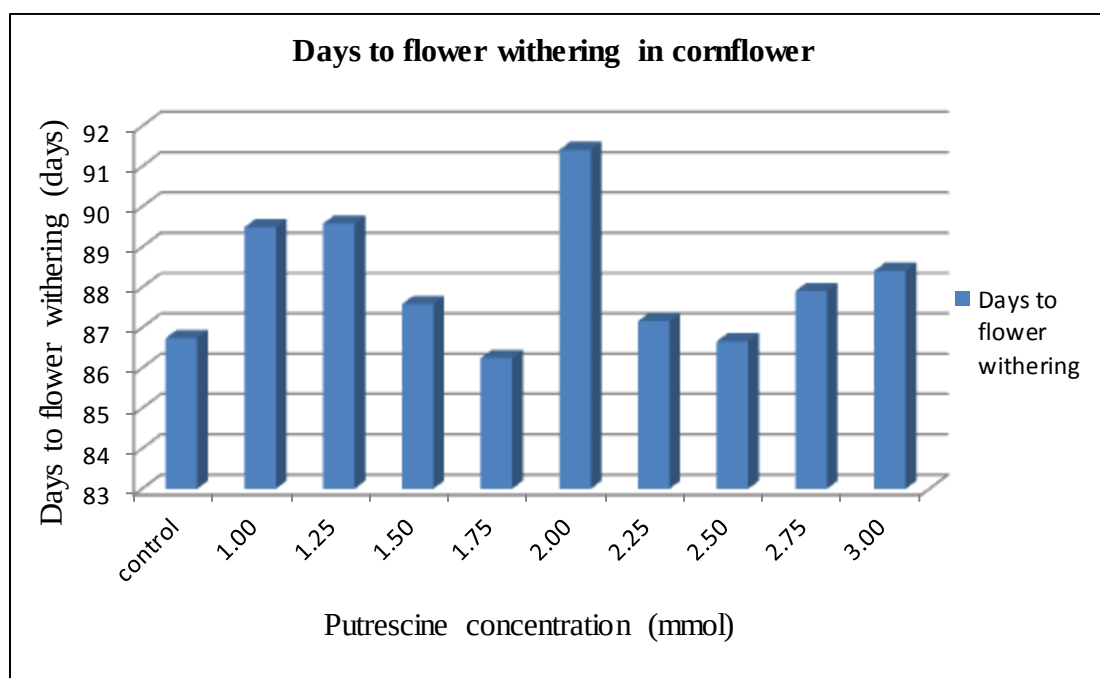


Fig 4.18: Graphical representation of various concentrations of putrescine on fresh weight of flower in cornflower

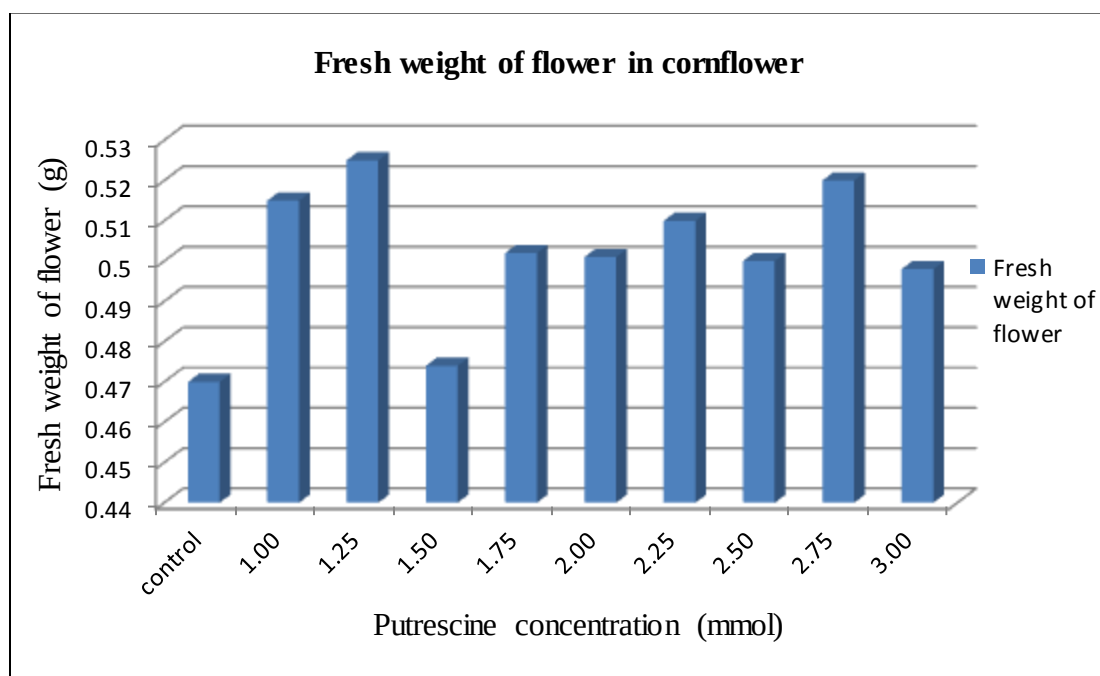


Fig 4.19: Graphical representation of various concentrations of putrescine on dry weight of flower in cornflower

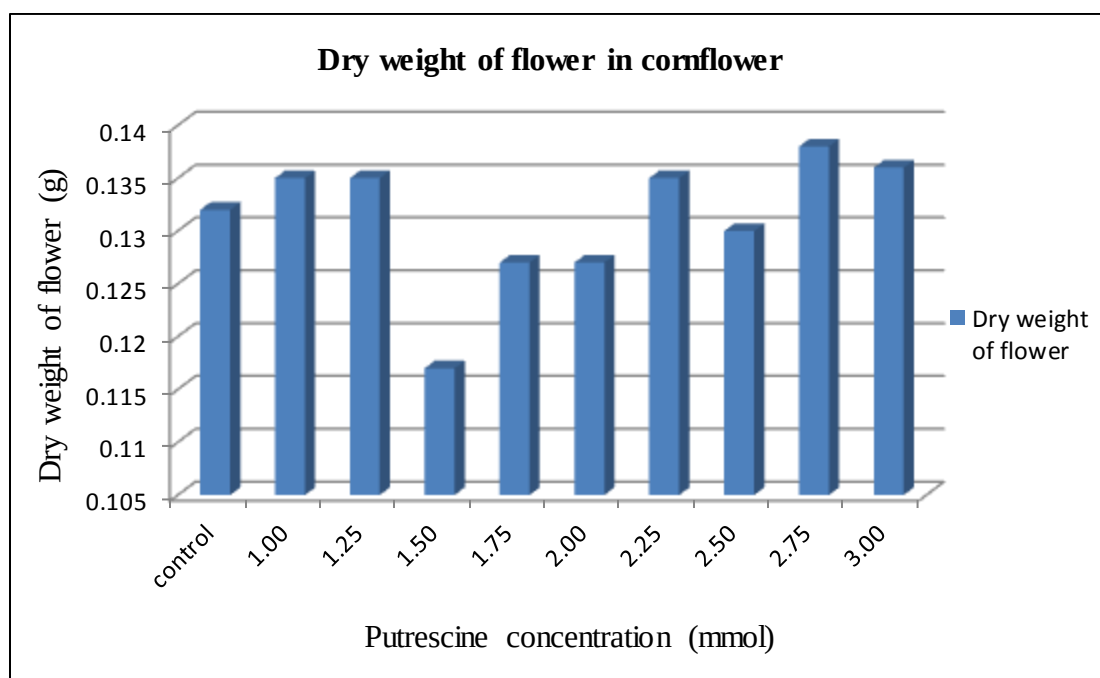
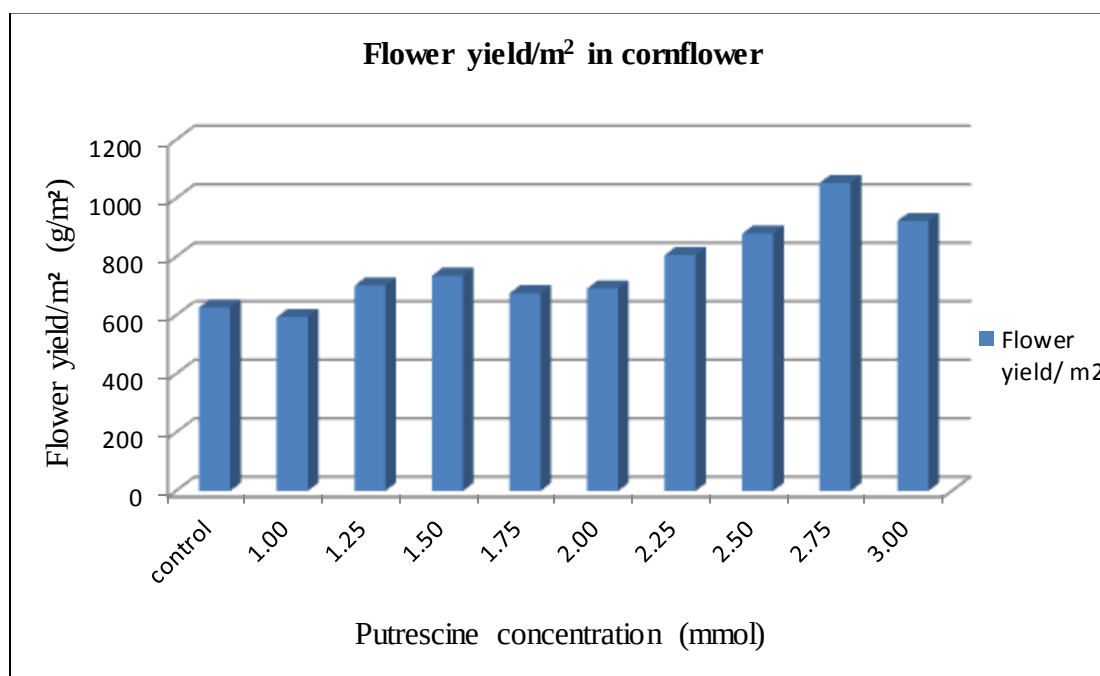


Fig 4.20: Graphical representation of various concentrations of putrescine on flower yield/m² in cornflower



4.1.3 Observations recorded on seed characters

4.1.3.1 Days to seed maturity

Table 4.9 and Fig. 4.21 showed days to seed maturity being highly influenced by different putrescine treatments. It varies from 100.07 days to 105.08 days. Putrescine concentration 2.00 mmol resulted in maximum days to seed maturity (105.08 days) which was statistically at par with 1.25 mmol (103.24 days), 1.00 mmol (103.08 days) and significant to 3.00 mmol (102.16 days), 2.75 mmol (101.66 days), 1.50 mmol (100.91 days), 2.25 mmol (100.58 days), 2.50 mmol (100.24 days), 1.75 mmol (100.16 days), while, minimum was noticed in control (100.07 days).

4.1.3.2 Number of seeds/flower

Table 4.9 and Fig. 4.22 shows number of seeds/flower being highly influenced by different putrescine treatments. It varies from 44.77 to 56.02. Putrescine @ 1.00 mmol (56.02) concentration resulted in maximum number of seeds/flower which was significant to all other treatments *i.e.*, 3.00 mmol (52.13), 1.25 mmol (50.93), 1.75 mmol (50.80), 1.50 mmol (49.38), 2.00 mmol (48.80), 2.50 mmol (48.46), 2.25 mmol (47.49), 2.75 mmol (46.07). Minimum number of seeds/flower was recorded with control (44.77).

Table 4.9: Effect of various concentrations of putrescine on days to seed maturity and number of seeds/flower in cornflower

Treatment (mmol)	Days to seed maturity (days)	No. of seeds/flower
Control	100.07	44.77
1.00	103.08	56.02
1.25	103.24	50.93
1.50	100.91	49.38
1.75	100.16	50.80
2.00	105.08	48.80
2.25	100.58	47.49
2.50	100.24	48.46
2.75	101.66	46.07
3.00	102.16	52.13
C.D. at 5%	2.12	3.50

Fig 4.21: Graphical representation of various concentrations of putrescine on days to seed maturity in cornflower

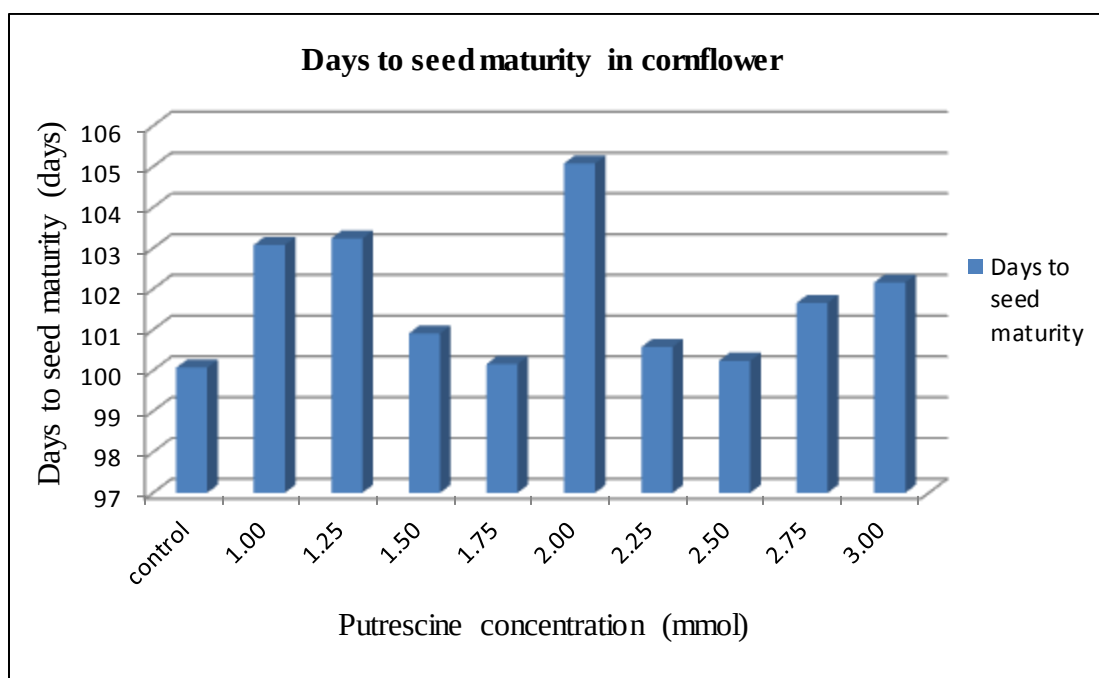
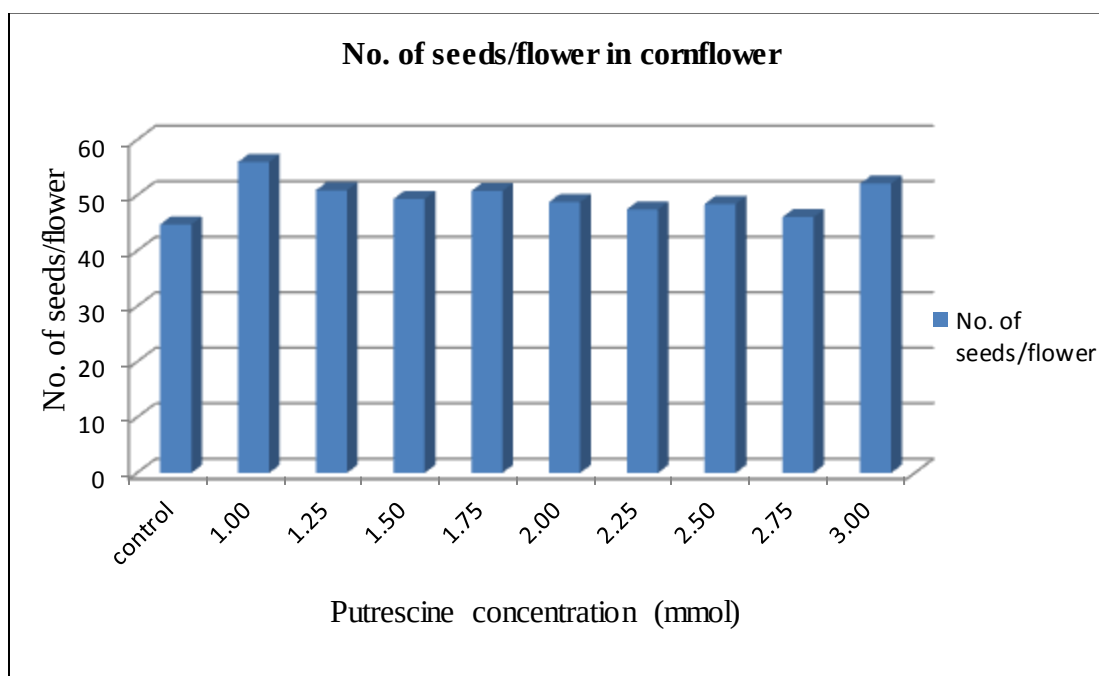


Fig 4.22: Graphical representation of various concentrations of putrescine on no. of seeds/flower in cornflower



4.1.3.3 1000 seed weight (g)

The data pertaining to 1000 seed weight is presented in Table 4.10 and Fig. 4.23. It was found to fall in between 4.64 g to 5.34 g. Maximum weight of 1000 seeds (5.34 g) was recorded at 3.00 mmol which was statistically at par with 2.25 mmol (5.32 g), 2.75 mmol (5.29 g), 2.50 mmol (5.18 g), 2.00 mmol (5.10 g), 1.50 mmol (5.07 g) and significant to 1.25 mmol (5.00 g), 1.00 mmol (4.97 g), control (4.94 g). Minimum weight of 1000 seeds (4.64 g) was attained by 1.75 mmol.

4.1.3.4 Seed yield/plant (g)

The data pertaining to seed yield/plant is presented in Table 4.10 and illustrated graphically in Fig. 4.24. It was found to lie in the range between 91.69 g to 151.64 g. Maximum seed yield/plant (151.64 g) was recorded at 2.75 mmol which was statistically at par with 2.50 mmol (133.31 g), 2.25 mmol (122.46 g), 3.00 mmol (122.00 g) and significant to 1.50 mmol (117.16 g), 2.00 mmol (105.46 g), 1.25 mmol (102.29 g), 1.00 mmol (97.52 g), 1.75 mmol (92.69 g). Minimum seed yield/plant (91.69 g) was attained by control.

4.1.3.5 Seed yield/m² (g/m²)

Table 4.10 and Fig. 4.25 showed seed yield/m² being highly influenced by different putrescine treatments. It varies from 297.72 g/m² to 510.17 g/m². Putrescine @ 3.00 mmol concentration resulted in maximum seed yield/m² (510.17 g/m²) which was statistically at par with 2.75 mmol (494.79 g/m²), 2.50 mmol (435.31 g/m²), 2.25 mmol (397.53 g/m²), 1.50 mmol (381.63 g/m²) and significant to 2.00 mmol (341.01 g/m²), 1.25 mmol (330.78 g/m²), 1.00 mmol (315.31 g/m²), 1.75 mmol (302.31 g/m²). Minimum seed yield/m² (297.72 g/m²) was reported by distilled water treated plants as control.

Table 4.10: Effect of various concentrations of putrescine on 1000 seed weight, seed yield/plant and seed yield/m² in cornflower

Treatment (mmol)	1000 seed weight (g)	Seed yield/plant (g)	Seed yield/m² (g/m²)
Control	4.94	91.69	297.72
1.00	4.97	97.52	315.31
1.25	5.00	102.29	330.78
1.50	5.07	117.16	381.63
1.75	4.64	92.69	302.31
2.00	5.10	105.46	341.01
2.25	5.32	122.46	397.53
2.50	5.18	133.31	435.31
2.75	5.29	151.64	494.79
3.00	5.34	122.00	510.17
C.D. at 5%	0.31	32.42	140.60

Fig 4.23: Graphical representation of various concentrations of putrescine on 1000 seed weight in cornflower

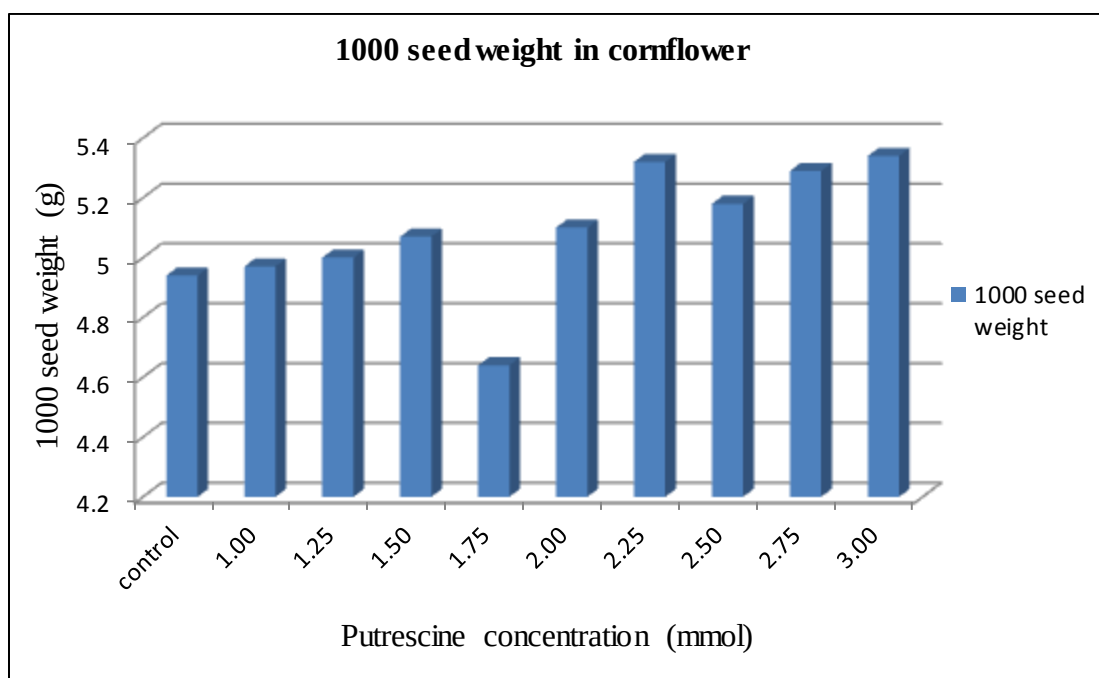


Fig 4.24: Graphical representation of various concentrations of putrescine on seed yield/plant in cornflower

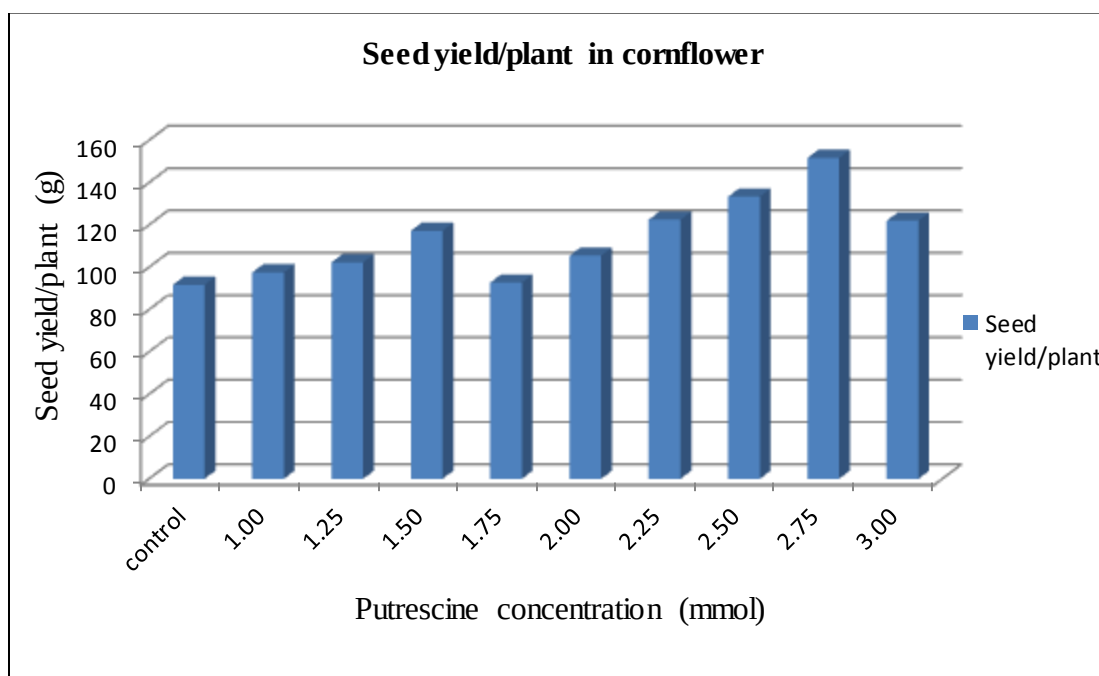
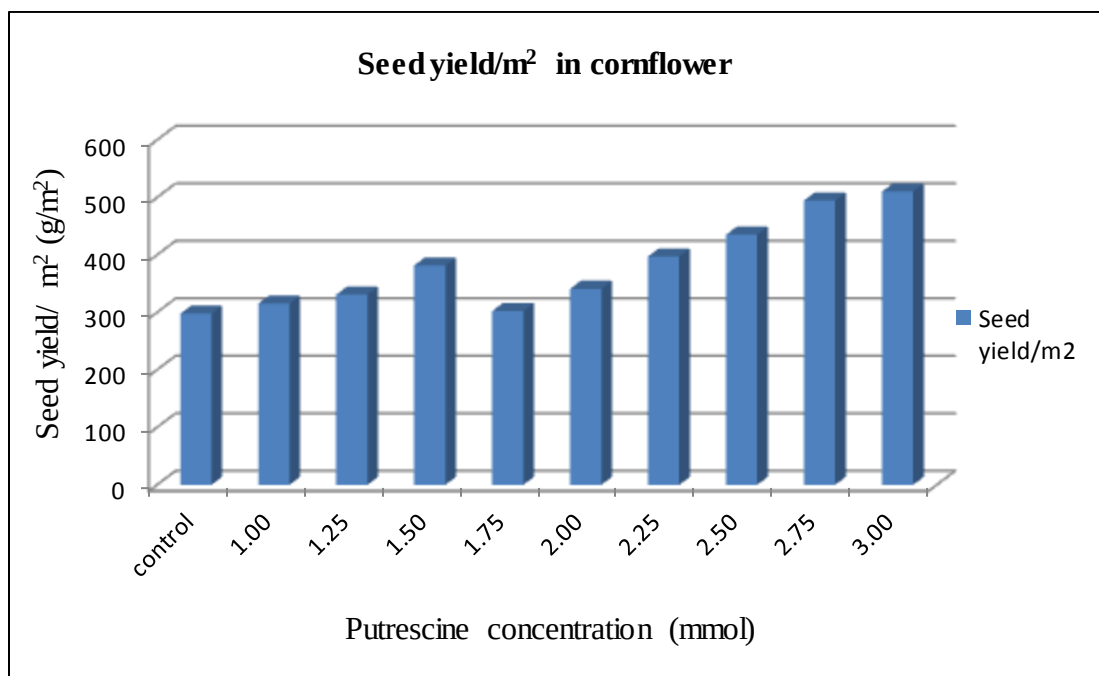


Fig 4.25: Graphical representation of various concentrations of putrescine on seed yield/m² in cornflower



4.2 Helichrysum

4.2.1 Observations recorded on growth characters

4.2.1.1 Plant height (cm)

The data adverting to plant height is presented in the Table 4.11 and Fig. 4.26. It is perceptible from the data that different concentrations of putrescine significantly influenced the plant height. Plant height varied from 24.44 cm to 34.38 cm at 60 DAT while at 90 DAT it varied from 84.56 cm to 94.64 cm. Putrescine @ 1.25 mmol showed maximum plant height (34.38 cm) at 60 DAT which was statistically at par with 1.50 mmol (34.34 cm), 2.50 mmol (32.83 cm) and significant to 2.25 mmol (31.84 cm), 2.00 mmol (31.54 cm), 1.00 mmol (30.25 cm), 1.75 mmol (28.86 cm), 3.00 mmol (25.83 cm), 2.75 mmol (25.55 cm) while, minimum plant height (24.44 cm) registered by control. Similarly, putrescine @ 1.75 mmol showed the maximum plant height (94.64 cm) at 90 DAT which was statistically at par with 2.25 mmol (93.16 cm), 1.50 mmol (93.06 cm), 2.75 mmol (92.66 cm) and significant to 2.50 mmol (91.03 cm), 1.25 mmol (89.43 cm), 2.00 mmol (89.23 cm), control (88.74 cm), 1.00 mmol (86.16 cm) whereas, putrescine @ 3.00 mmol recorded minimum plant height (84.56 cm).

4.2.1.2 Plant spread (cm)

The results for plant spread as influenced by different concentrations of putrescine are presented in the Table 4.11 and Fig. 4.27. Plant spread varied from 28.13 cm to 33.37 cm at 60 DAT and 46.97 cm to 60.95 cm at 90 DAT. At 60 DAT, maximum plant spread (33.37 cm) was obtained at 2.00 mmol concentration which was statistically at par with 2.25 mmol (33.31 cm), 2.50 mmol (33.00 cm), 1.50 mmol (32.07 cm) and significant to control (31.88 cm), 3.00 mmol (29.99 cm), 2.75 mmol (29.91 cm), 1.25 mmol (29.89 cm), 1.75 mmol (29.79 cm) while minimum plant spread (28.13 cm) was found with treatment 1.00 mmol. Similarly, maximum plant spread (60.95 cm) at 90 DAT was shown by 2.50 mmol which was significant to all other treatments *i.e.*, 2.25 mmol (56.26 cm), 2.00 mmol (55.13 cm), 1.75 mmol (54.14 cm), 2.75 mmol (53.54 cm), 1.50 mmol (52.15 cm), 3.00 mmol (49.36 cm), control (48.12 cm), 1.25 mmol (46.98 cm) while, minimum plant spread (46.97 cm) was reported by putrescine @ 1.00 mmol.

Table 4.11: Effect of various concentrations of putrescine on plant height and plant spread in helichrysum

Treatment (mmol)	Plant height at 60 DAT (cm)	Plant height at 90 DAT (cm)	Plant spread at 60 DAT (cm)	Plant spread at 90 DAT (cm)
Control	24.44	88.74	31.88	48.12
1.00	30.25	86.16	28.13	46.97
1.25	34.38	89.43	29.89	46.98
1.50	34.34	93.06	32.07	52.15
1.75	28.86	94.64	29.79	54.14
2.00	31.54	89.23	33.37	55.13
2.25	31.84	93.16	33.31	56.26
2.50	32.83	91.03	33.00	60.95
2.75	25.55	92.66	29.91	53.54
3.00	25.83	84.56	29.99	49.36
C.D. at 5%	1.98	2.12	1.47	1.49

Fig 4.26: Graphical representation of various concentrations of putrescine on plant height in helichrysum

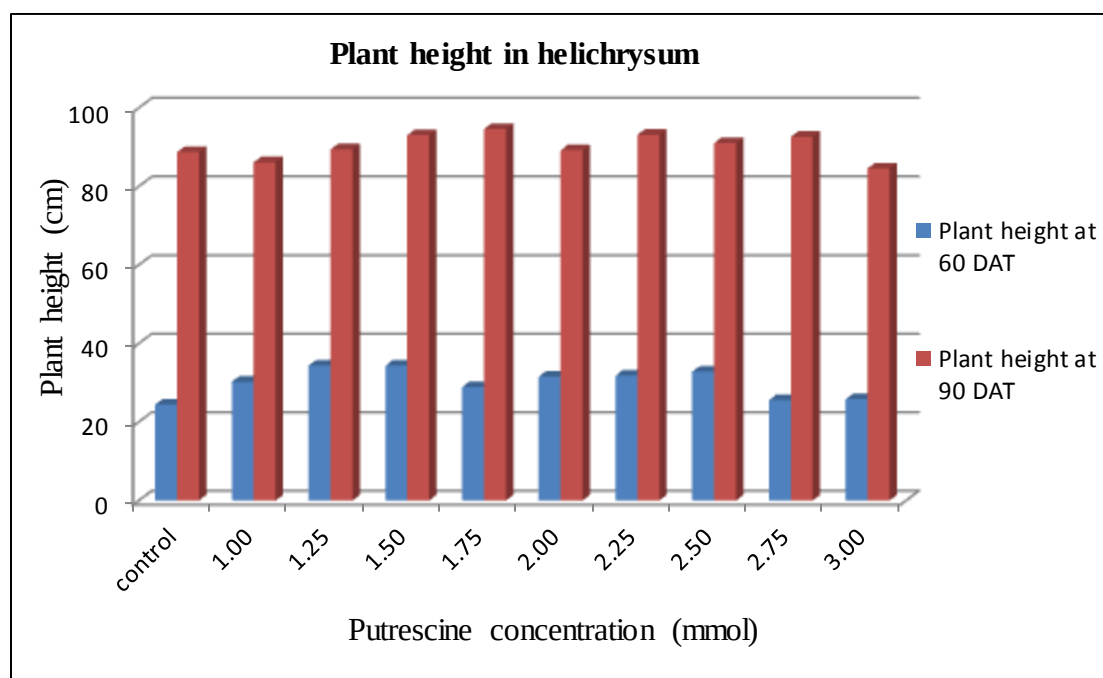
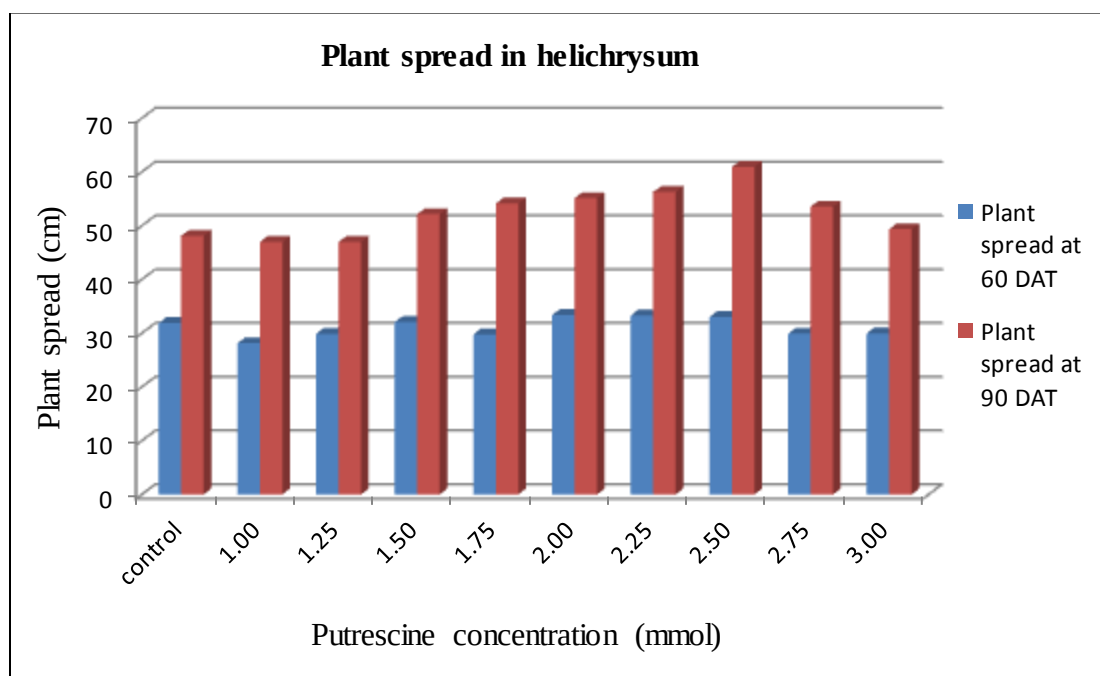


Fig 4.27: Graphical representation of various concentrations of putrescine on plant spread in helichrysum



4.2.1.3 Number of primary branches

The data of number of primary branches governed by different doses of putrescine are presented in the Table 4.12 and Fig. 4.28. It is clearly seen that the number of primary branches varied from 6.82 to 15.41 at 60 DAT and from 17.08 to 29.08 at 90 DAT. Putrescine concentration 2.00 mmol showed maximum number of primary branches (15.41) at 60 DAT which was statistically at par with 2.50 mmol (14.08), 1.50 mmol (12.41), 1.25 mmol (10.99), 1.00 mmol (10.08), 2.25 mmol (9.74), 1.75 mmol (9.41) and significant to 2.75 mmol (8.49), 3.00 mmol (6.91) while minimum number of primary branches (6.82) were reported by control. Putrescine concentration 2.25 mmol showed maximum number of primary branches (29.08) at 90 DAT which was statistically at par with 2.50 mmol (26.58) and significant to 2.75 mmol (22.24), 2.00 mmol (21.49), 1.50 mmol (20.74), 1.25 mmol (20.33), 1.00 mmol (19.49), 3.00 mmol (18.99), 1.75 mmol (17.91) while minimum number of primary branches (17.08) were found in control.

4.2.1.4 Number of secondary branches

The result pertaining to the number of secondary branches as governed by different concentrations of putrescine are presented in the Table 4.12 and Fig. 4.29. It is noticeable that number of secondary branches varies from 0.00 to 2.33 for 60 DAT and from 6.08 to 24.33 for 90 DAT. At 60 DAT, maximum number of secondary branches (2.33) were shown by 2.00 mmol concentration which were significant to all other treatments *i.e.* 1.25 mmol (1.16), 2.50 mmol (0.58), 1.50 mmol (0.49), 2.25 mmol (0.33), 1.75 mmol (0.16), while, minimum number of secondary branches (0.00) were found in 1.00 mmol, 2.75 mmol, 3.00 mmol and control. Similarly, maximum number of secondary branches (24.33) at 90 DAT were shown by putrescine @ 2.25 mmol which were statistically at par with 2.50 mmol (24.24), 2.00 mmol (22.99), 1.50 mmol (21.41), 1.75 mmol (20.74), 1.25 mmol (18.58), 2.75 mmol (16.91) and significant to 1.00 mmol (15.99), 3.00 mmol (12.74) whereas, minimum number of secondary branches (6.08) registered by control.

Table 4.12: Effect of various concentrations of putrescine on number of primary and secondary branches in helichrysum

Treatment (mmol)	No. of primary branches at 60 DAT	No. of primary branches at 90 DAT	No. of secondary branches at 60 DAT	No. of secondary branches at 90 DAT
Control	6.82	17.08	0.00	6.08
1.00	10.08	19.49	0.00	15.99
1.25	10.99	20.33	1.16	18.58
1.50	12.41	20.74	0.49	21.41
1.75	9.41	17.91	0.16	20.74
2.00	15.41	21.49	2.33	22.99
2.25	9.74	29.08	0.33	24.33
2.50	14.08	26.58	0.58	24.24
2.75	8.49	22.24	0.00	16.91
3.00	6.91	18.99	0.00	12.74
C.D. at 5%	4.69	4.98	0.21	7.93

Fig 4.28: Effect of various concentrations of putrescine on number of primary branches in helichrysum

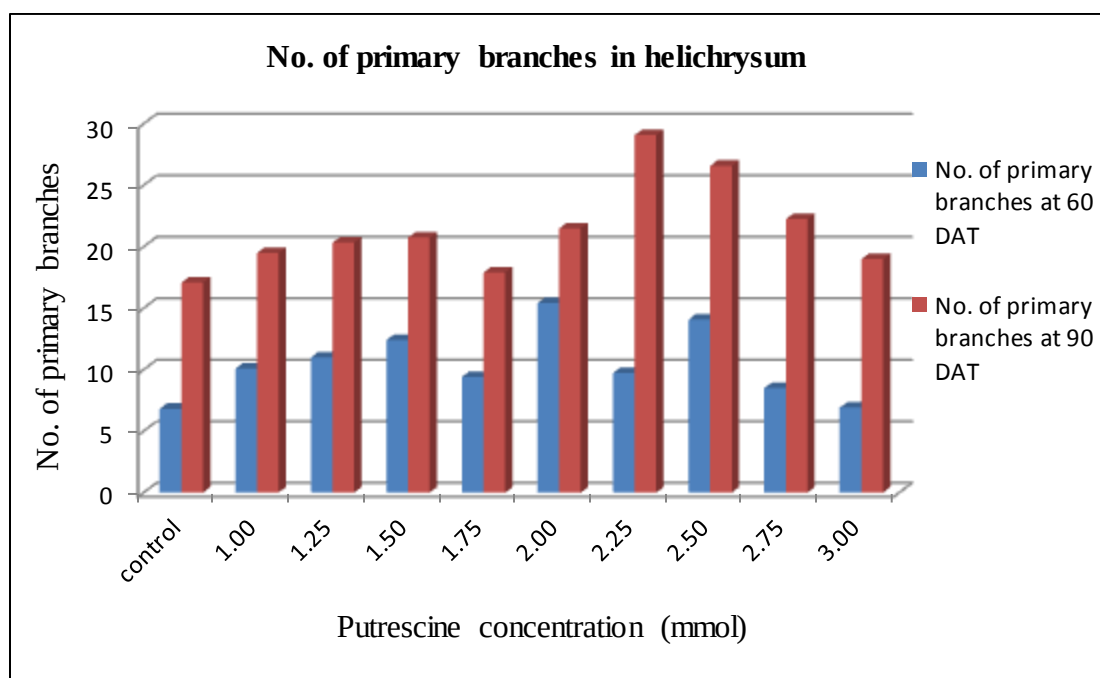
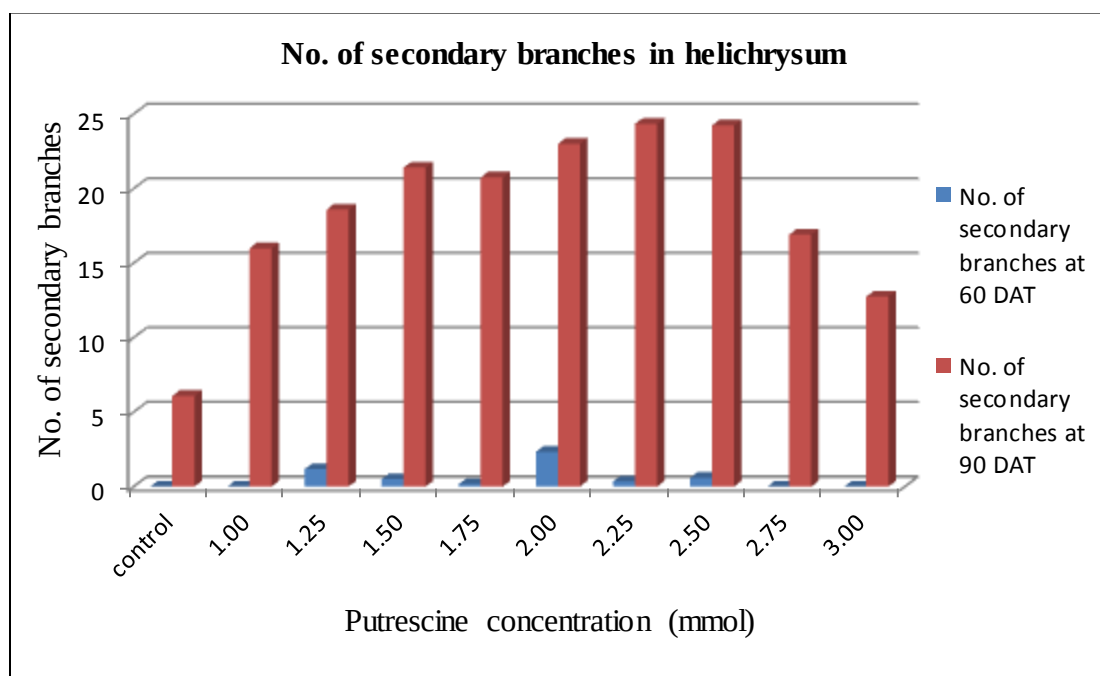


Fig 4.29: Graphical representation of various concentrations of putrescine on number of secondary branches in helichrysum



4.2.1.5 Fresh weight of leaf (g)

The table (Table 4.13) and graph (Fig. 4.30) shows that the fresh weight of leaf differed from 0.20 g to 0.71 g. Maximum fresh weight of leaf (0.71 g) was found in treatment 1.00 mmol which was significant to all other treatments *i.e.* 1.50 mmol (0.52 g), 2.00 mmol (0.50 g), 2.75 mmol (0.49 g), 2.25 mmol (0.48 g), 1.25 mmol (0.42 g), 3.00 mmol (0.40 g), 2.50 mmol (0.37 g), 1.75 mmol (0.36 g) and minimum fresh weight of leaf (0.20 g) was recorded in control.

4.2.1.6 Dry weight of leaf (g)

The data adverting to dry weight of leaf as governed by different treatments of putrescine is presented in the Table 4.13 and Fig. 4.31. It varied from 0.05 g to 0.13 g. Maximum dry weight of leaf (0.13 g) was observed at 1.00 mmol which was significant to all other treatments and minimum dry weight of leaf (0.05 g) was observed in control.

4.2.1.7 Leaf area (cm²)

The data of leaf area governed by different doses of putrescine is presented in the Table 4.13 and Fig. 4.32. It is clear from the table that the leaf area varied from 15.37 cm² to 30.40 cm². Maximum leaf area (30.40 cm²) was found in 2.25 mmol concentration which was statistically at par with 1.50 mmol (30.27 cm²), 3.00 mmol (24.78 cm²), 2.50 mmol (22.84 cm²) and significant to control (19.46 cm²), 1.75 mmol (18.83 cm²), 1.25 mmol (17.70 cm²), 2.75 mmol (17.52 cm²), 2.00 mmol (16.82 cm²), while minimum leaf area (15.37 cm²) was reported by treatment 1.00 mmol.

4.2.1.8 Diameter at shoot base (mm)

The data adverting to diameter at shoot base is presented in Table 4.13 and Fig. 4.33. It varied from 18.72 mm to 24.83 mm. Putrescine @ 2.25 mmol concentration attained maximum shoot base diameter (24.83 mm) which was statistically at par with 1.00 mmol (23.62 mm) and significant to 1.75 mmol (21.33 mm), 1.50 mmol (20.27 mm), 2.75 mmol (19.57 mm), 1.25 mmol (19.28 mm), control (18.96 mm), 2.50 mmol (18.93 mm), 3.00 mmol (18.73 mm). Minimum shoot base diameter (18.72 mm) was attained by 2.00 mmol concentration.

Table 4.13: Effect of various concentrations of putrescine on fresh weight of leaf, dry weight of leaf, leaf area and diameter at shoot base in helichrysum

Treatment (mmol)	Fresh weight of leaf (g)	Dry weight of leaf (g)	Leaf area (cm²)	Diameter at shoot base (mm)
Control	0.20	0.05	19.46	18.96
1.00	0.71	0.13	15.37	23.62
1.25	0.42	0.07	17.70	19.28
1.50	0.52	0.08	30.27	20.27
1.75	0.36	0.07	18.83	21.33
2.00	0.50	0.09	16.82	18.72
2.25	0.48	0.08	30.40	24.83
2.50	0.37	0.07	22.84	18.93
2.75	0.49	0.09	17.52	19.57
3.00	0.40	0.07	24.78	18.73
C.D. at 5%	0.18	0.03	10.48	3.39

Fig 4.30: Graphical representation of various concentrations of putrescine on fresh weight of leaf in helichrysum

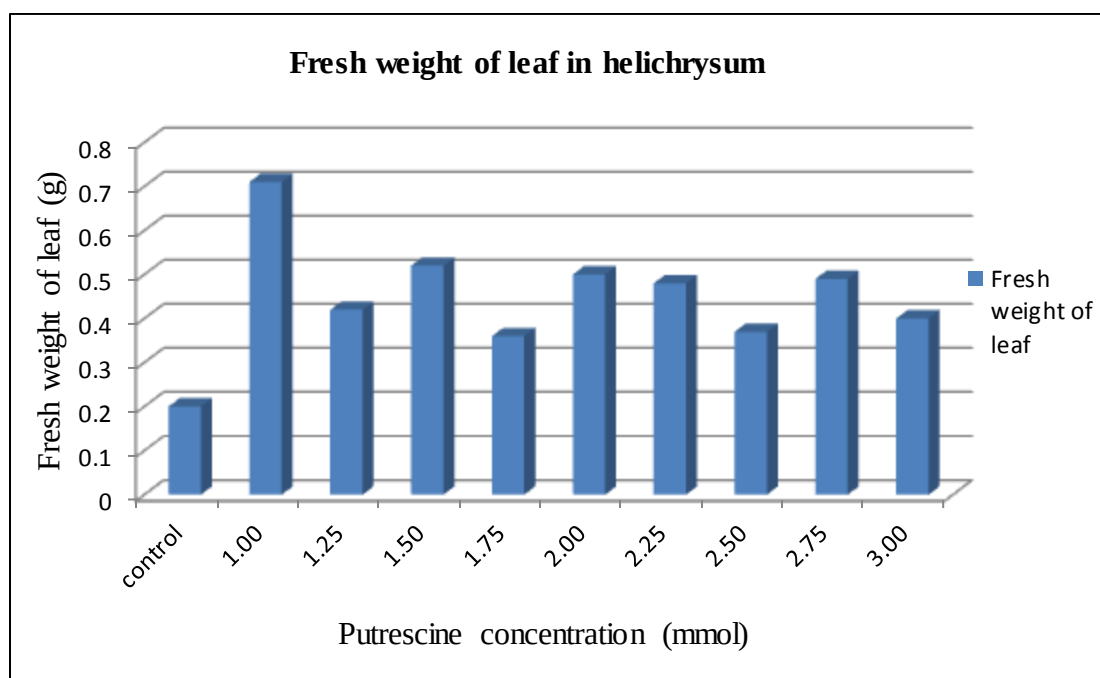


Fig 4.31: Graphical representation of various concentrations of putrescine on dry weight of leaf in helichrysum

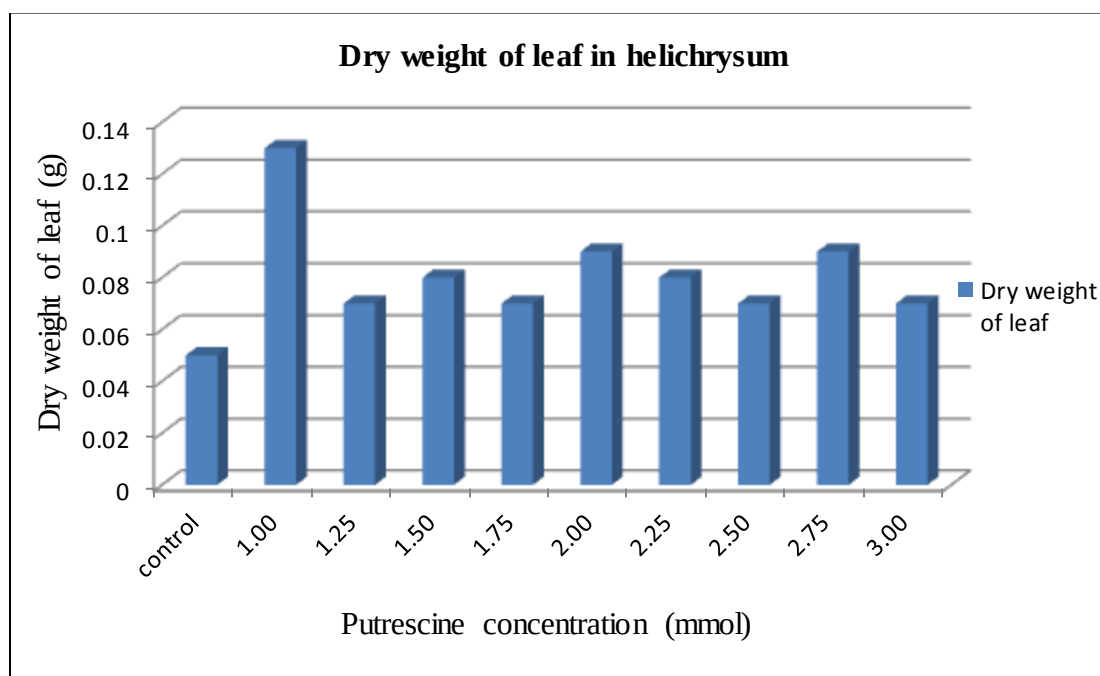


Fig 4.32: Graphical representation of various concentrations of putrescine on leaf area in helichrysum

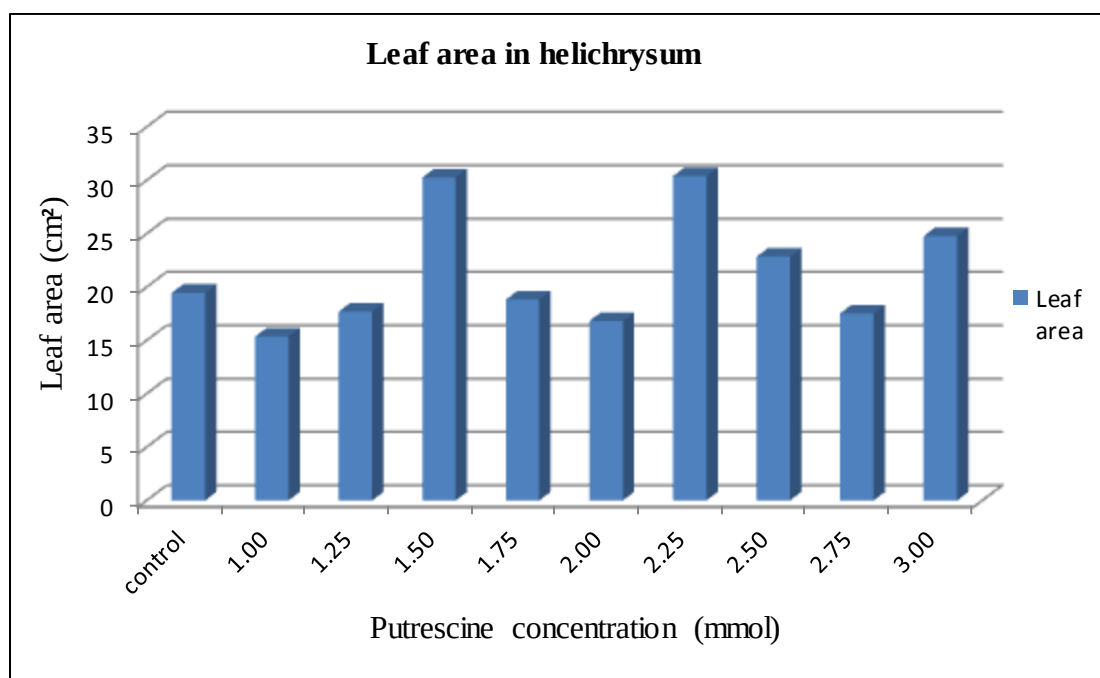
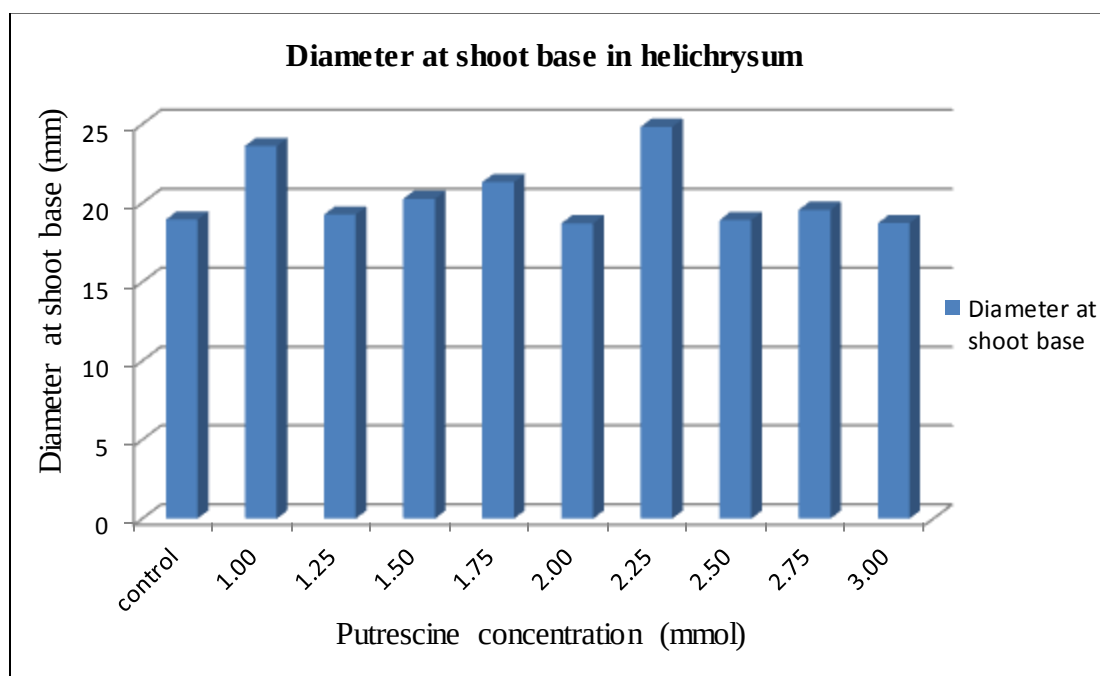


Fig 4.33: Graphical representation of various concentrations of putrescine on diameter at shoot base in helichrysum



4.2.2 Flowering characters

4.2.2.1 Days to bud initiation

The result pertaining to days to bud initiation is represented in Table 4.14 and Fig. 4.34. Days to bud initiation varied from 60.91 days to 68.16 days. Early bud initiation (60.91 days) was noticed in putrescine @ 1.50 mmol which was statistically at par with 1.25 mmol (62.41 days), 1.75 mmol (62.16 days), 2.25 mmol (61.99 days), both 1.00 mmol and 2.50 mmol (61.83 days), 2.00 mmol (61.25 days) and significant to 3.00 mmol (68.16 days), control (66.16 days), 2.75 mmol (65.95 days). Late bud initiation (68.16 days) was observed with concentration 3.00 mmol.

4.2.2.2 Days to bud development

The data presented in Table 4.14 and Fig. 4.35 clearly signifies the influence of various putrescine concentrations on days to bud development. Days to bud development varied from 75.49 days to 82.91 days. It is evident from the data that early bud initiation (75.49 days) was found with the application of 1.50 mmol which was statistically at par with 2.25 mmol (77.49 days), 1.75 mmol (77.33 days), 2.50 mmol (76.99 days), 2.00 mmol (76.91 days), 1.25 mmol (76.49 days), 1.00 mmol (75.82 days) and significant to 3.00 mmol (82.91 days), control (80.83 days), 2.75 mmol (80.12 days). Late bud development (82.91 days) was reported by putrescine @ 3.00 mmol.

4.2.2.3 Bud diameter (mm)

Table 4.14 and Fig. 4.36 represents data pertaining to bud diameter. The bud diameter has been highly influenced by various concentrations of putrescine. The bud diameter varied from 13.26 mm to 14.10 mm. Maximum bud diameter (14.10 mm) was recorded in putrescine @ 2.00 mmol concentration which was significant to all other treatments i.e. 2.50 mmol (13.92 mm), 1.00 mmol (13.91 mm), 1.50 mmol (13.75 mm), 1.75 mmol (13.74 mm), 2.25 mmol (13.72 mm), 1.25 mmol (13.55 mm), 3.00 mmol (13.42 mm), 2.75 mmol (13.34 mm). Minimum bud diameter (13.26 mm) was recorded with control.

Table 4.14: Effect of various concentrations of putrescine on days to bud initiation, days to bud development and bud diameter in helichrysum

Treatment (mmol)	Days to bud initiation (days)	Days to bud development (days)	Bud diameter (mm)
Control	66.16	80.83	13.26
1.00	61.83	75.82	13.91
1.25	62.41	76.49	13.55
1.50	60.91	75.49	13.75
1.75	62.16	77.33	13.74
2.00	61.25	76.91	14.10
2.25	61.99	77.49	13.72
2.50	61.83	76.99	13.92
2.75	65.95	80.12	13.34
3.00	68.16	82.91	13.42
C.D. at 5%	4.74	3.67	0.05

Fig 4.34: Graphical representation of various concentrations of putrescine on days to bud initiation in helichrysum

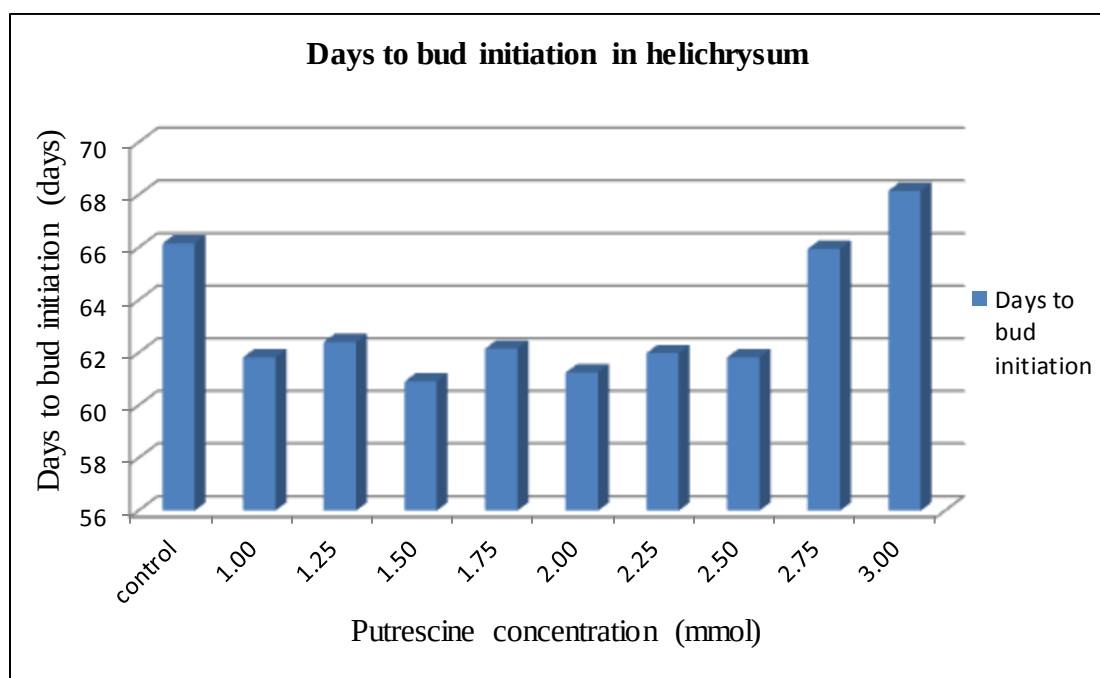


Fig 4.35: Graphical representation of various concentrations of putrescine on days to bud development in helichrysum

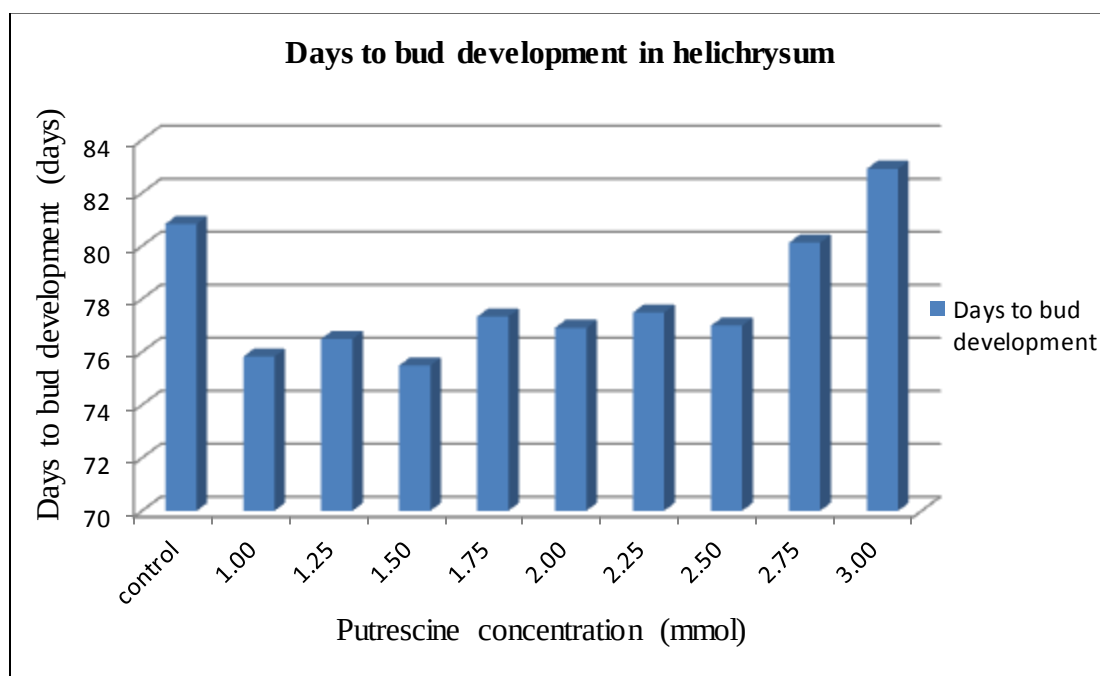
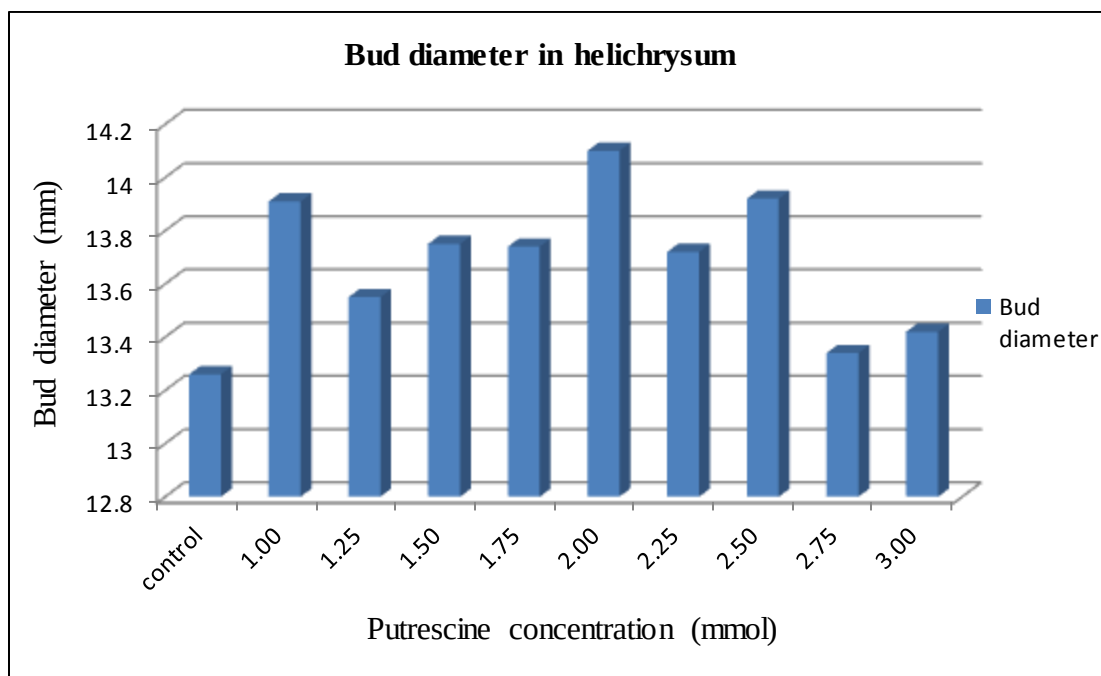


Fig 4.36: Graphical representation of various concentrations of putrescine on bud diameter in helichrysum



4.2.2.4 Disc diameter (cm)

The mean data adverting to disc diameter is given in Table 4.15 and Fig. 4.37. It is evident that different treatments of putrescine had a significant influence on the disc diameter. The disc diameter was in the range of 1.85 cm to 2.07 cm. Maximum disc diameter (2.07 cm) was attained in putrescine @ 2.00 mmol concentration which was significant to all other treatments *i.e.* 1.25 mmol (1.97 cm), 1.50 mmol (1.95 cm), all 2.25 mmol, 2.75 mmol and 3.00 mmol (1.94 cm) together, control (1.93 cm), both 1.75 mmol and 2.50 mmol (1.91 cm). The minimum disc diameter (1.85 cm) was attained with putrescine @ 1.00 mmol.

4.2.2.5 Flower diameter (cm)

The mean data adverting to the flower diameter is presented in the Table 4.15 and Fig. 4.38. It is perceptible from the data that different putrescine treatments had a significant effect on flower diameter. It varied from 4.36 cm to 4.64 cm. Maximum flower diameter (4.73 cm) was attained by putrescine @ 2.00 mmol concentration which was significant to all other treatments *i.e.* 1.75 mmol (4.68 cm), 1.50 mmol (4.64 cm), 1.25 mmol (4.63 cm), 2.75 mmol (4.62 cm), 2.50 mmol (4.59 cm), both 3.00 mmol and 2.25 mmol (4.52 cm), 1.00 mmol (4.50 cm). Minimum flower diameter (4.40 cm) was observed in control.

4.2.2.6 Days to flower blooming

It is evident from the data represented in Table 4.15 and Fig. 4.39 that different concentrations of putrescine significantly influenced the days to flower blooming. Days to flower blooming differed significantly from 83.24 days to 91.16 days. It is apparent from the data that early flower blooming (83.24 days) was recorded with putrescine @ 1.50 mmol which was statistically at par with 1.00 mmol (85.58 days), 2.25 mmol (85.24 days), 1.25 mmol (85.08 days), 2.50 mmol (84.74 days), 1.75 mmol (84.24 days), 2.00 mmol (84.08 days) and significant to 3.00 mmol (91.16 days), control (88.41 days), 2.75 mmol (87.79 days). Late flower blooming (91.16 days) was obtained by putrescine @ 3.00 mmol.

Table 4.15: Effect of various concentrations of putrescine on disc diameter, flower diameter and days to flower blooming in helichrysum

Treatment (mmol)	Disc diameter (cm)	Flower diameter (cm)	Days to flower blooming (days)
Control	1.93	4.40	88.41
1.00	1.85	4.50	85.58
1.25	1.97	4.63	85.08
1.50	1.95	4.64	83.24
1.75	1.91	4.68	84.24
2.00	2.07	4.73	84.08
2.25	1.94	4.52	85.24
2.50	1.91	4.59	84.74
2.75	1.94	4.62	87.79
3.00	1.94	4.52	91.16
C.D. at 5%	0.05	0.04	3.91

Fig 4.37: Graphical representation of various concentrations of putrescine on disc diameter in helichrysum

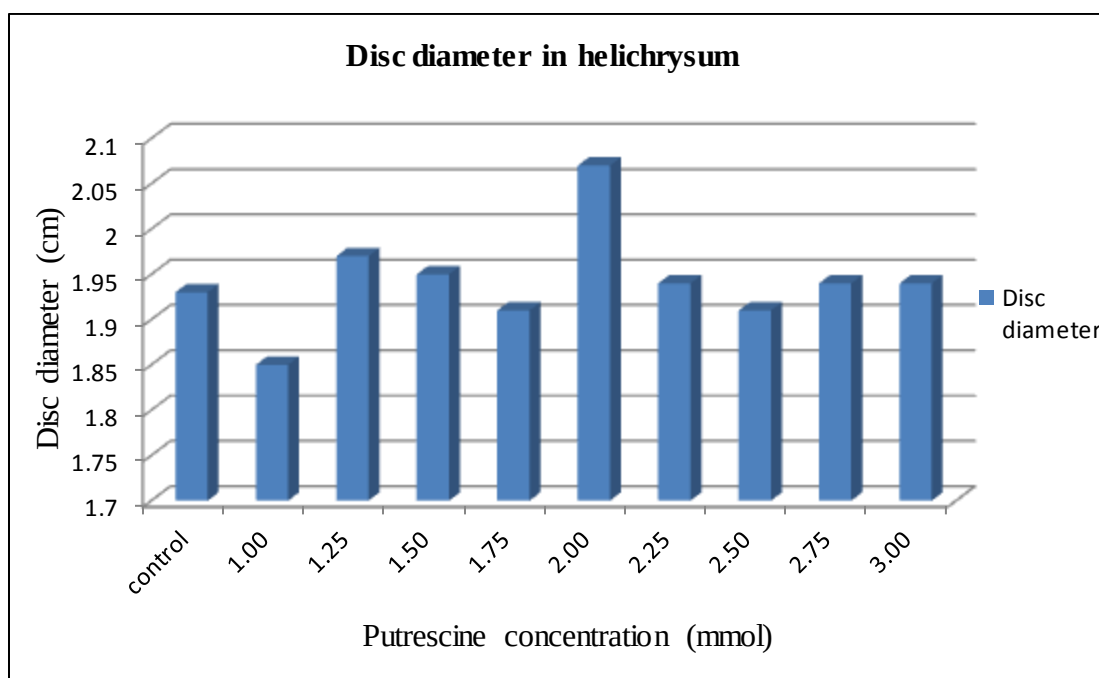


Fig 4.38: Graphical representation of various concentrations of putrescine on flower diameter in helichrysum

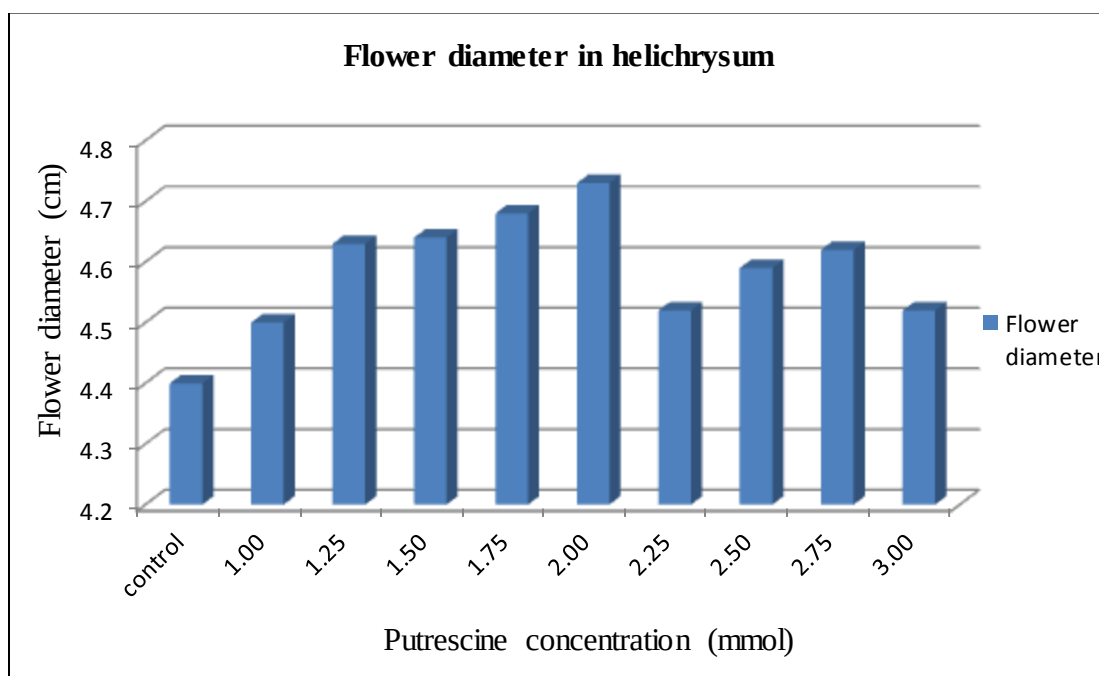
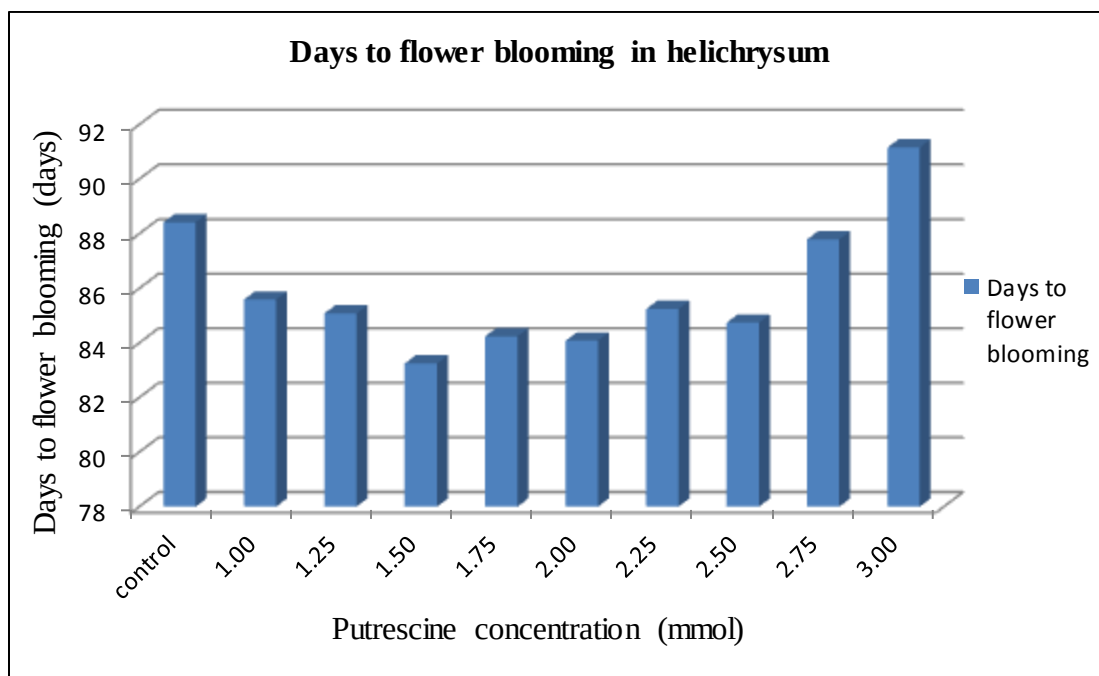


Fig 4.39: Graphical representation of various concentrations of putrescine on days to flower blooming in helichrysum



4.2.2.7 Number of flowers/plant

The result pertaining to number of flowers/plant is presented in Table 4.16 and Fig. 4.40. It was in the range from 38.08 to 60.66. Maximum number of flowers/plant (60.66) were found in putrescine @ 2.50 mmol which was statistically at par with 2.25 mmol (56.08), 2.75 mmol (54.29), 1.75 mmol (53.49), 2.00 mmol (52.49), 1.50 mmol (50.24) and significant to 3.00 mmol (46.08), 1.25 mmol (44.24), 1.00 mmol (43.99) while control recorded minimum number of flowers/plant (38.08).

4.2.2.8 Flower longevity

The data adverting to flower longevity is presented in Table 4.16 and Fig. 4.41. Flower longevity was greatly influenced by different concentrations of putrescine and was found in the range between 21.74 days to 26.08 days. Maximum flower longevity (26.08 days) was found in 1.50 mmol concentration which was statistically at par with 1.00 mmol (25.66 days) and other treatments and significant to 2.75 mmol (23.66 days). Minimum flower longevity (21.74 days) was recorded at 3.00 mmol concentration.

4.2.2.9 Days to flower withering

The data adverting to days to flower withering as given in Table 4.16 and Fig. 4.42 showed that various concentration of putrescine had significant effect on days to flower withering. It is varied from 108.66 days to 112.91 days. Late flower withering (112.91 days) was found in treatment 3.00 mmol which was statistically at par with control (111.82 days) and significant to 2.75 mmol (111.45 days), 1.00 mmol (111.24 days), 1.25 mmol (109.99 days), 2.50 mmol (109.75 days), 1.75 mmol (109.49 days), 1.50 mmol (109.33 days), 2.00 mmol (108.99 days). Early flower withering (108.66 days) was recorded at 2.25 mmol treatment of putrescine.

Table 4.16: Effect of various concentrations of putrescine on no. of flowers/plant, flower longevity and days to flower withering in helichrysum

Treatment (mmol)	No. of flowers/plant	Flower longevity (days)	Days to flower withering (days)
Control	38.08	23.41	111.82
1.00	43.99	25.66	111.24
1.25	44.24	24.91	109.99
1.50	50.24	26.08	109.33
1.75	53.49	25.24	109.49
2.00	52.49	24.91	108.99
2.25	56.08	23.41	108.66
2.50	60.66	24.99	109.75
2.75	54.29	23.66	111.45
3.00	46.08	21.74	112.91
C.D. at 5%	12.59	2.21	1.42

Fig 4.40: Graphical representation of various concentrations of putrescine on number of flowers/plant in helichrysum

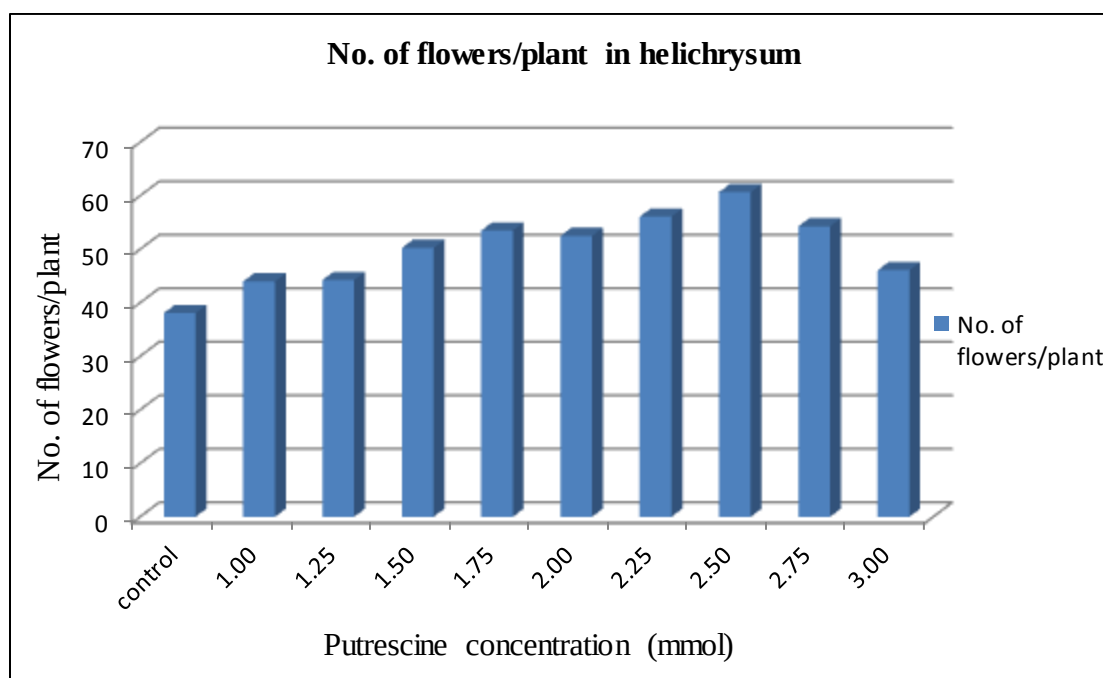


Fig 4.41: Graphical representation of various concentrations of putrescine on flower longevity in helichrysum

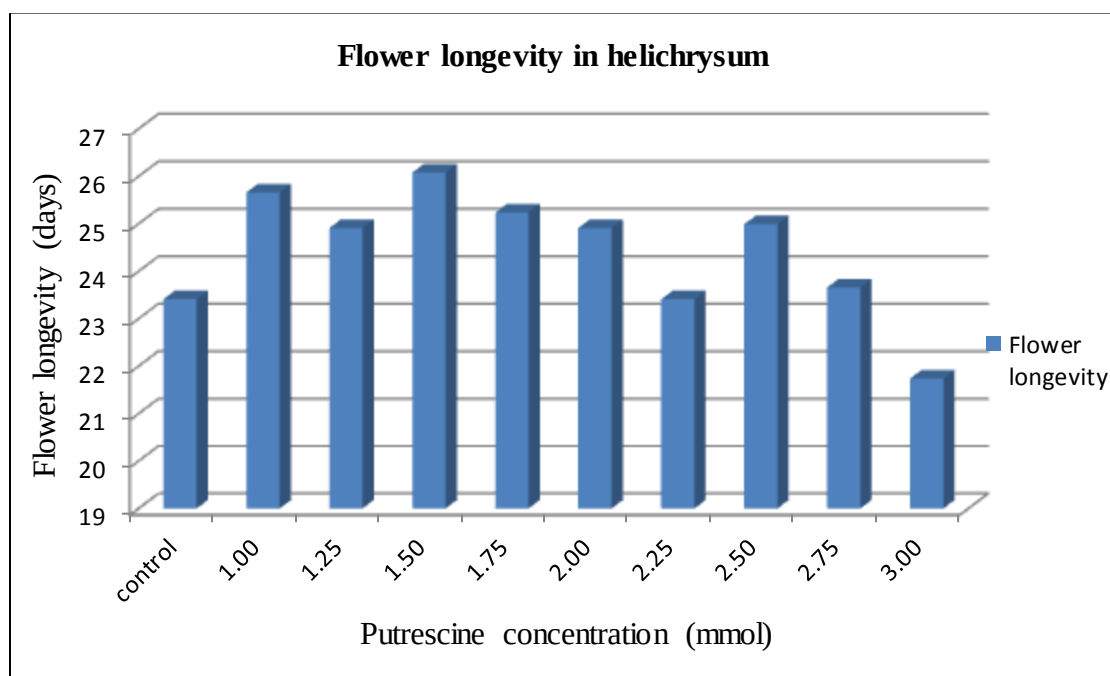
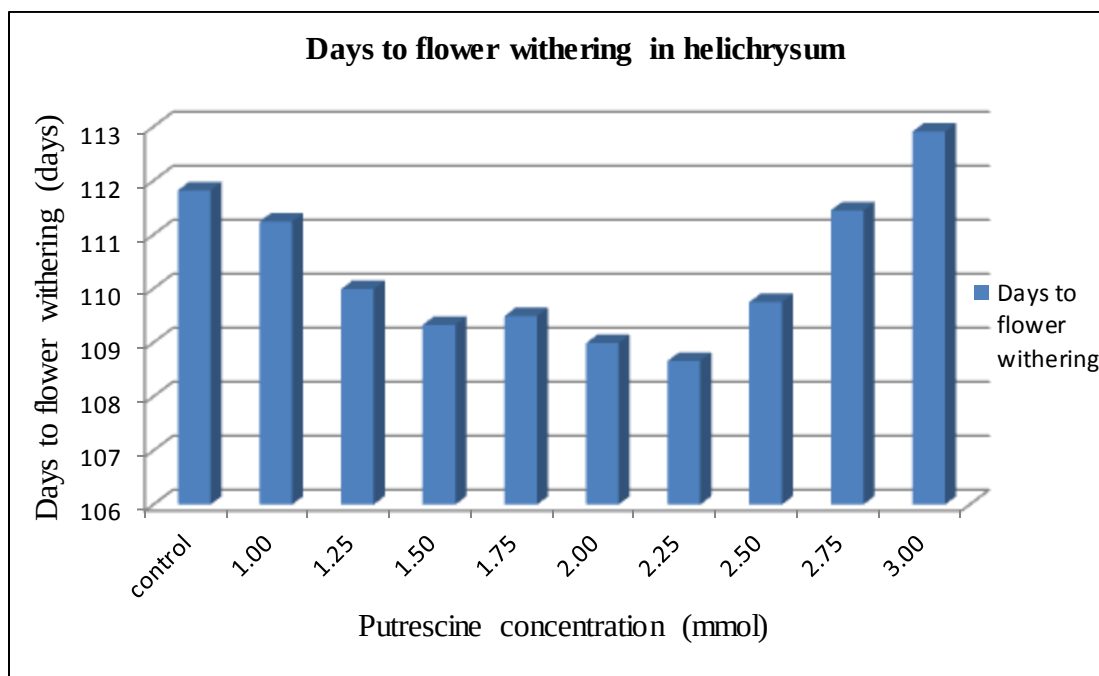


Fig 4.42: Graphical representation of various concentrations of putrescine on days to flower withering in helichrysum



4.2.2.10 Fresh weight of flower (g)

The mean data governing fresh weight of flower is presented in the Table 4.17 and Fig. 4.43. It lies in the range from 2.40 g to 3.07 g. Maximum fresh weight of flower (3.07 g) was noticed in control which was statistically at par with 2.75 mmol (3.03 g) and significant to 3.00 mmol (2.77 g), 1.00 mmol (2.77 g), 2.50 mmol (2.66 g), 1.50 mmol (2.61 g), 1.25 mmol (2.54 g), 2.00 mmol (2.51 g), 1.75 mmol (2.41 g), whereas, minimum fresh weight of flower (2.40 g) was observed at 2.25 mmol.

4.2.2.11 Dry weight of flower (g)

The result pertaining to dry weight of flower is presented in Table 4.17 and Fig. 4.44. It was found to lie between 0.64 g to 0.84 g. Maximum dry weight of flower (0.84 g) was attained with control which was statistically at par with 2.75 mmol (0.82 g), 3.00 mmol (0.79 g), 1.00 mmol (0.78 g) and significant to 2.50 mmol (0.74 g) then both 1.25 mmol and 2.00 mmol (0.71 g), 1.50 mmol (0.70 g), 2.25 mmol (0.69 g) while, minimum dry weight of flower (0.64 g) was recorded with putrescine @ 1.75 mmol.

4.2.2.12 Flower yield/m²

The mean data pertaining to flower yield/m² is represented in Table 4.17 and Fig. 4.45. It varied from 366.82 g/m² to 530.48 g/m². Maximum flower yield/m² (530.48 g/m²) was reported by putrescine @ 2.75 mmol which was significant to all other treatments i.e. 2.50 mmol (523.06 g/m²), 2.25 mmol (437.79 g/m²), 2.00 mmol (431.34 g/m²), 1.50 mmol (429.39 g/m²), 1.75 mmol (421.19 g/m²), 3.00 mmol (415.22 g/m²), 1.00 mmol (402.10 g/m²), 1.25 mmol (368.21 g/m²) while, minimum flower yield/m² (366.82 g/m²) was recorded with control.

Table 4.17: Effect of various concentrations of putrescine on fresh weight of flower, dry weight of flower and flower yield/m² in helichrysum

Treatment (mmol)	Fresh weight of flower (g)	Dry weight of flower (g)	Flower yield/m² (g/m²)
Control	3.07	0.84	366.82
1.00	2.77	0.78	402.10
1.25	2.54	0.71	368.21
1.50	2.61	0.70	429.39
1.75	2.41	0.64	421.19
2.00	2.51	0.71	431.34
2.25	2.40	0.69	437.79
2.50	2.66	0.74	523.06
2.75	3.03	0.82	530.48
3.00	2.77	0.79	415.22
C.D. at 5%	0.23	0.08	4.63

Fig 4.43: Graphical representation of various concentrations of putrescine on fresh weight of flower in helichrysum

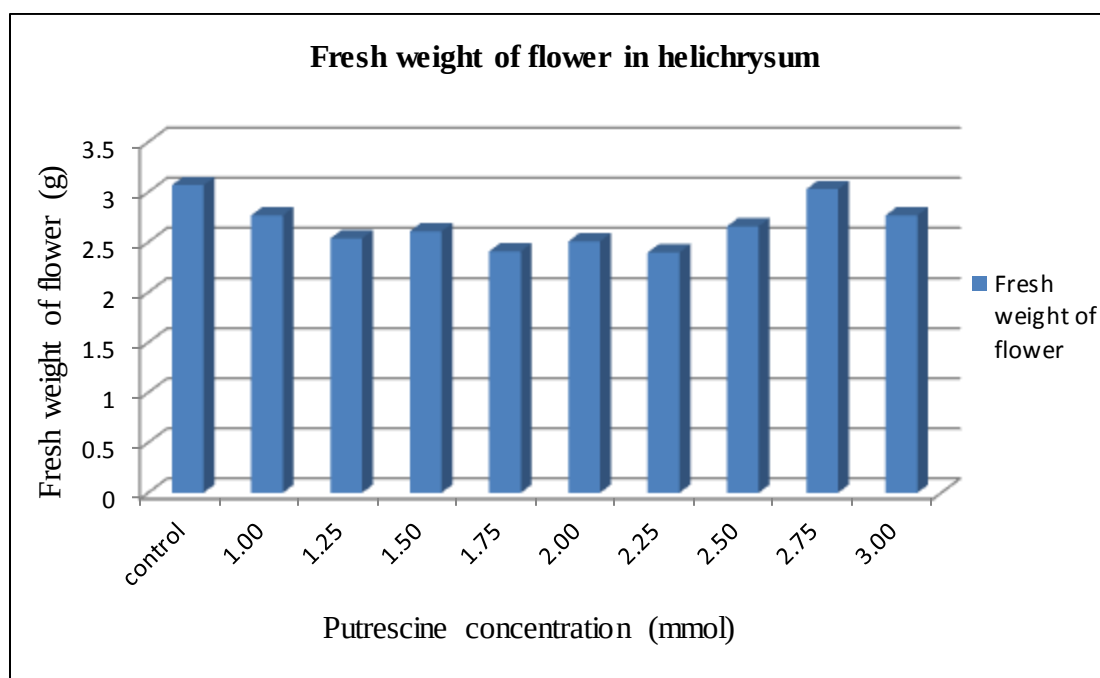


Fig 4.44: Graphical representation of various concentrations of putrescine on dry weight of flower in helichrysum

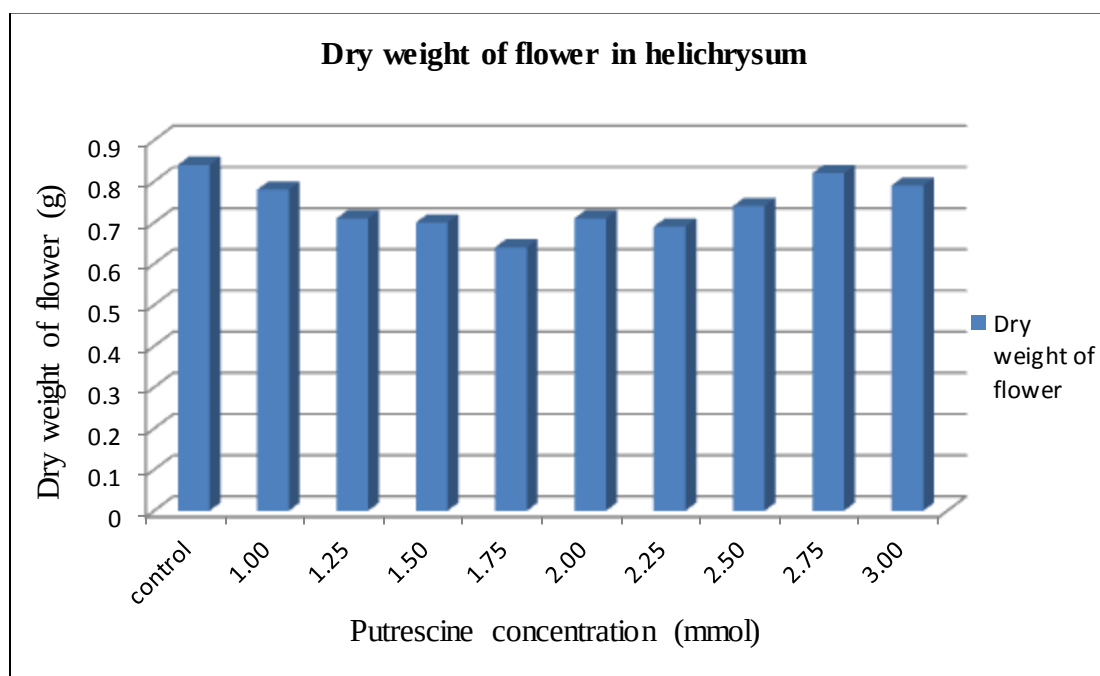
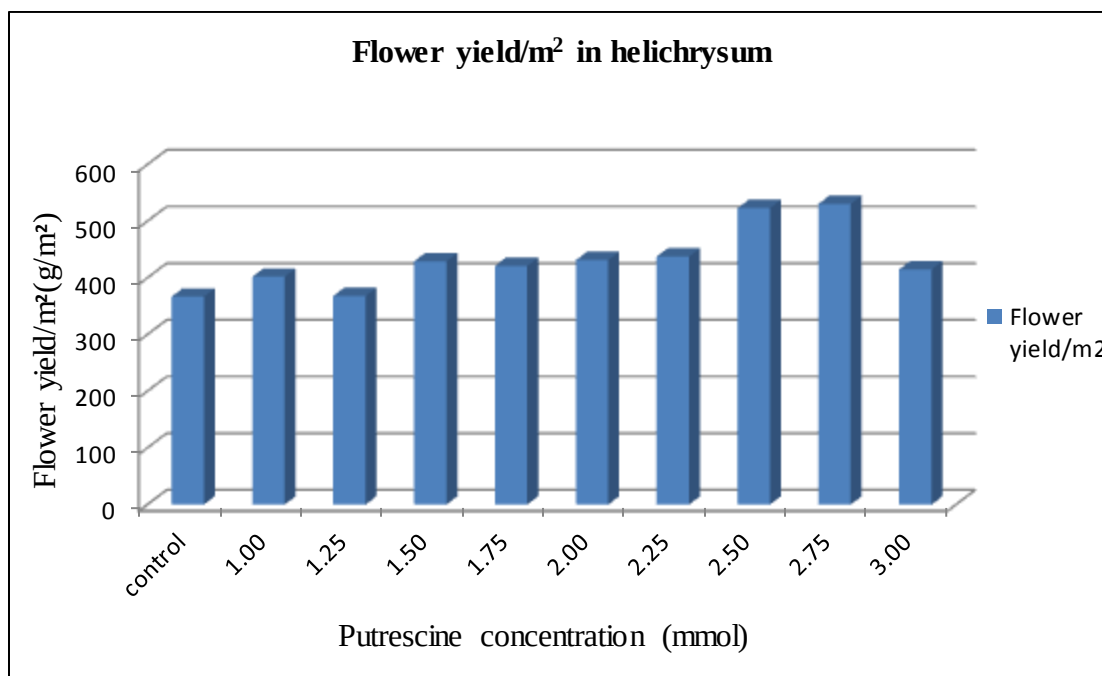


Fig 4.45: Graphical representation of various concentrations of putrescine on flower yield/m² in helichrysum



4.2.3 Observations recorded on seed characters

4.2.3.1 Days to seed maturity

Table 4.18 and Fig. 4.46 shows days to seed maturity being highly influenced by different putrescine treatments. It varies from 114.41 days to 119.75 days. Putrescine @ 3.00 mmol concentration resulted in significant maximum days to seed maturity (119.75 days) which was statistically at par with control (118.24 days), 2.75 mmol (117.41 days) and significant to 1.00 mmol (116.24 days), 1.25 mmol (115.83 days), 2.25 mmol (114.91 days), 2.50 mmol (114.74 days), 1.75 mmol (114.49 days) while, minimum (114.41 days) was found in putrescine @ 1.50 mmol and 2.00 mmol.

4.2.3.2 Number of seeds/flower

Table 4.18 and Fig. 4.47 shows number of seeds/flower being highly influenced by different putrescine treatments. It varies from 631.66 to 751.08. Putrescine @ 2.75 mmol (751.08) concentration resulted in maximum number of seeds/flower which was statistically at par with 2.50 mmol (732.46), 1.25 mmol (702.82) and significant to 3.00 mmol (678.30), 2.00 mmol (677.30), 1.00 mmol (673.07), 1.75 mmol (668.63), control (664.21), 1.50 mmol (641.08). Minimum number of seeds/flower (631.66) was recorded in treatment 2.25 mmol.

4.2.3.3 1000 seed weight (g)

The data pertaining to 1000 seed weight is represented in Table 4.18 and Fig. 4.48. It was found to lie in the range between 0.81 g to 1.04 g. Maximum weight of 1000 seeds (1.04 g) was recorded with putrescine treatment 1.50 mmol which was statistically at par with 2.00 mmol (1.01 g), 1.75 mmol (0.98 g), control (0.95 g) and significant to 1.25 mmol (0.93 g), 2.50 mmol (0.92 g), 1.00 mmol (0.91 g), 2.25 mmol (0.84 g), 2.75 mmol (0.82 g). Minimum weight of 1000 seeds (0.81 g) was noticed in treatment 3.00 mmol.

4.2.3.4 Seedyield/plant (g)

The data pertaining to seed yield/plant is represented in Table 4.18 and illustrated graphically in Fig. 4.49. It was found to lie in the range between 24.21 g to 41.09 g. Maximum seed yield/plant (41.09 g) was recorded with treatment 2.75 mmol which was statistically at par with 2.00 mmol (35.95 g), 1.75 mmol (35.15 g), 1.50 mmol (33.44 g), 2.50 mmol (33.27 g) and significant to 2.25 mmol (29.93 g), 1.25 mmol (29.05 g), 1.00 mmol (27.04 g), 3.00 mmol (25.31 g). Minimum seed yield/plant (24.21 g) was found in control.

4.2.3.5 Seed yield/m² (g/m²)

Table 4.18 and Fig. 4.50 showed seed yield/m² being highly influenced by different putrescine treatments. It varies from 75.89 g/m² to 130.36 g/m². Putrescine @ 2.50 mmol concentration resulted in maximum seed yield/m² (130.36 g/m²) which was statistically at par with 2.00 mmol (114.40 g/m²), 1.75 mmol (111.49 g/m²), 1.50 mmol (106.12 g/m²), 2.75 mmol (105.78 g/m²) and significant to 2.25 mmol (96.01 g/m²), 1.25 mmol (91.63 g/m²), 1.00 mmol (84.75 g/m²), 3.00 mmol (79.54 g/m²). Minimum seed yield/m² (75.89 g/m²) was recorded in distilled water treated plants as control.

Table 4.18: Effect of various concentrations of putrescine on days to seed maturity, number of seeds/flower, 1000 seed weight, seed yield/plant and seed yield/m² in helichrysum

Treatment (mmol)	Days to seed maturity (days)	No. of seeds/flower	1000 seed weight (g)	Seed yield/plant (g)	Seed yield/m² (g/m²)
Control	118.24	664.21	0.95	24.21	75.89
1.00	116.24	673.07	0.91	27.04	84.75
1.25	115.83	702.82	0.93	29.05	91.63
1.50	114.41	641.08	1.04	33.44	106.12
1.75	114.49	668.63	0.98	35.15	111.49
2.00	114.41	677.30	1.01	35.95	114.40
2.25	114.91	631.66	0.84	29.93	96.01
2.50	114.74	732.46	0.92	33.27	130.36
2.75	117.41	751.08	0.82	41.09	105.78
3.00	119.75	678.30	0.81	25.31	79.54
C.D. at 5%	2.96	53.39	0.10	8.00	26.05

Fig 4.46: Graphical representation of various concentrations of putrescine on days to seed maturity in helichrysum

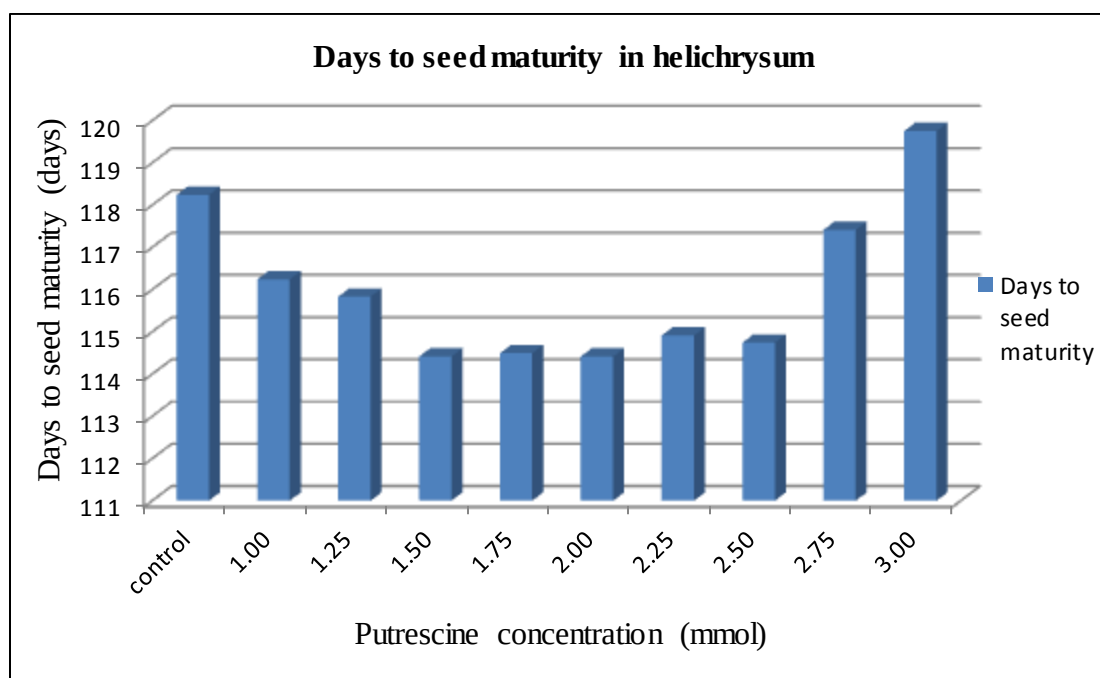


Fig 4.47: Graphical representation of various concentrations of putrescine on number of seeds/flower in helichrysum

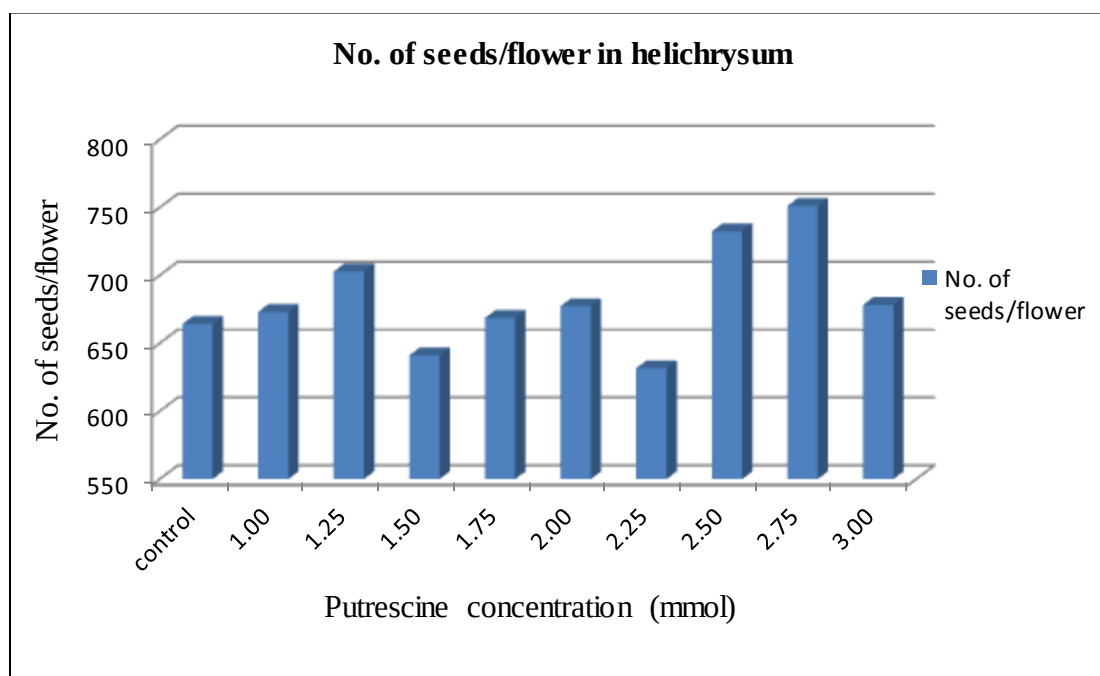


Fig 4.48: Graphical representation of various concentrations of putrescine on 1000 seed weight in helichrysum

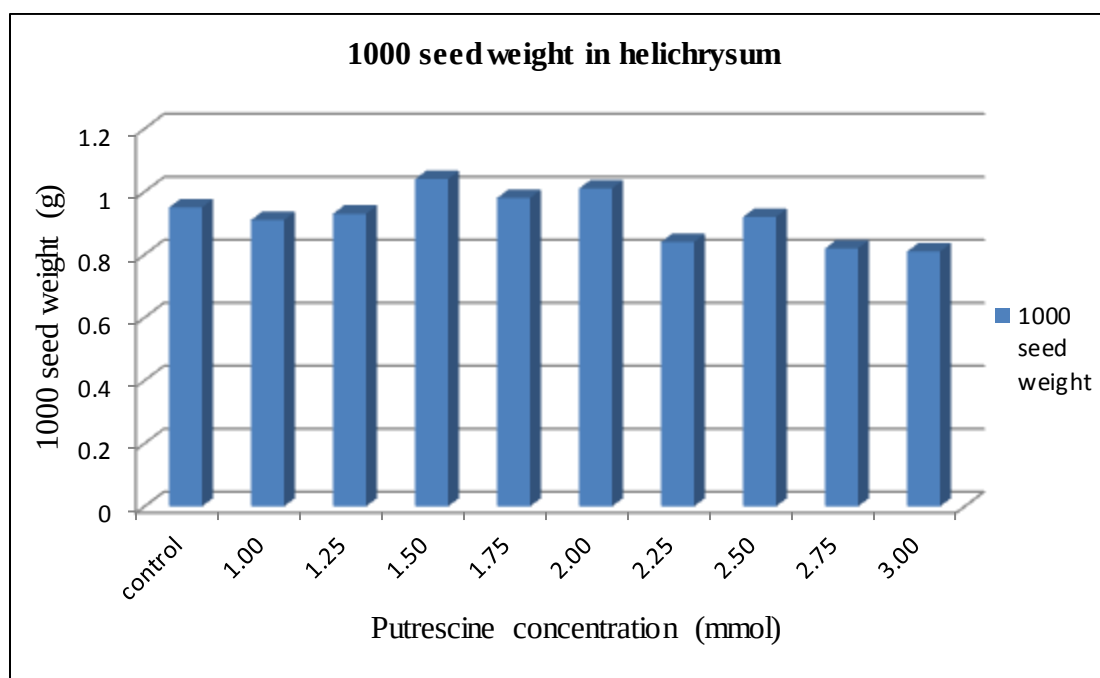


Fig 4.49: Graphical representation of various concentrations of putrescine on seed yield/plant in helichrysum

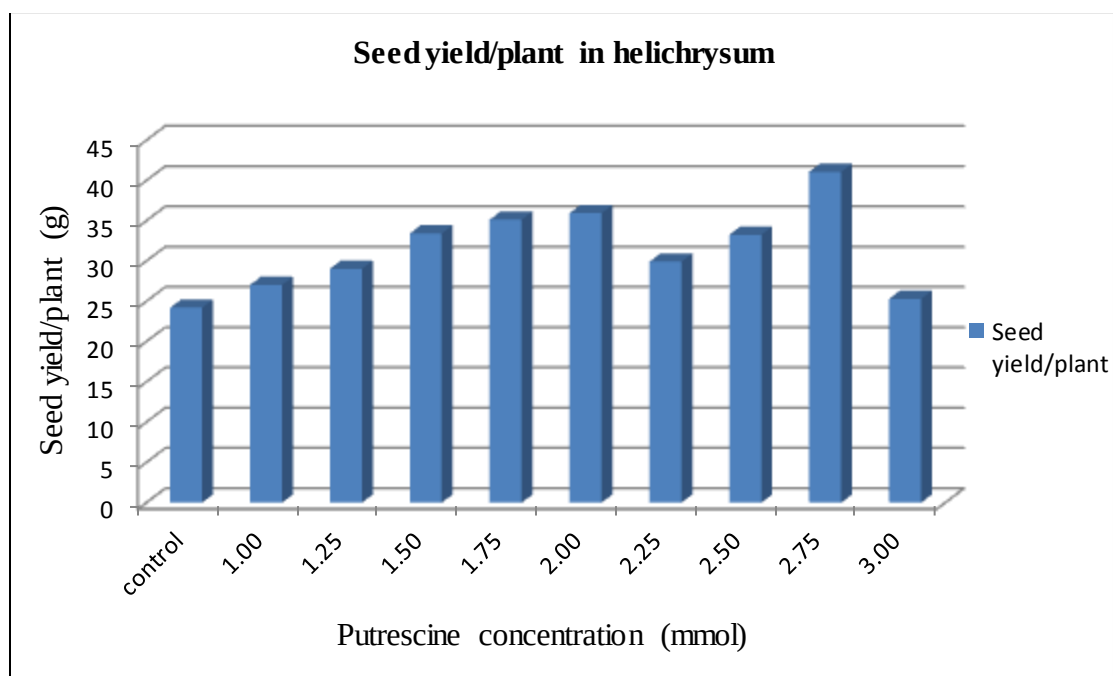
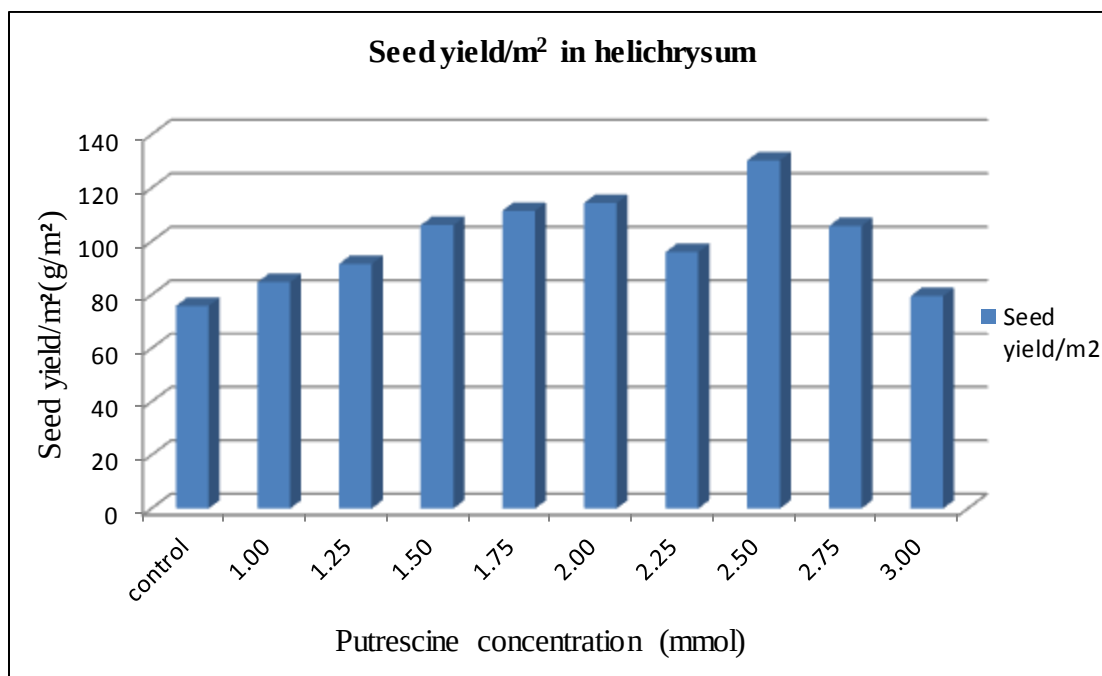


Fig 4.50: Graphical representation of various concentrations of putrescine on seed yield/m² in helichrysum



DISCUSSION

Different growth and developmental processes like cell division and differentiation, flowering, fruit ripening, embryogenesis, senescence etc. are affected by polyamines. Polyamines may also act as anti-senescence agents in plants (Galston and Sawhney, 1990). Therefore, it is necessary to study the effect of putrescine in winter annuals. The results obtained from the experiment entitled “Effect of various concentrations of putrescine on growth, flowering and seed yield in cornflower and helichrysum” conducted at the Horticulture farm of Institute of Agricultural Sciences, B.H.U., Varanasi, U.P. during 2021-2022. The experimental evidences collected during the investigations to explain the performance of different concentrations of putrescine in cornflower and helichrysum in relation to their vegetative growth, flowering and seed yield parameters have been discussed here. An attempt has been made to examine and evaluate the important observations in terms of cause and effect relationship. In the present investigation a total of ten treatments were critically evaluated. The chapter contains elucidation and verification of present research findings with the reported previous work along with analysis and justifications.

5.1 Cornflower

5.1.1 Growth characters

Application of putrescine at different levels had a markedly effect on all growth characters in cornflower.

Plant height plays an important role in influencing characters like yield traits. Increased plant height resulted in increased plant vigour. The plant height varied under different concentrations of putrescine. The maximum plant height (42.18 cm) was recorded at 2.50 mmol, whereas, minimum plant height (27.03 cm) was observed with 1.25 mmol at 60 DAT. The maximum plant height (95.04 cm) was recorded at 2.75 mmol, whereas, minimum plant height (27.03 cm) was observed with 1.25 mmol

at 90 DAT. This significant increase in the plant height may be attributed to the action of putrescine which promote vegetative growth by cell division and cell differentiation which may have resulted in increase of plant height. Present findings were in compliance with result obtained by Nahed *et al.* (2009) in gladiolus, Youssef *et al.* (2004) in *Matthiola incana*, Talaat *et al.* (2005) in periwinkle, Chokami *et al.* (2019) in basil, Saeed and Taher (2019) in *Ranunculus asiaticus*.

The plant spread varied under different concentrations of putrescine. The maximum plant spread (42.50 cm) was recorded at 2.75 mmol, while, minimum plant spread (36.78 cm) was observed with 1.00 mmol at 60 DAT. The maximum plant spread (58.39 cm) was recorded at 2.75 mmol, whereas, minimum plant spread (42.94 cm) was observed with 1.00 mmol at 90 DAT. Putrescine at optimum dose of 2.75 mmol may have enhanced the metabolic activities of the plant and influenced water and nutrients uptake, therefore, the plant spread might have increased. This finding was in accordance with Mahgoub *et al.* (2006) who found that foliar application of putrescine at 200 ppm in *Dianthus caryophyllus* significantly increased growth parameters.

The maximum number of primary branches (17.99) were obtained at 2.25 mmol, whereas, minimum number of primary branches (4.58) were noticed at 1.25 mmol at 60 DAT. The maximum number of primary branches (36.99) were obtained at 2.75 mmol and minimum number of primary branches (24.66) were noticed with 1.00 mmol at 90 DAT. Increase in primary branches might have resulted due to enhanced cell division, increased cell size as well as higher leaf area and thus grater photosynthesis activity because of effect of putrescine on that plant. This finding was in compliance with result obtained by Mahgoub *et al.* (2011) in dahlia, Badawy *et al.* (2015) in *Antirrhinum majus*, El-Quesni *et al.* (2007) in *Bougainvillea glabra*, Talaat and Gamal El-din (2005) in *Nigella sativa*.

The maximum number of secondary branches (9.83) were obtained at 2.25 mmol, whereas, minimum number of secondary branches (1.00) were noticed with 1.00 mmol at 60 DAT. The maximum number of secondary branches (176.99) were obtained at 2.75 mmol and minimum number of secondary branches (113.74) were

noticed with 1.00 mmol at 90 DAT. The increase in number of secondary branches with application of putrescine seems to be due to enhanced cell division and cell enlargement, promotion of protein synthesis with higher dry matter accumulation in plant. This finding was in accordance with Mahgoub *et al.* (2006) in *Dianthus caryophyllus*, Talaat *et al.* (2005) in periwinkle.

Maximum fresh weight of leaf (0.41 g) was noticed at 1.00 mmol, whereas, minimum fresh weight of leaf (0.15 g) was recorded at 2.00 mmol. The increase in fresh weight of leaf with putrescine might be due to the production of more number of flowers and bigger sized flowers. This finding was in accordance with Rakbar *et al.* (2008) in gerbera.

Maximum dry weight of leaf (0.064 g) was noticed at 1.00 mmol, whereas, minimum dry weight of leaf (0.035 g) was recorded at 2.50 mmol. The positive effect of polyamines on growth enhances cell division and expansion (Cohen 1998). These findings are in accordance with Youssef *et al.* (2004) who reported that foliar application of diamine putrescine to *Matthiola* plants significantly promoted fresh and dry weight of leaves/plant in the vegetative growth stage, especially at 250 mg/l treatment.

Maximum leaf area (14.81 cm²) was observed at 2.75 mmol, whereas, minimum leaf area (6.97 cm²) was recorded with control. Cell division enhancement, increase in cell size results in higher leaf area due to putrescine. This finding was in accordance with Rakbar *et al.* (2008) in gerbera, El-Quesni *et al.* (2010) in *Syngonium podophyllum*, Saeed *et al.* (2019) in gerbera, El-Quesni *et al.* (2007) in *Bougainvillea glabra*.

It is apparent from the data that putrescine at all levels significantly increased most of the growth parameters. The protective effects of putrescine on cell membrane stability index (MSI) and leaves chlorophyll content as well as on photosynthetic activity have been reported (Rahemi *et al.* 2017). Different levels of putrescine in comparison with control significantly increased the primary and secondary branches, plant spread, fresh and dry weight of leaf. This might be due to the fact that PAs play

important role in cell division and differentiation (Hummel *et al.*, 2004; Mattoo *et al.*, 2010; Paschalidis and Roubelakis, 2005). It is an established fact that growth regulators enhance various growth characters probably due to their physiological action which ultimately increase the number and size of cell of meristematic tissue.

5.1.2 Flowering characters

The different concentrations of putrescine used had significantly affected the number of days to bud formation. Early bud initiation (56.99 days) was noticed in control, while, late bud initiation (62.58 days) was observed at concentration 1.25 mmol.

The maximum pedicel length (24.18 cm) was obtained at 2.75 mmol. However, minimum pedicel length (17.51 cm) was observed at 1.00 mmol concentration. Putrescine increased significantly the pedicel length of flowers as compared with the control plants. This might be due to enhanced cell division effect of putrescine. This finding was in accordance with Kandil *et al.* (2011) in chrysanthemum, Nahed *et al.* (2009) in gladiolus, Badawy *et al.* (2015) in *Antirrhinum majus*, Saeed *et al.* (2019) in gerbera, Farahi *et al.* (2012) in rose.

Early bud development (74.41 days) was observed at 2.50 mmol, while, putrescine @ 2.00 mmol showed late bud development (78.66 days).

Maximum bud diameter (10.69 mm) was recorded at 2.50 mmol. Minimum bud diameter (9.49 mm) was recorded at 1.25 mmol. Increase in bud diameter might be due to cell differentiation in the bud due to effect of putrescine. These findings are in conformity with finding of Farahi *et al.* (2012) in rose.

Maximum disc diameter (2.13 cm) was obtained at 2.00 mmol, whereas, minimum disc diameter (1.80 cm) was noticed with control.

The maximum flower diameter (4.64 cm) was obtained at 2.00 mmol, whereas, putrescine @ 3.00 mmol showed minimum flower diameter (4.36 cm). The role of putrescine in improving the bud size may be due to its effect on physiological

activities by formation of the photosynthetic and translocation from source to sink. This finding was in accordance with Kandil *et al.* (2011) in chrysanthemum, Mohammadi *et al.* (2014) in gladiolus, Saeed and Taher (2019) in *Ranunculus asiaticus*.

Early flower blooming (79.24 days) was recorded at 2.50 mmol, while, late flower blooming (82.83 days) was noticed at 2.00 mmol. This effect may be due to the positive effect of putrescine on the physiological activities by formation of the photosynthetic and translocation from source to sink in accordance to El-Bassiouny *et al.* (2008). Putrescine affects IAA synthesis, which increases the synthesis of IAA enzyme and increasing the tryptophane levels, which are precursors of IAA hormone (Kandil *et al.*, 2011).

Maximum number of flowers/plant (622.24) was obtained at 2.75 mmol. However, putrescine @ 1.00 mmol recorded minimum number of flowers/plant (348.24). The increase in the number of flowers may be attributed to an increased plant height and number of branches as influenced by putrescine treatments. This finding was in compliance with result obtained by Yousefi *et al.* (2019) in rose, Kandil *et al.* (2011) in chrysanthemum, Saeed and Taher (2019) in *Ranunculus asiaticus*. Mahgoub *et al.* (2006) hypothesized that foliar application of putrescine at 200 ppm to *Dianthus caryophyllus* plants significantly increased number of flowers/plant, fresh and dry weight of flowers.

Maximum flower longevity (8.58 days) was obtained at 2.00 mmol, whereas, minimum flower longevity (6.74 days) was recorded at 1.75 mmol. This finding was in compliance with result obtained by Yousefi *et al.* (2019) in rose, Kahrobaiyan *et al.* (2019) in sunflower. Since polyamines retarded the senescence that leads to enhance flower longevity. Present study was in agreement with the findings of Iman *et al.* (2005) who reported retardation in senescence of leaf discs of two diverse species of roses. PAs inhibit the biosynthesis of ethylene in plants as S-adenosylmethionine, the precursor of both polyamine and ethylene synthesis will be used mainly for PAs synthesis rather than that of ethylene (Liang and Lur, 2002).

Late flower withering (91.41 days) was showed at 2.00 mmol, while, putrescine @ 1.75 mmol recorded early flower withering (86.24 days). Glucose metabolism of petals was affected as putrescine postponed cell expansion of petals and opening of rose (Nowak and Rudnicki, 1990). This finding was in accordance with Mohammadi *et al.* (2014) in gladiolus, Badawy *et al.* (2015) in *Antirrhinum majus*, Saeed *et al.* (2019) in gerbera.

Maximum fresh weight of flower (0.525 g) was observed at 1.25 mmol, while, minimum fresh weight of flower (0.470 g) was recorded with control. Mahgoub *et al.* (2006) in *Dianthus caryophyllus*, Nahed *et al.* (2009) in gladiolus reported that putrescine was more effective on fresh weight of plants. This might be due to effect of putrescine which enhances the accumulation of the produced in the plant tissues (flowers). These findings are in conformity with finding of Kahrobaiyan *et al.* (2019) in sunflower, Soleimany-Fard *et al.* (2014) in alstroemeria.

Maximum dry weight of flower (0.138 g) was observed at 2.75 mmol. However, minimum dry weight of flower (0.117 g) was noticed at 1.50 mmol. Mahgoub *et al.* (2006) in *Dianthus caryophyllus*, Nahed *et al.* (2009) in gladiolus reported that putrescine was more effective on dry weight of plants. This may be explained that putrescine enhanced the accumulation of the produced in the plant tissues (flowers). The conjugated polyamines are known to be associated with the physiology of flowering (Slocum and Galston, 1985). These results are in agreement with those obtained by Singh and Bist (2003) on rose, Mahgoub *et al.* (2006) on *Calendula officinalis*, El-Quesni *et al.* (2007) on *Bougainvillea glabra* plants, they found that paclobutrazole or putrescine increased dry weight of flowers.

Maximum flower yield/m² (1053.33 g/m²) was obtained at 2.75 mmol, whereas, minimum flower yield/m² (594 g/m²) was recorded at 1.00 mmol. This finding was in accordance with Badawy *et al.* (2015) in *Antirrhinum majus*. The highest values in flower yield were found at 200 ppm putrescine by Kandil *et al.* (2011) in chrysanthemum. These results are in agreement with obtained by Mahgoub *et al.* (2006) on *Dianthus caryophyllus* plants they found that putrescine at 200 and

400 ppm caused a significant increase in flower yield as compared with untreated plants.

Flowering parameters enhanced with different levels of putrescine. This might be due to the fact that it modulates several growth and developmental processes viz., cell division, differentiation, flowering, embryogenesis (Kandil *et al.*, 2011). Polyamines have a various roles such as that of a new class of plant growth regulators, hormonal second messengers and one of the reserves of carbon and nitrogen at least in cultured tissues (Slocum and Flores, 1991). Putrescine increases the amount of endogenous promoters (auxin, gibberellins and cytokinins) accompanied by decrease in content and activity of inhibitors (ABA) according to El-Bassiouny *et al.* (2008).

5.1.3 Seed characters

Minimum days to seed maturity (100.07 days) was observed in control, while, it was maximum (105.08 days) at 2.00 mmol concentration.

The quantitative parameters in relation with number of seeds/flower was significantly influenced by putrescine treatments. Number of seeds/flower (56.02) was reported to be maximum at 1.00 mmol, whereas, minimum number of seeds/flower (44.77) was recorded with control. Results were also in congruence with findings of earlier workers who found beneficial effect of putrescine by Nahed *et al.* (2009) in gladiolus, Kahrobaiyan *et al.* (2019) in sunflower.

Maximum weight of 1000 seeds (5.34 g) was recorded at 3.00 mmol. However, minimum weight of 1000 seeds (4.64 g) was obtained at 1.75 mmol. This finding was in accordance with Kahrobaiyan *et al.* (2019) in sunflower, Nahed *et al.* (2009) in gladiolus.

Maximum seed yield/plant (151.64 g) was recorded at 2.75 mmol, while, minimum seed yield/plant (91.69 g) was recorded with control. This might be due to the effect of putrescine as PAs play an important role in regulating sugar and carbohydrate biosynthesis. They act as plant growth regulators and may be involved in many biological activities and are closely associated with carbohydrate

biosynthesis. This was in agreement with Nahed *et al.* (2009) in gladiolus, Talaat and Gamal El-din (2005) in *Nigella sativa*.

Putrescine @ 3.00 mmol showed maximum seed yield/m² (510.17 g/m²), whereas, minimum seed yield/m² (297.72 g/m²) was recorded with control. This suggests that putrescine enhances seed yield/m². A relationship between high number of seed/flower and per plant was due to the fact that polyamines and other growth regulators enhance cell division (Crisosto *et al.*, 1988) thus increase carbohydrate level which leads to increase in seed yield (Movahed *et al.*, 2012).

5.2 Helichrysum

5.2.1 Growth characters

Application of putrescine at different levels had a markedly effect on all growth characters in helichrysum.

Plant height plays an important role in influencing characters like yield traits. Increased plant height resulted in increased plant vigour. The plant height varied under different concentrations of putrescine. The maximum plant height (34.38 cm) was recorded at 1.25 mmol, whereas, minimum plant height (24.44 cm) was observed with control at 60 DAT. The maximum plant height (94.64 cm) was recorded at 1.75 mmol, whereas, minimum plant height (84.56 cm) was observed with 3.00 mmol at 90 DAT. This significant increase in the plant height may be attributed to the action of putrescine which promote vegetative growth by cell division and cell differentiation which may have resulted in increase of plant height. Present findings were in compliance with result obtained by Nahed *et al.* (2009) in gladiolus, Youssef *et al.* (2004) in *Matthiola incana*, Talaat *et al.* (2005) in periwinkle, Chokami *et al.* (2019) in basil, Saeed and Taher (2019) in *Ranunculus asiaticus*.

The maximum plant spread (33.37 cm) was recorded at 2.00 mmol, whereas, minimum plant spread (28.13 cm) was observed with 1.00 mmol at 60 DAT. The maximum plant spread (60.95 cm) was recorded at 2.50 mmol, whereas, minimum plant spread (46.97 cm) was observed with 1.00 mmol at 90 DAT. Putrescine at

optimum dose of 2.50 mmol may have enhanced the metabolic activities of the plant and influenced water and nutrients uptake, therefore, the plant spread might have increased. This finding was in accordance with Mahgoub *et al.* (2006) who found that foliar application of putrescine at 200 ppm in *Dianthus caryophyllus* significantly increased growth parameters.

The maximum number of primary branches (15.41) were obtained at 2.00 mmol, whereas, minimum number of primary branches (6.82) were noticed with control at 60 DAT. The maximum number of primary branches (29.08) were obtained at 2.25 mmol, whereas, minimum number of primary branches (17.08) were noticed with control at 90 DAT. Increase in primary branches might have resulted due to enhanced cell division, increased cell size as well as higher leaf area and thus greater photosynthesis activity because of effect of putrescine on that plant. This finding was in compliance with result obtained by Mahgoub *et al.* (2011) in dahlia, Badawy *et al.* (2015) in *Antirrhinum majus*, El-Quesni *et al.* (2007) in *Bougainvillea glabra*, Talaat and Gamal El-din (2005) in *Nigella sativa*.

The maximum number of secondary branches (2.33) were obtained at 2.00 mmol, whereas, minimum number of secondary branches (0.00) were noticed with 1.00 mmol, 2.75 mmol, 3.00 mmol and control at 60 DAT. The maximum number of secondary branches (24.33) were obtained at 2.25 mmol, whereas, minimum number of secondary branches (6.08) were noticed with control at 90 DAT. The increase in number of secondary branches with application of putrescine seems to be due to enhanced cell division and cell enlargement, promotion of protein synthesis with higher dry matter accumulation in plant. This finding was in accordance with Mahgoub *et al.* (2006) in *Dianthus caryophyllus*, Talaat *et al.* (2005) in periwinkle.

Maximum fresh weight of leaf (0.71 g) was noticed at 1.00 mmol, whereas, minimum fresh weight of leaf (0.20 g) was recorded with control. The increase in fresh weight of leaf with putrescine might be due to the production of more number of flowers and bigger sized flowers. This finding was in accordance with Rakbar *et al.* (2008) in gerbera.

Maximum dry weight of leaf (0.13 g) was noticed at 1.00 mmol. The minimum dry weight of leaf (0.05 g) was recorded with control. The positive effect of polyamines on growth enhances cell division and expansion (Cohen 1998). These findings are in accordance with Youssef *et al.* (2004) who reported that foliar application of diamine putrescine to *Matthiola* plants significantly promoted fresh and dry weight of leaves/plant in the vegetative growth stage, especially at 250 mg/l treatment.

Maximum leaf area (30.40 cm²) was observed at 2.25 mmol. The minimum leaf area (15.37 cm²) was recorded at 1.00 mmol. Cell division enhancement, increase in cell size results in higher leaf area due to putrescine. This finding was in accordance with Rakbar *et al.* (2008) in gerbera, El-Quesni *et al.* (2010) in *Syngonium podophyllum*, Saeed *et al.* (2019) in gerbera, El-Quesni *et al.* (2007) in *Bougainvillea glabra*.

Maximum shoot base diameter (24.83 mm) was obtained at 2.25 mmol concentration, whereas, minimum shoot base diameter (18.72 mm) was seen at 2.00 mmol. The aforementioned results of putrescine concerning the vegetative growth may be due to putrescine which might have caused cell differentiation by enzyme induction weakening the cell wall leading to stretching of cell. This finding was in compliance with result obtained by Mahgoub *et al.* (2011) in dahlia, Kahrobaiyan *et al.* (2019) in sunflower, Nahed *et al.* (2009) in gladiolus, El-Quesni *et al.* (2010) in *Syngonium podophyllum*.

It is apparent from the data that putrescine at all levels significantly increased most of the growth parameters. The protective effects of putrescine on cell membrane stability index (MSI) and leaves chlorophyll content as well as on photosynthetic activity have been reported (Rahemi *et al.* 2017). Different levels of putrescine in comparison with control significantly increased the primary and secondary branches, plant spread, fresh and dry weight of leaf. This might be due to the fact that PAs play important role in cell division and differentiation (Hummel *et al.*, 2004; Mattoo *et al.*, 2010; Paschalidis and Roubelakis, 2005). It is an established fact that growth

regulators enhance various growth characters probably due to their physiological action which ultimately increase the number and size of cell of meristematic tissue.

5.2.2 Flowering characters

The different concentrations of putrescine used had significantly affected the number of days to bud formation. Early bud initiation (60.91 days) was noticed in 1.50 mmol, while, late bud initiation (68.16 days) was observed at concentration 3.00 mmol.

Early bud development (74.49 days) was observed at 1.50 mmol, while, putrescine @ 3.00 mmol showed late bud development (82.91 days).

Maximum bud diameter (14.10 mm) was recorded at 2.00 mmol. Minimum bud diameter (13.26 mm) was recorded with control. Increase in bud diameter might be due to cell differentiation in the bud due to effect of putrescine. These findings are in conformity with finding of Farahi *et al.* (2012) in rose.

Maximum disc diameter (2.07 cm) was obtained at 2.00 mmol, whereas, minimum disc diameter (1.85 cm) was observed with 1.00 mmol.

The maximum flower diameter (4.73 cm) was obtained at 2.00 mmol, whereas, minimum flower diameter (4.36 cm) was observed at control. The role of putrescine in improving the bud size may be due to its effect on physiological activities by formation of the photosynthetic and translocation from source to sink. This finding was in accordance with Kandil *et al.* (2011) in chrysanthemum, Mohammadi *et al.* (2014) in gladiolus, Saeed and Taher (2019) in *Ranunculus asiaticus*.

Early flower blooming (83.24 days) was recorded at 1.50 mmol, while, late flower blooming (91.16 days) was noticed at 3.00 mmol. This effect may be due to the positive effect of putrescine on the physiological activities by formation of the photosynthetic and translocation from source to sink in accordance to El-Bassiouny *et al.* (2008). Putrescine affects IAA synthesis, which increases the synthesis of IAA

enzyme and increasing the tryptophane levels, which are precursors of IAA hormone (Kandil *et al.*, 2011).

Maximum number of flowers/plant (60.66) was obtained at 2.50 mmol. However, minimum number of flowers/plant (38.08) was recorded with control. The increase in the number of flowers may be attributed to an increased plant height and number of branches as influenced by putrescine treatments. This finding was in compliance with result obtained by Yousefi *et al.* (2019) in rose, Kandil *et al.* (2011) in chrysanthemum, Saeed and Taher (2019) in *Ranunculus asiaticus*. Mahgoub *et al.* (2006) hypothesized that foliar application of putrescine at 200 ppm to *Dianthus caryophyllus* plants significantly increased number of flowers/plant, fresh and dry weight of flowers.

Maximum flower longevity (26.08 days) was obtained at 1.50 mmol, whereas, minimum flower longevity (21.74 days) was recorded at 3.00 mmol concentration. This finding was in compliance with result obtained by Yousefi *et al.* (2019) in rose, Kahrobaiyan *et al.* (2019) in sunflower. Since polyamines retarded the senescence that leads to enhance flower longevity. Present study was in agreement with the findings of Iman *et al.* (2005) who reported retardation in senescence of leaf discs of two diverse species of roses. PAs inhibit the biosynthesis of ethylene in plants as S-adenosylmethionine, the precursor of both polyamine and ethylene synthesis will be used mainly for PAs synthesis rather than that of ethylene (Liang and Lur, 2002).

Late flower withering (112.91 days) was showed at 3.00 mmol, whereas, early flower withering (108.66 days) was recorded at 2.25 mmol. Glucose metabolism of petals was affected as putrescine postponed cell expansion of petals and opening of rose (Nowak and Rudnicki, 1990). This finding was in accordance with Mohammadi *et al.* (2014) in gladiolus, Badawy *et al.* (2015) in *Antirrhinum majus*, Saeed *et al.* (2019) in gerbera.

Maximum fresh weight of flower (3.07 g) was recorded with control, while, minimum fresh weight of flower (2.40 g) was obtained at 2.25 mmol. Mahgoub *et al.* (2006) in *Dianthus caryophyllus*, Nahed *et al.* (2009) in gladiolus reported that

putrescine was more effective on fresh weight of plants. This might be due to effect of putrescine which enhances the accumulation of the produced in the plant tissues (flowers). These findings are in conformity with finding of Kahrobaiyan *et al.* (2019) in sunflower, Soleimany-Fard *et al.* (2014) in alstroemeria.

Maximum dry weight of flower (0.84 g) was observed with control. However, minimum dry weight of flower (0.64 g) was noticed at 1.75 mmol. Mahgoub *et al.* (2006) in *Dianthus caryophyllus*, Nahed *et al.* (2009) in gladiolus reported that putrescine was more effective on dry weight of plants. This may be explained that putrescine enhanced the accumulation of the produced in the plant tissues (flowers). The conjugated polyamines are known to be associated with the physiology of flowering (Slocum and Galston, 1985). These results are in agreement with those obtained by Singh and Bist (2003) on rose, Mahgoub *et al.* (2006) on *Calendula officinalis*, El-Quesni *et al.* (2007) on *Bougainvillea glabra* plants, they found that paclobutrazole or putrescine increased dry weight of flowers.

Maximum flower yield/m² (530.48 g/m²) was obtained at 2.75 mmol, whereas, minimum flower yield/m² (366.82 g/m²) was recorded with control. This finding was in accordance with Badawy *et al.* (2015) in *Antirrhinum majus*. The highest values in flower yield were found at 200 ppm putrescine by Kandil *et al.* (2011) in chrysanthemum. These results are in agreement with obtained by Mahgoub *et al.* (2006) on *Dianthus caryophyllus* plants they found that putrescine at 200 and 400 ppm caused a significant increase in flower yield as compared with untreated plants.

Flowering parameters enhanced with different levels of putrescine. This might be due to the fact that it modulates several growth and developmental processes viz., cell division, differentiation, flowering, embryogenesis (Kandil *et al.*, 2011). Polyamines have a various roles such as that of a new class of plant growth regulators, hormonal second messengers and one of the reserves of carbon and nitrogen at least in cultured tissues (Slocum and Flores, 1991). Putrescine increases the amount of endogenous promoters (auxin, gibberellins and cytokinins) accompanied by decrease in content and activity of inhibitors (ABA) according to El-Bassiouny *et al.* (2008).

5.2.3 Seed characters

Minimum days to seed maturity (114.41 days) was observed at 1.50 mmol and 2.00 mmol, while, it was maximum (119.75 days) at 3.00 mmol concentration.

The quantitative parameters in relation with number of seeds/flower was significantly influenced by putrescine treatments. Number of seeds/flower (751.08) was reported to be maximum at 2.75 mmol, whereas, minimum number of seeds/flower (631.66) was recorded at 2.25 mmol. Results were also in congruence with findings of earlier workers who found beneficial effect of putrescine by Nahed *et al.* (2009) in gladiolus, Kahrobaiyan *et al.* (2019) in sunflower.

Maximum weight of 1000 seeds (1.04 g) was recorded at 1.50 mmol. However, minimum weight of 1000 seeds (0.81 g) was obtained at 3.00 mmol. This finding was in accordance with Kahrobaiyan *et al.* (2019) in sunflower, Nahed *et al.* (2009) in gladiolus.

Maximum seed yield/plant (41.09 g) was recorded at 2.75 mmol, while, minimum seed yield/plant (24.21 g) was recorded with control. This might be due to the effect of putrescine as PAs play an important role in regulating sugar and carbohydrate biosynthesis. They act as plant growth regulators and may be involved in many biological activities and are closely associated with carbohydrate biosynthesis. This was in agreement with Nahed *et al.* (2009) in gladiolus, Talaat and Gamal El-din (2005) in *Nigella sativa*.

Putrescine @ 2.50 mmol showed maximum seed yield/m² (130.36 g/m²), whereas, minimum seed yield/m² (75.89 g/m²) was recorded with control. This suggests that putrescine enhances seed yield per m². A relationship between high number of seed/flower and per plant was due to the fact that polyamines and other growth regulators enhance cell division (Crisosto *et al.*, 1988) thus increase carbohydrate level which leads to increase in seed yield (Movahed *et al.*, 2012).



SUMMARY AND CONCLUSION

The present investigation entitled “Effect of various concentrations of putrescine on growth, flowering and seed yield in cornflower and helichrysum” was conducted at Horticulture farm of Institute of Agricultural Sciences, B.H.U., Varanasi, U.P. during 2021-2022. The experiment was laid out in Randomized Block Design with one factor and four replications. Nine treatments as plant growth regulator viz., putrescine (1.00 mmol, 1.25 mmol, 1.50 mmol, 1.75 mmol, 2.00 mmol, 2.25 mmol, 2.50 mmol, 2.75 mmol and 3.00 mmol) along with control was applied in cornflower and helichrysum. The salient findings of the present investigation are summarized below.

6.1 Effect of various concentrations of putrescine on growth, flowering and seed yield in cornflower

- The maximum plant height (42.18 cm) was recorded with putrescine @ 2.50 mmol, whereas, minimum plant height (27.03 cm) was observed with putrescine 1.25 mmol at 60 DAT. The maximum plant height (95.04 cm) was recorded with putrescine @ 2.75 mmol, whereas, minimum plant height (27.03 cm) was observed with putrescine 1.25 mmol at 90 DAT.
- The maximum plant spread (42.50 cm) was recorded with putrescine @ 2.75 mmol. The minimum plant spread (36.78 cm) was observed with putrescine 1.00 mmol at 60 DAT. The maximum plant spread (58.39 cm) was recorded with putrescine @ 2.75 mmol, whereas, minimum plant spread (42.94 cm) was observed with putrescine 1.00 mmol at 90 DAT.
- The maximum number of primary branches (17.99) were obtained with putrescine @ 2.25 mmol, whereas, minimum number of primary branches (4.58) were noticed with putrescine 1.25 mmol at 60 DAT. The maximum number of primary branches (36.99) were obtained with putrescine @ 2.75

mmol, whereas, minimum number of primary branches (24.66) were noticed with putrescine 1.00 mmol at 90 DAT.

- The maximum number of secondary branches (9.83) were obtained with putrescine @ 2.25 mmol, whereas, minimum number of secondary branches (1.00) were noticed with putrescine 1.00 mmol at 60 DAT. The maximum number of secondary branches (176.99) were obtained with putrescine @ 2.75 mmol. The minimum number of secondary branches (113.74) were noticed with putrescine 1.00 mmol at 90 DAT.
- Maximum fresh weight of leaf (0.41 g) was noticed with putrescine @ 1.00 mmol, whereas, minimum fresh weight of leaf (0.15 g) was recorded with putrescine @ 2.00 mmol.
- Maximum dry weight of leaf (0.064 g) was noticed with putrescine @ 1.00 mmol, whereas, minimum dry weight of leaf (0.035 g) was recorded with putrescine @ 2.50 mmol.
- Maximum leaf area (14.81 cm²) was observed with putrescine @ 2.75 mmol, whereas, minimum leaf area (6.97 cm²) was recorded with control.
- Early bud initiation (56.99 days) was noticed in control, while, late bud initiation (62.58 days) was observed at concentration 1.25 mmol.
- The maximum pedicel length (24.18 cm) was obtained with putrescine @ 2.75 mmol. However, minimum pedicel length (17.51 cm) was observed with putrescine @ 1.00 mmol concentration.
- Early bud development (74.41 days) was observed with putrescine @ 2.50 mmol, while, putrescine @ 2.00 mmol showed late bud development (78.66 days).
- Maximum bud diameter (10.69 mm) was recorded with putrescine @ 2.50 mmol, while, minimum bud diameter (9.49 mm) was recorded with putrescine @ 1.25 mmol.
- Maximum disc diameter (2.13 cm) was obtained with putrescine @ 2.00 mmol, whereas, minimum disc diameter (1.80 cm) was noticed with control.

- The maximum flower diameter (4.64 cm) was obtained with putrescine @ 2.00 mmol, whereas, putrescine @ 3.00 mmol showed minimum flower diameter (4.36 cm).
- Early flower blooming (79.24 days) was recorded with putrescine @ 2.50 mmol, while, late flower blooming (82.83 days) was noticed with putrescine @ 2.00 mmol.
- Maximum number of flowers/plant (622.24) was obtained with putrescine @ 2.75 mmol. However, putrescine @ 1.00 mmol recorded minimum number of flowers/plant (348.24).
- Maximum flower longevity (8.58 days) was obtained with putrescine @ 2.00 mmol, whereas, minimum flower longevity (6.74 days) was recorded with putrescine @ 1.75 mmol.
- Late flower withering (91.41 days) was observed with putrescine @ 2.00 mmol, while, putrescine @ 1.75 mmol recorded early flower withering (86.24 days).
- Maximum fresh weight of flower (0.525 g) was observed with putrescine @ 1.25 mmol, while, minimum fresh weight of flower (0.470 g) was recorded with control.
- Maximum dry weight of flower (0.138 g) was observed with putrescine @ 2.75 mmol. However, minimum dry weight of flower (0.117 g) was noticed with putrescine @ 1.50 mmol.
- Maximum flower yield/m² (1053.33 g/m²) was obtained with putrescine @ 2.75 mmol, whereas, minimum flower yield/m² (594 g/m²) was recorded with putrescine @ 1.00 mmol.
- Minimum days to seed maturity (100.07 days) was observed in control, while, it was maximum (105.08 days) with putrescine @ 2.00 mmol concentration.
- Number of seeds/flower (56.02) was reported to be maximum with putrescine @ 1.00 mmol, whereas, minimum number of seeds/flower (44.77) was recorded with control.

- Maximum weight of 1000 seeds (5.34 g) was recorded with putrescine @ 3.00 mmol. However, minimum weight of 1000 seeds (4.64 g) was obtained with putrescine @ 1.75 mmol.
- Maximum seed yield/plant (151.64 g) was recorded with putrescine @ 2.75 mmol, while, minimum seed yield/plant (91.69 g) was recorded with control.
- Putrescine @ 3.00 mmol showed maximum seed yield/m² (510.17 g/m²), whereas, minimum seed yield/m² (297.72 g/m²) was recorded with control.

6.2 Effect of various concentrations of putrescine on growth, flowering and seed yield in helichrysum

- The maximum plant height (34.38 cm) was recorded with putrescine @ 1.25 mmol, whereas, minimum plant height (24.44 cm) was observed with control at 60 DAT. The maximum plant height (94.64 cm) was recorded with putrescine @ 1.75 mmol, whereas, minimum plant height (84.56 cm) was observed with putrescine 3.00 mmol at 90 DAT.
- The maximum plant spread (33.37 cm) was recorded with putrescine @ 2.00 mmol, whereas, minimum plant spread (28.13 cm) was observed with putrescine 1.00 mmol at 60 DAT. The maximum plant spread (60.95 cm) was recorded with putrescine @ 2.50 mmol, whereas, minimum plant spread (46.97 cm) was observed with putrescine 1.00 mmol at 90 DAT.
- The maximum number of primary branches (15.41) were obtained with putrescine @ 2.00 mmol, whereas, minimum number of primary branches (6.82) were noticed with control at 60 DAT. The maximum number of primary branches (29.08) were obtained with putrescine @ 2.25 mmol, whereas, minimum number of primary branches (17.08) were noticed with control at 90 DAT.
- The maximum number of secondary branches (2.33) were obtained with putrescine @ 2.00 mmol, whereas, minimum number of secondary branches (0.00) were noticed with putrescine @ 1.00 mmol, 2.75 mmol, 3.00 mmol and control at 60 DAT. The maximum number of secondary branches (24.33) were

obtained with putrescine @ 2.25 mmol, whereas, minimum number of secondary branches (6.08) were noticed with control at 90 DAT.

- Maximum fresh weight of leaf (0.71 g) was noticed with putrescine @ 1.00 mmol, whereas, minimum fresh weight of leaf (0.20 g) was recorded with control.
- Maximum dry weight of leaf (0.13 g) was noticed with putrescine @ 1.00 mmol. The minimum dry weight of leaf (0.05 g) was recorded with control.
- Maximum leaf area (30.40 cm²) was observed with putrescine @ 2.25 mmol, while, minimum leaf area (15.37 cm²) was recorded with putrescine @ 1.00 mmol.
- Maximum shoot base diameter (24.83 mm) was obtained with putrescine @ 2.25 mmol concentration, whereas, minimum shoot base diameter (18.72 mm) was seen with putrescine @ 2.00 mmol.
- Early bud initiation (60.91 days) was noticed with putrescine @ 1.50 mmol, while, late bud initiation (68.16 days) was observed at putrescine concentration 3.00 mmol.
- Early bud development (74.49 days) was observed with putrescine @ 1.50 mmol, while, putrescine @ 3.00 mmol showed late bud development (82.91 days).
- Maximum bud diameter (14.10 mm) was recorded with putrescine @ 2.00 mmol. Minimum bud diameter (13.26 mm) was recorded with control.
- Maximum disc diameter (2.07 cm) was obtained with putrescine @ 2.00 mmol, whereas, minimum disc diameter (1.85 cm) was observed with putrescine 1.00 mmol.
- The maximum flower diameter (4.73 cm) was obtained with putrescine @ 2.00 mmol, whereas, minimum flower diameter (4.36 cm) was observed with control.

- Early flower blooming (83.24 days) was recorded with putrescine @ 1.50 mmol, while, late flower blooming (91.16 days) was noticed with putrescine @ 3.00 mmol.
- Maximum number of flowers/plant (60.66) was obtained with putrescine @ 2.50 mmol. However, minimum number of flowers/plant (38.08) was recorded with control.
- Maximum flower longevity (26.08 days) was obtained with putrescine @ 1.50 mmol, whereas, putrescine @ 3.00 mmol recorded minimum flower longevity (21.74 days).
- Late flower withering (112.91 days) was observed with putrescine @ 3.00 mmol, whereas, early flower withering (108.66 days) was recorded with putrescine @ 2.25 mmol.
- Maximum fresh weight of flower (3.07 g) was recorded with control, while, minimum fresh weight of flower (2.40 g) was obtained with putrescine @ 2.25 mmol.
- Maximum dry weight of flower (0.84 g) was observed with control. However, minimum dry weight of flower (0.64 g) was noticed with putrescine @ 1.75 mmol.
- Maximum flower yield/m² (530.48 g/m²) was obtained with putrescine @ 2.75 mmol, whereas, minimum flower yield/m² (366.82 g/m²) was recorded with control.
- Minimum days to seed maturity (114.41 days) was observed with putrescine @ 1.50 mmol and 2.00 mmol, while, it was maximum (119.75 days) with putrescine 3.00 mmol concentration.
- Number of seeds/flower (751.08) was reported to be maximum with putrescine @ 2.75 mmol, whereas, minimum number of seeds/flower (631.66) was recorded with putrescine 2.25 mmol.

- Maximum weight of 1000 seeds (1.04 g) was recorded with putrescine @ 1.50 mmol. However, minimum weight of 1000 seeds (0.81 g) was obtained with putrescine 3.00 mmol.
- Maximum seed yield/plant (41.09 g) was recorded with putrescine @ 2.75 mmol, while, minimum seed yield/plant (24.21 g) was recorded with control.
- Putrescine @ 2.50 mmol showed maximum seed yield/m² (130.36 g/m²), whereas, minimum seed yield/m² (75.89 g/m²) was recorded with control.

Conclusion

Based on the results obtained from present investigation, it was concluded that

In cornflower most of the vegetative growth characters such as plant height at 90 DAT, plant spread at both 60 DAT and 90 DAT, number of primary and secondary branches at 90 DAT and leaf area were maximum obtained with putrescine @ 2.75 mmol. However, most of the flowering characters such as pedicel length, number of flowers/plant, flower yield and dry weight of flower were maximum obtained with putrescine @ 2.75 mmol while, some of the flowering characters such as maximum flower longevity, disc and flower diameter and late flower withering duration were obtained with putrescine @ 2.00 mmol.

In helichrysum most of the vegetative growth characters such as number of primary and secondary branches at 90 DAT, leaf area and shoot base diameter were maximum obtained with putrescine @ 2.25 mmol. Flowering characters such as early bud initiation, bud development, flower blooming and maximum flower longevity were obtained with putrescine @ 1.50 mmol while other flowering characters like bud diameter, disc and flower diameter were maximum obtained with putrescine @ 2.00 mmol in helichrysum.

In both cornflower and helichrysum maximum seed yield/plant was obtained with putrescine @ 2.75 mmol.



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