STUDIES ON THE EFFECT OF NUTRIENT SOURCES ON CUTTING PRODUCTION AND ROOTING IN CHRYSANTHEMUM (*Dendranthema grandiflora* Tzvelev)

Thesis

by

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CERTIFICATE - I

This is to certify that the thesis titled, **"Studies on the effect of nutrient sources on cutting production and rooting in chrysanthemum (*Dendranthema grandiflora* Tzvelev)"**, submitted in partial fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE (HORTICULTURE) FLORICULTURE AND LANDSCAPE ARCHITECTURE** in the discipline of **HORTICULTURAL SCIENCE** to Dr Yashwant Singh Parmar University of Horticulture and Forestry, (Nauni) Solan (HP)- 173 230 India is a bonafide research work carried out by **Ms Medalis Pala (H-2017-20-M)** daughter of Mr Seibor Shadap under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been fully acknowledged.

Place: Nauni, Solan
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CERTIFICATE – II

This is to certify that the thesis titled, **"Studies on the effect of nutrient sources on cutting production and rooting in chrysanthemum (*Dendranthema grandiflora* Tzvelev),** submitted by **Ms Medalis Pala (H-2017-20-M)** daughter of Mr Seibor Shadap to the Dr Yashwant Singh Parmar University of Horticulture and Forestry, (Nauni) Solan (HP) - 173 230 India in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (HORTICULTURE) FLORICULTURE AND LANDSCAPE ARCHITECTURE** in the discipline of **HORTICULTURAL SCIENCES** has been approved by the Advisory Committee after an oral examination of the student in collaboration with the External Examiner.

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Dated:
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CONTENTS

ABBREVIATIONS USED

%	:	Per cent
@	:	At the rate of
<	:	Less than
>	:	Greater than
AM	:	Arbuscular Mycorrhizae
ANOVA	:	Analysis of Variance
B	:	Boron
C	:	Carbon
Ca	:	Calcium
$Ca(NO_3)_2$	:	Calcium Nitrate
CD	:	Critical difference
Cfu	:	Colony forming unit
cm	:	Centimeter
cm^2	:	Square centimeter
Cu	:	Copper
cv./ cvs	:	Cultivar/ Cultivars
DAP	:	Days after planting
DF		Degree of Freedom
dSm^{-1}	:	Deci Siemens per meter
EC	:	Electrical conductivity
et al.	:	Co- worker
etc.	:	Et cetera
FYM	:	Farm yard manure
g	:	Gram
GA_3	:	Gibberellic acid
ha	:	Hectare
HP	:	Himachal Pradesh
i.e.	:	That is
IAA	:	Indole acetic acid
K	:	Potassium
K_2O	:	Potassium oxide
kg	:	Kilogram
kg/ha	:	Kilogram per hectare

KSB	:	Potassium Solubilizing Bacteria
l	:	Liter
L.	:	Linnaeus
lac	:	Lakh
m	:	Meter
m^2	:	Square meter
mg	:	Milligram
Mg	:	Magnesium
mg/l	:	Milligram per litre
ml	:	Milliliter
mm	:	Millimeter
Mn	:	Maganese
MOP	:	Muriate of potash
N	:	Nitrogen
N	:	Normal
NAA	:	Naphthalene acetic acid
NH_4^+	:	Ammonium ion
NH_4NO_3	:	Ammonium nitrate
NO_3^-	:	Nitrate
NS	:	Non significant
OC	:	Organic carbon
$^\circ C$	:	Degree Celsius
P	:	Phosphorous
P_2O_5	:	Phosphorous pentoxide
pH	:	Potential of hydrogen
PO_4	:	Phosphate
ppm	:	Parts per million
PSB	:	Phosphorous solubilizing bacteria
PSM	:	Phosphate Solubilizing Miicroorganisms
q	:	Quintal
RBD	:	Randomized block design
RDF	:	Recommended dose of fertilizers
RDN	:	Recommended dose of nitrogen
RH	:	Relative humidity
S	:	Sulphur

spp/sp.	:	Species
SSP	:	Single super phosphate
T	:	Treatment
t	:	Tonnes
VAM	:	Vescicular arbuscular mycorrhizae
var.	:	Variety
VC	:	Vermicompost
viz.	:	Videlicet (namely)
w.e.f	:	with effect from
Zn	:	Zinc

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Chapter-1

INTRODUCTION

Chrysanthemum (*Dendranthema grandiflora* Tzvelev) is one of the leading commercial flower crops grown for cut and loose flower and also as pot plant. The genus Chrysanthemum belongs to the family Asteraceae and comprises of about 200 species. It is grown in many parts of the world owing to its unsurpassed beauty and economic values.

It is commonly known as 'Guldaudi' in our country and 'Glory of the East' or 'Mum' in U.S.A. It is one of the most widely cultivated garden flowers and ranks probably next to rose in popularity. In India, chrysanthemum is not only being grown for cut flower and pot plant, it is also used for garland making, general decoration, hair adornment and religious function.

Propagation plays a vital role in chrysanthemum production. Although chrysanthemum can be propagated both sexually and through vegetative means, the most common method of propagation practiced commercially is through shoot tip cuttings taken from healthy mother plants (Mukherjee, 2008). Vegetative propagation serves an important role in the commercial production of flowers as the growers want to reproduce the highest-quality plants and ensure consistency of a variety of plant.

The varied agro-climatic conditions of our country are highly suitable for the cultivation of chrysanthemum throughout the year. It is being grown in almost every part of the country. In the hills of Himachal Pradesh, it starts blooming much earlier than plain areas of the country. The total area under floriculture in Himachal Pradesh is 705.77 hectares out of which about 222.11 hectares is under chrysanthemum (Anonymous, 2019).

Apart from various factors influencing the growth and flowering of chrysanthemum, balanced nutrition is very important. Chrysanthemum is a heavy feeder crop and among all the essential nutrients, it requires larger quantities of nitrogen, phosphorous and potassium. Lunt and Kofranek (1958) advocated maintaining high levels of N during the first seven weeks of chrysanthemum growth. Plants require phosphorous throughout their growing period and it should be applied

as basal dose. At present, these nutrients are supplied through chemical fertilizers. The indiscriminate and continuous use of chemical fertilizers has led to an imbalance of nutrients in soil which has adversely affected the soil health, affecting the yield and quality of the produce.

In order to safeguard the environment from further degradation and to maintain the purity of air, water and food, the use of chemicals is required to be reduced and shift from chemicals to ecological agriculture to fertilize our fields. Therefore, to maintain production at higher levels, recourse has to be made to the application of fertilizers. In recent years, integrated use of inorganic and organic manures has become important for higher agricultural production, as no single source of plant nutrients, be it chemical fertilizer, organic manure or even bio-fertilizer can meet the entire needs of crop in present day agriculture.

Integrated nutrient management (INM) provides an excellent opportunity to overcome all the imbalances beside sustaining soil health and enhancing crop production. The basic concept of INM is the maintenance or adjustment of soil fertility and of plant nutrient supply to an optimum level for sustaining the desired crop production, through optimization of the benefits from all possible sources of plant nutrients in an integrated manner (Chand, 2008). Therefore, emphasis is now focused on the use of organic manures such as farm yard manure, vermicompost and bio-fertilizers like; *Azospirillum* and Phosphate Solubilising Bacteria (PSB) (Verma *et al.*, 2011). Commercial availability of vermicompost and biofertilizer inoculants paved the way for their use in commercial flower production as it increases C: N ratio and water holding capacity of soil which leads to better soil health.

Vermicompost is a nutrient-rich manure produced from the breakdown of organic matter with the help of earthworms. It serves as organic fertilizer, since it is a rich source of nutrients like nitrogen, phosphorus, potassium, humic acids and micronutrients. The application of vermicompost influences the microbial activity in the soil thereby resulting in more availability of nitrogen and phosphorous to the plants.

Bio-fertilizers or more appropriately called microbial inoculants are the preparations containing live or latent cells of efficient strains of micro-organisms. These may be biological nitrogen fixers, P-solubilizing, mineralization of nitrogen

and transformation of several elements like sulphur and iron into available forms. These bio-fertilizers benefit agriculture production by supplying nutrients. Common bio-fertilizers used in horticulture crops are *Azotobacter, Azospirillum,* PSB and VAM fungi. *Azotobacter* is a free living N-fixing bacteria and it can be applied in many non-leguminous crops. Besides, it is also known to promote the production of certain growth substances like; auxins, gibberellins and cytokinins. *Azospirillum* is a non-symbiotic N-fixing bacterium. *Azotobacter* and *Azospirillum* fix atmospheric nitrogen when inoculated to plants, which help to save the application of N fertilizers to an extent of 20-25 percent.

One of the major barriers to commercial cultivation of chrysanthemum is the unavailability of planting material. Chrysanthemum being the most cultivated crop in HP has a high demand for quality planting material. However, the demand for planting material can only be achieved when healthy rooted cuttings are obtained. Healthy planting material plays a vital role in commercial production as it influence the growth and flowering of the crop. At present, the influence of mineral nutrition on cutting production and rooting has become a seemingly ubiquitous point of interest in the production of commercial flowers. Vegetative propagated crops react positively to the alimentation of mother plants resulting in the production of good planting material. Inadequate nutrition in the plants may result in nutritional deficiency which eventually affects the plant health and vigour. Therefore, it is important to work out the optimal nutrition for quality cutting production and subsequent rooting of cuttings. Keeping view the above mentioned facts, the present study was taken up with following specific objective:

- To find out the effect of nutrient sources on cutting production and rooting in chrysanthemum cultivars.

Chapter-2

REVIEW OF LITERATURE

Propagation plays a vital role in the commercial production of chrysanthemum. At present, vegetative propagation is a matter of interest among the growers as they want to reproduce the highest quality plants and ensure true to type variety of plant. Vigorous and healthy mother plants are required for production of planting material in a large scale. Many factors can affect the vegetative propagation of chrysanthemum *viz.* irrigation, light, temperature, humidity, plant growth regulators and nutrition. Amongst them, nutrition is said to influence both cutting production and rooting of chrysanthemum. The quality of cuttings is directly associated with the mother plants. Therefore, proper nutrition of mother plants at regular intervals can affect the cutting yield and subsequent rooting of the cuttings. Good planting material is responsive to the application of nutrients (Grunewaldt, 1988). Therefore, the focus is on the effects of mineral nutrition on quality of cutting (e.g., stem diameter, length and weight), yield and rooting response.

The relevant literature on effect of nutrient sources *viz.*, chemical fertilizers, biofertilizers, vermicompost and biostimulants on cutting production and rooting in chrysanthemum (*Dendranthema grandiflora* Tzvelev) has been reviewed under the following headings:

2.1 Effect of inorganic fertilizers

Two experiments were conducted to optimize the levels of nitrogen and potassium for proper growth and flowering of *Chrysanthemum morifolium* 'Bluechip'. N and K were supplied @ 50, 100, 200 and 400 ppm N and 41.5, 83, 166 and 332 ppm K in experiment I. On the other hand, N was supplied @ 50, 100, 200 and 300 ppm N and 41.5, 83, 166 and 249 ppm K in experiment II. Vigorous growth was observed when N and K were supplied @ 100 and 166 ppm, respectively (Joiner and Smith, 1962).

Morton and Boodley (1969) suggested that the loss of nutrients from the leaves of chrysanthemum during propagation can be balanced with the incorporation of small quantity of water soluble fertilizers into the misting unit. They reported an

increase in the height and weight of cuttings when propagation benches were misted with complete fertilizer (23-4-12).

Rober (1976) suggested that proper fertilization of chrysanthemum mother plants can influence quality cutting production. Increase in the weight of the cuttings was observed when provided with 120 mg of N and 160 mg of K. However, the weight of the cuttings decreased with increasing level of nitrogen dose. Furthermore, he stated that K does not play any role in increasing the yield of cutting, instead it intensifies root development in the cuttings under low light condition.

Krause (1981) studied the stock plant nutrition to evaluate the influence of NPK levels in basic fertilization and top dressing on the cutting production of chrysanthemum. Top dressing with compound fertilizer Florovit or ammonium nitrate at 20 mg l^{-1} resulted in greater number of cuttings. However, no difference was observed in the fresh weight and rooting of cuttings. Therefore, he specified that K may not be the only element influencing the increase in the yield of cuttings but may have been due to the micronutrients contained in Florovit i.e. iron, copper, zinc, manganese and boron.

Komosa (1982) conducted an experiment on high and low critical levels of nitrogen, phosphorus and potassium for *Chrysanthemum morifolium* cv. 'Balcombe Perfection' and observed that optimum nutrient levels of 150-450 mg $N\text{-}NO_3$, 80-2200 mg $P\text{-}PO_4$ and 150-1200 mg K l^{-1} produced better growth and quality of chrysanthemum plants.

Blazich (1988) stated that stock plant nutrition plays an important part in plant growth and development and the production of quality cuttings. He further advocated that nutrition affects cutting yield as well as root development in the cuttings. Different researchers have conducted studies on the effect of stock plant nutrition on the rooting of chrysanthemum, poinsettia, coleus and dianthus cuttings. Nutrients like N, P, Ca, Mn and Zn are known to be responsible for root initiation and N, P, K, Ca and B for root growth and development.

Kher (1988) advocated that chrysanthemum is a heavy feeder crop and it requires high levels of nitrogen and phosphorus during its vegetative growth.

Nutrients like potassium, calcium, magnesium and sulphur are the four other elements required in larger quantities.

Jayanti and Gowda (1988) observed highest plant height in chrysanthemum plants receiving 40 g N + 40 g P_2O_5 per square meter, while increased plant spread and number of branches per plant was noted when supplied with 30 g N + 40 g P_2O_5 per square meter.

Lodhi and Tiwari (1993) recorded increased plant height with the application of 45g N/m^2, while maximum plant spread was noted when supplied with 30g N/m^2.

Barman and Pal (1999) observed appreciable improvement in the vegetative and floral attributes of chrysanthemum cv. 'Chandrama' when the plants were supplied with 30 gm N and 20 gm K per square meter area.

Zerche *et al.* (1999) recorded maximum cutting yield/ plant (29-33) and fresh weight of cuttings (1.13-1.5 g) when nitrogen was provided @ 1.5-2 g N/m^2 per week. He further stated that increased N rates highly influenced the rooting of cuttings under natural light conditions.

Druege *et al.* (2000) advocated that the rooting response of chrysanthemum cuttings (number of roots and root length) was corresponded to the initial total tissue nitrogen concentration. As initial N concentration increased from 2 to 7% N, root number in stored cuttings increased from approximately 5 to 15 and root length increased from 1 to 2.5 cm.

Effect of nitrogen, phosphorous and potassium on growth and flowering of chrysanthemum was studied by Sharma (2003). He concluded that maximum plant height, number of branches per plant and plant spread were obtained when plants were supplied with 30 g each of NPK/m^2.

Fertilizer application significantly affected root quality of the cuttings i.e. number of visible roots and root length (Budiarto *et al.*, 2006). NPK fertilizers (a compound of 25:7:7) were mixed in distilled water and two concentrations of 1.75 and 2.5 g l^{-1} were tested. The results indicated that cuttings supplemented with NPK compound (25:7:7) at a concentration of 2.5 g l^{-1} showed higher number of roots,

shoot fresh weight, and longer roots compared to those supplemented with NPK 1.75 g l^{-1}.

Deshmukh *et al.* (2006) stated that application of N & P @ 45 and 40 g/m^2 resulted in maximum plant height (100.20 cm). However, maximum fresh weight and dry weight of shoot and root and number of primary branches was recorded with the application of N & P @ 30 and 40 g/m^2, respectively.

The response of nitrogen, phosphorous and potassium on growth and flower production of chrysanthemum (*Chrysanthemum morifolium* Ramat.) was studied by Parekh *et al.* (2010). It was concluded that plant height increased significantly with the application of 100 kg N/ ha, while plant spread was recorded highest with the application of 200 kg N/ha.

Rahman *et al.* (2016) investigated on rooting and growth of chrysanthemum cultivars in response to different levels of calcium (0, 10, 20, 30 and 40 %) in four cultivars ('Candy Floss', 'Lilian Jackson', 'Elizabeth Lawson' and 'Herry Revil') and observed increased plant height (26.40cm) and number of roots per plant (35.92) when calcium was applied at the rate of 30% while minimum days (16.75) for sprouting and higher percent sprouting (63.33%) were noted in cuttings treated with no calcium. However, among the cultivars, 'Elizabeth Lawson' showed best result related to plant height (24.80 cm) and number of roots per plant (34.17).

Azeezahmed *et al.* (2016) evaluated the different concentration of N & K at vegetative stage and found an increase in plant spread, shoot biomass and root biomass of chrysanthemum when supplied with 250 ppm N and 200 ppm K.

2.2 Effect of biofertilizers

Biofertilizers or more appropriately called microbial inoculants are the preparations containing live or dormant cells of productive strains of micro-organisms (Kumari *et al.,* 2015). Biofertilizers are eco-friendly, low cost organic agricultural input playing a significant role in improving availability of nutrients to the crops. Biofertilizers add nutrients through the natural processes of nitrogen fixation, solubilizing phosphorus, and stimulating plant growth through the synthesis of growth-promoting substances. The biofertilizers contain microorganisms that help restore the natural nutrient cycle in the soil and build soil organic matter. They are

technically living, hence, they can symbiotically associate with plant roots as well. Biofertilizers such as *Azospirillum, Azotobacter, Bacillus, Glomus* and *Pseudomonas* are mostly used in commercial flower production.

Bhattacharya and Mishra (1995) studied the role of biofertilizers in ornamental plants like rose, jasmine, chrysanthemum, marigold, dahlia, aster, tuberose, gladiolus and lilies and concluded that the inoculation of the biofertilizers significantly influence the root development.

Sukhda (1999) stated that biofertilizers are living micro-organisms that are capable of stimulating proper growth by increasing the availability of primary nutrients to the host plant and helps in maintaining the soil productivity They are also useful as biological agents, since they control many pathogens and harmful microorganisms.

The effect of organic manures and bioinoculants on vegetative and floral attributes of chrysanthemum cv. Little darling was studied by Bohra and Kumar (2014). It was observed that the plants receiving VAM (20 g/plant) + vermicompost (300 g/m^2) resulted in maximum plant height (30.17 cm), number of primary and secondary branches (3.78 and 19.78, respectively), plant spread (28.53 cm) and number of leaves per plant (184.33).

The effect of VAM fungi on growth and nutrient uptake in *Rosa multiflora* was studied by Davies (1987). He concluded that plants grown in bark: sand medium (4:1 v/v) and inoculated with VAM fungi had longer shoots than those uninoculated ones.

Balasubramanian (1989) observed that the application of three fourth of recommended dose of N and P fertilizer (93.75 kg N/ ha and 90 kg P/ ha) with *Azospirillum* and VAM resulted in increased growth attributes like plant height, number of branches per plant, plant spread and leaf area index of marigold.

Shiva Kumar (2005) found that the carnation cv. ‘Raggio-de-Sole’ when raised in media containing sand + soil + vermicompost (1:1:1) (v/v) + inorganic fertilizers + biofertilizers @ 2g/plant resulted in increased plant height (73.20 cm) and improved flowering parameters.

The effect of different biofertilizers (*Azospirillum*, *Azotobacter* and Phosphate Solubilising Bacteria) in combination with FYM on yield parameters and nutrient content of marigold cv. 'Pusa Narangi Gainda' was studied by (Kumar *et al.,* 2006). They observed that yield parameters of the plant increased significantly when treated with FYM + Phosphate Solubilising Bacteria which is followed by the treatment consisting of FYM + *Azotobacter*.

Ali *et al.* (2014) investigated the influence of biofertilizers on vegetative growth, flower quality, bulb yield and nutrient uptake in gladiolus (*Gladiolus grandiflorus* L.) and recorded highest plant height, florets spike^{-1}, spike length, florets fresh weight and earlier sprouting in the treatment containing *Azospirillum*.

Patel *et al.* (2017) examined the effect of organic manures and biofertilizers on growth, flowering and flower yield of rose (*Rosa hybrida* L.) cv. 'Gladiator' and observed that castor cake @ 0.8 kg + *Azotobacter* @ 1 ml + PSM @ 1 ml + KSB @ 1 ml/ plant significantly resulted in better performance. Maximum plant height (98.50 cm), plant spread (64.86 cm), number of branches per plant (7.20) and stem diameter (1.18 cm), minimum days to first flower (37.95), maximum days to flowering span (118.18), diameter of flower (7.58 cm), number of petals per flower (72.55), stalk length (30.03 cm), stalk diameter (0.30 cm), number of flowers per plant (64.83), number of flowers per plot (324.15), number of flower per hectare (4.32 lac), flower yield per plot (5.82 kg) and flower yield per hectare (7753.66 kg) were recorded with castor cake @ 0.8 kg + *Azotobacter* @ 1 ml + PSM @ 1 ml + KSB @ 1 ml / plant.

2.3 Effect of Vermicompost

Vermicompost is a nutrient-rich fertilizer produced from the breakdown of organic matter with the help of earthworms. It is a peat like material with a low C: N ratio and high porosity and water holding capacity that contain most nutrients in forms that are readily taken up by the plants (Dominguez, 2004). Incorporation of vermicompost has shown to influence the physical properties of plant growing substrates (Hidalgo and Harkess, 2002 and Hidalgo *et al.,* 2006)

Kale *et al.* (1987) advocated that with the application of vermicompost, there is a reduction in the fertilizer levels without any reduction in the yield owing to higher 'P' fertilization due to symbiotic association in salvia and other ornamental plants.

Additionally, a significant increase in the leaf area was noted with the application of vermicompost.

Raha (2015) studied the effect of vermicompost on growth, yield and quality of chrysanthemum (*Chrysanthemum coronarium* L.) cv. 'Kasturba Gandhi' and observed an improved vegetative growth *viz.* plant height (21.24 cm) and average leaf area (23.40 cm^2) with 40% vermicompost + 60% basal mixture + NPK (150:100:100 kg/ha).

Beneficial effect of vemicompost @ 1000 g per square meter and pinching after 30 days of transplanting of marigold cv. 'Pusa Narangi Gainda' was reported by Chauhan *et al*. (2005) which resulted in maximum number of branches per plant, number of buds per plant, individual flower weight and flower yield per square meter.

Shadonpour *et al*. (2011) observed that marigold seeds (*Tagetes erecta* cv. 'Tiashan') cultivated on 60% vermicompost medium had improved growth and yield of plants than in the control and had the highest weight, size and dry weight of shoot.

2.4 Effect of biostimulants

According to Palekar (2006), jeevamrit is a fermented liquid product prepared by mixing up cow dung (10 kg) with cow urine (10 litres), jaggery (2 kg), legume flour (2 kg) and handful of soil brought from the bunds of the lands where cultivation is to be taken up. Jeevamrit also contains enormous amount of microbial load which multiply and act as a soil tonic. It is said to enhance microbial activity in soil and ultimately ensuring the availability and uptake of nutrients by the crops.

Vasanthkumar (2006) declared that Jeevamrit is not a source of nutrients, but it is a fermented liquid product containing huge quantity of microbial load and which enhances soil bio-mass upon its application to soil even at very lesser rate as it act as a tonic to soil besides improving soil health.

Devakumar *et al.* (2014) stated that higher colony forming units (CFU) in jeevamrutha was observed between 9th to 12th days after preparation (DAP). Increased amount of bacteria, different fungi and N-fixers clearly indicate that the jeevamrutha is enriched consortia of native soil microorganisms. The study also revealed that higher bacterial population was recorded followed by N-fixers, P-

solubilizers, fungi and actinomycetes. Therefore, the higher beneficial microbial load would mobilise more of plant nutrients and provide plant growth promoting substances and also other micro nutrients required by the plants.

Sreenivasa *et al*. (2009) reported that the organic liquid manures *viz.* panchagavya, jeevamrit and beejamrit prepared by using cow products are known to contain beneficial microflora like azotobacter, azospirillum, phosphobacteria, lactic acid bacteria, pseudomonas and methylotrophs in abundant numbers and also contain some useful fungi and actinomycetes.

Gore and Sreenivasa (2011) reported that jeevamrit is a low cost improvised preparation that enhances the soil with indigenous microorganisms, which are essential for mineralization of soil. Further they also reported that the existence of beneficial microorganisms in these fermented liquid formulations might be mainly due to their constituents such as cow urine, cow dung, legume flour and jaggery containing both macro and micro nutrients, essential amino acids, many vitamins, growth promoting substances like Gibberlic Acid (GA_3), Indole Acetic Acid (IAA) and beneficial microorganisms.

Singh (2018) observed that minimum days taken for first bud initiation and for first flower harvesting along with maximum plant height, plant spread and number of leaves per plant were recorded in the treatment consisting of cocopeat + vermicompost (1:1) along with application of jeevamrit at 20 days interval.

Amarewari and Sujathamma (2014) conducted an experiment on jeevamrutha as an alternative of chemical fertilizers in rice production to evaluate the impact of jeevamrutha on yield and returns of two varieties of rice (*Oryza sativa*) Masura and Hamsa and concluded that the yield with the application of jeevamrutha is 2.775 tons/acre in Masura and 2.625 tons /acre in Hamsa variety of rice while the yield by chemical method of farming were 3.0 tons and 2.5 tons per acre.

2.5 Effect of integrated nutrient management

Chauhan (2005) studied the effect of biofertilizers and chemical nitrogenous fertilizer on growth and flower yield of chrysanthemum (*Chrysanthemum morofolium* Ramat) and observed that maximum plant height at first flower picking (70.93 cm),

number of branches per plant (6.29) and plant spread (24.20 cm^2) were recorded in the treatment consisting 175 kg N/ha + *Azotobacter* + *Azospirillum.*

Verma *et al.* (2011) conducted an experiment on growth, yield and quality of chrysanthemum (*Chrysanthemum morifolium* Ramat.) cv. 'Raja' as influenced by integrated nutrient management and recorded highest plant height, number of branches, plant spread, dry matter accumulation and yield attributes such as number of flower per plant and flower yield in the treatment which comprised of *Azospirillum*, Phosphate Solubilising Bacteria (PSB), vermicompost and 50% recommended NPK. The same treatment revealed significantly higher quality parameters such as stalk length, flower diameter, shelf life of garland flowers.

Laishram (2011) carried a study on integrated nutrient management for commercial flower production of chrysanthemum (*Dendranthema grandiflora* Tzvelev) and observed maximum plant height (63.65 and 78.04 cm) and length of side shoots (57.51 and 67.60cm) with the application of 22.5 g/m^2 each of NPK+ vermicompost ($1kg/m^2$) + biofertilizers in both cultivars 'Purnima' and 'Ajay'.

In a two-year pot experiment,combined effect on growth, yield and quality of chrysanthemum (*Chrysanthemum morifolium* Ramat.) cv. 'Dolly Orange' was assessed through the use of biofertilizers (PSB and mycorrhiza) and different levels of phosphorus (0, 10, 15 and 20 g/m^2). The results revealed that maximum plant height (31.77 and 33.33 cm), fresh weight of plant (100.90 and 96.77 g) and dry weight of plant (10.85 and 10.15 g) were noted with PSB + phosphorus 15 g/m^2 in both the years, respectively (Kumari *et al.*, 2014).

Mridubhashini *et al.* (2014) examined the effect of integrated nutrient management on the growth, development and yield of chrysanthemum and stated that the application of *Azospirillum* + PSB + 50% recommended dose of N through vermicompost +50% RDF was found to be more effective in increasing the vegetative growth parameters *viz.* plant height (57.02 cm), plant spread (41.91 cm), number of branches per plant (23.07), fresh weight of plant (141.13 g $plant^{-1}$), dry weight of plant (41.7 g $plant^{-1}$), fresh weight of root (22.8 g $plant^{-1}$) and dry weight of root (4.10 g $plant^{-1}$).

A two-year field experiment on the effect of bio-fertilizers and inorganic manures on plant growth and flowering of chrysanthemum (*Chrysanthemum grandiflora*) cv. Haldighati was conducted by (Pandey *et al.,* 2018). Different levels of biofertilizers and inorganic manures were applied to assess their combined effect on growth parameters. The results indicated that maximum plant height (28.80 cm) and (30.30 cm), number of secondary branches (10.47) and (12.77), number of leaves (78.47) and (79.73), plant spread (29.77 cm) and (32.07 cm) and leaf area (13.13) and (15.57) was observed in both years in the treatment comprising of *Azospirillum* + PSB + NPK @175:125:125. Likewise, number of primary branches (3.77) was increased significantly during the first year in the same treatment.

Manonmani (1992) observed increased plant height, number of tertiary branches, shot and leaf area, dry weight and root biomass in jasmine with the inoculation of *Azospirillum* along with nitrogenous fertilizer application.

Rajadurai *et al.* (2000) advocated that an application of NPK @ 45:45:37.5 kg/ha along with *Azospirillum* and VAM resulted in increased height (144.50 cm) in marigold.

Swaminathan and Sambandamurthi (2000) studied the integrated nutrient management on growth and yield of triploid crossandra cv. 'Delhi' and observed maximum plant height and number of branches per plant with N @ 120kg/ha + K_2O @ 70kg/ha + *Azospirillum* @ 2kg/ha + FYM @ 30 t/ha.

Rathod *et al.* (2002) concluded that the highest number of branches per plant (41.00) in gaillardia was recorded with an application of 75% recommended dose NPK @ 100:50:50 kg/ha in combination with *Azospirillum* + Phosphate solubilizing bacteria (PSB).

Kumar *et al.* (2011) revealed that maximum plant height (101.2 cm), spike length (88.2 cm), rachis length (62.4 cm), number of florets per spike (14.4), average corm weight (36.0 g), leaf and soil NPK (2.27%, 0.18%, 3.38% and 99.9 kg/ha, 34.2 kg/ha, 165.3 kg/ha) was recorded in the treatment T_{17} in gladiolus.

Momin (2012) conducted two experiments on the effect of nutrient management on cutting production storage and rooting of carnation (*Dianthus caryophyllus* L.) and reported that fertilizer module FM_5 comprising of 20-5-5 g/m^2

NPK as basal application along with 200 ppm N + 280 ppm K as fertigation given twice a week resulted in the production of cuttings with diameter (0.75cm), weight (5.22g), number of cuttings per plant per harvest (4.25), number of cuttings (16.98), yield of cuttings per square meter (152.78) and cost benefit ratio (1:1.95).

In another study, the biofertilizers used were three different rhizobacterial strains *viz. Azotobacter chroococcum* (Mac27), *Pseudomonas strain* (WPS73) and PSB (P36) along with reducing levels of inorganic fertilizers (50 % and 75% of RDF 30:20:20g NPK/m^2) to evaluate the potency and compatabiltity of different biofertilizers for nutrient management in gladiolus cv. 'Advance Red' The results revealed that minimum number of days taken for sprouting of corms (12.42 days), maximum percent of sprouting of corms (100%) were recorded in treatment comprising of 50% RDF + Pseudomonas strain (WPS73). It was also observed that the biofertilizers performed well when applied singly along with inorganic fertilizers (Salma *et al.,* 2015).

Harshvardhan *et al.* (2016) studied the growth and development of carnation (*Dianthus caryophyllus* L.) as influenced by integrated nutrient management and recorded highest plant height (92.60 cm), number of branches per plant (6.00), number of leaves per plant (171.30), individual leaf area (6.20 cm^2) and leaf area per plant (1062.06 cm^2) in plants receiving 75 per cent recommended dose of nitrogen and phosphorus and 100 % potassium + *Azospirillum brasilense* + *Glomus fasciculatum* + *Bacillus megaterium* (VAM Fungi) + *Trichoderma harzianum* + vermicompost + jeevamrutha + panchagavya.

Pithiya *et al.* (2016) investigated on the effect of integrated nutrient management on growth, yield and quality in China aster (*Callistephus chinensis* L.) cv. 'Phule Ganesh Pink' to evaluate the combined effect of inorganic and organic fertilizers and concluded that highest plant height, plant spread, number of primary branches, dry matter accumulation and yield attributes were recorded in the treatment receiving 50% RDF + Vermicompost @ 1.5 t/ha + *Azotobacter* 3 l/ha + PSB @ 2 l/ha.

Sharma *et al.* (2016) concluded that the application of *Azospirillum* + PSB + cow urine (5%) + 50% recommended dose of N through vermicompost + 50% recommended dose of NPK fertilizer resulted in increased vegetative growth

parameters such as plant height, number of branches and plant spread in African marigold.

Gurung *et al.* (2018) carried out an experiment to assess the effect of integrated nutrient management on growth and production of hydrangea and revealed that vegetative parameters like plant height (137.67 cm), stem length (55.18 cm), number of shoots per plant (21.59) and number of leaves per plant (248.52) were found maximum in treatment composed of *Azotobacter* @ 2g/plant+ PSB @ 2g/plant + 70% RDF. However, maximum stem thickness (12.26 mm) was noted in plants receiving *Azotobacter* + PSB + 80% RDF.

Leisan (2018) studied the effect of organic fertilizers in conjunction with chemical fertilizers on the growth and flowering of Gerbera (*Gerbera jamesonii* Bolus ex. Hook) and revealed that vegetative parameters like plant height (68.01 cm), plant spread (69.73 cm), length of leaf (48.96 cm), number of suckers (2.00) were recorded maximum in cv. 'Goliath' treated with 80 % of T_1 (NPK @ 10:15:20 g/m^2) + PSB + *Azotobacter* + Jeevamrit.

The effect of liquid bio-inoculants and fertilizer levels on growth and yield of African marigold (*Tagetes erecta* L.) cv. Calcutta was studied by (Shaikh *et al.*, 2018). The treatments comprised of four levels of RDF (60%, 80%, 100% and 120%) and bio-inoculants *viz.*, *Azotobacter*, PSB and *Azotophos* and it was found that plant height (65.66 cm), number of branches per plant (15.00), number of leaves per plant (276.67), plant spread (54.66 cm^2) and maximum flowering duration (100.00) were significantly higher in plants treated with 120% RDF + *Azotophos*.

Chapter-3

MATERIALS AND METHODS

The present investigation entitled **"Studies on the effect of nutrient sources on cutting production and rooting of chrysanthemum (*Dendranthema grandiflora* Tzvelev)''** were carried out under a naturally ventilated polyhouse at the Experimetal Farm of the Department of Floriculture and Landscape Architecture, Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) during 2018-19. The materials used and methodologies adopted for carrying out the present study has been described in this chapter under the different sub heads as below:

3.1 EXPERIMENTAL SITE

3.1.1 Location

The Experimental Farm of the Department of Floriculture and Landscape Architecture is situated at an elevation of 1276 m above mean sea level at a latitude of 30^{o}51'0" North and longitude of 77^{o}11'30" East. The area falls in the mid zone of Himachal Pradesh.

3.1.2 Climate

The climate of the area is typically sub-temperate to sub-tropical and is characterized by mild summers and cool winters. May and June are the hottest months while January and February are the coldest. Maximum rainfall is received during July to September (Monsoon season). The mean monthly meteorological data pertaining to the experimental period have been presented in Appendix-I.

3.1.3 Soil status

A basic study of the soil of the Experimental field for various characteristics was conducted before starting the experiment. Soil samples were collected from a depth of 0-15 cm from randomly selected spots of the experimental field. The soil was analysed for pH, EC, organic carbon, available nitrogen, phosphorus and potassium. The details of the chemical analysis are furnished in Table 3.1.

Table 3.1 Physico-chemical properties of the soil before planting

Contents	Values obtained
Soil pH	6.94
Electrical Conductivity (dSm^{-1})	0.42
Organic Carbon (%)	1.35
Available Nitrogen (kg/ha)	386.3
Available Phosphorus (kg/ha)	33.51
Available Potassium (kg/ha)	297.48

Table 3.2 Interpretation of soil pH, OC and available N, P and K

Interpretation of pH			
Below 6.5		Acidic	
6.5-8.7		Normal	
Above 8.7		Alkaline	
Interpretation of electrical conductivity (dS m^{-1})			
Below 0.8		Normal- Suitable for all crops	
0.8-1.6		Critical for salt sensitive crops	
1.6-2.5		Critical for salt tolerant crops	
Above 2.5		Injurious to all crops	
Interpretation of organic carbon (%)			
Below 0.25		Very low	
0.25-0.50		Low	
0.50-1.00		Medium	
1.00-1.50		High	
Above 1.50		Very High	
Interpretation of available N, P and K (kg/ha)			
Nutrient	**Low**	**Medium**	**High**
Nitrogen	< 272	272-544	>544
Phosphorus	< 12.4	12.4-22.4	> 22.4
Potassium	< 137	137-337	>337

The soil under study was found with normal pH 6.94 and electrical conductivity 0.42dS m^{-1}. Organic carbon percentage was high i.e. 1.35%. Among available NPK, nitrogen and potassium were in medium range whereas, phosphorus was available in higher amounts (Table 3.2).

3.2 EXPERIMENTAL DETAILS

3.2.1 Plant material

Three commercial cultivars of chrysanthemum namely; 'Purnima', 'Solan Shringar' and 'Surf' were selected for undertaking the present investigation. The salient features of these cultivars are as given below:

Purnima: It is a standard cultivar with large sized flowers (8-11 cm diameter) and used mostly for cut flower production. The inflorescence is ball type and flower is white in colour. The stalk length of the flower ranges from 50-60 cm. It starts blooming in mid October under mid hill conditions of Himachal Pradesh.

Solan Shringar: It is standard type, seedling selection of 'Honey Comb' having tall plants, bears many large double type (7.0 cm), white coloured flowers. It starts blooming in mid October under mid hills Himachal Pradesh and it is suitable for cut, pot as well as loose flower production.

Surf: It is dwarf in height (30-40 cm), medium in spread (23-30 cm), bears many medium sized (6.60 cm) white coloured flowers. It starts blooming in mid September under the mid hill of Himachal Pradesh.

3.2.2 Bed preparation and application of chemical fertilizers

The land was thoroughly ploughed with power tiller and was brought to a fine tilth and finally levelled. Stones, pebbles and weeds were removed manually from the experimental area. Raised beds of 1.0 m x 0.4 m were prepared for planting. The cross influence of treatments was taken care by separating each bed with a channel of 30 cm wide and 20 cm deep (Plate 1a). One week before planting, well rotten farm yard manure (FYM) (5kg/m^2) was applied uniformly. Along with this, vermicompost (1kg/m^2), full dose of phosphorous and potassium and half dose of nitrogen were incorporated into the beds as per the treatment requirements. The remaining half dose of nitrogen was applied after 30 days of planting. Nitrogen, phosphorous and potassium were applied through urea, single super phosphate and muriate of potash, respectively.

3.2.3 Planting and application of biofertilizers

Planting of rooted cuttings of the three cultivars, 'Purnima', 'Solan Shringar' and 'Surf' was done on June 12, 2018. The rooted cuttings were planted in lines at a spacing of 20 cm × 20 cm. Application of nutritional treatments was done at regular interval. Because of poor quality shoot tip cuttings (bud formation occurred due to prevailing short days) produced by the plants of almost all cultivars even after providing night break lighting, the plants were allowed to flower. The application of nutritional treatments was temporarily arrested during flowering phase. After harvesting of flowers, the plants were headed back which was followed by the incorporation of FYM @ 5 kg/m^2. The allocation of nutritional treatments was again started after the visible formation of suckers. In order of formation of more lateral branches, the apical growing portion of the suckers were pinched after 15 days of their emergence. Biofertilizers *viz. Azotobacter chroococcum,* phosphorous solubilising micro-organisms (*Bacillus polymyxa* + *Pseudomonas striata*) and vesicular arbuscular mycorrhiza (*Glomus mosseae* + *G. fasiculatum*) were procured from the Division of Microbiology, Indian Agricultural Research Institute, New Delhi. *Azotobacter* and phosphorous solubilising micro-organism were applied by dipping the roots of the cuttings into the slurry of 200g of the inocula dissolved in one litre of 10 % sugar solution at the time of planting whereas, VAM (2g/plant) was incorporated in the planting pit (Plate 2).

3.2.4 Harvesting of cuttings

Harvesting of healthy shoot tip cuttings (6-8 cm) from mother plants was done from 23 March, 2019 onwards. The cuttings were disinfected by dipping in a solution of Dithane M-45 (0.2 %) and Bavistin (0.1 %) for 30 minutes. After disinfecting the cuttings, the basal leaves of each cutting were removed followed by sharp cut just below the basal node. The basal portions of the prepared cuttings were then dipped in a solution of NAA (500 ppm) by following quick dip method preceding planting. Rooting of cuttings was done in pro-trays containing a mixture of river sand and cocopeat in the ratio 1:1 (v/v) and were kept in a mist chamber. Intermittent misting was maintained till rooting of cuttings (Plate 4). The harvesting of cuttings was continued up to the 4^{th} flush as the quality of cuttings deteriorated afterwards.

Plate 1a. Preparation of beds

Plate 1b. General view of the experimental field after 15 days of transplanting

Azotobacter chroococcum

Phosphorus Solubilising Bacteria

Azotobacter and phosphorous solubilizing bacteria were applied by dipping the roots of the cuttings into a slurry of 200g inocula dissolved in 1 litre of 10% sugar solution at the time of planting

Plate 2. Application of *Azotobacter* and Phosphorous Solubilizing Bacteria

Plate 3a. General view of the experimental field after 30 days of transplanting

Plate 3b. General view of the experimental field after the second harvesting of cuttings

Cutting preparation (removal of lower leaves)

Disinfecting cuttings in Bavistin (0.1%) and Dithane M-45 (0.2 %) solution

Dipping in NAA (500 ppm) solution

Rooted cutting

Cuttings kept in mist chamber for rooting

Plate 4. Rooting of shoot tip cuttings

3.2.5 Intercultural operations

Routine intercultural operations like; irrigation, weeding, hoeing and control of insect-pest and diseases etc., were done as per the necessity. In order to induce multi-stemmed plants, pinching was done by removing 2-3 cm apical growing portion of the plant after 15 days of planting.

The predominant weed population of *Capsella bursa-pastoris, Convolvulus arvensis, Oxalis latifolia*, *Stellaria media* and *Trifolium repens* was controlled by manual weeding with the help of hand hoe which also indirectly helped in providing better aeration to the roots of the crop.

As far as diseases and insect-pests attack is concerned, the crop was infested by *Septoria* leaf spot, aphids and mites. *Septoria* infested leaves were removed to control the spread of the disease. Aphid infestation was controlled by the spray of Agniastra @ 2.5%.

3.2.6 Experimental details

The study was carried out on three commercial cultivars of chrysanthemum namely; 'Purnima', 'Solan Shringar' and 'Surf' by imposing 5 nutrient source treatments. The details of the experiment conducted are as follows:

A. Number of cultivars : 3

B. Nutrient source treatments : 5 (as given below)

T_1 = 22.5g/m^2 each of NPK + Biofertilizers + Vermicompost (1kg/m^2) + FYM (5kg/m^2)

T_2 = T_1 + 100 ppm N& K (through fertigation twice a week)

T_3 = Cow urine (5%)

T_4 = T_1 + T_3

T_5 = Jeevamrit (5%)

Methods of application:

i. For supplying 100ppm of N, 60ppm was given as nitrate N [potassium nitrate (multi K)–40ppm and $Ca(NO_3)_2$- 20ppm] by dissolving 311 mg of multi K and

129 mg of $Ca(NO_3)_2$ in one litre of water. Remaining 40 ppm was given as ammonical form through urea by dissolving 87 mg in one litre of water. The supply of K_2O was met entirely with the application of multi K.

ii. Cow urine was applied as spray once a week @ 5% i.e. 1:20 dilution.

iii. Jeevamrit @ 5% was applied twice a month by soil drenching @250ml/plant.

C. Number of replications : 3

D. Number of treatment combinations : 15

E. Plot size : 1.0 m x 0.4m

F. Spacing : 20 cm x 20 cm

G. Number of plants per plot : 10

H. Experimental design : Randomized Block Design (RBD)

3.2.7 Ingredients and composition of bio-stimulants

Table 3.3 Composition of Jeevamrit and method of its application

Ingredients	Quantity
Cow dung	10 kg
Cow urine	10 litres
Jaggery	2 kg
Pulse flour	1 kg
Live soil	A handful
Water	200 litres

*Foliar spray/drench @ 2.5% i.e. dilution of 2.5 litres of Jeevamrit in 100 litres of water

All the concentrations are formulated accordingly.

Flow chart of preparation of Jeevamrit

Add fresh cow dung + cow urine in water

↓

Mix jaggery + pulse flour and live soil in water

↓

Mix the above both and stir properly (morning and evening) for 4 days

↓

On the fifth day, the solution and filtrate is ready for soil drenching/ spray

Cow dung (10 kg)

Cow urine (10 l)

Jaggery (2 kg)

Pulse flour (1 kg)

A handful of soil

+ Water (200 l)

Jeevamrit

Plate 5. Preparation of Jeevamrit

3.3 OBSERVATIONS RECORDED

The observations on cutting production were recorded till fourth successive harvests as cuttings thereafter become very weak and thin like grass in all the cultivars. Observations based on rooting were recorded of third and fourth harvesting of cuttings only.

3.3.1 Time taken for first and successive harvesting of cuttings (days): The time taken for first and successive harvesting of cuttings was recorded as number of days starting from emergence of suckers.

3.3.2 Number of cuttings per plant/harvest: The number of cuttings harvested per plant in each harvest was counted.

3.3.3 Total number of cuttings/plant: The total number of cuttings produced by a plant in all four flushes was counted.

3.3.4 Yield of cuttings/m²: The yield of cuttings per square meter was calculated by multiplying the average number of cuttings per plant with total number of plants per square meter i.e. 25 plants.

3.3.5 Weight of cutting (g): The weight of each cutting from every plant was recorded at the time of harvesting of cuttings. .

3.3.6 Days taken for rooting: The number of days taken for rooting was counted from the date of planting of cuttings till roots are properly visible coming out from the bottom holes of pro-trays.

3.3.7 Number of roots per cutting: The cuttings were thoroughly washed before counting of roots per cutting.

3.3.8 Root length (cm): The length of the longest root was measured with the help of a scale and average was calculated.

3.3.9 Weight of rooted cutting (g): The rooted cuttings was washed thoroughly before weighing.

3.3.10 Internodal length (cm): The length of the middle internode of the cutting was measured with the help of a scale. For analysis, the average of all harvestings was used.

3.3.11 Percentage of healthy rooted cuttings: The percentage of healthy rooted cuttings was calculated from the number of healthy surviving rooted plants using the formula i.e.

Percentage of healthy rooted cuttings = $\frac{\text{Number of surviving rooted plants}}{\text{Number of cuttings planted for rooting}}$ x 100

3.3.12 Colour of leaves: The colour of the leaves of each cutting was recorded with the help of RHS colour chart.

3.3.13 Statistical analysis: The statistical analysis for Randomized Block Design was done as per design of the experiment suggested by Gomez and Gomez (1984).

ANOVA for RBD (factorial):

Source of variation	**Degree of freedom**	**Sum of squares**	**Mean sum of squares**	**F.Cal.**
Replications	r-1	S_r	$M_r = \frac{Sr}{(r-1)}$	$\frac{Mr}{Me}$
Cultivars	p-1	S_p	$M_p = \frac{Sp}{(p-1)}$	$\frac{Mp}{Me}$
Treatments	q-1	S_q	$M_q = \frac{Sq}{(q-1)}$	$\frac{Mq}{Me}$
Cultivar × Treatment	(p-1)(q-1)	S_{pq}	$Mpq = \frac{Spq}{(p-1)(q-1)}$	$\frac{Mpq}{Me}$
Error	$(r-1)(pq-1)$	S_e	$M_e = \frac{Se}{(pq-1)\times(r-1)}$	-
Total	$pqr-1$	S_T	-	-

Where,

r =Number of replications

p = Number of cultivars

q= Number of treatments

S_r=Sum of squares due to replications

S_p=Sum of squares due to cultivar

S_q= Sum of squares due to treatments

S_e= Sum of squares due to error

S_T= Total sum of squares

M_r= Mean sum of squares due to replications

M_p= Mean sum of squares due to cultivar

M_q= Mean sum of squares due to treatments

M_{pq}= Mean sum of squares due to interaction

M_e= Mean sum of squares due to error

The replication and treatment mean sum of square shall be tested against mean sum of squares due to error by 'F' test at (r-1), (r-1) × (t-1) and (t-1), (r-1) ×(t-1) degree of freedom for RBD at 5% level of significance. The calculated F-values shall be compared with tabulated F-value. When F-test shall be found significant, critical difference shall be calculated to find out the superiority of one treatment over the others.

Critical difference (CD) shall be calculated as follows:

$CD_{0.05}$ = S.E. (d) x $t_{(0.05)}$ (r-1) (t-1) df

SE (d) ± = $\sqrt{\frac{2 \times M_e}{r}}$

SE (m) ± = $\sqrt{\frac{M_e}{r}}$

Where,

SE (m) ± = Standard error of mean

SE (d) ± = Standard error of difference of mean

$CD_{0.05}$ = Critical difference at 5 per cent level of significance

Chapter-4

RESULTS AND DISCUSSION

The results obtained of the present investigation entitled **"Studies on the effect of nutrient sources on cutting production and rooting in chrysanthemum (*Dendranthema grandiflora* Tzvelev)"** on various parameters have been presented in this chapter.

Analysis of variance for cutting production and rooting parameters in chrysanthemum have been embodied in Appendix-II.

4.1 Time taken for first and successive harvesting of cuttings (days)

Rooted cuttings of three commercial cultivars of chrysanthemum namely; 'Purnima', 'Solan Shringar' and 'Surf' were transplanted on June 12, 2018. All the required intercultural operations including irrigation, weeding and hoeing, application of nutritional treatments, pinching, control of diseases and insect – pest etc. were followed as and when required. Because of poor quality shoot tip cuttings (bud formation occurred due to prevailing short days) produced by the plants of almost all cultivars even after providing night break lighting, the plants were allowed to flower. The application of nutritional treatments was temporarily arrested during the flowering phase. After harvesting of flowers, the plants were headed back which was followed by the incorporation of FYM @ 5 kg/m^2. The allocation of nutritional treatments was restarted after the visible formation of suckers. In order to induce more lateral branches, the apical growing portion of the suckers was pinched after 15 days of commencement of suckers. The shoot tip cuttings of the lateral shoots were harvested and the time taken from the commencement of suckers to first harvesting of cuttings was recorded. Likewise, the time taken from first harvesting to second harvesting and so on up to the fourth harvesting was noted and the data have been presented in Table 4.1.

The data presented in Table 4.1 revealed that cultivar 'Solan Shringar' took minimum time (39.10, 26.77, 26.67 and 25.87 days, respectively) to produce cuttings during all harvests, which was closely followed by the cultivar 'Purnima' during first to third harvest (39.27, 27.30 and 26.67 days, respectively). The cuttings of

Table 4.1 Effect of nutrient sources on time taken (days) for successive harvesting of cuttings of commercial chrysanthemum cultivars from first to fourth harvest

Nutrient sources (T)	First harvest				Second harvest				Third harvest				Fourth harvest			
	Solan Shringar	Surf	Purnima	Mean	Solan Shringar	Surf	Purnima	Mean	Solan Shringar	Surf	Purnima	Mean	Solan Shringar	Surf	Purnima	Mean
T_1	38.67	41.67	38.17	39.50	27.50	29.17	28.83	28.50	27.33	28.33	26.67	27.44	26.17	28.00	26.67	26.94
T_2	38.00	40.00	40.17	39.39	25.83	28.00	25.67	26.50	26.33	27.67	26.83	26.94	25.33	28.17	26.17	26.56
T_3	39.17	43.00	41.00	41.06	26.83	29.00	27.17	27.67	25.83	28.00	27.00	26.94	26.17	29.00	26.33	27.17
T_4	39.67	40.00	37.83	39.17	27.00	28.83	27.67	27.83	27.17	26.50	27.17	26.94	25.67	29.33	27.50	27.50
T_5	40.00	41.00	39.17	40.06	26.67	28.00	27.17	27.28	26.67	28.17	26.67	27.17	26.00	29.50	26.83	27.44
Mean	39.10	41.13	39.27	-	26.77	28.60	27.30	-	26.67	27.73	26.87	-	25.87	28.80	26.70	-
$CD_{0.05}$: Cultivar Nutrient sources V x T	0.95 1.22 NS				0.67 0.86 NS				0.56 NS NS				0.51 0.65 NS			

T_1= 22.5g/m^2 each of NPK + Biofertilizers (Azotobacter +PSB + VAM) + Vermicompost (1kg/m²) + FYM (5kg/m²), T_2= T_1 + 100 ppm N& K (through fertigation twice a week), T_3=Cow urine (5%), T_4= T_1 + T_3, T_5= Jeevamrit (5%)

‘Purnima’ in fourth harvest took more time to reach the harvest stage. In contrast, maximum time (41.13, 28.60, 27.73 and 28.80 days, respectively) for cutting production was noted in the cultivar ‘Surf’ in all harvests.

As regard the influence of nutritional treatments on number of days taken for cutting production, all except T_3 (41.06 days) took almost similar time with least in case of T_4 (39.17 days) for harvesting of cuttings of the first harvest. The second harvest of cuttings was noticed earliest in case of T_2 (26.50 days) and was found to be at par with T_5 (27.28 days). During the second harvest, cuttings took maximum time to reach the harvest stage when supplied with T_1 (28.50 days) which was found to be at par with T_3 (27.67 days) and T_4 (27.83 days). As far as third harvest of cuttings is concerned, all treatments behaved equally for time taken to reach harvesting stage. Fourth harvest of cuttings took least time with T_2 (26.56 days) and was at par with T_1 (26.94 days) and T_3 (27.17 days). However, T_4 (27.50 days) and T_5 (27.44 days) delayed it significantly.

As far as interaction between the cultivars and nutritional treatments is concerned, it was found to be non-significant during all harvests (Appendix-II). However, minimum time for cutting production (37.83 and 25.67 days) was noted in T_4 and T_2 in the cultivar ‘Purnima’ during first and second harvest, respectively. During the third and fourth harvest, minimum time for cutting production (25.83 and 25.33 days) was noticed in T_3 and T_2 in the cultivar ‘Solan Shringar’.

The variation in the time required by the cultivars for reaching harvesting stage of cuttings may be because of their genetic makeup. In general, the number of days taken for cutting production in chrysanthemum ranges from 25.87 to 41.13 days. Relatively, minimum number of days taken for cutting production was observed in third and fourth harvest which was done during the months of May-June. Generally, chrysanthemum requires long day conditions (>12 hours) and optimum night temperature (10-16ºC) for its vegetative growth (Datta and Gupta, 2012). The delay in days taken for cutting production may probably be due to prevailing environmental factors *viz.* temperature and relative humidity which resulted in slower growth of the plant (Appendix-I) during other harvests. Higher relative humidity influences lateral bud break by reducing transpiration losses and affecting the water potential within the

lateral bud (Hicklenton, 1985). Similar findings have been reported by Kahar (2008); Karlovic *et al.* (2003) and Hayashi *et al.* (2001).

Earliest cutting production was recorded in the nutrient source treatment comprising of 22.5 g/m^2 + biofertilizers + vermicompost (1 kg/m^2) + FYM (5 kg/m^2) along with N & K @ 100 ppm as fertigation twice a week. This might be due to the more availability of nutrients to the mother plants due to the presence of nitrogen fixers and phosphate solubilizers which stimulated the plant growth through the synthesis of growth promoting substances resulting in the advancement in cutting production. Similar findings was also reported by Harshvardhan *et al. (*2016) in carnation; Salma *et al.* (2015) in gladiolus cv. 'Advance Red'; Mridubhashini *et al.* (2014) in chrysanthemum and Momin (2012) in carnation.

4.2 Number of cuttings per plant per harvest

Perusal of data presented in Table 4.2 revealed that there is significant difference among the cultivars in all the harvests, except in the first harvest (Appendix-II). In first harvest, the cultivars 'Solan Shringar' and 'Purnima' produced almost equal number of cuttings per plant per harvest (24.37 and 24.20, respectively). In second and third harvest, the cultivar 'Solan Shringar produced significantly higher number of cuttings (28.70 and 33.40, respectively). However, the cultivar 'Solan Shringar' produced comparatively less number of cuttings (45.10) in the fourth harvest while it was maximum in cultivar 'Purnima' (48.40). Minimum number of cuttings per plant was noted in cultivar 'Surf' in first, second and third harvests (23.23, 23.53 and 29.80, respectively).

As far as the effect of nutritional treatments on number of cuttings per plant in the first harvest is concerned, all treatments except T_1 (22.28) and T_5 (23.17) produced almost similar number of cuttings with highest recorded in T_2 (26.00) i.e. 22.5 g/m^2 each of NPK + biofertilizers + vermicompost (1 kg/m^2) + FYM @ 5 kg/m^2 (as basal) along with fertigation of N & K @ 100 ppm twice a week. In the second, third and fourth harvests, T_2 produced significantly higher number of cuttings (28.44, 34.33 and 50.50, respectively) and was found to be at par with T_5 (32.61) during third harvest and T_3 (48.22) during fourth harvest, respectively.

Table 4.2. Effect of nutrient sources on number of shoot tip cuttings (per plant per harvest) during different harvests of commercial chrysanthemum cultivars

Nutrient sources (T)	First harvest				Second harvest				Third harvest				Fourth harvest			
	Solan Shringar	Surf	Purnima	Mean	Solan Shringar	Surf	Purnima	Mean	Solan Shringar	Surf	Purnima	Mean	Solan Shringar	Surf	Purnima	Mean
T_1	24.17	19.17	23.50	22.28	26.67	21.83	22.83	23.78	33.50	28.50	25.83	29.28	46.17	42.67	47.00	45.28
T_2	26.33	24.83	26.83	26.00	32.83	26.33	26.17	28.44	35.00	31.50	36.50	34.33	48.50	52.50	50.50	50.50
T_3	21.83	25.50	24.67	24.00	27.83	24.67	21.83	24.78	30.67	32.17	34.33	32.39	46.17	49.33	49.17	48.22
T_4	27.33	20.33	25.00	24.22	28.00	21.17	28.00	25.72	33.00	27.17	29.50	29.89	42.50	41.50	48.17	44.06
T_5	22.17	26.33	21.00	23.17	28.17	23.67	23.17	25.00	34.83	29.67	33.33	32.61	42.17	45.17	47.17	44.83
Mean	24.37	23.23	24.20	-	28.70	23.53	24.40	-	33.40	29.80	31.90	-	45.10	46.23	48.40	-
$CD_{0.05}$: Cultivar	NS				2.44				1.40				1.91			
Nutrient sources	2.43				NS				1.81				2.47			
V x T	4.22				NS				3.14				NS			

T_1= 22.5g/m^2 each of NPK + Biofertilizers (Azotobacter +PSB + VAM) + Vermicompost (1kg/m^2) + FYM (5kg/m^2), T_2= T_1 + 100 ppm N& K (through fertigation twice a week), T_3=Cow urine (5%), T_4= T_1 + T_3 , T_5= Jeevamrit (5%)

The interaction between cultivars and nutrient sources was significantly different during the first and third harvest except during the second and fourth harvest where it was found to be non-significant (Appendix-II). During first and third harvest, the cultivar 'Purnima' recorded maximum number of cuttings (26.83 and 36.50, respectively) in T_2 and was found to be at par with cultivar 'Solan Shringar' (26.33 and 35.00, respectively) in the same treatment.

4.3 Total number of cuttings per plant

A scrutiny of data presented in Table 4.3 revealed that among the cultivars, total number of cuttings per plant of all four harvests (131.57) was recorded maximum in the cultivar 'Solan Shringar' and was found to be at par with the cultivar 'Purnima' (128.90). In contrast, minimum number of cuttings per plant of all four flushes (122.80) was noted in the cultivar 'Surf'.

Table 4.3 Effect of nutrient sources on total number of shoot tip cuttings per plant during different harvests of commercial chrysanthemum cultivars

Nutrient sources (T)	Solan Shringar	Surf	Purnima	Mean
T_1	130.50	112.17	119.17	120.61
T_2	142.67	135.17	140.00	139.28
T_3	126.50	131.67	130.00	129.39
T_4	130.83	110.17	130.67	123.89
T_5	127.33	124.83	124.67	125.61
Mean	131.57	122.80	128.90	-
$CD_{0.05}$: Cultivar Nutrient sources V x T	3.34 4.31 7.46			

T_1= 22.5g/m^2 each of NPK + Biofertilizers (Azotobacter +PSB + VAM) + Vermicompost (1kg/m^2) + FYM (5kg/m^2), T_2= T_1 + 100 ppm N& K (through fertigation twice a week), T_3=Cow urine (5%), T_4= T_1 + T_3 , T_5= Jeevamrit (5%)

In regard with the effect of nutrient sources, the application of 22.5 g/m^2 each of NPK + biofertilizers + vermicompost (1 kg/m^2) + FYM @ 5 kg/m^2 (as basal) along with fertigation of N & K @ 100 ppm twice a week (T_2) resulted in maximum number

of cuttings per plant of all four harvests (139.28). However, minimum number of cuttings per plant (120.61) was recorded with T_1 i.e. basal application of 22.5 g/m^2 each of NPK + biofertilizers + vermicompost (1 kg/m^2) + FYM (5 kg/m^2) and was closely followed by T_4 (123.89) and T_5 (125.61).

In concern with interaction between cultivars and nutrient sources, total number of cuttings per plant (142.67) was recorded in T_2 in the cultivar 'Solan Shringar' which was statistically at par with cultivar 'Purnima' (140.00) in the same treatment. On another note, minimum number of cuttings per plant during all four harvests (112.17) was noted in T_1 in cultivar 'Surf' and was found at par with cultivar 'Purnima' (119.17) in the same treatment.

4.4 Yield of cuttings per square meter

The data presented in Table 4.4 revealed that there is significant difference among the cultivars in all the flushes, except in the first flush (Appendix-II). In first harvest, the cultivars 'Solan Shringar' and 'Purnima' produced almost equal number of cuttings per plant per harvest (609.17 and 605.00, respectively). In second and third harvest, the cultivar 'Solan Shringar produced significantly higher number of cuttings (717.50 and 835.00, respectively). However, the cultivar 'Solan Shringar' produced comparatively less number of cuttings (1127.50) in the fourth harvest while it was maximum in cultivar 'Purnima' (1210.00). Minimum number of cuttings per plant was noted in cultivar 'Surf' in first, second and third harvests (580.83, 588.33 and 745.00, respectively).

In regard with effect of nutritional treatments on number of cuttings per plant in the first harvest is concerned, all treatments except T_1 (556.95) and T_5 (579.17) produced almost similar number of cuttings with highest recorded in T_2 (650.00) i.e. 22.5 g/m^2 each of NPK + biofertilizers + vermicompost (1 kg/m^2) + FYM @ 5 kg/m^2 (as basal) along with fertigation of N & K @ 100 ppm twice a week. In the second, third and fourth harvests, T_2 produced significantly higher number of cuttings (711.11, 858.33 and 1262.50, respectively) and was found to be at par with T_5 (815.28) during third harvest and T_3 (1205.56) during fourth harvest, respectively.

Table 4.4 Effect of nutrient sources on yield of shoot tip cuttings (No./m^2) during different harvests of commercial chrysanthemum cultivars

Nutrient sources (T)	First harvest				Second harvest				Third harvest				Fourth harvest			
	Solan Shringar	Surf	Purnima	Mean	Solan Shringar	Surf	Purnima	Mean	Solan Shringar	Surf	Purnima	Mean	Solan Shringar	Surf	Purnima	Mean
T_1	604.17	479.17	587.50	556.95	666.67	545.83	570.83	594.45	837.50	712.50	645.83	731.95	1154.17	1066.67	1175.00	1131.94
T_2	658.33	620.83	670.83	650.00	820.83	658.33	654.17	711.11	875.00	787.50	912.50	858.33	1212.50	1312.50	1262.50	1262.50
T_3	545.83	637.50	616.67	600.00	695.83	616.67	545.83	619.45	766.67	804.17	858.33	809.72	1154.17	1233.33	1229.17	1205.56
T_4	683.33	508.33	625.00	605.56	700.00	529.17	700.00	643.06	825.00	679.17	737.50	747.22	1062.50	1037.50	1204.17	1101.39
T_5	554.17	658.33	525.00	579.17	704.17	591.67	579.17	625.00	870.83	741.67	833.33	815.28	1054.17	1129.17	1179.17	1120.83
Mean	609.17	580.83	605.00	-	717.50	588.33	610.00	-	835.00	745.00	797.50	-	1127.50	1155.83	1210.00	-
$CD_{0.05}$: Cultivars	NS				60.95				35.09				47.82			
Nutrient sources	60.85				NS				45.30				61.74			
V x T	105.40				NS				78.47				NS			

T_1= 22.5g/m^2 each of NPK + Biofertilizers (Azotobacter +PSB + VAM) + Vermicompost (1kg/m^2) + FYM (5kg/m^2), T_2= T_1 + 100 ppm N & K (through fertigation twice a week), T_3=Cow urine (5%), T_4= T_1 + T_3 , T_5= Jeevamrit (5%)

The interaction between cultivars and nutrient sources was significantly affected the yield of cuttings during the first and third harvest except during the second and fourth harvest where it was found to be non-significant (Appendix-II). During the first and third harvest, the cultivar 'Purnima' recorded maximum yield of cuttings (670.83 and 912.50, respectively) in T_2 comprising of 22.5 g/m^2 each of NPK + biofertilizers + vermicompost (1 kg/m^2) + FYM @ 5 kg/m^2 (as basal) along with fertigation of N & K @ 100 ppm twice a week and was found to be at par with 'Solan Shringar' (658.33 and 875.00, respectively) in the same treatment.

The variation among the cultivars for yield of cuttings could be attributed to the high magnitude of genotypic differences amongst them. The increase in the yield may be due to increased number of lateral branches which resulted in vigorous growth of the plant. Similar findings have also been reported by Krause (1981), Kumar *et al.* (2015) and Shabnam (2017).

The improvement in the number of cuttings may be due to more availability of macronutrients nutrients like nitrogen and potassium which are essential for plant growth and development. Nitrogen inhabits a vital place in plant metabolism system associated with protein, of which nitrogen is an essential constituent. Potassium is an activator of enzyme and carbohydrate metabolism and improved health and vigour of plant enabling it to withstand adverse condition resulting in higher yield. These findings are in line with those of Mridubhashini (2014) in chrysanthemum; Sharma *et al.* (2016) in African marigold; Leisan (2018) in gerbera and Momin (2012) in carnation.

4.5 Weight of cutting (g)

The difference in the weight of cuttings among the cultivars and the interaction effect of cultivars and treatments were found significant during the first and fourth harvest, except during the second and third harvest (Appendix-II).

Among the cultivars, maximum weight of cuttings (1.90, 2.92 and 1.97 g, respectively) was noted in 'Surf' during first, second and fourth harvest and minimum weight was recorded in 'Solan Shringar' (1.59, 2.48, 1.85 and 1.34 g, respectively) in all four harvests which proved to be at par with 'Purnima' (1.60 g) during first harvest.

Table 4.5 Effect of nutrient sources on weight of shoot tip cutting (g) during different harvests of commercial chrysanthemum cultivars

Nutrient sources (T)	First harvest				Second harvest				Third harvest				Fourth harvest			
	Solan Shringar	Surf	Purnima	Mean	Solan Shringar	Surf	Purnima	Mean	Solan Shringar	Surf	Purnima	Mean	Solan Shringar	Surf	Purnima	Mean
T_1	1.55	1.84	1.58	1.65	2.29	2.98	2.71	2.66	1.67	1.99	2.27	1.98	1.34	1.80	1.64	1.59
T_2	1.58	1.94	1.57	1.70	2.60	2.61	2.97	2.73	1.99	2.24	2.56	2.26	1.32	2.01	1.88	1.74
T_3	1.53	1.85	1.58	1.66	2.61	3.21	2.66	2.83	1.98	2.17	2.67	2.28	1.36	2.12	1.67	1.72
T_4	1.63	1.85	1.63	1.71	2.49	2.88	2.77	2.71	1.73	1.98	2.57	2.09	1.38	2.02	1.55	1.65
T_5	1.64	2.00	1.62	1.75	2.42	2.94	2.79	2.71	1.87	1.84	2.48	2.06	1.30	1.87	1.73	1.63
Mean	1.59	1.90	1.60		2.48	2.92	2.78		1.85	2.04	2.51		1.34	1.97	1.69	
$CD_{0.05}$: Cultivar	0.03				0.26				0.21				0.02			
Nutrient sources	0.04				NS				NS				0.03			
V x T	0.06				NS				NS				0.05			

T_1= 22.5g/m^2 each of NPK + Biofertilizers (Azotobacter +PSB + VAM) + Vermicompost (1kg/m²) + FYM (5kg/m²), T_2= T_1 + 100 ppm N& K (through fertigation twice a week), T_3=Cow urine (5%), T_4= T_1 + T_3 , T_5= Jeevamrit (5%)

Perusal of Table 4.5 revealed that T_5 i.e. Jeevamrit (5%) resulted in maximum weight of cuttings (1.75 g) during the first harvest and was statistically at par with T_4 (1.71 g) i.e. 22.5 g/m^2 each of NPK + biofertilizers + vermicompost (1 kg/m^2) + FYM (5 kg/m^2 (as basal) along with cow urine @ 5% (as spray once a week). As regard the second and third harvest, all treatments except T_1 (2.66 and 1.98 g, respectively) behaved equally in the weight of cuttings with highest in T_3 (2.83 and 2.28 g, respectively) i.e. cow urine @ 5%. The fourth harvest recorded maximum weight of cuttings (1.74 g) in T_2 and found to be at par with T_3 (1.72 g). However, minimum weight of cuttings was significantly less when supplied with T_1 (1.59 g).

The interaction between cultivars and nutritional treatments exhibited that soil drenching with Jeevamrit @ 5% (T_5) twice a month resulted in maximum weight of cuttings (2.00 g) during the first harvest in the cultivar 'Surf' which was statistically at par with T_2 (1.94 g) in the same cultivar. However, all treatments in both cultivars i.e. 'Solan Shringar' and 'Purnima' behaved similarly in the weight of cuttings during the first harvest. The second and fourth harvest revealed that the cultivar 'Surf' produced healthy cuttings with highest weight (3.21 and 2.12 g, respectively) when sprayed with cow urine @ 5% once a week which was also noticed in cultivar 'Purnima' (2.67 g) during third harvest. The fourth harvest recorded minimum weight of cuttings (1.30 g) in the cultivar 'Solan Shringar' when supplied with T_5 (1.30 g) i.e. Jeevamrit @ 5% and was statistically at par with T_1 (1.34 g) and T_2 (1.32 g) in the same cultivar.

The variation among the cultivars might be attributed to their genetic makeup which resulted in the variation in their weight. The findings are in correspondence with those of Singh *et al.* (2019); Kumar *et al.* (2015); Kim *et al.* (2014); Baskaran *et al.* (2004) and Kulkarni and Reddy (2004).

The weight of the cuttings was found maximum when the mother plants were supplied with jeevamrit (5%), cow urine (5%) and 22.5 g/m^2 each of NPK + biofertilizers + vermicompost (1 kg/m^2) + FYM @ 5 kg/m^2 (as basal) along with N & K @ 100 ppm (as fertigation). This might be due to increased microbial activity which enhances the ability of plants to absorb nutrients like nitrogen, phosphorous and potassium which stimulated the protein production in the stock plants resulting in increased weight of the cuttings. Jeevamrit is known to contain major nutrients like

nitrogen, phosphorous and potassium (Sreenivasa *et al*., 2011) and essential amino acids, many vitamins, growth promoting substances like Gibberellic Acid (GA_3), Indole Acetic Acid (IAA) and beneficial microorganisms (Gore and Sreenivasa, 2011). Cow urine is said to be a good source of nitrogen, phosphate, potassium, calcium, magnesium, chlorite and sulphate. It contains 95% water, 2.5% urea, 2.5% others (mineral salts, hormones and enzymes) (Pradhan *et al.,* 2018). The results of the present findings are in accordance with that of Tamrakar *et al.* (2016) in gladiolus; Jandaik *et al.* (2015) in bhindi and methi and Momin (2012) in carnation.

4.6 Days taken for rooting

An appraisal of Table 4.6 shows that there is significant difference between cultivars during the third and fourth harvest and revealed that minimum time for rooting (21.80 and 19.93 days, respectively) was recorded in the cultivar 'Solan Shringar'. However, maximum time for rooting (24.43 and 23.07 days, respectively) was observed in cultivar 'Surf' during both harvests.

Table 4.6 Effect of nutrient sources on days taken for rooting of shoot tip cuttings during third and fourth harvests of commercial chrysanthemum cultivars

Nutrient sources (T)	Third harvest				Fourth harvest			
	Solan Shringar	Surf	Purnima	Mean	Solan Shringar	Surf	Purnima	Mean
T_1	22.67	25.50	23.00	23.72	19.83	24.00	19.33	21.06
T_2	20.00	22.67	21.33	21.33	18.17	22.33	22.67	21.06
T_3	21.17	25.00	22.83	23.00	21.00	24.50	19.00	21.50
T_4	22.17	24.67	23.33	23.39	20.33	22.50	20.83	21.22
T_5	23.00	24.33	22.67	23.33	20.33	22.00	20.17	20.83
Mean	21.80	24.43	22.63	-	19.93	23.07	20.40	-
$CD_{0.05}$: Cultivar	0.57				0.49			
Nutrient sources	0.74				NS			
V x T	NS				1.10			

T_1= 22.5g/m^2 each of NPK + Biofertilizers (Azotobacter +PSB + VAM) + Vermicompost (1kg/m²) + FYM (5kg/m²), T_2= T_1 + 100 ppm N& K (through fertigation twice a week), T_3=Cow urine (5%), T_4= T_1 + T_3 , T_5= Jeevamrit (5%)

The effect of nutrient sources revealed T_2 i.e. 22.5g/m^2 each of NPK + biofertilizers + vermicompost (1 kg/m²) + FYM @ 5 kg/m² (as basal) along with 100 ppm N & K (through fertigation twice a week) took significantly less number of days for rooting (21.33 days) during the third harvest, while T_1 took more days for rooting (23.72 days) which was found to be statistically at par with the rest of the treatments i.e. T_3 (23.00), T_4 (23.39) and T_5 (23.33). During the fourth harvest, all treatments took almost similar time for rooting with least in case of T_5 (20.83).

The interaction between cultivars and nutrient sources on the days taken for rooting during the third and fourth harvest was found minimum in T_2 (20.00 and 18.17) in the cultivar 'Solan Shringar' and was at par with T_3 (19.00) i.e. cow urine (5%) in the cultivar 'Purnima' during fourth harvest. In contrast, the cultivar 'Surf' took more time to produce roots when supplied with T_1 (25.50) and T_3 (24.50) in third and fourth harvest, respectively.

The variation among the cultivars for days taken for rooting of cuttings could be attributed to the high magnitude of genotypic differences among them. The result may be further attributed to the availability of stored food in the cuttings which resulted in early formation and development of roots. Similar findings have also been reported by Shabnam (2017); Kumar *et al.* (2015) and Krause (1981) in chrysanthemum.

Minimum days taken for rooting during the third and fourth harvest have been observed with the basal application of 22.5 g/m^2 each of NPK + biofertilizers + vermicompost (1 kg/m^2) + FYM @ 5 kg/m^2 (as basal) along with N & K @ 100 ppm as fertigation twice a week (T_2) and T_5 i.e. soil drenching with jeevamrit (5%). This might be due to the accumulation of nutrient from jeevamrit which is known to contain 0.16% nitrogen, 0.02% phosphorous and 0.12% potassium (Chadha *et al.*, 2012) and beneficial microorganisms (Gore and Sreenivasa, 2011). The increased activity of the beneficial microorganisms might have influenced the ability of the mother plants to absorb nutrients like phosphorous from the soil which is relatively inaccessible to the plants (Miller, 2000). Phosphorous is a key component formed during photosynthesis which is essential for health and vigour of plants. The properties of these sources are perhaps responsible for early root formation in the cuttings. The findings are in agreement with those of Rahman *et al.* (2016) in

chrysanthemum; Ali *et al.* (2014) in gladiolus and Budiarto *et al.* (2006) in chrysanthemum.

4.7 Number of roots per cutting

Perusal of data in Table 4.7 illuminated that the number of roots per cutting was significantly variant due to cultivars and nutrient sources in both harvests i.e. third and fourth harvest (Appendix-II).

In the third and fourth harvest, the cultivar 'Solan Shringar' recorded significantly highest number of roots (29.31 and 30.94) which was found similar in the case of 'Purnima' (29.40) in the fourth harvest. The cultivar 'Surf' recorded minimum number of roots (18.33 and 18.95) in both the harvests i.e. third and fourth harvest.

Table 4.7 Effect of nutrient sources on number of roots per cutting during third and fourth harvests of commercial chrysanthemum cultivars

Nutrient sources (T)	Third harvest				Fourth harvest			
	Solan Shringar	Surf	Purnima	Mean	Solan Shringar	Surf	Purnima	Mean
T_1	27.00	16.45	27.11	23.52	29.22	17.33	25.33	23.96
T_2	36.89	20.44	29.56	28.96	34.78	21.89	34.78	30.48
T_3	29.78	18.67	26.22	24.89	31.00	20.33	28.55	26.63
T_4	26.22	16.11	27.11	23.15	29.78	16.56	27.55	24.63
T_5	26.67	20.00	27.56	24.74	29.44	18.66	30.78	26.29
Mean	29.31	18.33	27.51	-	30.84	18.95	29.40	-
$CD_{0.05}$: Cultivar	0.98				2.81			
Nutrient sources	1.26				3.63			
V x T	2.18				NS			

T_1= 22.5g/m^2 each of NPK + Biofertilizers (Azotobacter +PSB + VAM) + Vermicompost (1kg/m^2) + FYM (5kg/m^2), T_2= T_1 + 100 ppm N& K (through fertigation twice a week), T_3=Cow urine (5%), T_4= T_1 + T_3 , T_5= Jeevamrit (5%)

It is evident from Table 4.7 that influence of nutrient sources on the number of roots during the third and fourth harvest resulted in almost similar number of roots in all treatments with least in T_4 and T_1 (23.15 and 23.96, respectively) except in T_2

(28.96 and 30.48, respectively) i.e. 22.5 g/m^2 each of NPK + biofertilizers + vermicompost (1 kg/m^2) + FYM @ 5 kg/m^2 (as basal) along with N & K @ 100 ppm as fertigation twice a week (T_2) where number of roots was found to be maximum.

As regard the interaction between cultivars and nutrient sources significantly affected the number of roots during the third harvest, while it was found to be non-significant during the fourth harvest (Appendix-II). The results exhibited that maximum number of roots (36.89 and 34.78) was recorded in T_2 in the cultivar 'Solan Shringar' during the third and fourth harvest, respectively. However, minimum number of roots (16.11 and 16.56) was noticed with the basal application of 22.5 g/m^2 each of NPK + biofertilizers + vermicompost (1 kg/m^2) + FYM @ 5 kg/m^2 along with cow urine @ 5% (T_4) in the cultivar 'Surf' and it proved to be at par with T_1 (16.45) in the same cultivar in the third harvest.

The variation among the cultivars for could be attributed to the genotypic differences among them. The result may be further attributed to the stored food in the cuttings which resulted in better root development. Similar findings have also been reported by Shabnam (2017); Kumar *et al.* (2015) and Krause (1981) in chrysanthemum.

An increase in the number of roots have been observed during the third and fourth harvest with the basal application of 22.5 g/m^2 each of NPK + biofertilizers + vermicompost (1 kg/m^2) + FYM @ 5 kg/m^2 along with N & K @ 100 ppm as fertigation twice a week. This could be due to the presence of microorganisms which resulted in readily available macronutrients. Biofertilizers and vermicompost are known to contain beneficial microorganisms which are responsible for promoting plant growth as they enhance the ability of plants to absorb primary nutrients like phosphorous from the soil which is relatively inaccessible to the plants (Miller, 2000). Phosphorous is a vital component of ATP formed during photosynthesis which is essential for health and vigor of plants resulting in stimulated root development. The findings are in accordance with those of Budiarto *et al.* (2006) in chrysanthemum; Ali *et al.* (2014) in gladiolus and Rahman *et al.* (2016) in chrysanthemum.

4.8 Root length (cm)

The data concerning the length of roots in the cuttings during the third harvest revealed significant difference due to cultivars, treatments and the its interaction effect has been presented in Table 4.8.

Among the cultivars, 'Solan Shringar' exhibited longer roots (3.36 and 2.76 cm) during the third and fourth harvest, respectively. In contrast, minimum root length was noted in cultivar 'Surf' (2.15 and 1.20 cm, respectively) in both harvests.

In concern with the influence of nutrient sources, all treatments exhibited almost similar root length during the third harvest, except in T_3 (3.19 cm) i.e. cow urine (5%) which was found to be maximum. The fourth harvest revealed that maximum root length (2.18 cm) was noted in T_2, while minimum root length (1.71 cm) was recorded in T_5.

Table 4.8 Effect of nutrient sources on root length (cm) of cuttings during third and fourth harvests of commercial chrysanthemum cultivars

Nutrient sources (T)	Third harvest				Fourth harvest			
	Solan Shringar	Surf	Purnima	Mean	Solan Shringar	Surf	Purnima	Mean
T_1	3.27	1.48	3.14	2.63	3.29	1.38	1.44	2.04
T_2	2.89	2.03	3.50	2.81	2.94	1.35	2.25	2.18
T_3	3.91	2.85	2.82	3.19	2.48	1.09	1.84	1.80
T_4	3.48	2.06	2.71	2.75	2.52	1.13	1.82	1.82
T_5	3.22	2.34	3.26	2.94	2.56	1.03	1.53	1.71
Mean	3.36	2.15	3.09	-	2.76	1.20	1.78	-
$CD_{0.05}$: Cultivar	0.16				0.31			
Nutrient sources	0.21				NS			
V x T	0.36				NS			

T_1= 22.5g/m^2 each of NPK + Biofertilizers (Azotobacter +PSB + VAM) + Vermicompost (1kg/m^2) + FYM (5kg/m^2), T_2= T_1 + 100 ppm N& K (through fertigation twice a week), T_3=Cow urine (5%), T_4= T_1 + T_3 , T_5= Jeevamrit (5%)

The interaction effect exhibited that cultivar 'Solan Shringar' recorded maximum length of roots (3.91 cm) when supplied with cow urine @ 5% (T_3) which was closely followed by T_2 (3.50 cm) in the cultivar 'Purnima'. Likewise, during the

fourth harvest, maximum root length (3.29 cm) was noticed in the cultivar 'Solan Shringar' with the basal application of 22.5 g/m^2 each of NPK + biofertilizers + vermicompost (1 kg/m^2) + FYM @ 5 kg/m^2 (T_1). However, minimum root length was recorded in T_1 (1.48 cm) and T_5 (1.03) in the cultivar 'Surf' during the third and fourth harvest, respectively.

The difference among the cultivars is ascertained to the fact that there is a great variation among the genotypes. Similar findings have also been reported by Shabnam (2017); Kumar *et al.* (2015) and Krause (1981) in chrysanthemum.

An increase in the root length was observed with the spray of cow urine @ 5% once a week during the third harvest, except in the fourth harvest where maximum root length was recorded with 22.5 g/m^2 each of NPK + biofertilizers + vermicompost (1 kg/m^2) + FYM @ 5 kg/m^2 (as basal) along with N & K @ 100 ppm (as fertigation twice a week). Cow urine contains essential elements like nitrogen, phosphorous and potassium (Pradhan *et al.*, 2018). Nitrogen is said be a constituent of chlorophyll and is also a primary building block of proteins. Some proteins play an important role in the development of cell membranes and also as enzymes which are the constituent of various biochemical reactions in plant cell. Phosphorus being an essential component in the plant structure compounds and nucleic acid might have encouraged meristematic activity of plants. Potassium is said to be an activator of enzymes and is essential for production of Adenosine Triphosphate (ATP) which is essential for plant health and vigor. The properties of these elements are perhaps responsible for the improved root quality. The results of the present investigation is in line with those of Tamrakar *et al.* (2016) in gladiolus; Rahman *et al.* (2016) in chrysanthemum; Momin (2012) in carnation and Budiarto *et al.* (2006) in chrysanthemum.

4.9 Weight of rooted cuttings (g)

Data pertaining weight of rooted cuttings (g) as influenced by nutrient sources have been presented in Table 4.9. It is apparent from the table that the variation among the cultivars, nutrient sources and its interaction significantly affected the weight of rooted cuttings in both harvests.

Maximum weight of rooted cuttings (1.94 and 1.96 g) was recorded in the cultivar 'Purnima' and 'Surf' during the third and fourth harvest, respectively. The

cultivar 'Surf' recorded significantly minimum weight of rooted cuttings (1.74 g) during the third harvest and was found to be at par with cultivar 'Solan Shringar' (1.80 g). In fourth harvest, minimum weight of rooted cuttings (1.36 g) was recorded in the cultivar 'Solan Shringar'.

As regard the nutritional treatments, T_2 comprising of 22.5 g/m^2 each of NPK + biofertilizers + vermicompost (1 kg/m^2) + FYM @ 5 kg/m^2 (as basal) along with N & K @ 100 ppm as fertigation twice a week recorded maximum weight of cuttings (1.93 g) which was statistically at par with T_1 (1.87 g). In the fourth harvest, maximum weight of rooted cuttings (1.78 g) was noticed in T_3 i.e. cow urine (5%) which proved to be at par with T_2 (1.73 g). In contrast, minimum weight of rooted cuttings during the third and fourth harvest was recorded in T_4 (1.73 and 1.61 g, respectively) i.e. 22.5 g/m^2 each of NPK + biofertilizers + vermicompost (1 kg/m^2) + FYM @ 5 kg/m^2 (as basal) along with cow urine @ 5% and found to be at par with T_5 (1.79 and 1.62 g, respectively) i.e. Jeevamrit (5%).

Table 4.9 Effect of nutrient sources on weight of rooted cuttings (g) during third and fourth harvests of commercial chrysanthemum cultivars

Nutrient sources (T)	Third harvest				Fourth harvest			
	Solan Shringar	Surf	Purnima	Mean	Solan Shringar	Surf	Purnima	Mean
T_1	1.90	1.66	2.04	1.87	1.44	1.93	1.60	1.66
T_2	2.01	1.75	2.04	1.93	1.37	2.01	1.81	1.73
T_3	1.86	1.82	1.86	1.85	1.41	2.08	1.85	1.78
T_4	1.59	1.73	1.87	1.73	1.29	1.85	1.69	1.61
T_5	1.67	1.85	1.87	1.79	1.28	1.89	1.68	1.62
Mean	1.80	1.76	1.94	-	1.36	1.96	1.73	-
$CD_{0.05}$: Cultivar	0.05				0.04			
Nutrient sources	0.06				0.05			
V x T	0.11				0.08			

T_1= 22.5g/m^2 each of NPK + Biofertilizers (Azotobacter +PSB + VAM) + Vermicompost (1kg/m^2) + FYM (5kg/m^2), T_2= T_1 + 100 ppm N& K (through fertigation twice a week), T_3=Cow urine (5%), T_4= T_1 + T_3 , T_5= Jeevamrit (5%)

The interaction between cultivars and nutritional treatments significantly affected the weight of rooted cuttings during third and fourth harvest. The results revealed that maximum weight of rooted cuttings (2.04 g) during the third harvest was recorded in T_1 and T_2 in the cultivar 'Purnima' (V_3). However, during the fourth harvest, maximum weight of rooted cuttings (2.08 g) was noticed in T_3 i.e. cow urine (5%) in the cultivar 'Surf' and was statistically at par with T_2 (2.01 g) in the same cultivar.

The variation among the cultivars in this character could be due to the influence of genetic makeup amongst them. The findings are in correspondence with those of Singh *et al.* (2019); Kumar *et al.* (2015); Kim *et al.* (2014); Baskaran *et al.* 2004 and Kulkarni and Reddy (2004).

Maximum weight of rooted cuttings was noticed in with 22.5 g/m^2 each of NPK + biofertilizers + vermicompost (1 kg/m^2) + FYM @ 5 kg/m^2 (as basal) along with N & K @ 100 ppm as fertigation twice a week (T_2) and cow urine @ 5% (T_3). This could probably be due to availability reserved food, nutrients and growth promoting substances like GA_3 and IAA (Gore and Sreenivasa, 2011) in the cuttings which influence the biomass of rooted cuttings. Cow urine is known to contain 95% water, 2.5% urea and 2.5% others (mineral salts, hormones and enzymes) which are effective in improving soil fertility (Pradhan *et al.*, 2018). Nitrogen is an important constituent of chlorophyll involved in photosynthesis, thereby acts as a component for supporting plant growth. Potassium however, plays a vital role in the osmo-regulation (uptake of water through plant roots and its loss through the stomata). Similar findings have also been reported by Tamrakar *et al.* (2016) in gladiolus; Rahman *et al.* (2016) in chrysanthemum; Momin (2012) in carnation; Budiarto *et al.* (2006) and Rober (1976) in chrysanthemum.

4.10 Internodal length (cm)

Perusal of data presented in Table 4.10 revealed that the variation among the cultivars significantly affected the internodal length in all harvestings. The influence of nutrient sources and the interaction effect between the cultivars and nutrient sources was found to be non-significant in all harvestings, except during the third and fourth harvests where the effect of nutrient sources was found to be significant.

Table 4.10 Effect of nutrient sources on internodal length of shoot tip cuttings (cm) during different harvests of commercial chrysanthemum cultivars

Nutrient sources (T)	First harvest				Second harvest				Third harvest				Fourth harvest			
	Solan Shringar	Surf	Purnima	Mean	Solan Shringar	Surf	Purnima	Mean	Solan Shringar	Surf	Purnima	Mean	Solan Shringar	Surf	Purnima	Mean
T_1	2.04	1.80	2.59	2.14	1.98	1.22	1.88	1.69	2.43	1.18	2.27	1.96	1.84	1.54	1.70	1.70
T_2	2.33	1.99	2.10	2.14	2.39	1.45	1.91	1.92	2.52	1.46	2.93	2.30	1.99	1.85	1.80	1.88
T_3	2.17	1.84	2.29	2.10	2.15	1.23	1.56	1.65	3.00	1.26	2.76	2.34	1.82	1.79	1.70	1.77
T_4	1.85	2.03	1.90	1.93	2.11	1.98	1.59	1.89	2.55	1.25	2.43	2.08	1.77	1.63	1.68	1.69
T_5	1.98	2.00	2.40	2.13	1.81	1.44	1.64	1.63	2.31	1.26	2.42	2.00	1.80	1.71	1.61	1.71
Mean	2.07	1.93	2.26	-	2.09	1.46	1.72	-	2.56	1.28	2.56	-	1.85	1.71	1.70	-
$CD_{0.05}$: Cultivar	0.22				0.26				0.20				0.06			
Nutrient sources	NS				NS				0.26				0.08			
V x T	NS				NS				NS				NS			

T_1= 22.5g/m^2 each of NPK + Biofertilizers (Azotobacter +PSB + VAM) + Vermicompost (1kg/m^2) + FYM (5kg/m^2), T_2= T_1 + 100 ppm N& K (through fertigation twice a week), T_3=Cow urine (5%), T_4= T_1 + T_3 , T_5=Jeevamrit (5%)

It is evident from the Table 4.10 that during the first, second and third harvest, the cultivar 'Surf' recorded minimum internodal length (1.93, 1.46 and 1.28 cm, respectively) and was found to be at par with cultivar 'Solan Shringar' during the first harvest and 'Purnima' during the second harvest. In the fourth harvest, minimum internodal length was noted in the cultivar 'Purnima' (1.70 cm) and proved to be statistically at par with the cultivar 'Surf' (1.71 cm). On the contrary, maximum internodal length was recorded in the cultivar 'Purnima' (2.26 and 2.56 cm, respectively) in the first and third harvest and cultivar 'Solan Shringar' (2.09, 2.56 and 1.85 cm) during the second, third and fourth harvest, respectively.

The influence of nutrient sources on internodal length revealed that, all treatments produced cuttings with longer internodes except in the case of T_4 (1.93 cm) where internodal length was recorded the least in the first harvest. During the second harvest, almost similar internodal length was noticed in T_1 (1.69 cm), T_3 (1.65 cm) and T_5 (1.63 cm). In the third harvest, minimum internodal length and was noted in T_1 (1.96 cm) and was closely followed by T_5 (2.00 cm). During the fourth harvest, all treatments except T_2 (1.88 cm) exhibited minimum internodal length with least recorded in T_4 (1.69 cm) i.e. 22.5 g/m^2 + biofertilizers + vermicompost (1 kg/m^2) + FYM @ 5 kg/m^2 (as basal) along with cow urine (5%). However, maximum internodal length was noticed in T_2 (1.92 and 1.88 cm, respectively) during the second and fourth harvest, while in third harvest, it was maximum in T_3 (2.34 cm) which was at par with T_2 (2.30 cm) and T_4 (2.08 cm).

The interaction between nutrient source treatments and cultivar on the internodal length revealed that T_1 resulted in minimum internodal length (1.80, 1.22, 1.18 and 1.54 cm) in the cultivar 'Surf' in all four flushes. In contrast, maximum internodal length was noticed in T_1 (2.59 cm) in the cultivar 'Purnima' during the first harvest. Maximum internodal length during the second and fourth harvest was recorded in T_2 (2.39 and 1.99, respectively) in the cultivar 'Solan Shringar', while in third harvest, it was found maximum in T_3 (3.00 cm) in the same cultivar.

A gradual increase in the internodal length was noticed in every harvest. This is ascribed to the fact that the quality of cuttings declined after multiple harvestings from the same plant resulting in the elongation of internodes. The results are in agreement with those of Zhang *et al,* (2013) and Klapwijk (1987) in chrysanthemum.

4.11 Percentage of healthy rooted cuttings

The data presented in Table 4.11 shows that the percentage of healthy rooted cuttings was significantly influenced by cultivars, nutrient sources and their interactions in both harvestings, except during the fourth harvest, the influence of nutrient sources was found non-significant (Appendix-II).

During the third harvest, highest percent rooting (96.59 %) was noticed in the cultivar 'Solan Shringar' and 'Purnima' and during the fourth harvest it was noticed in cultivar 'Solan Shringar' (96.93 %). In contrast, minimum percent rooting (94.74 and 95.07 %, respectively) during both harvests was noted in cultivar 'Surf'.

Amongst the treatments, T_2 i.e. 22.5 g/m^2 + biofertilizers + vermicompost (1 kg/m^2) + FYM @ 5 kg/m^2 (as basal) along with N & K @ 100 ppm as fertigation twice a week recorded highest percent survival of cuttings (97.68 and 96.65 %) during both harvests. However, minimum percent survival of cuttings (94.07 %) during third harvest was recorded in T_3 and during fourth harvest, it was recorded in T_1 (95.23 %).

Interaction between cultivars and treatments showed that, maximum percentage of healthy rooted cuttings was noted in T_4 (98.84 %) in the cultivar 'Purnima' during the third harvest which was statistically at par with T_1 (97.45 %) and T_2 (98.54 %) in the same cultivar; T_2 (97.13 %) and T_4 (96.92 %) in the cultivar 'Solan Shringar' and T_2 (97.37 %) in the cultivar 'Surf'. In the third harvest, maximum percent survival of cuttings (98.55 %) was noticed in T_2 in the cultivar 'Solan Shringar' and proved to be at par with T_3 (97.82 %) and T_4 (96.90 %) in the same cultivar and T_2 (97.06 %) in the cultivar 'Purnima'. Minimum percent survival of cuttings during the third harvest was recorded in T_3 (92.79 %) in the cultivar 'Surf' which was at par with T_4 (93.85%) in the same cultivar and T_3 (93.19 %) in the cultivar 'Purnima'. During the fourth harvest, minimum percent survival of cuttings was recorded in T_2 (94.33 %) in the cultivar 'Surf' and found to be at par with T_3 (94.92 %) and T_4 (94.83 %) in the same cultivar and with the rest of the treatments in the cultivar 'Purnima' i.e. T_1 (95.40 %), T_3 (94.59 %), T_4 (96.23 %) and T_5 (95.81 %).

Table 4.11 Effect of nutrient sources on percentage of healthy rooted cuttings during third and fourth harvests of commercial chrysanthemum cultivars

Nutrient sources (T)	Third harvest				Fourth harvest			
	Solan Shringar	Surf	Purnima	Mean	Solan Shringar	Surf	Purnima	Mean
T_1	96.51 (9.88)	94.72 (9.78)	97.45 (9.92)	96.59 (9.86)	95.33 (9.82)	94.96 (9.80)	95.40 (9.82)	95.23 (9.81)
T_2	97.13 (9.91)	97.37 (9.92)	98.54 (9.98)	97.68 (9.93)	98.55 (9.98)	94.33 (9.76)	97.06 (9.90)	96.65 (9.88)
T_3	96.22 (9.86)	92.79 (9.68)	93.19 (9.71)	94.07 (9.75)	97.82 (9.94)	94.92 (9.79)	94.59 (9.78)	95.78 (9.84)
T_4	96.92 (9.90)	93.85 (9.74)	98.84 (9.99)	96.54 (9.88)	96.90 (9.89)	94.83 (9.79)	96.23 (9.86)	95.99 (9.85)
T_5	96.18 (9.86)	94.97 (9.80)	94.95 (9.80)	95.37 (9.82)	96.06 (9.85)	96.31 (9.86)	95.81 (9.84)	96.06 (9.85)
Mean	96.59 (9.88)	94.74 (9.78)	96.59 (9.88)	-	96.93 (9.90)	95.07 (9.80)	95.82 (9.84)	-
$CD_{0.05}$: Cultivar Nutrient sources V x T	(0.04) (0.05) (0.09)				(0.04) (NS) (0.10)			

*Figures in parenthesis are square root transformed values

T_1= 22.5g/m^2 each of NPK + Biofertilizers (Azotobacter +PSB + VAM) + Vermicompost (1kg/m^2) + FYM (5kg/m^2), T_2= T_1 + 100 ppm N& K (through fertigation twice a week), T_3=Cow urine (5%), T_4= T_1 + T_3, T_5= Jeevamrit (5%)

The variation among the cultivars in this character could be due to the influence of genetic makeup amongst them. The findings are in correspondence with those of Kumar *et al.* (2015) in chrysanthemum; Kim *et al.* (2014) in chrysanthemum and Momin (2012) in carnation.

Balanced nutrition in the mother plants not only affect the yield but also influence the rooting of cuttings (Blazich, 1988) as it mitigate the excessive vegetative growth and increase the C:N ratio stored in the shoots. Since cuttings require time to develop roots, the cutting depends exclusively on the stored food in the stem and leaves to provide the energy required for development of roots. The

augmentation of percent survival of cuttings might be attributed to the availability of stored nutrients in the cuttings. Potassium is known to be an activator of many growth related enzymes and plays a major role in osmo-regulation which might have influence the percent survival of cuttings. The results of the present investigation is in accordance with those of Rahman *et al.* (2016) in cvs 'Candy Floss', Lilian Jackson', 'Elizabeth Lawson' and 'Henry Revil' in chrysanthemum; Momin (2012) in carnation; Budiarto *et al.* (2006) and Rober (1976) in chrysanthemum.

4.12 Colour of leaves

The colour of leaves was recorded using RHS (Royal Horticulture Society) colour chart. The data presented in the table show that all the three cultivars belong to yellow green group. However, some were found to have an intense colour, while some were found to be lighter. The leaves of the plants showed an intense green colour in T_2 (Yellow Green Group 147 A) in the cultivar 'Solan Shringar'. The same leaf colour was also noticed in T_4 and T_5 in the cultivar 'Surf' and in the cultivar 'Purnima', this colour was seen in all nutrient source treatments except in T_4 (YGG 147 B). A slightly lighter shade Yellow Green Group (147 B) was observed in T_4 in the cultivar 'Solan Shringar' which was also noticed in the cultivar 'Surf' in T_3. Another shade of yellow green i.e. Yellow Green Group (137 A) was recorded in cultivars 'Solan Shringar' in T_3 and T_5 and 'Purnima' in T_1 and T_2.

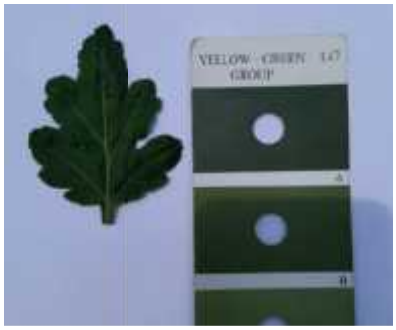
Table 4.12 Effect of nutrient sources on colour of leaves of shoot tip cuttings of commercial chrysanthemum cultivars

Nutrient sources (T)	Solan Shringar	Surf	Purnima
T_1	YGG 147 B	YGG 137 A	YGG 147 A
T_2	YGG 147 A	YGG 137 A	YGG 147 A
T_3	YGG 137 A	YGG 147 B	YGG 147 A
T_4	YGG 147 B	YGG 147 A	YGG 147 B
T_5	YGG 137 A	YGG 147 A	YGG 147 A

T_1= 22.5g/m^2 each of NPK + Biofertilizers (Azotobacter +PSB + VAM) + Vermicompost (1kg/m^2) + FYM (5kg/m^2), T_2= T_1 + 100 ppm N& K (through fertigation twice a week), T_3=Cow urine (5%), T_4= T_1 + T_3 , T_5= Jeevamrit (5%)

a) Solan Shringar

b) Surf



c) Purnima

Plate 6a. Effect of nutrient sources on colour of leaves of commercial chrysanthemum cultivars

a) Solan Shringar

b) Surf

c) Purnima

Plate 6b. General view of rooted cuttings

The colour of leaves varied with different genotypes. The intensity of the colour in the leaves might be due to presence of nitrogen which is an important constituent in the plant metabolism (a part of the chlorophyll molecule), providing plants their green color and is involved in creating food for the plant through the process of photosynthesis.

Chapter-5

SUMMARY AND CONCLUSION

The present investigation entitled, **"Studies on the effect of nutrient sources on cutting production and rooting in chrysanthemum (*Dendranthema grandiflora* Tzvelev)''** was carried out under a naturally ventilated polyhouse at the Experimental Farm of Department of Floriculture and Landscape Architecture, Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) during 2018-19. The experiment was laid out in a Randomized Block Design (RBD Factorial) using 3 cultivars, 5 treatments with three replications.

The salient results obtained from the present studies are given below:

- Application of 22.5 g/m^2 each of NPK + biofertilizers + vermicompost (1 kg/m^2) + FYM (5 kg/m^2) (as basal) along with N & K 100 ppm as fertigation twice a week (T_2) resulted in maximum number of cuttings per plant per harvest (32.83), total number of cuttings per plant (142.67), maximum yield/m^2 (820.83) in the cultivar 'Solan Shringar' during the second harvest. Similarly, in cultivar 'Purnima', number of cuttings per plant per harvest (26.83 and 36.50 in first and third harvest), total number of cuttings per plant (142.67), maximum yield/m^2 (670.83 and 912.50 during first and third harvests, respectively) was recorded maximum in T_2. Also, in the cultivar 'Surf', maximum number of cuttings per plant per harvest (52.50) and maximum yield/m^2 (1312.50) was recorded in T_2 during the fourth harvest.

- Minimum time for cutting production (37.83 and 25.67 days during first and second harvest, respectively) was recorded in T_4 and T_2 in the cultivar 'Purnima'. However, in the third and fourth harvest, minimum time for cutting production (25.83 and 25.33 days, respectively) was recorded in T_3 and T_2 in the cultivar 'Solan Shringar'.

- Maximum weight of cutting was recorded in T_5 (2.0 g) i.e. jeevamrit (5%) in first harvest and T_3 (3.21 and 2.12 g, respectively) i.e. cow urine (5%) in second and third harvest in the cultivar 'Purnima'. Likewise, in fourth harvest, spray of cow urine @ 5% (T_3) resulted in maximum weight of cutting (2.12 g) in the cultivar 'Surf'.

- Minimum days for rooting (20.00 and 18.17 in third and fourth harvest, respectively) were noticed in T_2 in the cultivar 'Solan Shringar'. Similarly, maximum number of roots (36.89 and 34.78, respectively) was noted in T_2 in the cultivar 'Solan Shringar' in both harvests i.e. third and fourth harvest. Likewise, the cultivar 'Purnima' also recorded maximum number of roots (34.78) in the same treatment during the fourth harvest.

- Maximum weight of rooted cutting (2.04 g in third harvest) was recorded in T_1 and T_2 in cultivar 'Purnima'. However, the cultivar 'Surf' recorded maximum weight of rooted cutting (2.08 g during fourth harvest) with the spray of cow urine @ 5% once a week (T_3). The internodal length (1.80, 1.22, 1.18 and 1.54 cm, respectively) in the same cultivar i.e. 'Surf' was found to be minimum in all harvests with the basal application of 22.5 g/m^2 each of NPK + biofertlizers + vermicompost (1 kg/m^2) + FYM @ 5 kg/m^2 (T_1).

- In the third harvest, maximum root length (3.91 cm) was recorded in T_3 i.e. cow urine (5%), while in fourth harvest, it was found to be maximum in T_1 (3.29 cm) in the cultivar 'Solan Shringar'.

- Percent survival of cuttings (98.84 % during third harvest) was found to be maximum with the application of 22.5 g/m^2 each of NPK + biofertilizers + vermicompost (1 kg/m^2) + FYM (5 kg/m^2) (as basal) along with the spray of cow urine @ 5% once a week (T_4). Nevertheless, maximum percent survival of cuttings (98.55 % in fourth harvest) was noted in T_2 i.e. 22.5 g/m^2 each of NPK + biofertilizers + vermicompost (1 kg/m^2) + FYM @ 5 kg/m^2 (as basal) along with N & K 100 ppm as fertigation twice a week.

CONCLUSION:

From the present investigation, it has been concluded that T_2 comprising of 22.5 g/m^2 each of NPK + biofertilizers + vermicompost (1kg/m^2) + FYM (5 kg/m^2) (as basal) along with 100 ppm N & K (as fertigation twice a week) is recommended for quality cutting production and rooting of commercial chrysanthemum cultivars i.e. 'Solan Shringar' and 'Purnima'. However, the quality of cuttings declined after multiple harvestings from a single plant.

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APPENDIX- I

Mean monthly meteorological data of Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP) for the year 2018-19 (*w.e.f.* June, 2018 to July, 2019)

Months	Temperature (îC)			Relative Humidity (%) (Mean)	Rainfall (mm)
	Maximum	Minimum	Mean		
June, 2018	29.70	18.90	24.30	62	190.00
July, 2018	26.70	20.20	22.45	81	340.20
August, 2018	27.60	20.00	23.80	79	216.60
September, 2018	26.50	16.90	21.70	76	224.30
October, 2018	25.10	9.10	17.10	53	2.60
November, 2018	21.70	6.50	14.10	59	24.80
December, 2018	18.10	1.60	9.85	58	21.60
January, 2019	15.70	2.00	8.85	59	73.00
February, 2019	16.30	4.40	10.35	63	103.10
March, 2019	20.30	6.60	13.45	54	54.60
April, 2019	27.30	12.70	20.00	49	36.80
May, 2019	30.50	14.70	22.60	44	21.30
June, 2019	33.70	17.80	25.75	48	98.50
July, 2019	27.70	19.90	23.80	79	218.10

Source: Meterological Observatory, Department of Environmental Science, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP) 173230

APPENDIX- II

Analysis of variance for various cutting quality and rooting parameters as influenced by nutrient source treatments

Source of Variation	df	Character Mean Sum of Squares (MSS)													
		Time taken for first and successive harvesting of cuttings				No of cuttings per plant per harvest				Total number of cuttings per plant	Yield/m^2	Weight of cutting (g)			
		1st harvest	2nd harvest	3rd harvest	4th harvest	1st harvest	2nd harvest	3rd harvest	4th harvest			1st harvest	2nd harvest	3rd harvest	4th harvest
Replication	2	9.15	0.84	2.44	3.77	46.12	3.62	35.12	15.37	305.69	140972.29	0.0003	0.13	0.04	0.0002
Cultivars	2	19.12	13.34	4.82	34.27	5.62	114.84	49.05	42.17	302.94	181,133	0.45	0.76	1.74	1.48
Nutrient source	4	5.17	4.89	0.44	1.35	17.30	28.01	39.12	65.66	463.55	306,389	0.02	0.03	0.15	0.03
Cultivar X Nutrient source	8	3.41	0.53	1.22	0.62	23.13	11.13	18.35	13.25	112.11	80,433	0.01	0.10	0.03	0.03
Error	28	1.59	0.79	0.56	0.45	6.29	10.52	3.49	6.47	19.71	24,052	0.001	0.12	0.08	0.005
Total	44	38.43	20.38	9.48	40.47	98.45	168.11	145.12	142.93	1204.00	732,979	0.48	1.15	2.03	1.55

Source of Variation	df	Character Mean Sum of Squares (MSS)													
		Days taken for rooting		No of roots per cutting		Root length (cm)		Weight of rooted cutting (g)		Internodal length (cm)				Percentage of healthy rooted cutting	
		3rd harvest	4th harvest	3rd harvest	4th harvest	3rd harvest	4th harvest	3rd harvest	4th harvest	1st harvest	2nd harvest	3rd harvest	4th harvest	3rd harvest	4th harvest
Replication	2	3.54	1.05	5.11	28.54	0.15	0.70	0.0002	0.0004	0.11	0.27	0.08	0.07	0.01	0.01
Cultivars	2	27.17	42.87	520.01	631.38	5.99	9.35	0.12	1.36	0.39	1.48	8.21	0.10	0.04	0.03
Nutrient source	4	7.99	0.55	48.15	58.05	0.42	0.34	0.05	0.05	0.08	0.17	0.28	0.06	0.04	0.01
Cultivar X Nutrient source	8	0.87	6.47	14.01	5.36	0.53	0.20	0.04	0.01	0.14	0.17	0.09	0.01	0.01	0.01
Error	28	0.58	0.43	1.69	14.01	0.05	0.17	0.005	0.007	0.08	0.12	0.07	0.01	0.001	0.001
Total	44	0.22	1.43	0.80	2.20	8.73	0.25	0.11	0.06	Total	44	0.22	1.43	0.80	2.20

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Title of Thesis	:	**"Studies on the effect of nutrient sources on cutting production and rooting in chrysanthemum (*Dendranthema grandiflora* Tzvelev)"**
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ABSTRACT

The present investigation on the effect of nutrient sources on cutting production and rooting in chrysanthemum (*Dendranthema grandiflora* Tzvelev) was carried out at Experimental Farm of Department of Floriculture and Landscape Architecture, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan (H.P) during 2018-2019 under a naturally ventilated polyhouse with the objective to find out the effect of nutrient sources on cutting production and rooting in chrysanthemum cultivars. The experiment was laid out in Randomized Block Design (factorial) with five treatments on three commercial chrysanthemum cultivars replicated thrice. Vermicompost, full doses of P and K and half dose of N were incorporated into the beds one week before planting according to the treatment. The remaining half dose of nitrogen was applied after 30 days of planting. *Azotobacter* and PSB were applied by dipping the roots of the cutting into a slurry of 200g of the inocula dissolved in one litre of 10% sugar solution at the time of planting whereas VAM (2 g/plant) was applied directly into the planting pit. Besides the application of basal dose of N, P, and K, a single dose (100 ppm) of N and K was also applied through fertigation twice a week. Cow urine was sprayed once in a week @ 5% and jeevamrit (5%) was given at 15 days interval @ 250ml/plant as soil drenching. The results revealed that minimum time for cutting production (25.67 and 25.33 days in 2nd and 4th harvest), maximum number of cuttings/plant/harvest (26.83, 32.83, 36.50 and 52.50 in all four harvests, respectively), total number of cuttings/plant (142.67), yield of cuttings/m^2 (670.83, 820.83, 912.50 and 1312.50 in all four harvests, respectively), minimum days for rooting (20.00 and 18.17 days in 3rd and 4th harvest, respectively), maximum number of roots (36.89 and 34.78 in 3rd and 4th harvests, respectively), maximum weight of rooted cuttings (2.04 g in 3rd harvest), maximum percentage of healthy rooted cuttings (98.55 % in 4th harvest) and intense green colour of leaves (YGG 147 A) were recorded with the application 22.5 g/m^2 each of NPK + biofertilizers + vermicompost (1 kg/m^2) + FYM @ 5 kg/m^2 (as basal) along with N & K 100 ppm as fertigation twice a week (T_2). The nutritional treatment T_3 comprising of cow urine (5%) resulted in maximum fresh weight of cuttings (3.21 and 2.12 g in 2nd and 3rd harvest, respectively) and maximum root length (3.91 cm in 3rd harvest). The cutting yield and rooting response of commercial chrysanthemum cultivars was noted in T_2.

Signature of the Major Advisor **Signature of the Student**

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