SPACING AND NUTRIENT MANAGEMENT FOR *Gomphrena globosa* L.

By

RESHMA SHAJI

(2018-12-031)

DEPARTMENT OF FLORICULTURE AND LANDSCAPING

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR - 680 656

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THESIS

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KERALA, INDIA

2020

DECLARATION

I, hereby declare that this thesis entitled **"Spacing and nutrient management for *Gomphrena globosa* L."** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellanikkara
24-09-2020

Reshma Shaji
(2018-12-031)

CERTIFICATE

Certified that this thesis entitled **"Spacing and nutrient management for *Gomphrena globosa* L."** is a record of research work done independently by **Reshma Shaji (2018-12-031)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship or fellowship to her.

Vellanikkara

24-09-2020

Dr. A. Sobhana

Professor and Head

Fruit Crops Research Station,

Vellanikkara

CERTIFICATE

We, the undersigned members of the advisory committee of **Ms. Reshma Shaji (2018-12-031)** a candidate for the degree of **Master of Science in Horticulture**, with major field in **Floriculture and Landscaping**, agree that the thesis **"Spacing and nutrient management for *Gomphrena globosa* L."** may be submitted by **Ms. Reshma Shaji (2018-12-031),** in partial fulfilment of the requirement for the degree.

Dr. A. Sobhana (Major Advisor)
Professor and Head
Fruit Crops Research Station,
Vellanikkara

Dr. U. Sreelatha
(Member, Advisory Committee)
Professor and Head
Department of Floriculture and Landscaping
College of Horticulture, Vellanikkara

Dr. Anupama T. V.
(Member, Advisory Committee)
Assistant Professor
AICRP on Floriculture
Department of Floriculture and Landscaping
College of Horticulture, Vellanikkara

Dr. P. Prameela
Professor
Department of Agronomy
College of Horticulture, Vellanikkara

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LIST OF ABBREVIATIONS AND SYMBOLS USED

Symbols	Abbreviations
et al.	And others
RBD	Randomized Block Design
CD	Critical Difference
cv.	Cultivar
FYM	Farmyard manure
g	Gram
kg	Kilogram
t	Tonnes
cm	Centimetre
NS	Non-significant
ha	Hectare
N	Nitrogen
P	Phosphorus
K	Potassium
℃	Degree Celsius
mm	Millimetres

Introduction

1. INTRODUCTION

Annuality in plants is often described as their potential to complete their entire lifecycle in one year. They grow to maturity during a single growing season. Annuals are popular choice for gardening because they grow fast, require less maintenance and remain attractive all seasons adding vibrant colours and beauty to the garden. *Gomphrena globosa* L. is one such ornamental plant being grown as an annual flowering plant.

Gomphrena globosa is known by its common name 'globe amaranth' or 'bachelor's button'. *Gomphrena* is native to tropical and sub-tropical countries including India. It belongs to the family Amaranthaceae. There are about 100 species in the genus *Gomphrena* but only *Gomphrena globosa* and its varieties are commercially cultivated. It is a long lasting flower which is easy to cultivate. The name *Gomphrena* was originally used by Pliny the Elder for a kind of amaranth (Bailey and Bailey, 1976), which in Latin means 'a type of everlasting amaranth', on account of retention of colour and shape of the flower for a very long period after drying, and *globosa* means spherical, due to the spherical shape of flower heads.

Globe amaranth is commercially cultivated in the tropical and subtropical climatic regions of India. It is a compact annual with a bushy appearance that typically grows tall on upright branching stems. The leaves are hairy, light green, opposite and oblong-ovate, tapering towards the base. *Gomphrena* exhibits colourful and showy flower heads in varying shades of purple, white, pink, orange and red. The flower heads are globular, clover-like composed of bundles of stiff, attractive papery bracts for the purpose of pollination, supported on long, thin but strong stems above the foliage. However, the true flowers remain inconspicuous within the flower heads as yellow-white trumpets that are only visible when closed up.

Bachelor's button is mainly used as dry flower and as loose flower for making garlands. Dry flowers are gaining popularity as they are inexpensive, long-lasting, and eco-friendly, being available throughout the year. Because of its papery bracts, dried flowers of *Gomphrena* are highly suitable for making several value added products like potpourri, and find significance in button holes. Both fresh and dried flowers are used for flower arrangement. *Gomphrena* ornaments beds, borders and edges in the garden. By using contrasting colour scheme of planting, splashing mass planting effect is created by *Gomphrena.* It is also used in rockeries and as pot plants. Pot grown gomphrenas are used for indoor decorations and also in hanging baskets. It is also a potential summer cut flower as is available in vivid colours, for long blooming period and with its good stand in vases (Cocozza-Talia, 1993).

In addition, the flowers of *Gomphrena globosa* are rich source of the pigment betacyanins which can be utilized as additives and supplements in the food industry, cosmetics, and livestock feed. Betalain pigments that have red-violet colour are ideal as a natural food dye. The betacyanins identified are gomphrenin and isogomphrenin (Roriz *et al*., 2017).*Gomphrena globosa* also acts as a potential indicator of the phyto-toxicity and mutagenicity of pollutants (Bessonova *et al*., 1997). Furthermore, it is used as an indicator plant for potato x potexvirus (Cordero, 1988).

Different cultivars of *Gomphrena* like Alba, Rubra, Aureo and Soft pink are available for growing in the gardens in vibrant shades such as white, orange-yellow, rose, purple-violet and pink. 'Buddy' is a compact dwarf cultivar of gomphrena with long lasting vivid purple flower heads and 'Cissy' is a dwarf white flower cultivar suitable for edge and rock garden. 'Strawberry Fields' is another new variety of *Gomphrena* developed and grown for its brilliant red flower heads.

Nutrient demands and optimum plant density differ among crops, creating a complex crop-specific management. These factors are influential in the growth and development of any plant. Adequate spacing is essential for ornamentals to avoid competition in the consumption of sufficient sunlight, water, and soil nutrients. This enables easy intercultural operations and ensures better yield and quality of the plants. Since most soils do not have all the sufficient nutrients required by the plants to grow to their maximal potential, there is a need to supply nutrients in the form of fertilizers. It plays a key role in enhancing the growth and flowering phase of ornamentals by providing essential elements like nitrogen, phosphorus and potassium. The application of fertilizers containing the three fundamental nutrients and ideal spacing between the plants can increase productivity and improve quality of ornamental plants.

However, research on optimum spacing and nutrient demands for *Gomphrena* is very limited, particularly under humid tropical conditions of Kerala which highlights the need for further investigation. Hence, there remains a need to standardize plant spacing and nutritional requirements for the commercialization of *Gomphrena globosa* L., owing to the reasons that plant spacing along with adequate nutriment play a key role in promoting better growth and flowering in this crop. Through a combination of theoretical and applied knowledge, this type of work provides a practical understanding of nutrient management and plant density required for optimum productivity in *Gomphrena globosa* which has a great economic significance. In this background, the present study with the following objective was carried out:

- To standardize the spacing and fertilizer requirement of *Gomphrena globosa* for cultivation under the warm humid tropical regions of Kerala.

Review of Literature

2. REVIEW OFLITERATURE

Gomphrena globosa L., commonly known as globe amaranth or bachelor's button is a charming ornamental plant from the family Amaranthaceae. The round-shaped flower inflorescence is a visually dominant feature of this species. It is an annual plant used as loose flower, dry flower and even as cut flower. Apart from this, *Gomphrena* acts an impressive component in landscape gardens as annual beds, borders, edges and in rock garden. For proper growth and flowering, ornamentals require adequate spacing and optimum nutrition. The available literature regarding the effect of spacing and nutrients on growth and development of ornamentals are briefed hereunder.

EFFECT OF NPK ON GROWTH AND FLOWERING OFORNAMENTALS

Effect of Nitrogen on growth and flowering of ornamental plants

Nitrogen is a predominant element for plants as it is the major constituent of many plant structures and essential for metabolic processes. Nitrogen (N) is utilized by the plants in the form of NO_3 and NH_4. For enhancing the growth and development of plants nitrogen acts as a crucial element which leads to improvement in the yield and its quality (Leghari *et al*., 2016). Low nitrogen in soil results in stunted growth and all plant functions will be disturbed. Chlorosis of lower leaves, stunted and slow growth and necrosis of older leaves occur in the deficiency of nitrogen.

Frett *et al*. (1985) reported that floral, shoot and root parameters were found to be highest when plants received 100 mg l^{-1} N in *Petunia* × *hybrida* Hort. Vilm. - Andr. ‘Coral Sea’. Khan *et al.* (2004) studied the influence of different dose of nitrogen in *Zinnia elegans* cv. Meteor and observed that vegetative characteristics increased with increase in the dose of nitrogen from 5 to 20 g per pot. Number of flowers per plant, flower diameter and duration of blooming period were reduced and first flower emergence was delayed at higher level of nitrogen. For improvement in the vegetative and floral characteristics, nitrogen application @ 20 and 10 g per pot was found effective.

A study was carried out by Noshir (2004) to evaluate the influence of nitrogen in balsam (*Impatiens balsamina* L.) cv. "Double Pink" and found that the highest level of nitrogen (30 g/m^2) produced maximum plant height, plant spread, number of branches, number of leaves, dry matter content of plant and leaf, pod number per plant, seed per pod, seed yield per plant and seed yield per meter square, whereas application of nitrogen at 20 g/m^2 resulted in maximum leaf area and pod length. Application of 200kg/ha nitrogen significantly increased the plant height, fresh weight, leaf/stem ratio, leaf+flower/stem ratio, and NPK uptake compared to control in South American marigold (*Tagetes minuta*) (Singh and Rao,2005).

A study to find out the effect of nitrogen on the growth and yield of red amaranth conducted by Nahar (2006) indicated that treatment with 115 kg/ha nitrogen significantly improved both growth and yield of red amaranth. In Zinnia cv. 'Giant Dahlia Flowered', application of nitrogen @ 100 kg ha^{-1} enhanced vegetative growth and moderate dose (67 kg N ha^{-1}) produced the highest number of flowers per plant, flower diameter and leaf nitrogen contents (Ahmad *et al*., 2007). Increase in nitrogen fertilizers from 0 to 100 kg N ha^{-1} improved the fresh and dry weight of foliage of periwinkle (Gholamhosseinpour *et al*., 2011).

An experiment conducted by Khalaj *et al*. (2012) pointed out that nitrogen application of 200 kg/ha and planting at 25cm spacing improved growth and floral characters like flower stalk length and stem diameter in tuberose. Grewal and Thakur (2016) revealed that 300 mg urea/pot was found beneficial in chrysanthemum (*Chrysanthemum morifolium* Ramat) cv. Anmol.

Kumar *et al*. (2016) studied the response of nitrogen and GA_3 on growth and flowering behavior of African marigold (*Tagetes erecta* L.) cv. Pusa Narangi Gainda and found that soil application of nitrogen@100kg/ha with foliar application of GA_3 @ 200ppm, at 20 and 50 days after transplanting was found beneficial in promoting characters like plant height, primary branches, secondary branches, plant spread, stem diameter, flower diameter, number of flowers per plant, fresh weight of flower per plant and yield of flower.

In another study by Shafiullah *et al*. (2018) plant height, number of branches per plant, number of leaves per plant, minimum number of days for flowering, number of flowers per plant and flower weight (20.66 g) were found the highest in Marigold (*Tagetes erecta* L.) which received nitrogen at the rate of 110 kg ha^{-1}.

Effect of phosphorous on growth and flowering of ornamental plants

Phosphorus is considered as the genetic "memory unit" of all living things. It is a component of RNA and aids in translating DNA genetic code. Phosphorus is a vital component of ATP, the "energy unit" of plants. It helps to establish seedlings quickly by stimulating early root development. It is also an essential component for seed formation.

There was an improvement in vegetative, pod and seed characters in balsam (*Impatiens balsamina* L.) cv. "Double Pink" with the application of phosphorus @ 20 g/m^2(Noshir, 2004). Fresh and dry weights, plant height and flowers per plant was improved with the application of phosphorus @ 120 kg/ha in Mexican Marigold (*Tagetes minuta* L.) (Nehagban *et al.,* 2014). Mukthar *et al*. (2016) evaluated the response of zinnia cultivars to different phosphorus levels and reported that number of flowers per plant, flower diameter, plant height, fresh flower and root weight and earlier flower initiation were observed the highest with the application of phosphorus @ 200 kg ha^{-1}.

Effect of potassium on growth and flowering of ornamental plants

Potassium is essential for photosynthesis and development of chlorophyll. It improves the vigour of the plants to enable to withstand adverse climatic conditions. It also regulates the opening and closing of stomata and movement of ions within the plants.

According to Singh and Rao (2005) plant height and NPK uptake increased with the application of 83.0 kg/ha potassium compared to control in South American marigold (*Tagetes minuta*). In African marigold cv. Siracole, the flower yield was found increased with increase in application of potassium fertilization from zero to 200 kg/ha (Pal and Ghosh, 2010). Zeb *et al*. (2015) revealed that characters like plant height, plant spread, primary and secondary branches, flower size and NPK content of the leaf improved with increase in potassium level in chrysanthemum (*Dendranthema grandiflorum*). Early flowering, maximum plant height, number of leaves per plant as well as fresh and dry weight of flower were observed with the application of 200 mg K_2O per pot.

EFFECT OF SPACING ON GROWTH AND FLOWERING OF ORNAMENTALS

Ravindran *et al*. (1986) conducted a study to evaluate the influence of spacing on performance of African marigold and observed that closest spacing of 30 x 30 cm produced maximum flower yield per hectare. In *Helichrysum bracteatum* cv. Tall Double Mixed, plant height increased with closer spacing (30 cm x 20 cm), while number of branches per plant, number of flowers per plant, weight of flowers per plant and diameter of flower increased with wider spacing (30 cm x 40 cm) while the yield of flower increased in closer spacing (30 cm x 20 cm) as reported by Venugopal (1991).

John and Paul (1992) observed that plant spread, number of branches per plant, number of flowers per plant and weight of flowers per plant increased significantly with increase in spacing *i.e*., 20 cm x 60 cm, whereas total yield of flowers per unit area was more under 20 cm x 30 cm spacing in globe amaranth. In marigold cv. 'African Yellow', vegetative growth and number of branches per plant were maximum under wider spacing and the number of flowers per plant was maximum under the closest spacing of 30 cm x 20 cm (Mohanty *et al.*, 1993). Ryagi (1994) noticed taller plants, higher leaf area and higher yield in closer spacing of 45 cm x 20 cm than wider spacing in 'golden rod'. At 60 x 30 cm spacing, there was improvement in plant height, plant spread and leaf production in statice cv. 'Forever Purple' as reported by Kumar and Kaur(1997).

The response of China aster to various spacings was compared by Singh and Sangma (2001) and found that number of flowers, weight of flowers and seed yield per plant showed significant improvement under wider spacing of 40 x 40 cm. However, the closest spacing of 20 x 10 cm recorded the highest weight of flowers and seed yield per hectare. Karavadia and Dhaduk (2002) reported that number of branches, plant spread and stem diameter were significantly greater when grown under wider spacing of 30 cm x40 cm in annual chrysanthemum cv. Local white. However, taller plants were recorded in closest spacing (30 cm x 20 cm) with significant higher yield of flowers per hectare.

Out of four levels of spacings tried in Zinnia, taller plants, highest plant spread and greater number of branches per plant were obtained for plants spaced at 40 cm x 30 cm and was superior over other spacings. Size of flower, number of heads and seed yield were also significantly higher compared to other spacings (Poonam *et al*., 2002). Studies conducted by Sodha and Dhaduk (2002) showed that wider spacing of 30 cm x 40 cm produced maximum number of leaves per plant, number of suckers, plant height and plant spread in *Solidago canadensis*.

In cosmos, greater plant spread and numbers of branches per plant were recorded under the wider spacing, 40 cm x 30 cm (Dubey *et al*, 2002). Number of flowers, number of heads and seed yield per plant were also recorded maximum under the wider spacing, 40 cm x 30 cm. Karuppaiah and Krishna (2005) reported maximum plant height, number of branches per plant, number of leaves per plant and leaf area per plant under the spacing, 30 cm x 30 cm, in French marigold. Floral characters like greater number of flowers per plant, flower weight, flower diameter and stalk length of flower were also observed under the spacing, 30 cm x 30 cm, which was significantly predominant over other spacings.

Chaudhary *et al*. (2007) analysed the impact of spacing on the performance of *Zinnia elegans* and observed that 30 x 45 cm spacing produced the best results for growth characters like plant height, number of branches per plant, length of branches, internodal length and number of nodes per plant. In *Coreopsis lanceolata*, the spacing of 60 cm x 30 cm resulted in the tallest plants (94.47cm) and more number of branches (Dhatt and Kumar, 2007). Tallest plants were produced at the spacing of 60 cm x 30 cm and plants with more branches were observed under wider spacing of 60 cm x 60 cm. In *Coreopsis tinctoria*, the planting density of 60 cm x 60 cm resulted in increase in number of branches per plant.

Sunitha *et al*. (2007) concluded that there was an improvement in number of branches when grown under wider spacing of 60 cm x 60 cm in African marigold cv. Orange Double. Higher seed yield per plant and per hectare were also recorded under wider spacing (60 cm x 60 cm). According to Sharma *et al*. (2009) maximum plant height, early flowering, more number of flowers per plant and highest flower yield were observed in plants spaced at a closer spacing of 50 cm x 40 cm, while plant spread, number of leaves per plant, number of branches per plant, duration of flowering and days taken for flower opening to harvest recorded were maximum under wider spacing (50 cm x 50 cm) in African marigold cv. Pusa Narangi Gainda.

Hemalatha *et al.* (2010) conducted a study on the effect of spacing on growth and post-harvest life in bachelor’s button and found that a spacing of 30 x 30cm recorded the maximum plant height, stem girth, number branches per plant and spread of plant. Chauhan (2011) conducted a study to find out the effect of planting dates and spacing on growth and flowering of marigold. Among the different spacing, a spacing of 45 x 30 cm was found to be the best with respect to longest flowering duration and flower yield in African marigold cv. ‘Pusa Narangi Gainda’ and a spacing of 30 x 20 cm was found best in French marigold Sel. ‘FM 786’ with respect to maximum number of flowers per plant and flower yield. Khalaj *et al.* (2012) showed that 25 x 25 cm spacing had a significant influence on flower stalk length, stem diameter, spike length, floret diameter, floret weight, vase life and nutrient uptake in tuberose. Studies by Sharma (2014) indicated that plants grown under closest spacing (20 x 15 cm) produced taller plants, earlier bud initiation and flower yield per square metre in *Gomphrena globosa.*

EFFECT OF SPACING AND FERTILIZERS ON GROWTH AND FLOWERING OFORNAMENTALS

Plants need the right combination of nutrients and sufficient spacing for maximizing their productivity.

A study was conducted by Singatkar (1993) to find out the influence of of fertilizers on performance of gaillardia (*Gaillardia pulchella* var. Lorenziana L.) and concluded that application of NPK @ 173 kg/ha, 103 kg/ha and @ 63kg/ha respectively was found to have significant effect on growth and yield of gaillardia. Chrysanthemum plants produced taller plants with more primary and secondary branches and took lesser days for flower opening when nitrogen and phosphorus was applied @ 200 kg per ha (Belgaonkar *et al*., 1996).

Studies conducted by Birade *et al*. (2003) revealed that plants grown at 30 x 30 cm spacing and received NPK @ 150: 100: 75 kg/ ha showed better growth and yield in China aster (*Callistephus chinensis* Ness.) cv. 'Alandi Local'. Acharya and Dashora (2004) showed that growth and flowering of *Tagetes erecta* cv. Pusa Basanti Gainda can be enhanced by supply of nitrogen and phosphorus each @ 200 kg/ha. Taller plants were recorded under spacing of 40 x 30 cm by Yadav *et al*. (2004) in *Tagetes erecta* whereas, an increase in plant spread, number of flowers and flower yield per plant were recorded when the plants were grown under 60 x 45 cm spacing. Also plants spaced at 45 x 45 cm and applied with 120 kg/ha nitrogen showed improvement in flower yield per plant. Javid *et al*. (2005) found that application of NPK @ 30:20:20 g/m^2 was the best for enhanced growth and flowering in *Zinnia elegans* cv. Wiryging Shade.

Singh *et al*. (2008) investigated the influence of NPK and spacing on yield of African marigold cv. 'Pusa Narangi Gainda' and concluded that plants spaced at widest spacing of 60 x 60 cm exhibited better growth and yield per plant. Size of flower and fresh weight of flower was reported to be highest at plant spacing of 45 x 45 cm. Optimum level of NPK @ 40:20:20 g/m^2 gave the best results with respect to plant growth and flower yield. Sharma *et al.* (2009) evaluated the influence of spacing as well as N and P levels on the growth, yield and quality of African marigold (*Tagetes erecta* L.) cv. Pusa Narangi Gainda and reported that the duration of flowering period and duration from flower opening to harvest were maximum under wider spacing (50x50cm) as well as nitrogen and phosphorous @ 150 kg/ha and 100 kg/ha respectively.

Hassan *et al*. (2009) reported that plant height, number of branches per plant, fresh and dry weight of plant as well as herb yield showed the greatest value with high level of N(150kg/4200m^2) and P (75kg/4200m^2) in periwinkle (*Catharanthus roseus*).

The period of emergence of flower bud and opening of first flower reduced with increasing N and P levels, while there was positive effect on flower life, number of branches and flowers per plant and plant height with increase in N and P rates. N and P application at 50+10 g/1.5 m^2 was found to be suitable for better zinnia flower production (Baloch *et al*., 2010).

Vembu *et al*. (2010) studied the effect of NPK levels on the growth and yield of *Catharanthus roseus* and the result revealed that the application of NPK @ 30: 40: 40 kg ha^{-1} improved growth characters like plant height, number of branches per plant and dry weight of leaves and root. Awchar *et al*. (2010) indicated that closer spacing of 45 cm × 30 cm and higher dose of nitrogen (200 kg ha^{-1}) improved the height of plant in gaillardia. In addition to this, wider spacing (60 cm × 60 cm) with higher dose of nitrogen (200 kg ha^{-1}) produced maximum plant spread, primary branches per plant, leaves per plant, seed yield per flower and plant. Closer plant spacing (45 cm × 30 cm) along with the application of higher dose of nitrogen (200 kg ha^{-1}) was found to be better for seed production in gaillardia.

According to Ahirwar *et al*. (2012) closer plant density of 50 x 40 cm with nitrogen and phosphorus each @ 100 kg ha^{-1} increased the yield of flowers in African marigold cv. Pusa Narangi Gainda and shelf life of flowers enhanced due to wider (50x50 cm) spacing and higher P levels. Islam (2013) evaluated the influence of spacing and phosphorus on growth and flowering of cockscomb and reported that 35×25 cm spacing with 50 kg P_2O_5/ha was found the best for better performance of cockscomb.

Alkurdi (2014) studied the impact of nitrogen and phosphorus on the growth and flowering of *Helichrysum bractum*. It was observed that the highest number of flowers was produced when applied with 1 mg phosphate per pot. Also it was concluded that 0.5 mg nitrogen per pot was adequate for maximum fresh and dry weights of the plant. Optimum growth and maximum flower production was reported by Polara *et al*. (2014) in marigold var. Pusa Narangi with the application of 200 kg N and 150 kg P_2O_5 as basal dose per hectare.

Application of urea promoted growth of *Celosia cristata*. Maximum flower as well as seed yield was reported by Yagi *et al*. (2014) in celosia at a spacing of 30 x 40cm. Wider spacing improved the spread of the plant whereas reduced the plant height. There was no significant effect of spacing and nitrogen on flower initiation of *C. cristata*.

A study conducted by Singh *et al*. (2015) revealed that improved vegetative and floral parameters were recorded with recommended dose of 120:80:40 kg NPK/ha in marigold var. Pusa Narangi Gainda. 200 kg ha^{-1} nitrogen and 30 cm x 30 cm spacing resulted in higher number of inflorescence in golden rod (Agarwal, 2015). According to Naik (2015) nitrogen application advanced flowering, while, phosphorus application delayed flowering in African marigold cv. Cracker Jack.

Aslam *et al*. (2016) conducted an experiment to find the impact of nitrogen and potassium on marigold and concluded that plant height, leaf area, number of lateral branches were better under 15-10-10 NPK g/m^2. Days to flower appearance responded inversely to increasing doses of nitrogen and potassium, while control took the lowest days to flower appearance. Seed weight per plant and 1000 seed weight of flowers were found highest at 15-10-10 NPK g/m^2. Badole *et al*. (2016) studied the effect of nitrogen and phosphorus on yield and quality of gaillardia and concluded that maximum diameter of fully opened flowers and total blooming period were recorded with the application of nitrogen @ 150 kg N $ha^{-1}$and phosphorus @ 75 kg $P_2O_5ha^{-1.}$

Duggani (2016) reported that days taken for first and 50 per cent flowering increased in plants grown at closer spacing and increasing levels of fertilizers in *Gomphrena globosa* L. cv.AGS-5. Wider spacing of 45 x 30 cm and fertilizer dose of 250:75:150 NPK kg/ha significantly enhanced the flower production and floral characters like duration of flowering, flower diameter, flower weight, shelf life of flower on plant and seed yield

Ohshiro *et al.* (2016) reported that NPK fertilizer at 20–40 g /sqm was effective in gray soil in Okinawa for higher yield of *Amaranthus tricolor.* Saravanan and Kumar (2016) studied the effect of different doses of NPK on plant growth and flower yield of African marigold and found that application of NPK @

125:100:100 kg/ha was the best treatment for good vegetative as well as reproductive growth. Vinayak *et al*. (2017) observed that there was an improvement in growth and floral characters of salvia (*Salvia splendens* L.) grown under spacing of 30 × 30 cm along with application of 100 kg/ha nitrogen.

A fertilizer study conducted by Verma *et al*. (2017) in *Chrysanthemum cinerariaefolium* indicated that the growth and floral characters were significantly higher with nitrogen, phosphorus and potassium @ 100 kg/ha, 100 kg/ha and 60 kg/ha respectively. Singh (2018) proved that nitrogen (100 kg/ha) and phosphorus (200 kg/ha) application enhanced the flowering and yield of zinnia.

Saeed and Kareem (2018) recommended that nitrogen and phosphorus application @ 175 kg/ha and 125 kg/ha was found to be beneficial in increasing the vegetative and floral characters of zinnia (*Zinnia elegans*) var. Benary′s Giant Mix. Kundu *et al*. (2019) reported that nitrogen @ 30g/m^2 and phosphorous @ 20g/m^2 improved the floral and yield parameters in *Tagetes erecta* cv. Local selection. Application of nitrogen @ 150 kg/ha and P_2O_5 @ 75 kg/ha significantly improved vegetative growth as well as quality and yield of cut chrysanthemum cv. Thai Chen Queen whereas, taller plants were observed in plants receiving nitrogen @ 200 kg/ha (Rajan *et al*., 2019).

Materials and Methods

3. MATERIALS AND METHODS

The present study on ‘Spacing and nutrient management of *Gomphrena globosa* L. was carried out in the Department of Floriculture and Landscaping, College of Horticulture, Vellanikkara, Thrissur from May 2019 to December 2019. The materials used and methodology involved are described below.

LOCATION

Vellanikkara is situated 22.25 m above MSL at a latitude of $10^0$31’N and longitude of $76^0$13’E.

CLIMATE

The region experiences a humid tropical climate. During the study period, maximum temperature varied from 29.5^0C to 346^0C and minimum temperature varied from 21.4^0C to 24.9^0C whereas, rainfall ranged from 4.4 mm to 977.5 mm (minimum in December and maximum in August). The mean relative humidity was in the range of 63 per cent to 89 per cent. The meteorological data for the study period are given in Appendix I.

MATERIALS

a. Seed sowing

Seeds of *Gomphrena globosa* were sown in pro-trays filled with coirpith, vermiculite and perlite in the ratio 3:1:1.

b. Nursery management

Seedlings were irrigated regularly to provide sufficient moisture. Germination started within a week. Foliar application of NPK (19:19:19) weekly twice @ 0.1 % was given to the seedlings.

c. Transplanting

Transplanting of the seedlings was done after one month at 3-4 leaf stage. Seedlings were transplanted in the prepared beds of 2mx2m size.

The plant population at 30x30 cm was 30 plants per 4 m^2 (1, 11,111 plants/ha) and at 45x45 cm was 16 plants per 4 m^2 (49,383 plants/ha).

TREATMENTS

Design of the experiment: Randomized Block Design (RBD)

Number of treatments :8

Number of replications :3

T1 – NPK @ 50:25:50 kg/ha; Spacing – 30x30cm

T2 – NPK @ 50:25:50 kg/ha; Spacing – 45x45cm

T3 – NPK @ 75:50:75 kg/ha; Spacing – 30x30cm

T4 – NPK @ 75:50:75 kg/ha; Spacing – 45x45cm

T5 – NPK @ 100:50:100 kg/ha; Spacing –30x30cm

T6 – NPK @ 100:50:100 kg/ha; Spacing –45x45cm

T7 – Control; Spacing –45x45cm

T8 – Control; Spacing –30x30cm

Fertilizers were applied in two splits. First application was done at the time of planting (half nitrogen, full phosphorus and half potassium). Second application was done one month after planting (remaining nitrogen and potassium). Urea, Ammonium Phosphate Sulphate and Muriate of Potash were used as source of N, P_2O_5 and K_2O respectively. FYM @ 25 t/ha was applied uniformly to all treatments including control (T7 andT8).

Gomphrena seedlings used as planting material

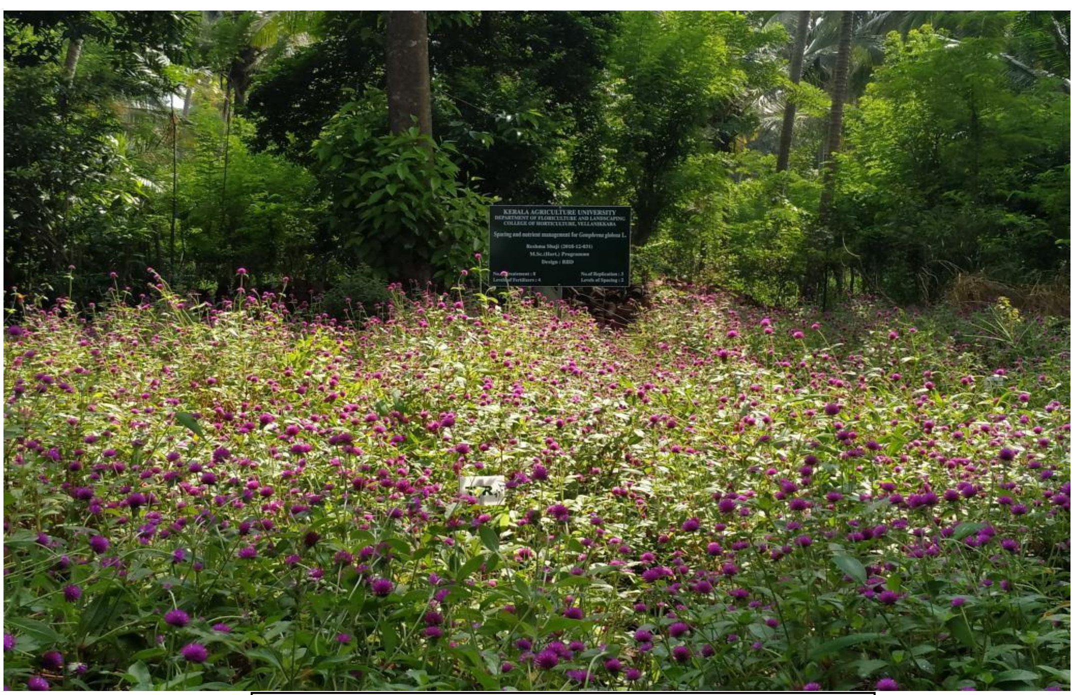
Raised beds

Plate 1 Materials used for experiment

30x30 cm

45x45cm

At planting



At peak flowering stage

Plate 2 General view of the field

Initiation of bud

Development of bud

Opening of flower

Complete opening of flower

Plate 3 Stages of flower development

N

a. Layout of the experiment

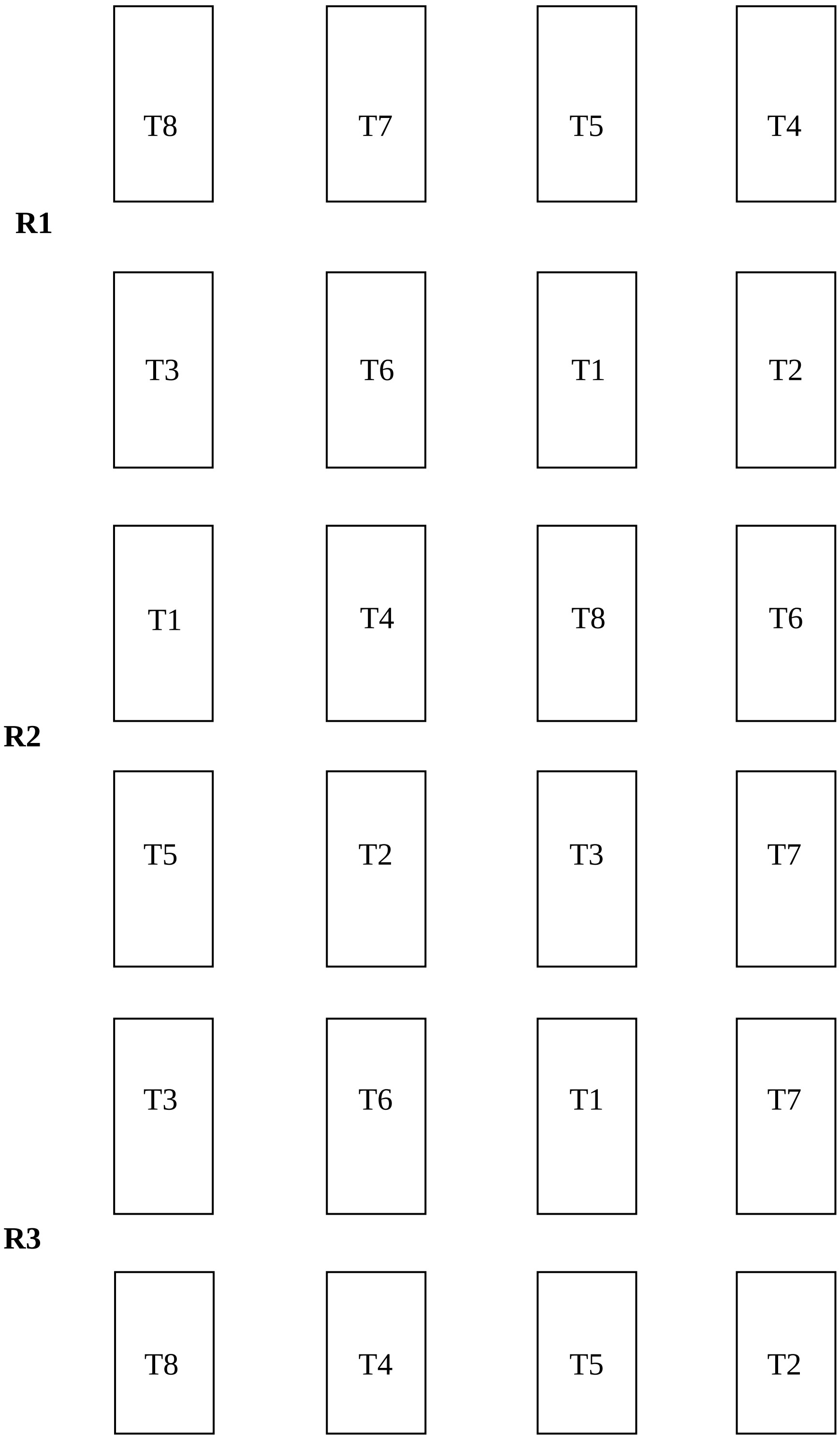


Figure 1 Layout of the experiment

No. of treatments: 8	Design: RBD
No. of replications: 3	Plot size: 2mx2m

b. Field management

Regular irrigation was given to ensure enough soil moisture. Timely application of fertilizers was done as per the treatments. Earthing up was carried out for better root anchorage. The field was maintained weed-free by timely weeding. Plant protection chemicals were also applied as required.

OBSERVATIONS

Vegetative parameters were recorded at bud initiation stage and floral observations were recorded during flowering phase. Observations of 12 plants per replication in 30x30 cm spacing treatments and 4 plants per replication in 45x45 cm spacing treatments were recorded.

Vegetative characters

a. Plant height

Height of the plants was measured from the base to the growing tip and expressed in centimetre.

b. Plant spread

Spread of the plant was measured in the North-South and East-West directions and the average was expressed in centimetre.

c. Number of branches per plant

Total number of branches present in the plant was counted and recorded as number of branches.

d. Total dry matter per plant (at harvest)

Weight of the oven dried plant was recorded and expressed in g/plant and t/ha.

Floral characters

a. Days to bud initiation

Days taken for flower bud formation were counted from the date of transplanting to appearance of first flower bud.

b. Days to complete flower opening

Days taken for complete flower opening were counted from appearance of flower bud to complete opening of flower.

c. Days to 50 %flowering

Number of days taken for 50% of the plant in a treatment started flowering was recorded.

d. Number of flowers per plant

Number of flowers from each plant was counted during each harvest and added to get number of flowers per plant.

e. Stalk length

Stalk length of ten flowers per replication were measured from the base of the flower shoot to the base of the flower head and expressed in centimetre.

f. Flower weight

Weight of 100 matured flowers per treatment were recorded immediately after harvest and expressed in grams.

g. Flower head diameter (cm)

Flower head diameter of ten flowers per replication was recorded and expressed in centimeter.

h. Flower yield

Weight of the flower obtained from each observational plant was recorded at each harvest and added to get yield in g/plant and t/ha.

i. Duration of flowering

Number of days from appearance of first flower bud to withering of last flower per replication was counted and recorded as duration of flowering, in days.

j. Days taken to first picking

Number of days taken from transplanting to harvesting was recorded as days taken to first picking.

k. Number of pickings

Number of harvests per treatment was recorded.

l. Seed yield per flower

Weight of seeds of individual flowers per replication was recorded and expressed in gram.

Post harvest parameters

a. Shelf life of flowers

Number of days taken for half of the flowers to wilt after harvest, was recorded and expressed as shelf life of flowers.

b. Physiological loss in weight

The loss in weight of ten flowers kept for shelf life was recorded by deducting the weight at the end of shelf life study from, the initial fresh weight of the flower and expressed in percentage.

Incidence of pest and diseases

Pest and disease incidence was observed and timely control measures were taken.

Nutrient analysis

Soil samples were collected and sampled to analyze pH, organic carbon, phosphorus and potassium, before and after the conduct of experiment. Dried plant samples were also analyzed for nitrogen, phosphorus and potassium and uptake of these nutrients were calculated. The samples were analyzed using the methods listed in Table1.

Table 1 Methods followed for the analysis of soil and plant samples

Sl. No.	Parameter	Nutrient status of soil (Before experiment)	Method followed	Reference
1	Organic carbon (%)	0.82	Walkley and Black's rapid titration method	Walkley and Black (1934)
2	Available phosphorus (kg/ha)	23.60	Bray-1 extractant Ascorbic acid reductant method	Watanabe and Oslen (1965)
3	Available potassium (kg/ha)	356.16	Neutral normal ammonium acetate extract using flame photometer	Jackson (1958)
4	Plant nitrogen (%)	-	Kjeldahl digestion and distillation method	Jackson (1958)
5	Plant phosphorus (%)	-	Vanado-molybdo phosphoric yellow colour method	Johnson and Ulrich(1959)
6	Plant potassium (%)	-	Flame photometer	Jackson (1958)
7	pH	6.2	Digital pH meter	-

STATISTICAL ANALYSIS

The statistical analysis of the recorded data was done using the software WASP 2.0 (Web Agri Stat Package).

Results

4. RESULTS

An experiment entitled 'Spacing and nutrient management of *Gomphrena globosa* L.' was carried out in the Department of Floriculture and Landscaping, College of Horticulture, Vellanikkara, Thrissur, to standardize the spacing and fertilizer requirement of *Gomphrena globosa* for cultivation under the warm humid tropical regions of Kerala. The results generated are presented below.

VEGETATIVE CHARACTERS

Data corresponding to the effect of spacing and nutrients on vegetative characters of *Gomphrena globosa* are presented in Table 2 and Table 3.

a. Plant height

Plant height was significantly influenced by spacing and nutrient doses. Highest plant height of 37.70 cm was observed in closer spacing of 30x30 cm than wider spacing of 45x45cm (34.65 cm). Among different fertilizer treatments with NPK @ 50:25:50kg/ha, 75:50:75 kg/ha and 100:50:100 kg/ha, plant height was found on par with one another except control (38.70 cm, 37.41 cm, 37.23 cm and 31.33 cm respectively). The interaction effect of spacing and nutrients on plant height was found non significant, which ranged from 29.96 cm to 41.08cm.

b. Plant spread

Significant variation was observed in plant spread with respect to different spacings. The maximum plant spread of 34.92 cm was observed in the wider spacing of 45x45 cm and lowest plant spread was recorded in the closer spacing (31.59 cm). Regarding the effect of different levels of nutrients on plant spread, all the treatments except control was found statistically on par (33.65 cm, 34.10 cm, 34.72 cm and 30.53 cm). There was no significant difference with respect to the interaction effect of spacing and nutrients on plant spread and varied from 26.61 cm to 37.69 cm.

c. Number of branches/plant

Number of branches was significantly influenced by different spacings. Treatment with 45x45 cm spacing was found to have the highest number of branches per plant (14.83) and 30x30 cm spacing produced lowest number of branches (11.62). NPK @ 100:50:100 kg/ha produced 15.05 branches per plant which was found on par with NPK @ 75:50:75 kg/ha and 50:25:50 kg/ha (13.63 and 13.23). The interaction effect of spacing and nutrients did not show significant difference among different treatments. The number of branches per plant varied from 10.14 to 17.75.

d. Total dry matter production

There was significant difference with respect to total dry matter content per plant among different spacing. Wider spacing of 45x45 cm recorded the significantly highest dry matter production (52.53 g/plant) and 30x30 cm spacing treatment had (44.97 g/plant). All nutrient treatments except control were found on par with one another (48.10, 50.27, 51.48 and 45.14 g/plant). The interaction effect was not found significant. And the dry matter production (t/ha) was found highest in closer spacing than wider spacing (4.00 and 2.08 t/ha). Among different nutrient treatments, NPK @ 100:50:100 kg/ha recorded the maximum dry matter production (3.18 t/ha) which was on par with NPK @ 75:50:75 kg/ha (3.12 t/ha). The lowest dry matter was produced in control treatment (2.85 t/ha). There was no significant difference among interaction effect of spacing as well as nutrients and varied from 1.86 to 4.14t/ha.

Table 2 Effect of spacing and nutrients on growth parameters of gomphrena

Treatments	Plant height (cm)	Plant spread (cm)	No. of branches/plant	Dry matter production (g/plant)	Dry matter production (t/ha)
S1- Spacing – 30x30cm	37.70	31.59	11.62	44.97	4.00
S2 - Spacing – 45x45cm	34.65	34.92	14.83	52.53	2.08
CD(0.05)	**2.36**	**1.73**	**1.20**	**2.60**	**0.12**
F1 - NPK @ 50:25:50 kg/ha	38.70	33.65	13.23	48.10	2.99
F2 - NPK @ 75:50:75 kg/ha	37.41	34.10	13.63	50.27	3.12
F3 - NPK @ 100:50:100 kg/ha	37.23	34.72	15.05	51.48	3.18
F4 – Control	31.33	30.53	10.98	45.14	2.85
CD(0.05)	**3.33**	**2.45**	**2.26**	**3.68**	**0.17**

Table 3 Interaction effect of spacing and nutrients on growth parameters of gomphrena

Treatments	Plant height (cm)	Plant spread (cm)	No. of branches/plant	Dry matter production (g/plant)	Dry matter production (t/ha)
T1- NPK @ 50:25:50 kg/ha; Spacing – 30x30cm	41.08	32.75	11.89	44.01	3.91
T2 - NPK @ 50:25:50 kg/ha; Spacing – 45x45cm	36.34	34.56	14.58	52.20	2.06
T3 - NPK @ 75:50:75 kg/ha; Spacing – 30x30cm	38.93	32.22	12.11	46.01	4.09
T4 - NPK @ 75:50:75 kg/ha; Spacing – 45x45cm	35.89	35.98	15.17	54.52	2.15
T5 - NPK @ 100:50:100kg/ha; Spacing -30x30cm	38.06	31.76	12.36	46.53	4.14
T6 - NPK @ 100:50:100 kg/ha; Spacing – 45x45cm	36.42	37.69	17.75	56.44	2.23
T7 – Control; Spacing – 30x30cm	32.70	29.61	10.14	43.32	3.85
T8 – Control; Spacing –45x45cm	29.96	31.46	11.83	46.97	1.86
CD(0.05)	**NS**	**NS**	**NS**	**NS**	**NS**

FLORAL CHARACTERS

The effect of spacing and nutrients on floral characters of gomphrena is furnished in Table 4 to Table 7.

a. Days to bud initiation

There was significant variation among the treatments with respect to days for bud initiation. Treatments with 30x30 cm spacing took the least number of days for bud initiation (46.81 days) when compared to 45x45 cm spacing (53.35 days). Nutrient treatment did have any significant influence on days to bud initiation. With respect to the interaction effect of spacing and nutrients, T1took the least number of days for bud initiation (42.78 days) and was on par with T7 (44.78 days). Also, all other treatments except T8 were found on par with one another. Maximum number of days for bud initiation was observed in T8 (58.33days).

b. Days to complete flower opening

Spacing and nutrients did not have significant influence on days taken for complete flower opening. The spacing x nutrient interaction was also found to be non significant.

c. Days to 50%flowering

There was significant effect of spacing on days taken for 50% flowering. Treatments with closer spacing took least number of days to 50% flowering compared to wider spacing (50.58 days and 54.92 days respectively). There was no significant influence of nutrients as well as interaction effect of spacing and nutrients, on 50% flowering.

d. Number of flowers/plant

Significant effect of spacing was observed with respect to number of flowers per plant. Wider spacing of 45x45 cm produced highest number of flowers (42.64) and 30x30 cm spacing produced least number of flowers (30.78) (Plate 4). Significant difference was not observed among different nutrient treatments and the interaction effects with respect to number of flowers.

e. Stalk length

Significant variation could not be observed among the treatments with respect to flower stalk length.

f. Hundred flower weight

Flower weight was not influenced significantly by spacing, nutrients and their interaction as evidenced from Table 5 and Table 6.

g. Flower head diameter

Spacing and nutrients had no significant effect on flower head diameter of gomphrena.

h. Flower yield

There was significant effect of spacing on flower yield of the plant. Highest flower yield of 40.90 g/plant was observed in wider spacing than closer spacing (28.15 g/plant). Treatments with NPK @ 50:25:50kg/ha had produced maximum flower yield (40.41 g/plant) which was on par with NPK @ 75:50:75 kg/ha (35.11 g/plant). The lowest flower yield was observed in control plants (29.93 g/plant) without fertilizer treatments. And the flower yield per hectare was found to be highest in closer spacing of 30x30 cm (2.50 t/ha) than wider spacing (1.56 t/ha). The interaction of spacing and nutrients did not have significant influence on floweryield.

i. Duration of flowering

Duration of flowering was not significantly influenced by spacing, nutrients and their interaction.

j. Days taken to first picking

Days taken for first picking did not vary significantly among different treatments which were observed in the narrow range of 102.67-103.33 days.

Plate 4 Effect of spacing and nutrients on number of flowers/plant

k. Number of pickings

Significant variation was not observed among the treatments with respect to number of flower pickings. Two pickings were obtained from all the treatments.

l. Seed yield/flower

From the results it is evident that spacing had significant influence on seed yield per flower. Seed yield per flower (0.29 g) was found highest in 45x45 cm spacing while lowest seed yield was observed in 30x30 cm spacing (0.25 g). Nutrients and their interaction with spacing did not produce any significant variation in seed yield per flower.

Table 4 Effect of spacing and nutrients on floral characters of gomphrena

Treatments	Days to bud initiation	Days to complete flower opening	Days to 50% flowering	Number of flowers per plant	Stalk length (cm)	Hundred flower weight (g)
S1- Spacing – 30x30cm	46.81	34.36	50.58	30.78	15.14	86.71
S2 - Spacing – 45x45cm	53.35	33.45	54.92	42.64	16.15	87.14
CD(0.05)	**2.13**	**NS**	**2.15**	**6.12**	**NS**	**NS**
F1 - NPK @ 50:25:50 kg/ha	47.68	36.68	50.83	42.96	15.15	84.04
F2 - NPK @ 75:50:75 kg/ha	49.90	33.80	52.17	37.08	16.04	89.89
F3 - NPK @ 100:50:100 kg/ha	51.18	32.43	53.00	35.25	16.76	92.00
F4 – Control	51.56	33.73	55.00	31.56	14.65	81.793
CD(0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

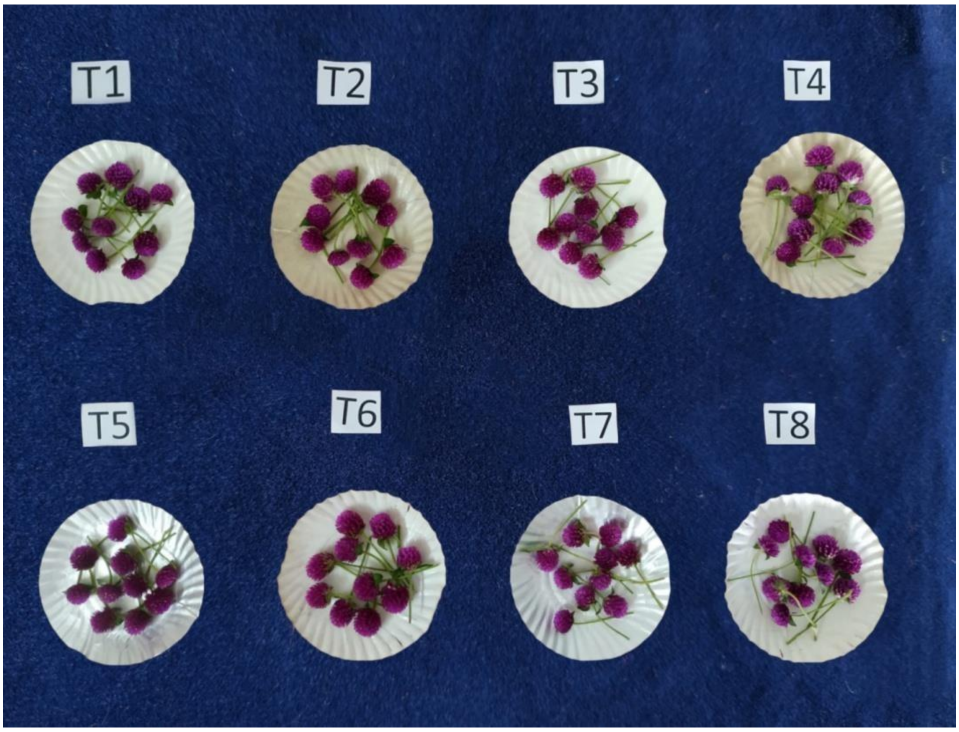


Plate 5 Flowers kept for shelf life study

Leaf spot disease

Leaf roller infestation

Plate 6 Incidence of disease and pest

Table 5 Interaction effect of spacing and nutrients on floral characters of gomphrena

Treatments	Days to bud initiation	Days to complete flower opening	Days to 50% flowering	Number of flowers per plant	Stalk length (cm)	Hundred flower weight (g)
T1- NPK @ 50:25:50 kg/ha; Spacing – 30x30cm	42.78	34.69	49.68	34.08	15.08	83.03
T2 - NPK @ 50:25:50 kg/ha; Spacing – 45x45cm	52.58	36.67	52.00	51.83	15.22	85.04
T3 - NPK @ 75:50:75 kg/ha; Spacing – 30x30cm	49.22	33.28	50.33	32.83	15.54	89.76
T4 - NPK @ 75:50:75 kg/ha; Spacing – 45x45cm	50.58	34.33	54.00	41.33	16.53	90.01
T5 - NPK @ 100:50:100kg/ha; Spacing -30x30cm	50.44	32.78	51.33	30.00	15.73	91.50
T6 - NPK @ 100:50:100 kg/ha; Spacing – 45x45cm	51.91	32.08	54.67	40.50	17.78	92.50
T7 – Control; Spacing – 30x30cm	44.78	36.72	51.00	26.19	14.23	81.02
T8 – Control; Spacing –45x45cm	58.33	30.75	59.00	36.91	15.09	82.56
CD(0.05)	**4.26**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 6 Effect of spacing and nutrients on floral characters of gomphrena

Treatments	Flower head diameter (cm)	Flower yield (g/plant)	Flower yield (t/ha)	Duration of flowering (days)	Days taken for first picking	Number of pickings	Seed yield per flower (g)
S1- Spacing – 30x30cm	1.93	28.15	2.50	91.74	102.33	2.00	0.25
S2 - Spacing – 45x45cm	1.96	40.90	1.56	92.66	103.00	2.17	0.29
CD(0.05)	**NS**	**5.10**	**0.33**	**NS**	**NS**	**NS**	**0.03**
F1 - NPK @ 50:25:50 kg/ha	1.92	40.41	2.35	90.19	103.00	2.17	0.26
F2 - NPK @ 75:50:75 kg/ha	1.97	35.11	2.13	93.36	103.00	2.17	0.28
F3 - NPK @ 100:50:100 kg/ha	2.00	32.63	1.90	95.79	103.00	2.00	0.28
F4 – Control	1.89	29.93	1.73	89.45	102.67	2.00	0.24
CD(0.05)	**NS**	**7.21**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 7 Interaction effect of spacing and nutrients on floral characters of gomphrena

Treatments	Flower head diameter (cm)	Flower yield (g/plant)	Flower yield (t/ha)	Duration of flowering (days)	Days taken for first picking	Number of pickings	Seed yield per flower (g)
T1- NPK @ 50:25:50 kg/ha; Spacing – 30x30cm	1.90	30.47	2.70	90.05	103.33	2.00	0.23
T2 - NPK @ 50:25:50 kg/ha; Spacing – 45x45cm	1.93	50.36	2.00	90.33	102.67	2.33	0.29
T3 - NPK @ 75:50:75 kg/ha; Spacing – 30x30cm	1.96	30.20	2.68	92.00	102.67	2.00	0.25
T4 - NPK @ 75:50:75 kg/ha; Spacing – 45x45cm	1.97	40.02	1.58	94.72	103.33	2.33	0.30
T5 - NPK @ 100:50:100kg/ha; Spacing -30x30cm	1.98	24.88	2.21	95.25	102.67	2.00	0.27
T6 - NPK @ 100:50:100 kg/ha; Spacing – 45x45cm	2.03	40.38	1.60	96.33	103.33	2.00	0.30
T7 – Control; Spacing – 30x30cm	1.89	27.03	2.40	89.67	102.67	2.00	0.23
T8 – Control; Spacing –45x45cm	1.91	32.82	1.06	89.25	102.67	2.00	0.26
CD(0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

POST HARVEST PARAMETERS

Data related to effect of spacing and nutrients on post-harvest parameters are furnished in Table 8.

a. Shelf life of flowers

There was no significant effect of spacing and nutrients on the shelf life of flowers.

b. Physiological loss in weight

Spacing and nutrients did not have any significant influence on physiological loss in weight.

INCIDENCE OF PESTS AND DISEASES

a. Incidence of pests

The larvae of leaf roller caused damage by curling the edges of leaves to create a rolled leaf shelter and by feeding on the folded leaves (Plate 6). Spraying of quinalphos (Ekalux 2ml/L) could control the pest.

b. Incidence of diseases

Leaf spot caused by *Alternaria gomphrenae* was found severe during the month of July and August. Leaf spots began as tiny reddish purple spots which later turned to grey spots with a reddish or purple border (Plate 6). Copper oxy chloride (Fytolan 3g/L) was sprayed to control the disease.

Table 8 Effect of spacing and nutrients on post-harvest parameters of gomphrena flower

Treatments	Shelf life of flowers (Days)	Physiological loss in weight (%)
S1- Spacing – 30x30cm	19.33	70.20
S2 - Spacing – 45x45cm	18.25	69.98
CD(0.05)	**NS**	**NS**
F1 - NPK @ 50:25:50 kg/ha	19.50	70.66
F2 - NPK @ 75:50:75 kg/ha	18.33	71.00
F3 - NPK @ 100:50:100 kg/ha	18.83	69.82
F4 – Control	18.50	68.89
CD(0.05)	**NS**	**NS**
T1- NPK @ 50:25:50 kg/ha; Spacing – 30x30cm	21.33	71.06
T2 - NPK @ 50:25:50 kg/ha; Spacing – 45x45cm	17.67	70.25
T3 - NPK @ 75:50:75 kg/ha; Spacing – 30x30cm	19.67	71.30
T4 - NPK @ 75:50:75 kg/ha; Spacing – 45x45cm	17.00	70.69
T5 - NPK @ 100:50:100kg/ha; Spacing -30x30cm	20.67	70.23
T6 - NPK @ 100:50:100 kg/ha; Spacing – 45x45cm	17.00	69.42
T7 – Control; Spacing – 30x30cm	19.33	68.23
T8 – Control; Spacing –45x45cm	17.67	69.53
CD(0.05)	**NS**	**NS**

NUTRIENT STATUS OF SOIL

Available nutrient status of the soil after the experiment is depicted in Table 9.

a. Soil pH

A soil pH of 6.2 was recorded before planting. There was no significant difference in soil pH after planting and it ranged from 6.3 to 6.5.

b. Organic carbon

Organic carbon content in the soil before the experiment was 0.82 %. After the final harvest the organic carbon did not vary significantly among the treatments and it ranged between 1.20 - 1.44%.

c. Available phosphorus

Before the experiment the available phosphorus in the soil was recorded as 23.60 kg/ha. After the experiment, the highest phosphorus was found in F3 and F2 (45.42 and 43.17 kg/ha). There was no significant effect of spacing nutrient interaction and the phosphorus content varied from 23.71 kg/ha to 45.94kg/ha.

d. Available potassium

Available potassium in the soil before experiment was 356.16 kg/ha. After the harvest the potassium content in the soil was highest in F3 and F2 (341.97 kg/ha and 300.53 kg/ha). The interaction effect was found non significant and was in the range of 191.68 kg/ha to 346.08kg/ha.

Table 9 Nutrient status of the soil after the experiment

Treatments	Soil pH	Organic carbon (%)	Available phosphorus (kg/ha)	Available potassium (kg/ha)
S1- Spacing – 30x30cm	6.3	1.30	34.37	262.77
S2 - Spacing – 45x45cm	6.4	1.38	35.93	287.93
CD(0.05)	**NS**	**NS**	**NS**	**NS**
F1 - NPK @ 50:25:50 kg/ha	6.3	1.39	27.21	255.36
F2 - NPK @ 75:50:75 kg/ha	6.4	1.29	45.42	300.53
F3 - NPK @ 100:50:100 kg/ha	6.4	1.38	43.17	341.97
F4 – Control	6.5	1.29	24.79	203.54
CD(0.05)	**NS**	**NS**	**8.83**	**82.59**
T1- NPK @ 50:25:50 kg/ha; Spacing – 30x30cm	6.3	1.34	26.75	222.88
T2 - NPK @ 50:25:50 kg/ha; Spacing – 45x45cm	6.4	1.44	27.67	287.84
T3 - NPK @ 75:50:75 kg/ha; Spacing – 30x30cm	6.3	1.26	44.90	298.67
T4 - NPK @ 75:50:75 kg/ha; Spacing – 45x45cm	6.4	1.32	45.94	302.40
T5 - NPK @ 100:50:100kg/ha; Spacing -30x30cm	6.4	1.36	42.11	337.87
T6 - NPK @ 100:50:100 kg/ha; Spacing – 45x45cm	6.4	1.39	44.23	346.08
T7 – Control; Spacing – 30x30cm	6.4	1.20	23.71	191.68
T8 – Control; Spacing –45x45cm	6.5	1.38	25.87	215.41
CD(0.05)	**NS**	**NS**	**NS**	**NS**

PLANT NUTRIENT CONTENT AND UPTAKE

Data pertaining to the nutrient content in the plant samples and nutrient uptake by plants are furnished in Table 10 and Table 11.

a. NPK content

Nitrogen content in the plant varied significantly among different spacing treatments. The highest nitrogen content (0.98 %) was recorded in 45x45 cm spacing when compared to 30x30 cm spacing (0.67 %). Among different nutrient treatments, all treatments except control were significantly on par. Spacing and nutrient interaction was not found have significant effect on NPK content of plant.

Significant effect of spacing and nutrients was found in phosphorus content of the plants. Treatment with wider spacing had highest P content (0.32 %) compared to closer spacing (0.30 %). Treatments with NPK @ 75:50:75 kg/ha and NPK @ 100:50:100 kg/ha had significantly the highest P content (0.35 %) and control had the lowest P content (0.24 %).There was no significant variation in phosphorus content of the plants with respect to interaction of spacing and nutrients.

Potassium content did vary significantly among different spacing treatments. K content was found to be highest in treatment with NPK @ 100:50:100 kg/ha (2.18 %) which was on par with NPK @ 75:50:75 kg/ha (1.73 %). The lowest K content was observed in control (1.30 %). The interaction of spacing and nutrients did not produce significant difference in potassium content of the plants.

b. Uptake of nutrients

There was a no significant effect of spacing in the nitrogen uptake by plants. However, N uptake was more in plants grown at closer spacing (26.93 kg/ha) than plants grown at wider spacing (20.70 kg/ha). N uptake of treatments with nutrient application, was found on par with one another other, except control (F1: 22.10 kg/ha, F2: 27.45 kg/ha, F3: 32.86 kg/ha and F4: 12.84 kg/ha). N uptake was not influenced significantly by the interaction of spacing and nutrients.

Phosphorus uptake was found to be significantly different among the spacing treatments. Maximum uptake of phosphorus was found in closer spacing (11.72

kg/ha) which was significantly higher than wider spacing. P uptake was found highest in the treatment with NPK @ 100:50:100 kg/ha (11.39 kg/ha) which was on par with NPK @ 75:50:75 kg/ha (10.05 kg/ha) and lowest in control (6.87 kg/ha). The interaction of both the factors did not influence the P uptake of the plants.

Significant variation was observed in potassium uptake by the plants with different spacing treatments. Potassium uptake was maximum in closer spacing (61.84 kg/ha) which was significantly superior to wider spacing (36.01 kg/ha). The nutrients and their interactions were not found to have significant effect on K uptake by the plants.

Table 10 Plant nutrient content of different treatments in gomphrena

Treatments	Nitrogen content (%)	Phosphorus content (%)	Potassium content (%)
S1- Spacing – 30x30cm	0.67	0.30	1.67
S2 - Spacing – 45x45cm	0.98	0.32	1.72
CD(0.05)	**0.26**	**0.02**	**NS**
F1 - NPK @ 50:25:50 kg/ha	0.81	0.30	1.54
F2 - NPK @ 75:50:75 kg/ha	0.92	0.35	1.73
F3 - NPK @ 100:50:100 kg/ha	1.10	0.35	2.18
F4 – Control	0.47	0.24	1.30
CD(0.05)	**0.36**	**0.02**	**0.51**
T1- NPK @ 50:25:50 kg/ha; Spacing – 30x30cm	0.87	0.28	1.50
T2 - NPK @ 50:25:50 kg/ha; Spacing – 45x45cm	1.33	0.31	1.57
T3 - NPK @ 75:50:75 kg/ha; Spacing – 30x30cm	0.78	0.35	1.61
T4 - NPK @ 75:50:75 kg/ha; Spacing – 45x45cm	1.06	0.36	1.87
T5 - NPK @ 100:50:100kg/ha; Spacing -30x30cm	0.61	0.34	2.14
T6 - NPK @ 100:50:100 kg/ha; Spacing – 45x45cm	1.02	0.37	2.22
T7 – Control; Spacing –30x30cm	0.40	0.23	1.22
T8 – Control; Spacing –45x45cm	0.54	0.26	1.38
CD(0.05)	**NS**	**NS**	**NS**

Table 11 Plant nutrient uptake with different treatments in gomphrena

Treatments	Nitrogen uptake (kg/ha)	Phosphorus uptake (kg/ha)	Potassium uptake (kg/ha)
S1- Spacing – 30x30cm	26.93	11.72	61.84
S2 - Spacing – 45x45cm	20.70	6.79	36.01
CD(0.05)	**NS**	**0.57**	**11.56**
F1 - NPK @ 50:25:50 kg/ha	22.10	8.72	45.47
F2 - NPK @ 75:50:75 kg/ha	27.45	10.05	52.88
F3 - NPK @ 100:50:100 kg/ha	32.86	11.39	59.39
F4 – Control	12.84	6.87	37.98
CD(0.05)	**12.10**	**0.81**	**NS**
T1- NPK @ 50:25:50 kg/ha; Spacing – 30x30cm	23.86	11.08	59.00
T2 - NPK @ 50:25:50 kg/ha; Spacing – 45x45cm	20.34	6.36	31.94
T3 - NPK @ 75:50:75 kg/ha; Spacing – 30x30cm	32.12	12.52	65.53
T4 - NPK @ 75:50:75 kg/ha; Spacing – 45x45cm	22.78	7.57	40.23
T5 - NPK @ 100:50:100kg/ha; Spacing -30x30cm	36.08	14.30	69.55
T6 - NPK @ 100:50:100 kg/ha; Spacing – 45x45cm	29.65	8.47	49.20
T7 – Control; Spacing – 30x30cm	15.66	8.98	53.28
T8 – Control; Spacing –45x45cm	10.02	4.77	22.67
CD(0.05)	**NS**	**NS**	**NS**

Discussion

5. DISCUSSION

An investigation entitled ‘Spacing and nutrient management of *Gomphrena globosa* L. was carried out in the Department of Floriculture and Landscaping, College of Horticulture, Vellanikkara, Thrissur, to standardize the spacing and fertilizer requirement of *Gomphrena globosa* for cultivation under the warm humid tropical regions of Kerala. The results of the study are discussed hereunder.

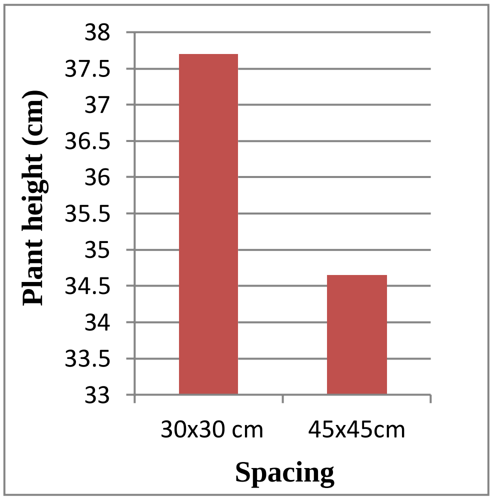
VEGETATIVE CHARACTERS

Vegetative characters like plant height, plant spread and number of branches per plant were influenced by different levels of spacing and nutrients. The highest plant height of 37.70 cm was observed in closer spacing of 30x30 cm compared to wider spacing of 45x45 cm (34.65 cm). Among different fertilizer treatments, plant height was found on par with each other except control (F1: 38.70 cm, F2: 37.41 cm, F3: 37.23 cm and F4: 31.33 cm) (Figure 2). The maximum plant spread of 34.92 cm was observed in wider spacing of 45x45 cm. Regarding the effect of nutrients on plant spread, all the treatments except control was found statistically comparable and on par (F1: 33.65 cm, F2: 34.10 cm, F3: 34.72 cm and F4: 30.53 cm) (Figure 3). Plants in the wider spacing of 45x45 cm were found to have the highest number of branches per plant (14.83) and 30x30 cm spacing produced the least number of branches (11.62). All nutrient treatments except control were found on par with each other with respect to number of branches (F1: 13.23, F2: 13.63, F3: 15.05 and F4: 10.98) (Figure 4). Similar trend was observed in dry matter production also (Figure 5). This clearly shows the more spreading growth of plants in 45x45cm spacing compared to 30x30cm, since they get more space for their growth under wider spacing. The space for more sunlight, nutrients and water availability reduced the competition between plants which in turn enhanced growth thus resulted in more plant spread. But dry matter production (t/ha) was found highest in closer spacing as there are more number of plants per unit area than in wider spacing (Figure 6). However, there was no significant difference with respect to growth parameters while considering the interaction effect of spacing and nutrients.

It is evident that higher dose of nutrients (NPK @ 100:50:100 kg/ha) and wider spacing (45x45 cm) resulted in improved vegetative growth of the plants in general. However, closer spacing (30x30 cm) enhanced plant height even though plant spread and number of branches were observed more in the wider spacing (45x45 cm). Lesser spacing results in more competition between plants for nutrients, moisture and space for both root and shoot growth, ultimately leading to reduced plant growth. Widely spaced plants along with higher dose of nutrients faced less competition for space, moisture, and light and along with, they also received more nutrition over narrowly spaced plants to satisfy their requirement for getting better growth. This has contributed to the highest plant spread, number of branches and dry matter production. Production of significantly taller plants under closer spacing had been reported by Hemalatha *et al*. (2010) and Sharma (2014) in gomphrena. Similar results were also reported by Karuppaiah and Krishna (2005) in French marigold and by Ahirwar *et al*. (2012) in African marigold. Similarly, the beneficial effect of wider spacing and higher dose of nutrients on plant spread and number of branches/plant had also been reported by John and Paul (1992) and Duggani (2016) in gomphrena. The present findings are also in conformity with the findings of Venugopal (1991) in helichrysum, Karavadia and Dhoduk (2002) in chrysanthemum, Dhatt and Kumar (2007) in *Coreopsis lanceolata,* Sunitha *et al*. (2007) and Chauhan (2011) in African marigold, and Awchar *et al*., (2010) in gaillardia, Baloch *et al*. (2010) in zinnia, Khalaj *et al*. (2012) in tuberose and Yagi *et al*. (2014) in *Celosia cristata.*

FLORAL CHARACTERS

Significant variation was observed in floral characters due to the application of different levels of nutrients and spacing. Treatments with 30x30 cm spacing took the least number of days for bud initiation (46.81 days) when compared to 45x45 cm spacing (53.35 days) (Figure 7). Among the different treatment combinations, the earliest bud initiation (42.78 days) was observed in T1 which received NPK @ 50:25:50 kg/ha and spaced at 30x30cm which was on par with T7 (44.78 days),which was also spaced at 30x30cm (Figure 8). The longest period (58.33 days) for bud initiation was observed in T8 (Control with spacing – 45x45 cm). However, days to complete flower opening was not significantly influenced by the treatments.



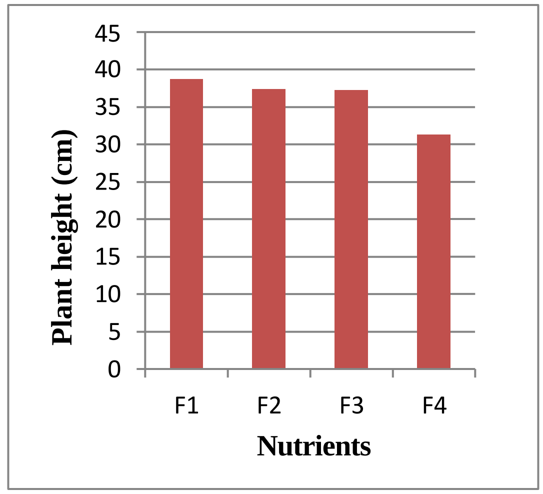
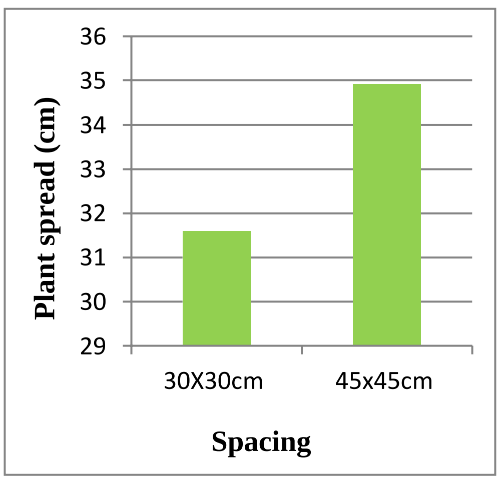


Figure 2 Effect of spacing and nutrients on plant height



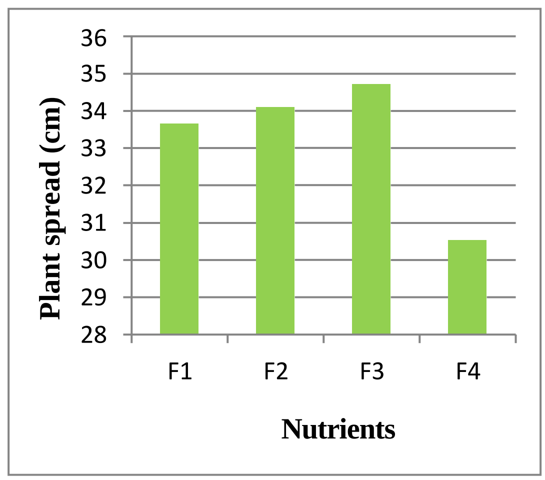
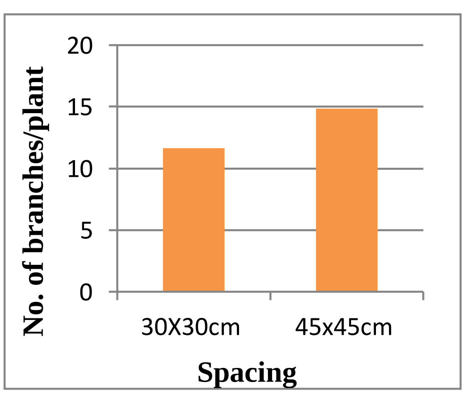


Figure 3 Effect of spacing and nutrients on plant spread



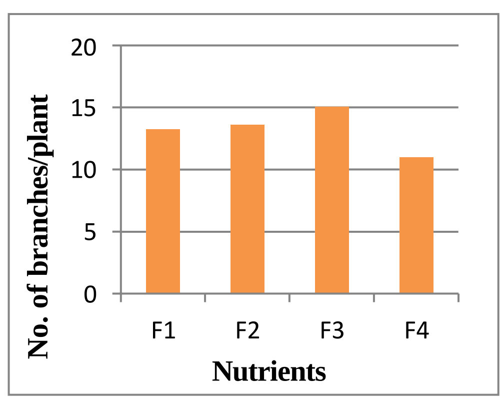


Figure 4 Effect of spacing and nutrients on No. of branches/plant

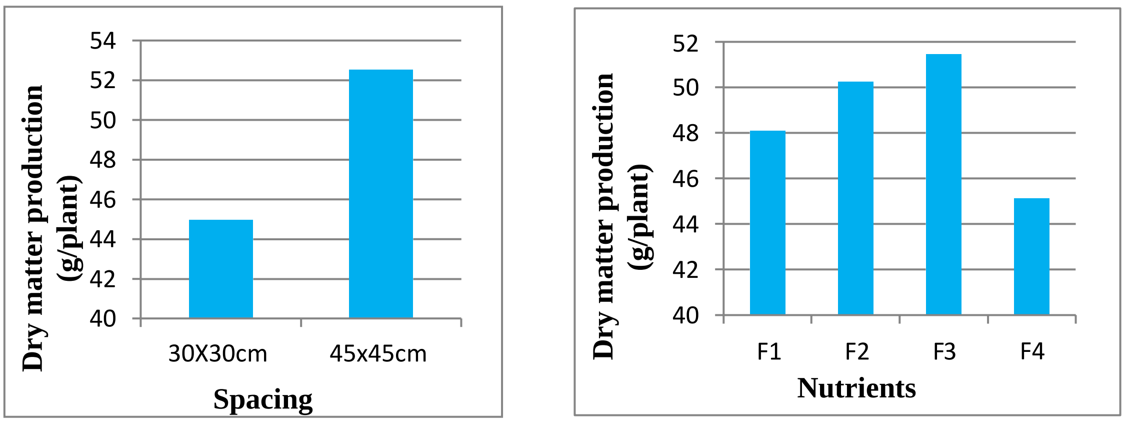


Figure 5 Effect of spacing and nutrients on dry matter production (g/plant)

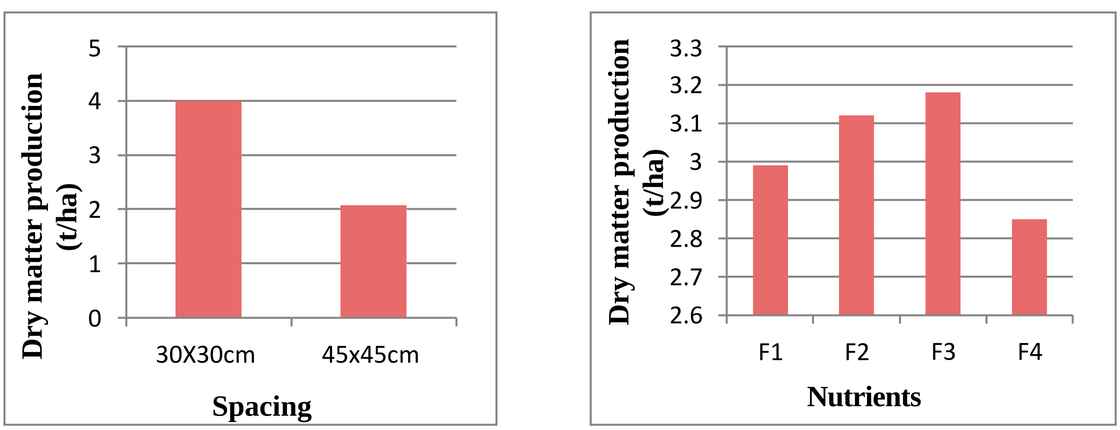


Figure 6 Effect of spacing and nutrients on dry matter production (t/ha)

Treatments with closer spacing took least number of days to 50% flowering than wider spacing (50.58 and 54.92 days respectively) (Figure7).

Wider spacing of 45x45 cm produced highest number of flowers (42.64) and 30x30 cm spacing produced lowest number of flowers (30.78) (Figure 9). The flower yield was also found maximum with 45x45cm spacing than 30x30 cm spacing. Treatments with NPK @ 50:25:50 kg/ha produced maximum flower yield (40.41 g/plant) and was on par with NPK @ 75:50:75 kg/ha (35.11 t/ha). The lowest flower yield was observed in control (29.93 g/plant) (Figure 10). However, the flower yield per hectare was found to be highest in closer spacing of 30x30 cm (2.50 t/ha) than wider spacing (1.56 t/ha) (Figure 11). The spacing and nutrient doses did not significantly influence flower stalk length, flower weight and flower head diameter. However, maximum stalk length, flower weight and flower head diameter were observed under the treatment T6 (NPK @ 100:50:100 kg/ha; Spacing – 45x45 cm), which received higher dose of fertilizers and with wider spacing, compared to all other treatments.

Other floral characters like duration of flowering, days taken to first picking and number of pickings did not vary significantly among the different treatments. Seed yield per flower (0.29 g) was found highest in 45x45 cm spacing while lowest seed yield was observed in 30x30 cm spacing (Figure 11). However, the floral characters were not influenced by the interaction of different treatment combinations.

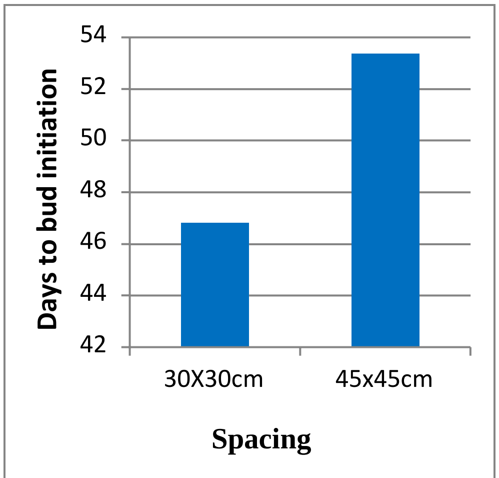
Earliest flower bud initiation was recorded in plants with closer spacing of 30x30 cm and with lower dose of nutrients. Also closer spacing took less number of days to 50% flowering compared to wider spacing. This might be due to reduction in growth at closer spacing that might have directed the plants towards the reproductive phase earlier than the plants grown at wider spacing. Also, excessive nitrogen may produce vegetative growth at the expense of reproduction. These results are in conformity with the observations of Venugopal (1991) in helichrysum, who observed that days taken for flower formation increased with increase in spacing. Agarwal (2015) also reported early bud initiation and 50% flowering in golden rod with lower dose of nitrogen and closer spacing. Similar result was reported by Aslam *et al*. (2016) in African marigold where in, increasing level of nitrogen and potash had inverse effect on days to flower appearance. The present findings are also in conformity with the findings of Poonam *et al*. (2002) and Chaudhary *et al*. (2007) in zinnia.

Even though the highest number of flowers per plant and flower yield were observed in the treatment with wider spacing and optimum nutrients and it was not significant from the treatments with higher level of nutrients along with wider spacing. The enhanced production in widely spaced plants may be attributed to higher photosynthetic activity due to greater exposure to light and increased availability of nutrients to the plants with wider spacing. These might have led to luxurious vegetative growth with greater number of branches resulting in the higher number of flowers and flower yield. As the nutrient status of the soil before planting was found higher there was no response of plants to higher dose of applied fertilizers. On the contrary, flower yield per hectare was found to be highest in closer spacing than wider spacing. This might be due to the increased number of plants per hectare at closer spacing which might have led to the increased yield. Similar results were observed by Sharma (2014) in gomphrena. Present findings are also in conformity with findings of Dubey *et al*. (2002) in cosmos, Poonam *et al*. (2002) and Ahmad *et al.* (2007) in zinna and Chauhan (2011) in African marigold. Widely spaced plants receiving more quantity of fertilizers would have luxurious growth and enhanced flowering.

Seed yield per flower was found high in treatments with wider spacing. Enhanced production of seeds might be attributed to the increased flower diameter due to less competition in wider spacing. The results are in accordance with the findings of Singh and Sangama (2001) in China aster and Dubey *et al.* (2002) in cosmos, Awchar *et al*. (2010) in gaillardia.

POST HARVEST PARAMETERS

Spacing and nutrients did not have any significant influence on shelf life of flowers and physiological loss in weight. The influence of nitrogen was found non significant with respect to shelf life of flowers in marigold (Ahirwar *et al*., 2012). Similar results were also obtained by Khalaj *et al*. (2012) in tuberose.



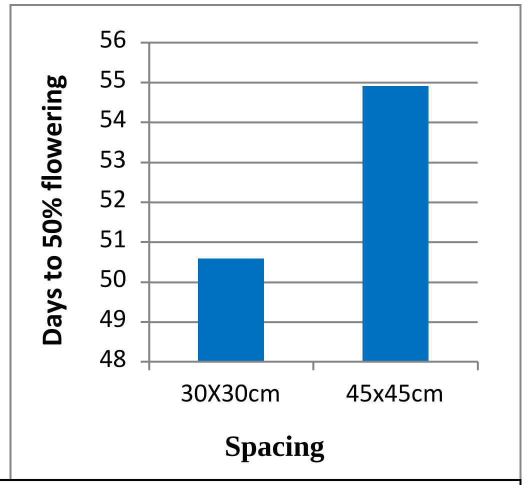


Figure 7 Effect of spacing on days to bud initiation and 50% flowering

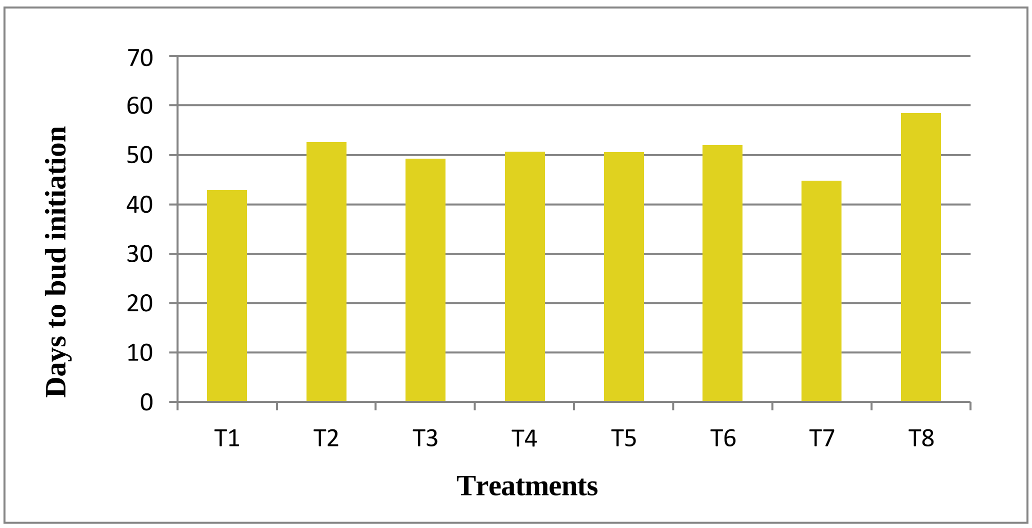


Figure 8 Interaction effect of spacing and nutrients on days to bud initiation

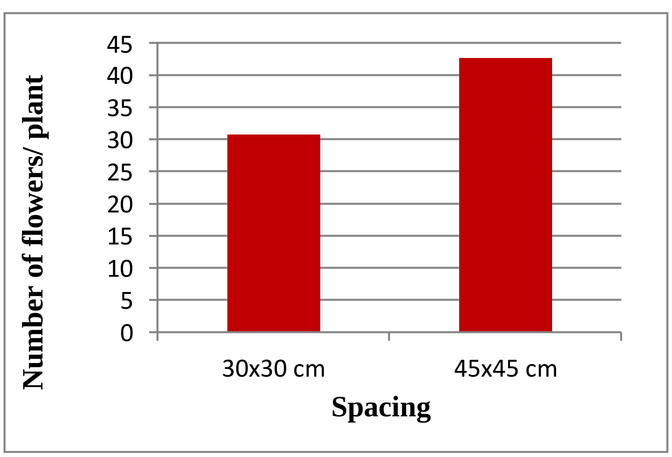
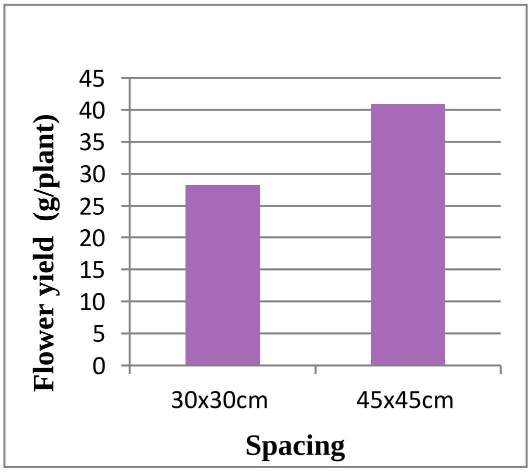


Figure 9 Effect of spacing on number of flowers/plant



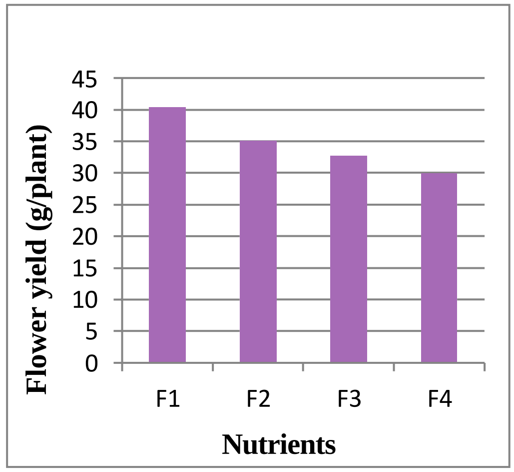
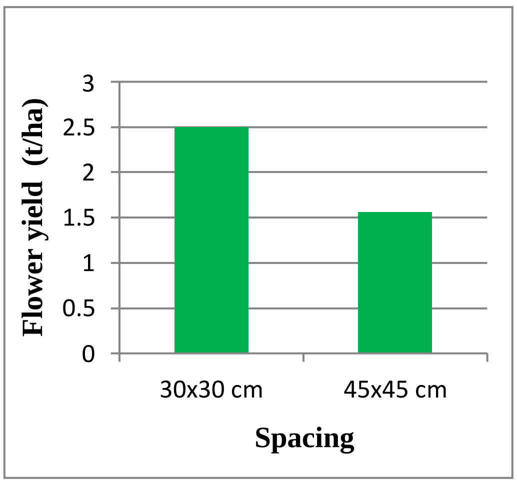


Figure 10 Effect of spacing and nutrients on flower yield (g/plant)



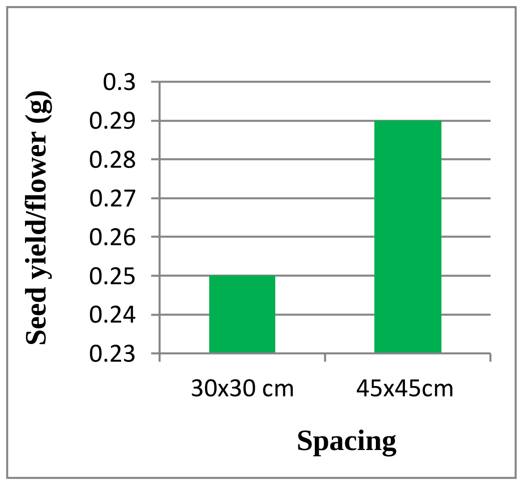


Figure 11 Effect of spacing on flower yield (t/ha) and seed yield/flower (g)

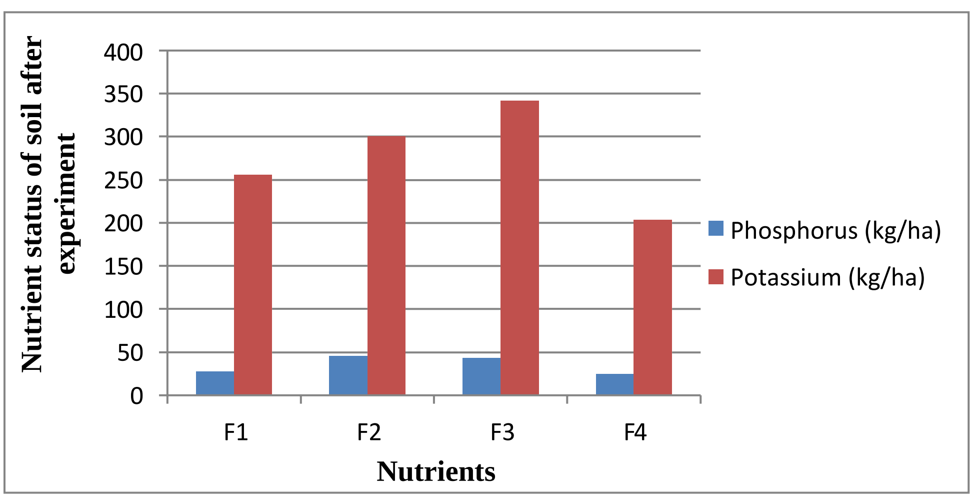


Figure 12 Effect of nutrients on nutrient status of soil after experiment

NUTRIENT STATUS OF SOIL

Initial soil pH was found to be 6.2. After the experiment it ranged from 6.3 to 6.5 among the different treatments, may be due to the application of lime. Organic carbon available in the soil before the experiment was 0.82%. After the final harvest there was an increase in organic carbon content and could be due to the effect of FYM application. Before the experiment the available phosphorous in the soil was recorded as 23.6 kg/ha. After the experiment, the phosphorus content was found highest in F3 (45.42 kg/ha) and F2 (43.17 kg/ha). This could be attributed to the addition of phosphatic fertilizer (P_2O_5:50 kg/ha). Available potassium in the soil before the experiment was 356.16 kg/ha. After the harvest the potassium content in the soil was highest in F3 and F2 (341.97 kg/ha and 300.53 kg/ha) due to application of potassium (Figure 12). The interaction effect of spacing and fertilizers did not have any significance on the nutrient status of the soil.

NUTRIENT CONTENT AND UPTAKE

The nutrient content (N, P_2O_5 and K_2O) in the plants varied significantly among different treatments. The highest N and P content were recorded in 45x45 cm spacing when compared to 30x30 cm spacing (Figure 13). The wider spaced plants face less competition for nutrients, water and light and thus showing better nutrient content than closely spaced plants. P and K content was found to be highest in treatment with NPK @ 100:50:100 kg/ha and was on par with NPK @ 75:50:75 kg/ha (Figure 14). Thus, there is an increase in plant nutrient content as the dose of nutrients applied increased. The interaction effect of spacing as well as nutrients was studied and found that it did not produce significant difference in N, P and K content of the plants.

There was a significant effect of spacing in the nutrient uptake by plants. P and K uptake was more in plants grown at closer spacing than plants grown at wider spacing (Figure 15). N and P uptake was found highest in treatment with higher dose of NPK (Figure 16). The interaction of both the factors did not influence the N, P and K uptake of the plant. Higher nutrient uptake in plots with closer spacing might be attributed to the enhanced competition for nutrients between the below and aboveground plant parts and all the applied resources might have been effectively utilized, which in turn resulted in higher growth and yield (Dev and Sarawgi, 2004). The present result is in conformity with the findings of Ullasa *et al.* (2014) as well as Ravichandran and Srinivasan (2017) in sunflower.

The nutrient uptake was found maximum at closer spacing. N*itrogen* is considered the most important component for *plant growth*. This is evident from the increase in vegetative characters like plant height and dry matter production which were more noticed in closer spacing. Phosphorus aids in root development, flower initiation, and seed development and potassium stimulates flowering and improve the quality of flowers (Uchida, 2000). This was clearly observed from the early bud initiation, days to 50% flowering and maximum flower yield per hectare in treatments with high phosphorus and potassium uptake (T1, T3, T5 andT8).

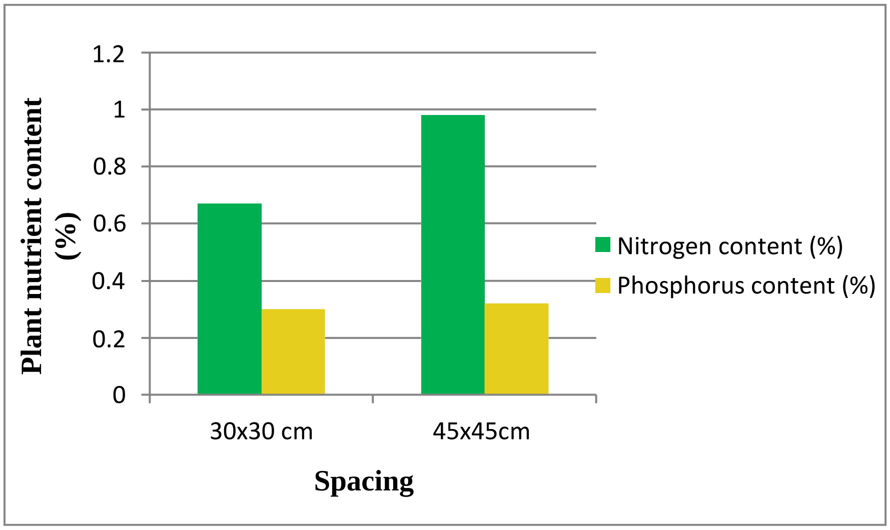


Figure 13 Effect of spacing on plant nutrient content (%)

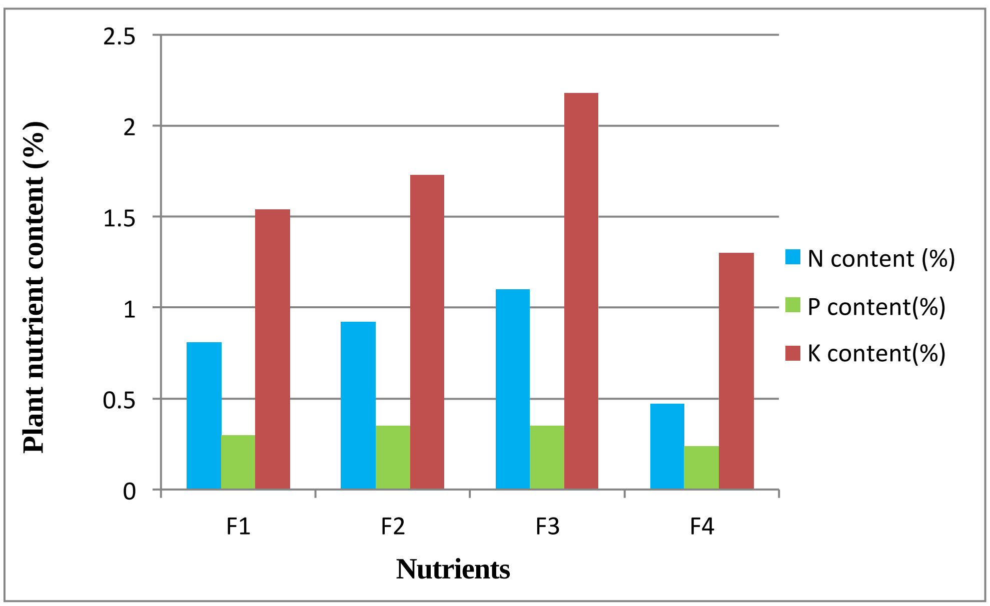


Figure 14 Effect of nutrients on plant nutrient content (%)

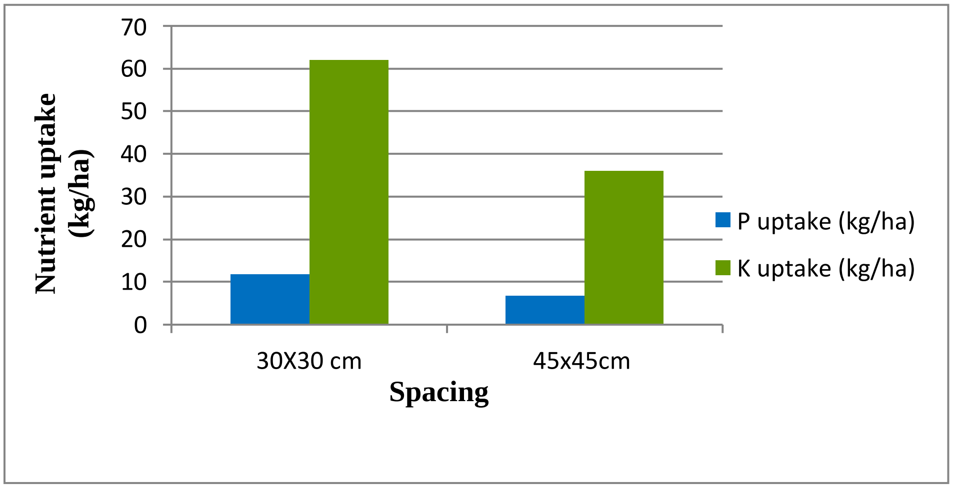


Figure 15 Effect of spacing on nutrient uptake by *Gomphrena*

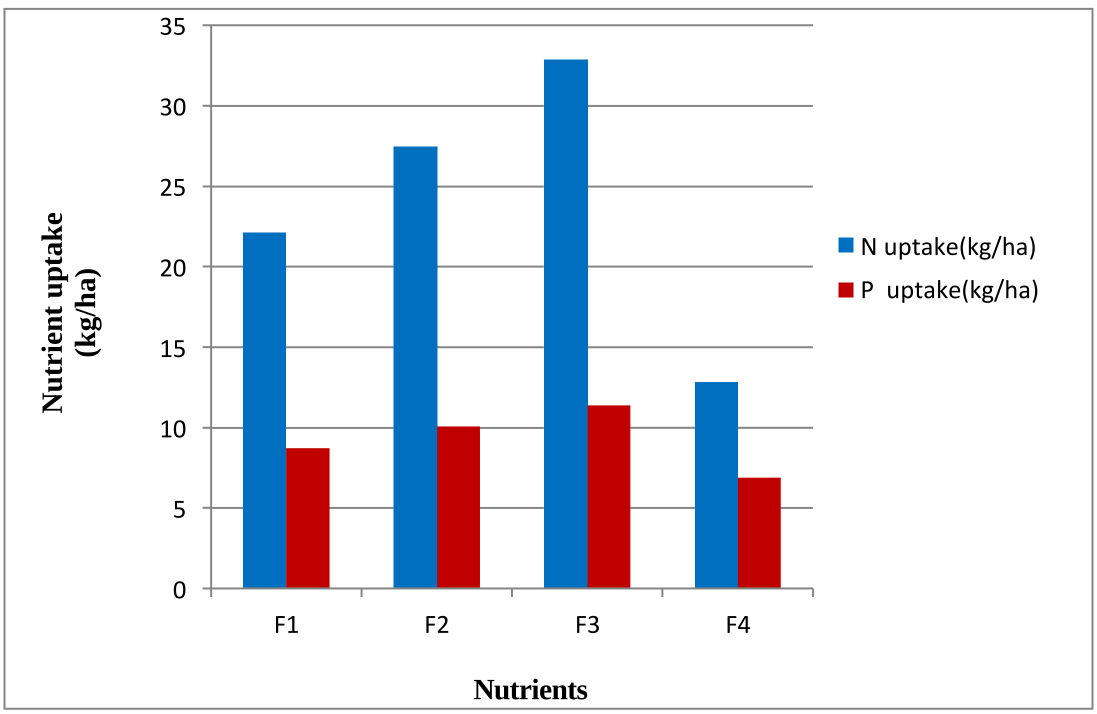


Figure 16 Effect of nutrients on nutrient uptake by *Gomphrena*

Summary

6. SUMMARY

A field experiment entitled 'Spacing and nutrient management of *Gomphrena globosa* L.' was carried out in the Department of Floriculture and Landscaping, College of Horticulture, Vellanikkara during 2019-20. The experiment was carried out in RBD with eight treatments comprising two levels of spacing i.e., 30x30cm and 45x45cm and three levels of fertilizers *viz;* NPK @ 50:25:50 kg/ha, 75:50:75 kg/ha and 100:50:100 kg/ha. The results obtained are summarized below:

- Closer spacing of 30x30 cm was found best for getting the highest plant height (37.70cm).
- Plant spread (34.92 cm) and number of branches per plant (14.83) were maximum when grown at wider spacing of 45x45cm.
- Dry matter production (52.53 g/plant) was also found highest at wider spacing.
- Eventhough the effect of nutrients on growth parameters were statistically comparable except control, all the vegetative characters like plant spread, number of branches per plant and dry matter production increased as the dose of nutrients increased.
- Regarding floral characters, bud initiation was found earliest in treatments with closer spacing (46.81 days). Among different treatment combinations, NPK @ 50:25:50 kg/ha along with closer spacing of 30x30 cm spacing was found superior compared to other treatments with respect to days to bud initiation.
- Days to 50% flowering was also found minimum when grown at closer spacing while days to complete flower opening was not found significant.
- Other floral characters like flower stalk length, flower weight and flower head diameter were not significantly influenced by spacing and fertilizer treatments.
- Wider spacing of 45x45 cm produced highest number of flowers per plant (42.64) and flower yield (40.90 g/plant). Among different nutrient treatments, NPK @ 50:25:50 kg/ha (40.41 g/plant) was found on par with NPK @ 75:50:75 kg/ha (35.11 g/plant). However, flower yield per hectare was found to be highest in closer spacing of 30x30 cm (2.50 t/ha) compared to wider spacing (1.56t/ha).

- Duration of flowering, days taken to first picking and number of pickings were not influenced by spacing and nutrients.
- Seed yield per flower (0.29g) was found highest in 45x45 cm spacing compared to closer spacing.
- Post harvest characters like shelf life of flowers and physiological loss in weight were not significantly influenced by spacing and fertilizers treatments.
- Nutrient content in the plants was found highest in wider spacing (45x45 cm) and the content in the plant increased as the dose of nutrient applied increased. However, the nutrient uptake by the plants was found the highest in plants grown under closer spacing (30x30cm).

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Appendix

APPENDIX I

Meteorological data during the period of research from May 2019 to December 2019

Month	**Temperature**		**Mean Relative Humidity (%)**	**Rainfall (mm)**	**Rainy days**	**Total Sunshine hours**	**Mean Sunshine hours/day**
	Max°C	**Min°C**					
May	34.6	24.9	74	48.8	4	211.0	6.8
June	32.2	23.5	83	324.4	15	111.7	3.7
July	30.4	22.8	85	654.4	21	81.6	2.6
August	29.5	21.9	89	977.5	24	45.9	1.5
September	31.2	22.0	85	419.0	19	98.3	3.3
October	32.4	21.4	79	418.4	16	170.2	5.5
November	32.9	21.7	71	205.0	5	224.9	7.5
December	32.3	22.1	63	4.4	1	208.8	6.7

SPACING AND NUTRIENT MANAGEMENT FOR *Gomphrena globosa* L.

By

RESHMA SHAJI
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THESIS

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COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680 656
KERALA, INDIA

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ABSTRACT

Gomphrena globosa L. is a charming ornamental annual plant, commonly known as globe amaranth or bachelor's button. *Gomphrena* is native to tropical and sub-tropical countries including India. It belongs to the family Amaranthaceae. Colourful and globular flower heads add colour and beauty to the garden and the flowers are suitable for cut and dried floral arrangements. Gomphrena is also an excellent choice for beds, borders and rock gardens. Among the various factors responsible for high crop yield, optimum spacing coupled with supply of appropriate quantity of nutrients at appropriate time plays a vital role in enhancing the productivity and the quality of the crop. For the commercialization of this crop, there is need to standardize optimum plant spacing and fertilizer levels. In this context, the study "Spacing and nutrient management for *Gomphrena globosa* L." was carried out in the Department of Floriculture and Landscaping, College of Horticulture, Vellanikkara during 2019- 2020. Objective of the study was to standardize the spacing and fertilizer requirement of *Gomphrena globosa* for cultivation in Kerala.

The experiment was carried out in Randomized Block Design (RBD) with eight treatments comprising two levels of spacing *i.e*., 30x30 cm and 45x45 cm and three levels of fertilizers *viz;* NPK @ 50:25:50 kg/ha, 75:50:75 kg/ha and 100:50:100 kg/ha. Observations on growth characters, yield, post-harvest parameters, nutrient status of the soil, plant nutrient content and uptake were recorded.

Among the growth characters, plant height was found significantly higher in the treatment with closer spacing of 30x30cm compared to 45x45cm spacing. Other growth characters including plant spread, number of branches per plant and dry matter production per plant showed significant improvement when grown under wider spacing (34.92 cm, 14.83, 52.53 g/plant respectively). However, dry matter production per unit area (4 t/ha) was found the highest under closer spacing. Different fertilizer doses were found to be on par with one another with respect to plant height and were superior over control. Similar trend was found in plant spread, number of branches per plant and dry matter production. There was no significant interaction effect of spacing and nutrients on growth parameters.

Early bud initiation (46.81 days) and minimum number of days to 50% flowering (50.58 days) was observed under closer spacing of 30x30cm. Wider spacing of 45x45 cm produced greater number of flowers per plant (42.64), flower yield (40.90 g/plant) and seed yield per flower (0.29 g). The flower yield per hectare was found to be highest in closer spacing (2.50 t/ha). The different nutrient doses had significant effect on flower yield (g/plant). Application of $N:P_2O_5:K_2O$ @ 50:25:50 kg/ha produced greater flower yield (40.41 g/plant) which was on par with $N:P_2O_5:K_2O$ @ 75:50:75 kg/ha (35.11 g/plant) and superior over control treatments without fertilizers. The earliest bud initiation was observed in plants applied with $N:P_2O_5:K_2O$ @ 50:25:50 kg/ha along with closer spacing of 30x30 cm (42.78 days). Other floral characters and post-harvest parameters were not significantly influenced by spacing and fertilizer treatments.

Nutrient content in the plants was found the highest in wider spacing (45x45 cm) and the content in the plant increased as the dose of nutrient applied increased. However, the nutrient uptake by the plants (kg/ha) was found to be the highest in plants grown under closer spacing (30x30 cm) and the uptake of the nutrients also increased with increase in fertilizer dose.

Results showed that higher dose of fertilizers ($N:P_2O_5:K_2O$ @ 100:50:100 kg/ha) and wider spacing (45x45 cm) promoted vegetative growth of plants. Plants spaced at 30x30 cm and fertilized with $N:P_2O_5:K_2O$ @ 50:25:50 kg/ha produced more flowers and higher flower yield and can be recommended for improving the growth and flowering of gomphrena plants.