

Original Research Article

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Effect of Sewage Sludge and Cadmium on Growth and Quality Features of Marigold (*Tagetes erecta* L.) Grown in Three Soils

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ABSTRACT

The present investigation was conducted to study the effect of sewage sludge and cadmium on growth and quality features of marigold (*Tagetes erecta* L.). The experiment was conducted in Factorial Complete Randomized Design. The treatments consisted of four doses of sewage sludge (0, 5, 10 and 15 g kg⁻¹) in combination with three doses of cadmium (0, 20 and 40 mg kg⁻¹) taking three replications. The treatments were studied in three types of soils Alluvial, Red and Black soil. In the present study, plant height, the number of branch per plant, shoot fresh weight, shoot dry matter, flower height, compactness, flower diameter and shelf life of flower were measured. Results revealed that the application of sludge and cadmium significantly influenced the plant growth properties. The interaction effect of sludge and cadmium was not significant on studied characters except for flower height, compactness and shelf life. The highest plant height, number of branches per plant, shoot fresh and dry weight, flower diameter was obtained with 15 g kg⁻¹ sludge amended soil. The treatment applied with higher dose of Cd (40 mg kg⁻¹) without sewage sludge showed minimum shoot fresh and dry weight. It was found that application of sewage sludge can reduce the toxicity effect of cadmium. In general, black soils showed more response to sewage sludge and Cd which was clearly evident from higher values in respective treatments compared to red and alluvial soils.

Keywords

Marigold, Sewage sludge, Cadmium, Growth and quality.

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Introduction

Industrial and agricultural activities have led to a considerable increase in heavy metals in the different environmental compartments especially in soil over the course of recent decades. There are some reports which indicate that heavy metals pollution in soil arises as a result of various anthropogenic activities such as continuous use of sewage water, sewage sludge and fertilizers.

Among the various types of heavy metals, cadmium is one of the most toxic trace metal

having toxicity 2-20 times higher than many other heavy metals and it is easily transferable in food chain through soil and environment. Cadmium is found mainly in association with zinc sulfide based ores in a ratio of about 1:100 and to a lesser degree as an impurity in lead and copper ores. The average cadmium content of the lithosphere is estimated at 0.2 mg kg⁻¹ and the range for soils is found as 0.01 to 0.7 mg kg⁻¹ (Das 2000). Fossil fuels contain 0.5 to 1.5 ppm Cd, but phosphate fertilizers contain from 10 to 200 ppm Cd

(Cook and Morrow 1995). In natural soils, the amount of Cd content varies with the types of parent material. Cd in soils is derived from both natural and anthropogenic sources. The major natural sources for mobilizations of Cd from the earth's crust are volcanoes and weathering of rocks. Cadmium is a naturally-occurring constituent in a wide range of materials which are utilized for industrial and consumer purposes. It is sometimes found in high concentrations in phosphate fertilizers since some marine phosphates and phosphorites have been reported to contain cadmium levels as high as 500 ppm (WHO 1992, Cook and Morrow 1995).

Cadmium has a very limited downward movement in soil and is thus usually retained in the top 0-15 cm layer of soil (Chang *et al.*, 1984). The impact of Cd contamination on agricultural soils depends on soil physical, chemical and biological properties which influence plant uptake and availability of cadmium. Soil properties affect metal bioavailability to ecological receptors. The lower availability of cadmium in Inceptisol may be due to the fixation in clay, hydrous oxides of iron and manganese while clay fixation and precipitation as insoluble sulphides of cadmium may be ascribed in the Ultisol. The lower extractability of cadmium in Vertisol might be due to the formation of its relatively insoluble carbonate.

Excess Cd causes inhibition and abnormalities of general growth in many plant species. Visible symptoms of cadmium toxicity in plant leave include rolling, browning, chlorosis, reddish veins and petioles causing severe reduction in growth (Tran and Popova 2012). In case of human nutrition, Cd is a cumulative poison. It is mainly accumulated in the kidneys and to some extent also in the liver and spleen. Excess Cd causes damage to the kidney tubules, rhinitis, emphysema as well as other chronic disorders.

Production of huge amount of sewage sludge due to industrialization and urbanization, has created serious environmental problems for their disposal. Use of sewage sludge on agricultural land has become a common practice in India and is a very effective disposal technique. Sewage sludge, being organic waste, is a good source of plant nutrients such as N, P, K, S, Ca, Mg, Fe, Cu, Mn and Zn as well as other organic constituents (Martinez *et al.*, 2003). Sewage sludge application in agricultural soils is of most important in maintaining the tilth, fertility and productivity of the soils. It improves soil physical, chemical and biological properties such as porosity, aggregate stability, bulk density, soil fertility, water movement and retention. The application of sewage sludge to agricultural land enables us to reduce the use of artificial fertilizer and makes good use of resource.

Besides its nutritional value, it may also contain toxic heavy metals such as Cd, Cr, Ni, Pb, As, Hg etc. Some of the heavy metals at low doses are essential micronutrients for plants but in higher doses, may cause metabolic disorder and growth inhabitation for most of the plant species. The addition of sewage sludge to the soil diminishes the inhibitory effect of Cd on biological parameters. The addition of this kind of organic material can help in the remediation of Cd polluted soils provided the heavy metal content of the organic material is very low.

Marigold is widely used in India for religious purpose, decorations and offerings. It performs well in hot, dry climate. Marigold is short duration free flowering, hairy, hard and evergreen crop. The pigments in marigold are sometime extracted and used as a food colouring for human and livestock. Marigold is used as a medicinal, flavouring, dye and ornamental plant. The use of marigold is associated with marriage, social function and

festivals. The flower is endowed with spectrum of attraction colour, shape and size along with its keeping quality. Besides its pristine uses as cut flower for interior decorator in hanging basket, rock garden for landscaping purpose and for the beautification of halls.

African marigold (*Tagetes erecta* L.) is one of the earliest annual flowers to cultivate and has been widely adapted to different soils and climate condition. Marigold can uptake higher amount of Cd and accumulate in their body without showing toxicity symptoms. Sewage sludge being a rich source of nutrients and organic matter improves soil properties and can reduce the toxicity of Cd by forming clay humus complexes in soil.

Thus, keeping in view, the present investigation was done in order to evaluate the effect of sewage sludge and cadmium on growth and quality characteristics of marigold (*Tagetes erecta* L.).

Materials and Methods

Study area

The experiment was conducted as a pot culture study in the glass house of the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, India, during July 2011 to April 2012. The Varanasi is located between the parallels of 25.14° and 25.23° N latitude and 82.56° and 83.03° E longitude and falls in a semi-arid to sub humid climate with moisture deficit index between 20 - 40.

Collection of soil and sewage sludge

To conduct the pot experiment, the alluvial soil fine loamy, mixed hyperthermic, *typic* Ustochrepts was collected from Agricultural Research Farm, Banaras Hindu University,

Varanasi. Red fine loamy, mixed hyperthermic, *typic* Rhodustalfs was collected from Rajiv Gandhi South Campus, Barkachha, Mirzapur. Black soil fine loamy, mixed hyperthermic, *entic* Chromusterts was collected from village Shahanshahpur, Varanasi. The soil was ground to pass through 2 mm sieve and four kg of soil was filled in each pot. Sewage sludge was collected from Sewage Treatment Plant (STP) Bhagwanpur, Varanasi in the month of October 2011. The sewage sludge was dry at the time of collection it was then grounded to get homogenous mass.

Experimental design and raising of plants

The experiment was conducted in Factorial Complete Randomized Design. Marigold (*Tagetes erecta* var. Inka) was chosen as the test crop. One month old seedlings were used for transplanting purpose. The treatments consisted of four doses of sewage sludge (0, 5, 10 and 15 g kg⁻¹) in combination with three doses of cadmium (0, 20 and 40 mg kg⁻¹) applied through 3CdSO₄.8H₂O. Four kg soil was filled in each pot and required quantities of fertilizers were applied in liquid form using urea, S.S.P and muriate of potash as source of N, P and K, respectively. The recommended dose of N, P and K was taken as 200, 80 and 80 kg ha⁻¹ respectively. Half of N and full dose of P and K was applied at the time of transplanting of marigold and remaining N fertilizer was applied in the equal splits at 30 and 60 days after transplanting. Crop was harvested at 80 days after transplanting.

Observations recorded

The plant height, number of primary branch per plant, shoot fresh weight, shoot dry matter, chlorophyll content, number of flower, flower fresh weight, flower dry weight, compactness, flower height, flower diameter and shelf life were measured.

Plant height was measured from the surface of soil to the tip of plant with the help of a meter scale. Plants from each pot were cut with the help of scissors from 2 cm above surface of soil and the fresh weight was recorded by using electronic balance. Plant samples were kept in paper bags and dried in hot air oven at $60 \pm 2^\circ\text{C}$ till constant weight and their dry weight was recorded by an electronic balance.

The chlorophyll content was measured by using a SPAD (Soil Plant Analysis Device) at harvest by selecting six leaves randomly at the centre of the branch and the average was worked out. The total number of primary branches was counted at the time of harvest and averaged. Number of flowers pot^{-1} was counted at the time of harvest. Fully opened flowers were regularly harvested and just after harvesting their weight were taken by electronic balanced and expressed in gram. Diameter of flower was measured at the point maximum breadth and the average diameter was recorded with the help of Vernier caliper when flowers were fully opened and expressed in cm. Compactness was measured by noting the maximum breadth, after that the flowers were pressed and diameter was measured with Vernier caliper for minimum breadth. Compactness percentage was calculated by the following formula:

$$\text{Compactness} = \frac{\text{maximum breadth}}{\text{minimum breadth}} \times 100$$

Height of three flowers was measured with the help of Vernier caliper and their mean was calculated and expressed in cm. Shelf life of the flowers was assessed by recording the number of days up to which 50 per cent or more flowers maintained freshness without exhibiting brown pigmentation.

Four randomly selected flowers in each treatment were kept in room temperature for taking shelf life.

Statistical analysis

The statistical analysis was done using Factorial Complete Randomized Design with twelve treatments and three replications. The analysis was carried using two-way analysis of variance (ANOVA) by the method described by Gomez and Gomez, (1984) to test the significance of difference between the treatments. The test of significance was carried out at 5% level of significance by referring to 'F' table values.

Results and Discussion

Sewage sludge characteristics

The digested sewage sludge had pH (6.43), EC (2.88 dS m^{-1}), organic C (11.32%), available N, P and K content as 176.4, 52.2 and 173.4 mg kg^{-1} , respectively. DTPA extractable contents of Fe, Mn, Cu and Zn of sludge were 78.9, 36.5, 23.2 and 17.5 mg kg^{-1} , respectively. The permissible levels for potential toxic elements such as Zn, Cu, Cd, Pb, Ni and Cr in sludge to be used in agricultural soils are 2500, 1000, 20, 750, 300 and 750 mg kg^{-1} , respectively according to Council of the European Communities (1986). As regards to Cd, Cr, Ni and Pb the DTPA extractable amounts were 3.12, 7.90, 12.9 and 39.6 mg kg^{-1} , respectively. Hence the sewage sludge used in the present study had heavy metals content below the maximum permissible limits.

Effect of sludge and cadmium on plant height, fresh and dry weight

The plant height was significantly ($p \leq 0.01$) affected by sewage sludge and cadmium (Table 1). In alluvial soil it varied from 18.4 to 24.1 cm, whereas, in red and black soil it ranged from 18.8 to 23.7 cm and 21.1 to 24.5 cm, respectively. It was found that the plant height gradually decreased with increase in

soil Cd content, whereas, significant increase was recorded with sewage sludge application. The maximum plant height in all the three soil types was found in the treatment amended with 15 g kg⁻¹ sludge (Cd₀S₁₅) which showed 16, 14 and 7% increase over control (Cd₀S₀) in alluvial, red and black soil, respectively. The interaction effect of sewage sludge with cadmium was also significant. Sole application of 40 mg kg⁻¹ Cd (Cd₄₀S₀) significantly decreased the plant height by 14, 4 and 6 % over control (Cd₀S₀) in alluvial, red and black soil, respectively. The significant increase in plant height was observed for higher doses of sewage sludge i.e. 10 and 15 g kg⁻¹ sludge in all the three soil types. The height was in order black > alluvial > red.

Sewage sludge is rich in organic matter; therefore, it supplies most of the major and micronutrients for plant growth. The N is released after subsequent decomposition which improves the growth of plants. Also it functions to bind the heavy metals in soil by forming chelates. This might be a probable reason for reducing the toxicity of Cd in sludge amended soil and improving the growth of plant. The lower plant height in Cd amended treatments might be due to the toxicity of Cd. Toxicity of Cd may result from the binding of metals to sulphhydryl groups in proteins, leading to an inhibition of enzymatic activity or disruption of structure (Van Assche and Clijsters 1990). This was also supported by Zhou and Qiu (2005) that high concentrations of Cd cause toxicity in plants at it causes growth inhibition of root and shoot, leaf roll, and chlorosis and eventually plant death due to the reduction of enzyme activity, photosynthesis, respiration and transpiration and nutrient uptake.

The fresh weight of plant at harvest in alluvial, red and black soil ranged between 48.6 to 64.8, 30 to 47.8 and 50.6 to 72.2 g, respectively. Treatment Cd₀S₁₅ showed 9, 19

and 13 % increase over control (S₀Cd₀), in alluvial, red and black soil, respectively. The treatments amended with 20 and 40 mg kg⁻¹ Cd without sludge (treatments Cd₂₀S₀ and Cd₄₀S₀) showed 13 and 22% reduction in fresh weight in alluvial soil, whereas, the corresponding reduction in red soil was 10 and 34 % and in black soil it was 12 and 26 % over control, respectively. The dry weight of plant at harvest in alluvial and red soil ranged between 13.1 to 17.2 g and 12.4 to 16.1 g, whereas, in black soil it varied from 13.9 to 19.5 g. Sole application of 10 and 15 g kg⁻¹ SS (treatments Cd₀S₁₀ and Cd₀S₁₅) increased the dry weight of plant at harvest by 15 and 21 % in alluvial soil, 14 and 20 % in red soil and 11 and 19 % in black soil, respectively over control (Cd₀S₀). It was found that the fresh and dry weight of plant gradually decreased with increase content of Cd in soil, whereas, application of sewage sludge increased the fresh weight. The maximum fresh and dry weight of plant in all three soil types was found in the treatment amended with 15 g kg⁻¹ sewage sludge (Cd₀S₁₅).

Reduction in fresh and dry weight of plant was recorded in Cd treated soil. Red soils showed lowest fresh and dry weight in all the treatments compared to alluvial and black soil. This might be due to the higher availability of Cd in red soil due to low pH. The results corroborate the findings of Gupta *et al.*, (2009), their study revealed that the toxic effect of Cd pollution to plants was more in soils of low pH as compared to soils of higher pH. Kibria *et al.*, (2006) reported that 9 mg kg⁻¹ Cd decreased 17-35 % shoot weight of rice. Muramoto *et al.*, (1990) also reported that shoot weight 21 % reduced by 100 mg kg⁻¹ Cd. John *et al.*, (1972) reported effect of Cd on radish growth with 30 different surface soil. Shoot weight was reduced an average 47 % by addition 100 mg kg⁻¹ Cd. Lettuce growth was reduced by 23 % by the addition of 4 mg Cd kg⁻¹ in soil

investigated by Sadana and Singh (1987). Wu *et al.*, (2007) also observed that increasing Cd levels in the medium cause a significant decrease in height and fresh weight of different barley genotypes.

Adhikari *et al.*, (2005) found that application of Cd decreased the dry matter of spinach by 38 % reduction in dry weight of plant compared with control. Liu *et al.*, (2011) reported that shoot of *T. patula* can reach to 1800 mg plant⁻¹ DW. Thus, *T. patula* shows promising potential as a Cd accumulator for phytoremediation in Cd contaminated soil. The reduction in dry weight of spinach with increasing Cd application to soil may be due to the combined effect of Cd toxicity and ion imbalance (Root *et al.*, 1975). Similar result reported by Dalir *et al.*, (2013) found that application of 80 mg kg⁻¹ Cd decreased dry weight from 3.43 (control) to 0.197 g pot⁻¹, i.e. a 97 % decrease in plant growth.

Sewage sludge is a good source of major and micronutrients, its subsequent decomposition might have provided the nutrients to the plant resulting into the increase in dry matter accumulation. With the increase in levels of Cd the dry matter accumulation was found to be decreased. The interaction effect of Cd with sludge was also significant in all three soil types. The reduction in plant growth and dry matter yield with increasing soil metal load was reported by many workers (Chaudhary *et al.*, 2004; Sharma and Agrawal 2005; Chatterjee *et al.*, 2006; Wani *et al.*, 2007 and Hussain *et al.*, 2008).

Effect of sludge and cadmium on chlorophyll content and number of branches

The maximum leaf chlorophyll content at harvest (table 2) in alluvial (60.4 SPAD), red (56.5 SPAD) and black (63.0 SPAD) was found in the treatment amended with 15 g kg⁻¹ SS (S₁₅Cd₀), whereas, the lowest was

recorded in treatment amended with 40 mg kg⁻¹ Cd (Cd₄₀S₀). Sole application of 40 mg kg⁻¹ Cd (Cd₄₀S₀) significantly decreased the leaf chlorophyll content by 8, 8 and 11% over control (Cd₀S₀) in alluvial, red and black soil, respectively. The significant increase in plant height was observed for higher doses of sewage sludge i.e. 10 and 15 g kg⁻¹ SS in all the three soil types. Nitrogen is an essential component of chlorophyll structure, sewage sludge being organic fertilizer, contains N in available as well as combined form. This bound form of N releases after subsequent decomposition and is available to plant. This might be a probable reason for the increase in chlorophyll content in marigold. The chlorophyll content decreased with the increase in Cd content, this might be due to the higher uptake of Cd in plant tissue.

Stobart *et al.*, (1985) suggested that decline in the chlorophyll level might be due to the Cd-induced inhibition at protochlorophyllide stage which in sequence obstructs the activity of enzyme protochlorophyllide reductase. The reduction in chlorophyll due to excess level of Cd was reported by Wani *et al.*, (2007). Padmaja *et al.*, (1990) proposed that Cd induced inhibition of chlorophyll biosynthesis could be a result of diminishing level of δ-aminolevulinic acid dehydrogenase and dissociation of pigment or its precursors. Rai *et al.*, (2005) reported that the degree of depression in the pigments of *Phyllanthus* at Cd (100 μM) were about 30% for chlorophyll a, 48% for chlorophyll b and 40% for carotenoid which implied that chlorophyll b was severely affected than chlorophyll a; hence showed an increase in chlorophyll a/b ratio. Liu *et al.*, (2011) reported that after 14 days, chlorophyll content in *T. patula* leaves decreased by 45 and 74 % with 25 and 50 μ M CdCl₂ as compared to control.

The number of branches increased significantly with application of sewage sludge, while significantly decreased with

increasing levels of cadmium. It varied from 9.67 to 15.2, 11.0 to 14.3 and 9.8 to 15.2 in alluvial, red and black soil, respectively. Application of 15 g kg⁻¹ sewage sludge significantly increased the number of branches by 27 and 23 % over control in alluvial and black soil, respectively, while the effect was non-significant in red soil. The number of branches due to Cd 20 and 40 mg kg⁻¹ with 15 g kg⁻¹ sewage sludge (treatment Cd₂₀S₁₅ and Cd₄₀S₁₅) reduced by 11 and 23 %, 10 and 15 % and 14 and 18 % in alluvial, red and black soil, respectively compared with sole application of 15 g kg⁻¹ sewage sludge. The number of branches significantly decreased with treatment Cd₂₀S₀ and Cd₄₀S₀ by 11 and 23 % in alluvial soil, whereas, 10 and 17 % in red soil and 17 and 25 % in black soil, respectively over control. The interaction effect of Cd and sewage sludge was non-significant in all three soil types.

This might be a probable reason for increased number of branches, because it supplies higher amount of N after subsequent decomposition which improves the growth of plants (Rathore *et al.*, 1985). Similar result was also reported by Ahamad *et al.*, (2010). The Cd in plant cell reacts with pectin in plant cell. The cross linking of pectin in the middle lamella is responsible for inhibition of cell expansion resulting decreased plant growth (Prasad 1995). In the present study higher levels of Cd were applied this might have caused cell wall dysfunction and reduced number of branches.

Effect of sewage sludge and cadmium on flower number, fresh and dry weight

The fresh and dry weight of flowers per plant significantly varied with sewage sludge and cadmium, but, the interaction effect was non-significant (table 3). The fresh weight of flowers per plant in alluvial soil ranged between 23.3 to 57.8 g, whereas, in red and

black soil it ranged between 14.5 to 53.4 g and 29.9 to 79.2 g. The maximum fresh weight was showed with treatment Cd₀S₁₅ by 89, 119 and 91% increase over control (S₀Cd₀), in alluvial, red and black soil, respectively. Sole application of 20 and 40 mg kg⁻¹ Cd (treatments Cd₂₀S₀ and Cd₄₀S₀) significantly decreased the fresh weight of flower by 11 and 31% over control (Cd₀S₀) in alluvial soil, 22 and 68% in red soil and 21 and 39% in black soil. The treatment Cd₀S₁₅ showed 65, 68 and 64% higher fresh weight of flowers per plant over Cd₄₀S₁₅ in alluvial, red and black soil, respectively. Maximum dry weight was recorded with treatment Cd₀S₁₅ by 67, 70 and 73% increase over control (S₀Cd₀), in alluvial, red and black soil, respectively. Single application of 20 and 40 mg kg⁻¹ Cd (treatments Cd₂₀S₀ and Cd₄₀S₀) significantly decreased the dry weight of flower by 14 and 33% over control (Cd₀S₀) in alluvial soil, 26 and 69% in red soil and 24 and 34% in black soil. The treatment Cd₀S₁₅ showed 48, 30 and 43% higher dry weight of flowers per plant over Cd₄₀S₁₅ in alluvial, red and black soil, respectively.

The fresh and dry weight of flowers per plant decreased with increase in soil Cd content, whereas, it increased with graded levels of sewage sludge. The maximum fresh and dry weight of flowers plant⁻¹ in all the three soil types was found in the treatment amended with 15 g kg⁻¹ SS (Cd₀S₁₅). Amongst the three soil types the maximum fresh and dry weight of flower in respective treatments was reported in black soil.

Effect of sewage sludge and cadmium on flower quality

The compactness of flower and flower height in alluvial, red and black soils increased with increase in levels of sewage sludge and decreased with cadmium levels but the effect was non-significant except Cd in red soil

(table 4). The interaction effect of Cd and sewage sludge was also non-significant in all three soil types. There was no clear visible effect observed in compactness of marigold flower due to sewage sludge and cadmium. The flower compactness at harvest in alluvial and red soil ranged between 70.67 to 76.33 cm and 71.00 to 75.33 cm, whereas, in black soil it varied from 73.67 to 77.00 cm. The maximum flower compactness in alluvial (76.33cm) and red soil (75.33 cm) was recorded with Cd₄₀S₅, whereas, in black soil (77.0 cm) it was observed with Cd₀S₁₀. The lowest compactness of flower in alluvial, red and black soil was observed in treatment Cd₂₀S₀, Cd₂₀S₁₀ and Cd₄₀S₀, respectively.

The flower height at harvest in alluvial and red soil ranged between 3.37 to 3.86 cm and 3.29 to 3.88 cm, whereas, in black soil it varied from 3.49 to 3.86 cm. The maximum flower height in alluvial (3.86 cm), red (3.88 cm) and black soil (3.86 cm) was recorded in treatment Cd₀S₁₅, whereas, minimum was recorded with Cd₂₀S₀ in alluvial soil and with Cd₄₀S₀ in red and black soil.

The flower diameter of marigold varied significantly with cadmium, but the effect was non-significant with sewage sludge, the interaction effect was also non-significant. The flower diameter in alluvial soil ranged between 6.02 to 6.83 cm, whereas, in red and black soil it ranged between 4.71 to 6.36 cm and 6.60 to 7.01 cm. In general the flower diameter decreased with increase in soil Cd content, whereas, it increased with graded levels of sewage sludge.

The maximum flower diameter in all the three soil types was found in the treatment amended with 15 g kg⁻¹ SS (Cd₀S₁₅), whereas the lowest was in treatment Cd₄₀S₀. Amongst the three soil types the maximum flower diameter of flower in respective treatments was reported in black soil.

The shelf life of flowers in alluvial, red and black soil ranged between 4 to 5 days. It was found that the shelf life of flowers was non-significantly affected by sewage sludge and cadmium application. Sewage sludge being organic rich material supplies all essential nutrients for plant growth, resulting into the improved quality of flowers. The higher shelf life in some treatments might be due to the improved quality of flowers. It is evidence that storage temperature is the most important abiotic factor that affects the shelf-life (Connick *et al.*, 1997; Elzein *et al.*, 2004) by maintaining them in a state of low metabolic activity (Elzein *et al.*, 2004).

Sewage sludge is widely applied in crop production and provide proper supplements for chemical fertilizers. Application of sewage sludge significantly improved plant growth and quality characteristics of marigold. Maximum of plant growth features such as plant height, fresh and dry weight, chlorophyll content of leaf and the number of branches was obtained with 15 g kg⁻¹ sewage sludge amended soils, whereas, quality characteristics of flower *i.e.*, flower diameter and flower height were non significantly increased with graded application of sewage sludge in all three soils. Amongst the three soil types the maximum plant height, fresh and dry weight of plant was reported in black soil. There was no clear evidence of effect of sewage sludge and cadmium on flower compactness and shelf life. Therefore, it may be concluded that, sewage sludge can be used in cadmium contaminated soil for growing marigold crop.

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