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IMPLICATIONS OF DIFFERENT COMBINATIONS OF INORGANIC, ORGANIC, AND BIOFERTILIZERS ON GROWTH OF DAHLIA (*DAHLIA VARIABILIS* L.) CV. ZAIL SINGH

Krishna Kaushik[1]†, Mukesh Kumar[1]*†, Manoj Kumar Singh[2], Shishu Pal Singh[3], Sunil Malik[1], Bhim Singh[4], Kedar Mahadev Gheware[5] †, Rohan Tomar[1] and Abhishek Chandra[1]

[1]Department of Floriculture and Landscaping Architecture, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut 250110, India

[2]Department of Vegetable Science, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut 250110, India

[3]Department of Soil Science, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut 250110

[4]Department of Basic Science, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut 250110

[5]Division of Floriculture and Landscaping, SKUATS, Jammu 180009, India

†Authors contributed equally

*Corresponding author e-mail: k.mukesh123@yahoo.com

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ABSTRACT

The study on the effect of Integrated Nutrient Management (INM) on the growth and flowering of dahlia (*Dahlia variabilis* L.) aimed to explore the potential of combining organic and inorganic nutrient sources to enhance plant performance and was conducted at the HRC (Horticulture Research Center) of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (Uttar Pradesh, India). The experiment was laid out in a randomized complete block design (RCBD) with nineteen treatment combinations, each replicated three times. Findings from the experiment revealed the maximum plant height (105.02 ± 0.44 cm), stem length (85.73 ± 0.60 cm), and stalk length (29.40 ± 0.31 cm) were recorded under the treatment T_{17}, while plants integrated with T_{12} resulted in maximum plant spread (35.18 ± 0.35 cm), number of leaves (70.17 ± 0.96), and number of branches (14.75 ± 0.25 cm). Moreover, plants fertilized with treatment T_{13} showed maximum leaf width (6.68 ± 0.11 cm) and leaf length (9.90 ± 0.11 cm). The character association studies revealed that leaf width (0.79), leaf length (0.73), plant height (0.56), and number of leaves (0.51) showed a significant positive correlation with plant spread, whereas stem length (-0.11) and number of branches (-0.06) showed a significant negative correlation with leaf width. This suggests that these are the potential traits for improving the vegetative growth of plants.

***Keywords* :** Integrated Nutrient Management (INM), Dahlia, Growth, Flowering, Organic Manures, Bio-fertilizers, Chemical Fertilizers, Correlation.

Introduction

It is often known that flowers are essential to human life; people are born with flowers, grow up with flowers, and ultimately die with flowers. In general, flowers are associated with both joy and grief for the individual (Kumar *et al.*, 2024). The dahlia (*Dahlia variabilis* L.), a member of the Asteraceae family, is indigenous to Mexico and was recognized the nation's national flower in 1963. It was named for the Swedish botanist Dr. Andreas Dahl, a student of Linneaus who worked with Cavanilles in 1791 (Badgujar *et al.*, 2023; Kumar *et al.*, 2024a). Dahlia is a popular tuberous-rooted flower plant found in most gardens around the entire world. Dahlias are used as both cut flowers and loose flowers. The trade appreciation of the dahlia crop has been exploited in certain countries only (Millan, 2024). The Netherlands is a major producer of tuberous-rooted Dahlias, supplying 50 million tubers annually to international markets (Singh *et al.,* 2023; Kumar *et al.,* 2024). Dahlias are grown for ornamental purposes due to their aesthetic characteristics, which are crucial for the ornamental industry. Improved quality in these aspects requires proper rooting and vegetative growth, ensuring water, gas exchange, nutrient supply, and plant support (Galavi, 2013; Gohil *et al.,* 2018; Shukla *et al.,* 2023).

Nutrients are essential for plant growth and development. It has been well documented that farmers use huge amounts of chemical fertilizers to boost crop growth, and this practice can lead to several issues, including soil acidity, reduced microbial activity, and overall degradation of soil health (Kumar *et al.,* 2018). The overuse of inorganic fertilizers in intensive agriculture not only diminishes soil quality but also causes nutritional imbalances and environmental concerns, negatively affecting crop yields (Kumar *et al.,* 2018; Iqbal *et al.,* 2021; Owoeye *et al.,* 2024). Integrated nutrient management (INM) is defined as the combined use of inorganic, organic, and chemical fertilizers for sustaining soil fertility and enhancing soil health with increasing microbial biomass (Kumar *et al.,* 2018). INM helps improve the efficiency of recommended inorganic fertilizer and reduces its input cost. The basic concept of INM is sustaining desired crop productivity by optimizing all sources of plant nutrients in an integrated manner with protection of soil health on a long-term basis. Three main components of INM are such as: balanced fertilizers combined with organic and biological sources of plant nutrients are used for maintaining soil productivity; availability of plant nutrients is promoted in the soil; and the efficiency of plant nutrients is improved (Sri *et al.,* 2023). INM is the most appropriate method for mobilizing all the available plant nutrient sources in order to increase yield productivity while enhancing soil health and indirectly increasing economic return to farmers. Data from 267 sites in India, collected over three years, under various crops convincingly show a 22% increase in yield by INM (Govil and Kaore, 1997). Many other researchers have highlighted the effect of INM on several flower crops (Kumar *et al.,* 2012; Kumar, 2014, 2015; Singh *et al.,* 2014, 2015; Tiwari *et al.,* 2018; Kumar *et al.,* 2019; Garge *et al.,* 2020; Motla *et al.,* 2022; Kaur *et al.,* 2023).

A character's expression in a plant results from a series of interactions between characters, either directly or indirectly, caused by other occurrences. The degree of link between two characters is measured by character association, also known as correlation. Studies of correlation provide more insight into the relationship that exists between the majority of economically significant traits and highly heritable traits, as well as the role that each attribute plays in constructing the genetic composition of the crop (Irani *et al.,* 2016; Suhas and Singh, 2024). The path coefficient, which disentangles the link between various components and yield, offers a far more precise understanding of the relevant factor. As such, the route analysis technique, which allows correlation to be analyzed as a system of related variables, must be used (Sanketh *et al.,* 2024). Therefore, the present investigation had been carried out to assess the impact of different sources of nutrients on the growth of dahlia.

Materials and Methods

Experimental site and location

The field experiment has been conducted at HRC (Horticulture Research Center) of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (Uttar Pradesh, India). Meerut is situated on the NH-58 (Delhi-Dehradun highway). Geographically, the experiment site lies between 28°57’ to 29°02’ North latitude and 77°40’ to 77°45East longitude in the Indo-Gangetic plains of India at an altitude of 218 m above the mean sea level.

Climate and weather

Meerut is located in a subtropical and semiarid climatic zone with hot summers and cold winters. The maximum temperature ranges from 40 to 45°C during summer, and the mean minimum temperature varied from 7°C to 8°C during winter. The frost often occurs in the region from Dec to Feb. The monsoon generally arrives in the last week of June and ceases by the end of September. The total rainfall as well as its distribution in the region is highly uneven. About 80-90% of total rainfall in the season occurs during July to September. Few showers of cyclonic rain are also received in the region during December to January or late spring.

Materials required for the experiment

The cuttings of dahlia are purchased from Kolkata during the years 2022–23. Cuttings of dahlia are planted during the winter of 2022–23.

Treatment Details

A randomized, completely block design was used to evaluate the effect of nineteen different fertilizer treatments on vegetative parameters in Dahlia. Treatments comprised of nineteen treatments as given in Table 1.

Table 1 : Experimental treatments detail.

SI.No.	Treatment Details	Notations
1.	Control	**T_1**
2.	75% RDF+2.5ton/ha FYM+2Kg/ha Azotobacter+ 4.50 L/ha VAM	**T_2**
3.	75% RDF+2.5ton/ha FYM+2Kg/ha Azospirillium+4.50 L/ha VAM	**T_3**
4.	75% RDF+0.83ton/ha Vermicompost+2Kg/ha Azotobacter+4.50 L/ha VAM	**T_4**
5.	75% RDF+0.83ton/ha Vermicompost+2Kg/ha Azospirillium+4.50 L/ha VAM	**T_5**
6.	75% RDF+0.41ton/ha Poultry manure+2Kg/ha Azotobacter+4.50 L/ha VAM	**T_6**
7.	75% RDF+0.41ton/ha Poultry manure +2Kg/ha Azospirillium+4.50 L/ha VAM	**T_7**
8.	50% RDF+5ton/ha FYM+4Kg/ha Azotobacter+4.50 L/ha VAM	**T_8**
9.	50% RDF+5ton/ha FYM+4Kg/ha Azospirillium+4.50 L/ha VAM	**T_9**
10.	50% RDF+1.6ton/ha Vermicompost+4Kg/ha Azotobacter+4.50 L/ha VAM	**T_{10}**
11.	50% RDF+1.6ton/ha Vermicompost+4Kg/ha Azospirillium+4.50 L/ha VAM	**T_{11}**
12.	50% RDF+0.82ton/ha Poultry manure+4Kg/ha Azotobacter+4.50 L/ha VAM	**T_{12}**
13.	50% RDF+0.82ton/ha Poultry manure +4Kg/ha Azospirillium+4.50 L/ha VAM	**T_{13}**
14.	25% RDF+7.5ton/ha FYM+6Kg/ha Azotobacter+4.50 L/ha VAM	**T_{14}**
15.	25% RDF+7.5ton/ha FYM+6Kg/ha Azospirillium+4.50 L/ha VAM	**T_{15}**
16.	25% RDF+2.5ton/ha Vermicompost+6Kg/ha Azotobacter+4.50 L/ha VAM	**T_{16}**
17.	25% RDF+2.5ton/ha Vermicompost+6Kg/ha Azospirillium+4.50 L/ha VAM	**T_{17}**
18.	25% RDF+1.23ton/ha Poultry manure +6Kg/ha Azotobacter+4.50 L/ha VAM	**T_{18}**
19.	25% RDF+1.23ton/ha Poultry manure +6Kg/ha Azospirillium+4.50 L/ha VAM	**T_{19}**

Statistical Analysis

Data related to each parameter was recorded and statistically analysed by applying the technique of analysis of variance using Randomized Completely Block Design (Gomez, 1984). The level of significance for t-test was kept at 5% (P=0.05).

Results

Plant height

Among different treatments showed variable effects in plant height with integrated nutrient supply (Table 2). The treatment T_{17} with 25% inorganic dose of fertilizers with the combination of 2.5 ton per hectare vermicompost and 6 kg per hectare azospirillum, 4.50 liter per hectare VAM resulted in maximum plant height (105.02 cm), followed by T_{16} *i.e.* 25% RDF+2.5ton/ha Vermicompost+6Kg/ha Azotobacter +4.50 L/ha VAM (103.53 cm) while minimum plant height (85.07 cm) was recorded in control under the treatment T_1 treated with 100% inorganic dose of fertilizers.

Stem length

Stem length showed variable effects with the integration sources of nutrients (Table 2). Maximum length of stem (85.73 cm) was noticed in the treatment T_{17} comprise with 25% RDF+2.5ton/ha Vermicompost+6Kg/ha Azospirillium +4.50 L/ha VAM, followed by treatment T_{16} with 25% inorganic dose of fertilizers with the combination of 2.5 ton per hectare vermicompost and 6 kg per hectare azotobacter, 4.50 liter per hectare VAM (83.33 cm) and minimum stem length (60.80 cm) was recorded in the treatment T_{18} (25% RDF+1.23ton/ha Poultry manure +6Kg/ha Azotobacter +4.50 L/ha VAM).

Stalk length

Difference sources of nutrients exhibited differences among the treatments in regards to stalk length (Table 2). An application containing 25% RDF+2.5 tons/ha Vermicompost+6 kg/ha Azospirillium +4.50 L/ha VAM under the treatment T_{17} recorded maximum stalk length (29.40 cm); followed by T_8 50% RDF+5ton/ha FYM+4Kg/ha Azotobacter+4.50 L/ha VAM (27.00 cm) on the other hand, plants fertilized with T_2 with 75% RDF+2.5ton/ha FYM+2Kg/ha Azotobacter+4.50 L/ha VAM resulted in minimum stalk length (14.90 cm).

Plant spread

Plant spread exhibited differences among the treatments when applied with various sources of nutrients (Table 2). Maximum plant spread (35.18 cm^2) was noticed in the treatment T_{12} *i.e.* 50% RDF with the combination of 0.82ton/ha Poultry manure+4Kg/ha Azotobacter+4.50 L/ha VAM, followed by treatment T_{13} with 50% RDF+0.82ton/ha Poultry manure +4Kg/ha Azospirillium+4.50 L/ha VAM (35.08 cm^2) while plants fertilized with T_2 comprise with the combination of 75% RDF+2.5ton/ha FYM+2Kg/ha Azotobacter+4.50 L/ha VAM resulted in minimum plant spread (21.54 cm^2).

Number of leaves

Table 2 clearly indicates that plants fertilized with the various sources of nutrients had variable impacts on the number of leaves. Among the treatments, the application of treatment T_{13} comprise with 50% RDF+0.82ton/ha Poultry manure +4Kg/ha Azospirillium+4.50 L/ha VAM recorded the maximum number of leaves (72.58) followed by treatment T_{12} *i.e.* 50% RDF with the combination of 0.82ton/ha Poultry manure+4Kg/ha Azotobacter+4.50 L/ha VAM (70.17); however, the minimum number of leaves per plant (24.75) was recorded in control treatment T_1.

Number of branches per plant

The data presented in Table 2 clearly indicates that plants integrated with different sources of nutrients showed significant variation in terms of the number of branches per plant (Table 2). Plants fertilized with T_{12} with the combination of 50% RDF with the combination of 0.82ton/ha Poultry manure+4Kg/ha Azotobacter+4.50 L/ha VAM had the maximum number of branches per plant (14.75) followed by treatment T_{13} *i.e.* 50% RDF with the combination of 0.82ton/ha Poultry manure+4Kg/ha Azospirillum+4.50 L/ha VAM (13.58), while treatment T_1 with 100% inorganic dose of fertilizers resulted in the minimum number of branches per plant (7.50).

Leaf width

The data revealed in Table 2 showed leaf width variation among the treatments. Among the treatments, treatment T_{13} 50% RDF with 0.82ton/ha Poultry manure+4Kg/ha Azospirillum+4.50 L/ha VAM resulted in maximum leaf width (6.68 cm) followed by T_{12} 50% RDF with the combination of 0.82ton/ha Poultry manure+4Kg/ha Azotobacter+4.50 L/ha VAM (6.40 cm), while minimum leaf width (4.46 cm) was recorded under treatment T_{16} *i.e.* with the combination of 25% RDF+2.5ton/ha Vermicompost+6Kg/ha Azotobacter+4.50 L/ha VAM.

Leaf length

It is indicated in table 2 that the application of treatment T_{13} treated with the combination of 50% RDF with 0.82ton/ha Poultry manure+4Kg/ha Azospirillum+4.50 L/ha VAM resulted in maximum leaf length (9.90 cm) followed by treatment T_{12} treated with 50% RDF with 0.82ton/ha Poultry manure, 4Kg/ha Azotobacter and 4.50 L/ha VAM. On the other hand, minimum leaf length (6.00 cm) was noticed under the treatment T1 with 100% RDF.

Table 2 : Effect of integrated nutrient management on PH, SL, St.L, PS, No.L, No.B, LW and LL of dahlia.

Treatments	PH	SL	St.L	PS	No.L	No.B	LW	LL
T_1	85.07 ± 0.03	64.70 ± 0.76	19.00 ± 0.15	25.47 ± 0.20	24.75 ± 0.25	7.50 ± 0.25	5.76 ± 0.01	6.00 ± 0.36
T_2	88.50 ± 0.37	64.73 ±0.07	14.90 ± 0.06	21.54 ± 0.36	30.58 ± 0.44	9.75 ± 0.25	4.90 ± 0.01	7.47 ± 0.01
T_3	90.60 ± 1.23	66.27 ±0.64	20.60 ± 0.41	25.39 ± 0.35	49.67 ± 0.17	8.92 ± 0.08	5.56 ± 0.03	6.90 ± 0.05
T_4	91.80 ± 1.67	65.93 ±0.18	18.60 ± 0.12	26.34 ± 0.14	44.17 ± 0.17	12.08 ± 0.08	5.02 ± 0.01	6.05 ± 0.05
T_5	91.50 ± 0.43	70.47 ±0.07	20.80 ± 0.29	25.13 ± 0.36	53.25 ± 0.14	10.25 ± 0.25	5.82 ± 0.13	7.12 ± 0.14
T_6	93.60 ± 0.10	74.20 ±0.12	25.40 ± 0.34	28.17 ± 0.44	40.08 ± 0.96	10.75 ± 0.25	6.22 ± 0.01	7.50 ± 0.07
T_7	97.60 ± 0.40	73.33 ±0.07	17.00 ± 0.29	27.59 ± 0.40	25.58 ± 0.30	9.00 ± 0.00	5.90 ± 0.15	7.30 ± 0.08
T_8	99.00 ± 1.70	71.93 ±1.10	27.00 ± 0.57	30.99 ± 0.13	33.42 ± 0.74	9.17 ± 0.08	6.68 ± 0.02	6.94 ± 0.11
T_9	100.20 ± 1.36	71.07 ±0.07	17.20 ± 0.03	31.92 ± 0.66	64.25 ± 1.42	10.17 ±0.08	6.22 ± 0.11	8.30 ± 0.17
T_{10}	101.23 ± 1.05	72.60 ±1.40	21.20 ± 0.21	32.07 ± 0.27	53.17 ± 0.60	10.75 ± 0.00	6.20 ± 0.00	8.18 ± 0.01
T_{11}	101.00 ± 0.21	69.14 ±0.07	22.60 ± 0.01	26.79 ± 0.34	56.75 ± 0.90	9.92 ± 0.08	6.08 ± 0.09	7.20 ± 0.13
T_{12}	103.00 ± 0.27	73.73 ±0.64	25.00 ± 0.09	35.18 ± 0.35	70.17 ± 0.96	14.75 ± 0.25	6.40 ± 0.13	8.60 ± 0.04
T_{13}	102.00 ± 0.69	69.20 ±0.12	24.00 ± 0.16	35.08 ± 0.26	72.58 ± 0.82	13.58 ± 0.30	6.68 ± 0.11	9.90 ± 0.11
T_{14}	90.00 ± 2.33	67.54 ±0.07	22.60 ± 0.48	27.75 ± 0.22	35.67 ± 0.22	8.92 ± 0.08	6.31 ± 0.13	6.70 ± 0.04
T_{15}	95.06 ± 0.25	66.53 ±0.07	20.80 ± 0.44	25.64 ± 0.56	37.33 ± 0.68	9.42 ± 0.30	5.60 ± 0.16	6.14 ± 0.07
T_{16}	103.53 ± 2.53	83.33 ±0.41	26.60 ± 0.65	23.29 ± 0.39	62.58 ± 1.20	12.83 ± 0.08	4.46 ± 0.20	6.30 ± 0.06
T_{17}	105.02 ± 0.44	85.73 ±0.60	29.40 ± 0.31	28.62 ± 0.34	52.58 ± 1.06	12.42 ± 0.22	5.39 ± 0.14	7.92 ± 0.09
T_{18}	99.32 ± 0.57	60.80 ±0.12	20.20 ± 0.08	30.50 ± 0.34	36.58 ± 0.74	11.25 ± 0.00	6.14 ± 0.04	6.80 ± 0.04
T_{19}	98.50 ± 0.61	62.47 ±0.57	18.00 ± 0.04	25.51 ± 0.44	33.67 ± 0.60	11.67 ± 0.22	5.14 ± 0.14	6.26 ± 0.33
C.D.	**1.02**	**1.58**	**0.91**	**1.02**	**2.21**	**0.53**	**0.31**	**0.41**
SE(m)	**0.35**	**0.55**	**0.31**	**0.35**	**0.77**	**0.19**	**0.11**	**0.14**
SE(d)	**0.50**	**0.78**	**0.45**	**0.50**	**1.09**	**0.26**	**0.15**	**0.20**
C.V.	**2.19**	**1.35**	**2.52**	**2.19**	**2.89**	**3.01**	**3.19**	**3.40**

***PH- Plant height, SL- Stem length, St.L- Stalk length, PS- Plant spread, No.L- Number of leaves, No.B- Number of branches, LW- Leaf width, LL- Leaf length**

Correlation Analysis

All the traits under study were significantly different, hence were subjected to correlation studies, and results have been depicted in Table 3 and Fig 1.

The correlation table highlights several significant relationships among the plant traits. Plant height is significantly correlated with stem length (0.57), stalk length (0.53), and plant spread (0.56). It also shows a highly significant correlation with both the number of leaves (0.61) and the number of branches (0.67), indicating that taller plants tend to have more leaves and branches. Additionally, plant height is significantly correlated with leaf length (0.50). Similar results were also recorded (Kumar *et al.,* 2022; Zala *et al.,* 2023; Singh *et al.* 2023) when working on the correlation of different traits. Moreover, stem length is highly significantly correlated with stalk length (0.70), suggesting that as the stem length increases, so does the stalk length. Plant spread is highly significantly correlated with both leaf width (0.79) and leaf length (0.73), indicating that wider and longer leaves are associated with greater plant spread. It also has a significant correlation with the number of leaves (0.51). The results were in agreement with the findings of Kumar *et al.* (2022); Raghupathi *et al.* (2019) in the dahlia crop. In addition, the number of leaves is highly significantly correlated with the number of branches (0.70) and with leaf length (0.65), suggesting that plants with more leaves tend to have more branches and longer leaves. The number of branches is also significantly correlated with leaf length (0.69). The greater number of branches leads to higher leaf biomass that enhances the number of leaves by regulating the source-sink relationship (Manjula *et al.,* 2017). Our research results are comparable with the research findings of Singh *et al.,* (2023) in Delhi. Finally, leaf width and leaf length are significantly correlated, highlighting key relationships between plant structural traits, such as taller plants having more leaves and branches and plants with greater spread having larger leaves (Kumar *et al.,* 2022). Correlation analysis helps in examining the possibility of improving quality of vegetative growth through indirect selection of its component traits, which are highly correlated with standard vegetative growth (Cordea *et al.,* 2007; Balaram *et al.,* 2009). The present study is comparable with the findings of Kumar *et al.,* (2022) in dahlia, Sanketh *et al.,* (2024) in gillyflower, and Suhas and Singh, (2024) in gladiolus.

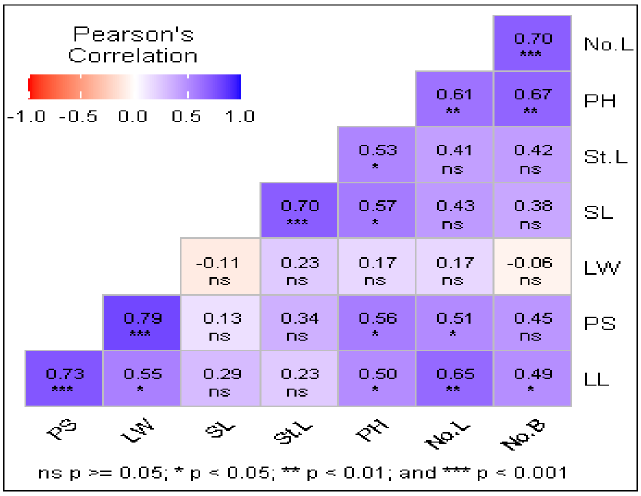

Fig. 1 : Correlation coefficient of various Dahlia parameters in response of application of fertilizers.

Table 3 : Correlation matrix of parameters of Dahlia in response of fertilizer application.

	Plant Height	**Stem length**	**Stalk length**	**Plant Spread**	**Number of leaves**	**Number of branches**	**Leaf width**	**Leaf length**
Plant Height	1	0.57*	0.53*	0.56*	0.61**	0.67**	0.17	0.5*
Stem length	0.57*	1	0.7***	0.13	0.43	0.38	-0.11	0.29
Stalk length	0.53*	0.7***	1	0.34	0.41	0.42	0.23	0.23
Plant Spread	0.56*	0.13	0.34	1	0.51*	0.45	0.79***	0.73***
Number of leaves	0.61**	0.43	0.41	0.51*	1	0.7	0.17	0.65**
Number of branches	0.67**	0.38	0.42	0.45	0.7***	1	-0.06	0.49*
Leaf width	0.17	-0.11	0.23	0.79***	0.17	-0.06	1	0.55*
Leaf length	0.5*	0.29	0.23	0.73***	0.65**	0.49*	0.55*	1

*Significant at 5% level of significance

**Significant at 1% level of significance

***Significant at 0.1% level of significance

Principal Component Analysis

In this study, PCA was performed on eleven yield and yield component traits in Indian mustard germplasm lines (Table 4).

According to Brejda *et al.* (2000), principal components with eigenvalues greater than 1 that explain at least 5 percent of the data variation should be considered. Eigenvalues measure the amount of variation a factor explains out of the total variation, while factor loadings (or component loadings) are the correlation coefficients between the original variables and the factors obtained (Sarwar *et al.,* 2021). The eigenvalues from PCA help determine the number of factors to retain, capturing most of the variability in the data (Munir *et al.,* 2020). Principal components with higher eigenvalues and high factor loadings were deemed best for representing system attributes. The sum of all eigenvalues equals the number of variables (Gupta *et al.,* 2024). In the present study, the first three principal components had eigenvalues greater than one and collectively explained 85.9 percent of the total variation in the data. Therefore, these three components were considered significant for further explanation. The first principal component explained 51.5 percent, while the second and third principal components exhibited 21.6 percent and 11.8 percent variability, respectively, among the treatments for the parameters under study. The first principal component accounts for as much of the variability in the data as possible, and each succeeding component accounts for as much of the remaining variability as possible (Table 4). This present result was in accordance with the findings of Saeed *et al.* (2014); Latif *et al.* (2015); Kaleri *et al.* (2015); Shah *et al.* (2018); Vinodhana and Gunasikaran (2019) in several crops.

The scree plot explains the percentage of variation associated with each principal component and is obtained by drawing a graph between principal component numbers (X-axis) and percentage of variation explained (Y-axis). The principal component 1 showed, 51.5 percent variability with an eigenvalue of 4.6, which then declined gradually. From the graph, it is clear that the maximum variation was observed in Principal Component 1 (Fig 2). The results of the Principal Component Analysis (PCA) highlighted the diversity among the traits. Eigenvalues were used to assess the significance and contribution of each principal component to the total variation, while factor loadings indicated the extent to which each original variable contributed to each principal component (Sarwar *et al.,* 2022). In the present study, all the parameters viz., plant height, number of leaves, number of branches, leaf length, salk length, stem length, and leaf width clustered towards the right quadrant of the PCA biplot, indicating a positive association among each other, and traits *viz.,* plant height, number of leaves, plant spread, leaf length, number of branches, and stalk length contributed to 86.69 percent of total variability towards PC1 (Fig 4). Parameters viz., stem length, leaf width, and plant spread contributed to 76.46 percent of total variability towards PC2 (Fig 5). Consequently, the first two principal components, which explained approximately 73.1 percent of the total variation, were significant in differentiating treatments based on various parameters studied. Saeed *et al.* (2014); Isong *et al.* (2017) also confirmed similar trends.

The traits contributing the most variability and segregating into different principal components tend to cluster together, which should be considered for further selection of treatments. The prominent characters identified in the first two principal components as prime contributors to total variability have the ability to differentiate different treatments on the basis of respective traits represented as vectors in the PCA biplot by selecting the treatments clustering together in the quadrant of the respective trait/parameter for which the selection has to be done. The treatment towards the extreme side of the quadrant can be selected for that trait/parameter.

The contribution of the first two principal components to the total variability was maximum (73.1 percent); thus, these two were plotted to reveal the relationship between them (Fig 3). Treatments *viz.*, T_{13}, T_{12} clustered towards the extreme end of PC1 in the upper right quadrant, indicating effectiveness of these treatments for traits present in this quadrant, *viz.*, leaf width, plant spread, and leaf length, while treatment viz., T_{17} clustered towards the extreme end of PC1 in the lower right quadrant indicates effectiveness for selection of parameters, viz., number of leaves, plant height, number of branches, stalk length, and stem length. The present investigation is comparable with the results of Kumar *et al.* (2022); Hegde *et al.* (2022) in Dahlia. After one year, Singh *et al.,* (2023), also find similar trends in Delhi. Kamal *et al.* (2024), revealed comparable data in chrysanthemum.

Table 4 : Eigen values and percentage of variance corresponding to each principal component

	Eigen value	Percentage of variance	Cumulative percentage of variance
comp 1	4.12	51.48	51.48
comp 2	1.73	21.61	73.09
comp 3	0.94	11.80	84.89
comp 4	0.47	5.84	90.73
comp 5	0.36	4.54	95.27
comp 6	0.24	2.95	98.22
comp 7	0.11	1.37	99.59
comp 8	0.03	0.41	100.00

Table 5 : Contribution of each parameter towards variance of principal components

	PC1	PC2	PC3	PC4	PC5
PH	16.75	2.79	0.17	12.95	42.75
SL	8.61	20.64	14.70	19.74	7.49
St.L	10.50	6.87	34.85	4.52	22.09
PS	14.89	17.79	0.14	6.51	0.64
No.L	16.10	0.75	11.63	9.85	19.02
No.B	13.61	5.14	20.89	15.66	5.42
LW	4.67	38.05	13.74	0.17	0.73
LL	14.86	7.98	3.88	30.59	1.87

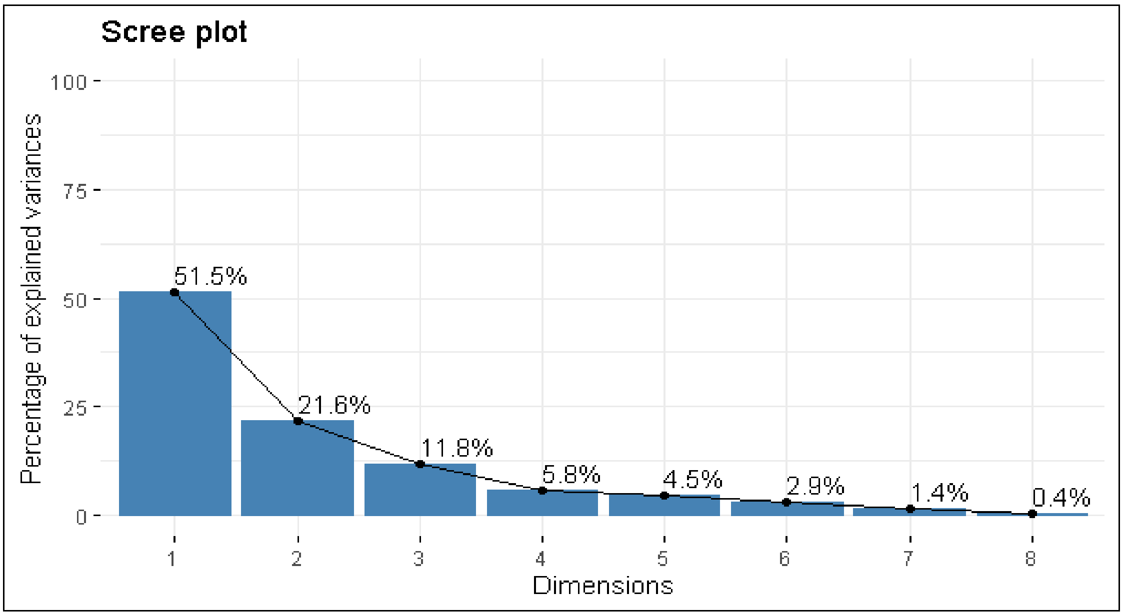

Fig. 2 : Scree plot of the PCA components for the Dahlia parameters in response of application of fertilizers.

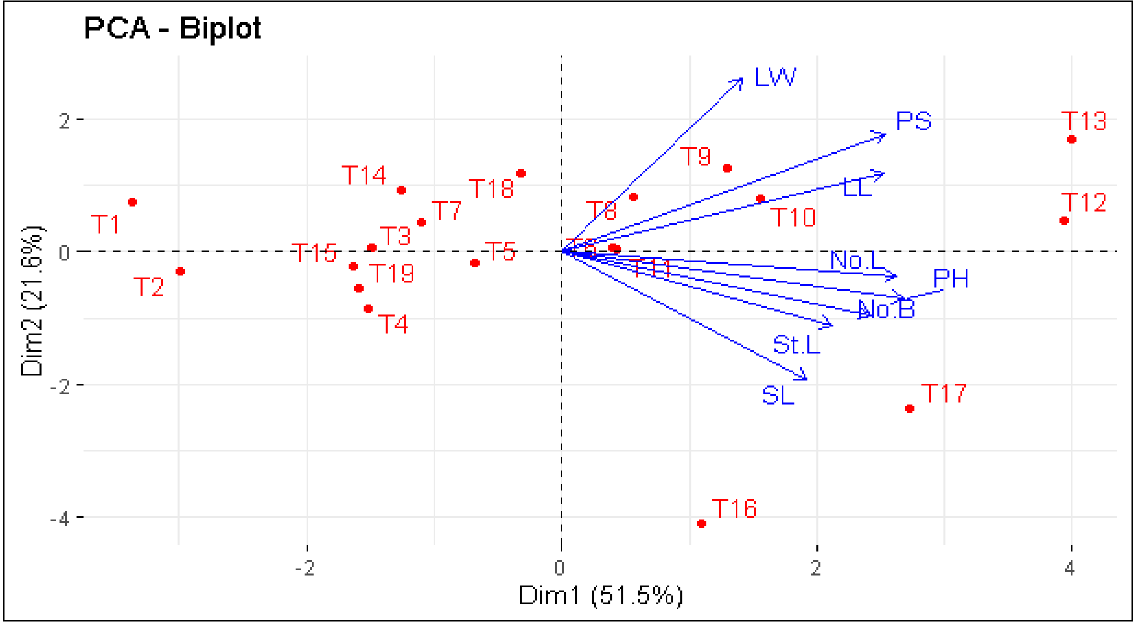

Fig. 3 : PCA Biplot representing different treatments of fertilizers along with various parameters of Dahlia

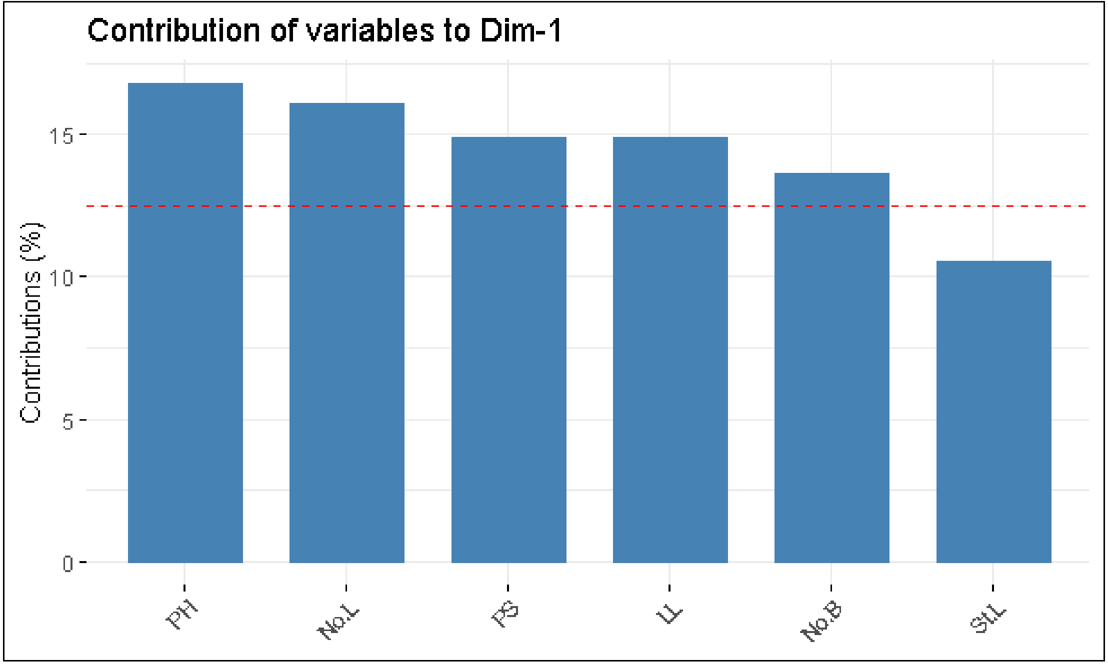

Fig. 4 : Contribution of various parameters in variation to Principal Component 1

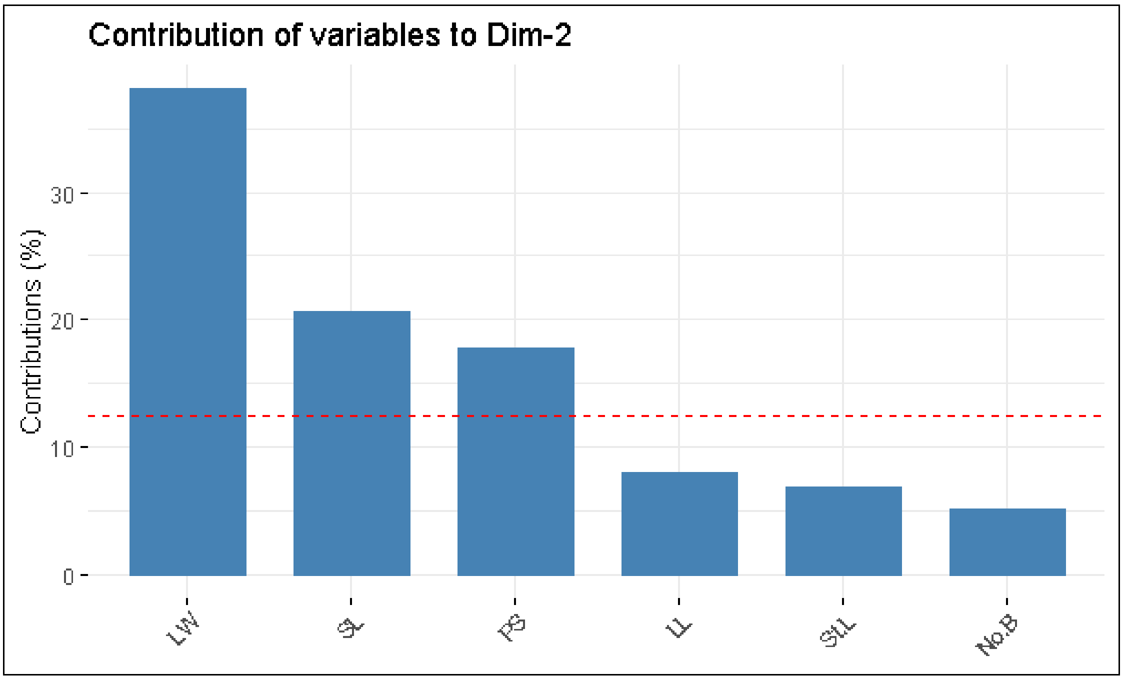

Fig. 5 : Contribution of various parameters in variation to Principal Component 2

Discussion

These increases in plant height may be attributed to the high content of organic residues of elemental nitrogen (Nazir *et al.,* 2012), which has a key role in the building of amino acids arginine, glycine, and tryptophan, reflected on the promotion of cell elongation, and thus increased the height of the plant (Abd-Elkader *et al.,* 2020). Similar findings were also reported by Pandey *et al.* (2017); Warakar *et al.* (2020).

Stem length is an important factor that is linked to rapid meristematic activity and strength of rapid cell division and elongation during the tender growth period (Asfaw, 2022). Increases in stem length might be due to enhancement in macronutrients (NPK), which have a key role in improving growth boosters and enzymes like lipases and amylases (Arancon *et al.,* 2020). Our results are in line with the earlier findings of Parmar *et al.* (2017); Warakar *et al.* (2020) in various crops.

The enhanced stalk length might be due to increased C:N ratio by the application of organic sources of nutrients (Ojo *et al.,* 2014) and to sink relationships and translocated nutrients from leaves to stalk due to the improved enzyme (proteases and cellulases) system of the plant (Munoz-Ucros *et al.,* 2020). The present investigation is comparable with the research findings of Moghadam and Shoor (2013) in Petunia, after 4 years. Pandey *et al.* (2017); Parmar *et al.* (2017) also noticed a similar trend in Dahlia and Marigold, respectively.

The results of maximum plant spread be due to the generation of dimethylamine as well as ketones and aldehydes by the application of organic nutrients (Myszograj and Puchalska, 2012), thus increasing the spread of the plant (CiobanuĚurlea *et al.,* 2021; Badulescu *et al.,* 2021). Swathi *et al.* (2017) also reported similar results. in Marigold cv. Pusa Narangi Gainda. Moreover, Yadav *et al.* (2023); Eglus *et al.* (2023); Rahman *et al.* (2024) also found significant effects of poultry manure in tomato plants in the context of plant spread.

Improved soil properties directly affect number of leaves per plant because soil properties play an important role in nutrient availability and increases in nutrient availability and increases in nutrient uptake (Kumar *et al.,* 2024), which indirectly affect microbial respiration and CO_2 output (Fawzy *et al.,* 2007). Slow release of nutrients might favor metabolic activity through enhancement in production of glycine, alanine, valine, phenylalanine, etc. in plant tissue (Baqir *et al.,* 2019; Abd-Elkader *et al.,* 2020). Moreover, optimal nutrients provided to plants might accelerate the rate of photosynthesis, thereby enhancing the vegetative growth of plants (Singh *et al.,* 2023). Our results are in line with the earlier findings of Warade *et al.* (2007); Verma *et al.* (2017); Prasad *et al.* (2018) in various crops.

The increase in the number of branches per plant in the treatment T_{12} might be due to the chlorophyll, which is promoting photosynthetic rates, which directly affects the vegetative growth such as the formation of primary branches and promoting branching patterns in plants through enhanced cell division, cell expansion, and green coloration of plant foliage (Omokaro and Ajakaye, 1989; Owoeye *et al.,* 2024). Similar findings were reported by Sheergojri *et al.* (2013); Rahman *et al.* (2024) in different crops.

Inoculation with biofertilizers significantly increased leaf width because it increased the rates of organic compost or mineral elements (El-Naggar, 2010). The current experimental results of various crops are comparable with the findings of Kumar *et al.,* (2015); Srivastava *et al.* (2018); Kangjam *et al.* (2024).

The enhancement in leaf growth as a result of organic fertilizers may be due to the production of pytohormones (tryptophan and cysteine; Baqir *et al.,* 2019) by improving the availability of nutrients (El-Ziat, 2015; El-Sayed *et al.,* 2018). Our results are in line with the earlier findings of Adison *et al.,* 2024 in spinach.

Conclusion

Based on the results of this investigation, it can be concluded that the application of 25% RDF combined with 2.5 tons/ha of vermicompost, 6 kg/ha of Azospirillum, and 4.50 L/ha of VAM is particularly beneficial for improving plant height, stem length, and stalk length. Additionally, applying 50% RDF with 0.82 tons/ha of poultry manure, 4 kg/ha of Azotobacter, and 4.50 L/ha of VAM effectively enhances plant spread, the number of leaves, and the number of branches. Moreover, the combination of 50% RDF, 0.82 tons/ha of poultry manure, 4 kg/ha of Azospirillum, and 4.50 L/ha of VAM significantly improves leaf width and leaf length. These findings suggest that strategic combinations of organic and biofertilizers with reduced RDF can optimize various growth parameters, offering valuable insights for sustainable horticultural practices.

Based on the result revealed, leaf width, leaf length, plant height, and number of leaves showed a significantly positive correlation with important vegetative growth trait plant spread in plant, while stem length and number of branches showed significantly negative correlation with leaf width. Those traits have potential, which should be taken into consideration while selecting for crop improvement with respect to better vegetative growth.

Conflict of Interest

The Authors declare that there is no conflict of interest to disclose in relation to this research paper. No financial support was received from any organizations that could have influenced the outcome or interpretation of the research findings.

Author's Contribution Statements

All authors have read and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

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