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Flower Production Index In Chhattisgarh Using Principal Component Analysis

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Abstract
Flower crops are commercially important horticultural crops that are primarily cultivated for sale rather than for self-consumption. These crops generate immediate income for farmers after harvest and play a significant role in improving their economic status. The present study focuses on the construction of a Composite Index for Flower Production at the district level in Chhattisgarh for the year 2023-24. Secondary data on district-wise production of selected flower crops as production of Rose (PR), production of Marigold (PM), production of Chrysanthemum (PC), production of Gladiolus (PG), production of Jasmine (PJ) and production of Tuberose (PT) were collected from Directorate of Horticulture and Farm Forestry, Govt. of Chhattisgarh Official Sources. A Composite Index was developed using Principal Component Analysis (PCA) to evaluate and compare the performance of different districts in terms of flower production. Based on the computed index values, districts were ranked to identify leading and lagging regions in flower production. The PCA methodology has been used for construction of index and the ranking of the districts was performed based on the developed FPI. It was found that Mahasamund ranked first in FPI followed by Mungeli and Surajpur. It was also investigated that the FPI was highly sensitive to byrose production followed by marigold, chrysanthemum and jasmine production.

Key words: Indicator, Flower Production Index, Principal Component Analysis.

INTRODUCTION

Floriculture is an important branch of horticulture that deals with the cultivation of flowering and ornamental plants for commercial purposes. Flower crops are primarily grown for marketing rather than for self-consumption, making them a significant source of income for farmers. With increasing demand for flowers in religious, cultural, decorative, and export markets, floriculture has emerged as a profitable agricultural enterprise in many parts of India.

In India, the diversity in agro-climatic conditions supports the cultivation of a wide range of flower crops such as marigold, rose, chrysanthemum, gladiolus, jasmine, and tuberose. Different states specialize in different flower crops depending on their climatic suitability and market demand. In Chhattisgarh, the area under floriculture is currently negligible. With the formation of the new state, it has become necessary to promote commercial flower cultivation among farmers to meet the increasing demand for flowers. Major flowers such as marigold, tuberose, gladiolus, roses, gaillardia, chrysanthemum, and orchids can be grown very well without requiring much care. In the state, the area under flower cultivation during 2024-25 is 13,053 hectares, and the production is 191,008 metric tons. In recent years, Chhattisgarh has shown considerable potential in floriculture due to its favorable climate, availability of land, and growing market opportunities. Flower cultivation in the state is gradually expanding from traditional farming to more commercial and organized production systems.

District-wise variation in flower production is an important aspect that reflects the regional strengths and disparities in floriculture development. Factors such as soil type, irrigation facilities, infrastructure, and market accessibility influence the production levels of different flower crops across districts. Major flower crops cultivated in Chhattisgarh include marigold, rose, chrysanthemum, gladiolus, jasmine, and tuberose, each contributing differently to the overall floriculture economy of the state.

To systematically assess and compare the performance of different districts, it is essential to develop a comprehensive measure that integrates multiple crop production indicators into a single index. In this context, the present study aims to construct a Composite Index for Flower Production using district-wise data for the year 2023-24. The index is developed using Principal Component Analysis (PCA), which helps in reducing dimensionality and assigning appropriate weights to different variables.
The constructed composite index facilitates the ranking of districts based on their overall performance in flower production. This approach not only highlights the leading and lagging districts but also provides insights into the relative contribution of different flower crops. The results of this study are expected to support policymakers, planners, and researchers in formulating strategies for balanced regional development, efficient resource allocation, and promotion of floriculture in Chhattisgarh.

An indicator is a quantitative or qualitative measure that can assign relative positions in a particular area. Indicators are useful for determining trends and making conclusions about particular issues in policy analysis. A composite indicator is formed when many indicators are compiled into a single index using a specific methodology. The composite indicator can measure multi-dimensional concepts, which cannot be explained using a single indicator.

Composite Index has been constructed by mainly authors using different methodology and technique. Among them, Analytic Hierarchy Process (AHP) is an important technique that is being usedextensively inmany areas. AHP is based on expert judgment and the experts of related field give their opinion/priorities to many alternatives to analyze and support decisions. It is subjective in nature because it is based on expert's judgment. Environmental problem index was developed using AHP considering public opinion as a weighting technique (Parker, 1991). AHP was also used in landfill siting using GIS (Siddique *et al.*, 1996). A methodology for construction of composite index was proposed and used in construction of development index (Narain*et al.*, 1991). The methodology involves the problem of multicollinearity. A potential agro forestry area was identified using Objective Analytic Hierarchy Process (OAHP) (Ahmad *et al.*, 2003). Socio-economic development of different districts of Kerala was also estimated (Narain*et al.*, 2005). The techniques used above to construct composite index is either subjective in nature or involves the problem of multicollinearity. In case of multicollinearity present in the dataset, the weight of one variable is added up to the weight of correlated variables, thus yields poorly constructed composite index. A new methodology was proposed and in this, Principal Component Analysis (PCA) was used in construction of composite index to overcome the problem of multicollinearity and Agriculture Development Index of Bihar State, India was developed (Kumar *et al.*, 2013). Also, Flower Production Index (FPI) was constructed using PCA for 18 districts of West Bengal State, India (Kumar *et al.*, 2015). The methodology developed by Kumar *et al.*, 2013 has been used for construction of flower production index. Secondary data on production of marigold, rose, chrysanthemum, gladiolus, jasmine, and tuberose for the year 2023-24 have been used for constructing the Flower Production Index in Chhattisgarh state.

MATERIAL AND METHODS

In the present paper, a composite index, namely the Flower Production Index, has been constructed using secondary data taken from the Directorate of Horticulture and Farm Forestry, Govt. of Chhattisgarh, Official Sources. The data on production of marigold, rose, chrysanthemum, gladiolus, jasmine, and tuberose for the year 2023-24 have been used in the construction of flower production index for 33 districts of Chhattisgarh state. The methodology developed by Kumar *et al.*, 2013 as given below has been used for constructing the Flower Production Index. The statistical analysis was performed using R Studio version 4.5.1.
Maximum Likelihood Estimate (M.L.E.) of variance-covariance matrix (Σ) of the given data set was estimated using equation-1

$$\hat{\Sigma} = \frac{1}{n}\sum_{i=1}^{n}\left(\underline{X}_i - \overline{\underline{X}}\right)\left(\underline{X}_i - \overline{\underline{X}}\right)' \qquad \ldots (1)$$

where

$$\underline{X} = \begin{bmatrix} X_1 \\ X_2 \\ . \\ . \\ . \\ X_q \end{bmatrix}$$

Where, q is the number of indictors / variables.

$$\overline{\underline{X}} = \frac{1}{n}\sum_{i=1}^{n}\underline{X_i}$$

and n is the total number of states.
Then, the Correlation Matrix (**CM**) was obtained using above variance-covariance matrix as

$$\mathbf{CM} = \left(\sqrt{\mathbf{V}}\right)^{-1}\hat{\Sigma}\left(\sqrt{\mathbf{V}}\right)^{-1} \quad \ldots (2)$$

where
V = Diagonal matrix obtained from variance-covariance matrix and
$\hat{\Sigma}$ = M. L.E. of variance-covariance matrix.
Next step was to obtain principal components using Eigen vectors of the estimated correlation matrix and standardized values of variables. The principal components were obtained by using the formula given below.

$$P_1 = a_{11}Z_1 + a_{12}Z_2 + \ldots + a_{1q}Z_q$$
$$P_2 = a_{21}Z_1 + a_{22}Z_2 + \ldots + a_{2q}Z_q$$
$$.$$
$$.$$
$$.$$
$$P_q = a_{q1}Z_1 + a_{q2}Z_2 + \ldots + a_{qq}Z_q$$

where
P_qs :q^{th} principal components
Z_qs : standardized values of q^{th} variable
a_{kq}: element belonging to k^{th} eigenvector and for q^{th} variable, k=1,2, …,q; q=1,2, …,q.
The composite index was constructed using the obtained eigenvalues and principal components given in equation-3:

$$CI_i = \frac{\lambda_1 P_1 + \lambda_2 P_2 + \ldots + \lambda_q P_q}{\sum_{j=1}^{q}\lambda_j} \quad \ldots (3)$$

Where,
CI_i= composite index for i^{th}district,
λ_js are eigen values,
P_q's are q^{th} principal components, i=1,2, …,n; j=1,2, …,q.
Further, the composite index of each district was normalized using the equation-4:

$$CI_{ni} = \frac{CI_i - \min(CI)}{\max(CI) - \min(CI)} \quad \ldots (4)$$

where,
CI_{ni}= normalized value of composite index of i^{th}district,
min (CI) = minimum value of composite index among all,
max (CI) = maximum value of composite index among all.

RESULTS AND DISCUSSION

The statistical analysis was performed using R Studio version 4.5.1 opensource free software used to analyze the data.

The correlation analysis of flower crops in Chhattisgarh shows mostly positive relationships, meaning districts producing one crop often produce others. The highest correlations were between rose and jasmine (r = 0.680) and marigold and rose (r = 0.646), suggesting similar growing conditions. Moderate links were also seen among rose, chrysanthemum, and gladiolus. However, tuberose showed very weak correlations with other crops, indicating a different cultivation pattern. None of the correlations were statistically significant ($p \leq 0.05$), suggesting that flower production across districts is influenced by varied and independent factors. Also, regression analysis was performed and Variance Inflation Factor (VIF) for each variable was obtained to detect multicollinearity by regressing one variable to other remaining variables. The Variance Inflation Factor for j^{th}variable can be obtained as under

$$VIF_j = \frac{1}{1 - R_j^2}$$

VIF_j is the variance Inflation Factors For the j^{th}variable.

Coefficients of determination (R_j^2) were obtained by regressing j^{th}variable on other variable(s).

Table 1. Correlation Matrix for Flower Crop Production

	PM	**PR**	**PC**	**PG**	**PJ**	**PT**
PM	1	0.646*	0.329	0.289	0.464	0.091
PR		1	0.525	0.372	0.680*	0.101
PC			1	0.414	0.331	0.281
PG				1	0.128	0.335
PJ					1	0.020
PT						1

Note: The value indicated by '*' is significant at p=0.05

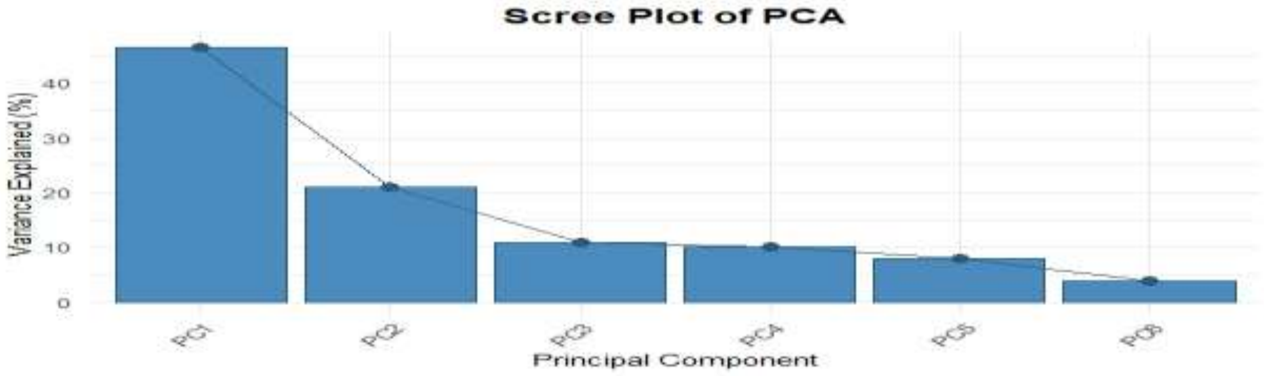
Regression results (Table 2) show significant linear relationships among variables, except for PG and PT. All VIF values are below 5, indicating no serious multicollinearity (Montgomery et al., 2001). A slight multicollinearity is observed only in PR, while other variables show none. Overall, multicollinearity is not a concern, and the variables are suitable for constructing the Flower Production Index. PCA was also used to further minimize any potential multicollinearity.

Table2. Detection of Multicollinearity

Model	Dependent Variable	Independent Variables	p value	R^2	VIF
1	PM	PR, PC, PG, PJ & PT	0.008	0.42	1.73
2	PR	PM, PC, PG, PJ & PT	0.000	0.68	3.10
3	PC	PR, PM, PG, PJ & PT	0.027	0.36	1.56
4	PG	PR, PM, PC, PJ & PT	0.087	0.29	1.40
5	PJ	PR, PM, PC, PG& PT	0.002	0.48	1.93
6	PT	PR, PM, PC, PG& PJ	0.940	0.15	1.17

The PCA results show that the first principal component (PC1) explains the highest variation (46.46%), followed by PC2 (20.94%) and PC3 (10.89%). Together, the first three components account for 78.29% of total variation, making them sufficient to represent the dataset. Although only two components have eigenvalues greater than 1, the scree plot (Fig. 1) indicates an elbow at PC3, supporting the selection of three components. The remaining components contribute little, so most variation in flower production is effectively captured by the first three PCs, with PC1 being dominant.

Fig 1. Scree Plot of Principal Components Analysis



Eigenvector analysis (Table 3a) indicates that PC1, PC2, and PC3 explain most of the variability in the dataset. In PC1, rose (0.531) has the highest positive loading, followed by marigold, chrysanthemum, and jasmine, showing their strong contribution to variation. This means districts with higher production of these crops score higher on PC1.

Table3. Eigenvalues of Principal Components (PCs)

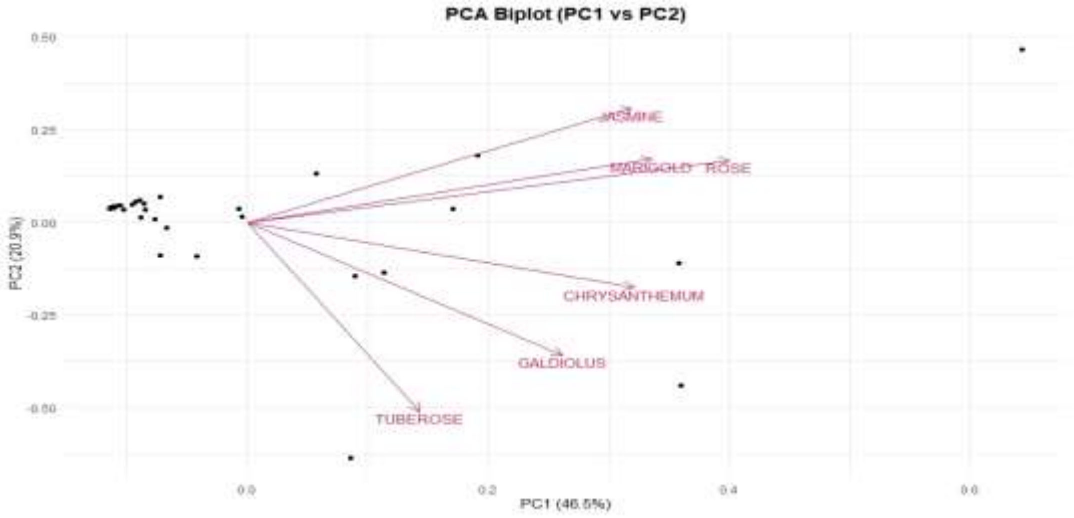
PCs	Eigenvalue	% Variance explained	Cumulative variance
PC1	2.79	46.46	46.46
PC2	1.26	20.94	67.40
PC3	0.65	10.89	78.29
PC4	0.61	10.09	88.38
PC5	0.47	7.867	96.25
PC6	0.22	3.745	1.00
		100	

Table 3a. Eigenvectors

Eigenvectors						
	1	**2**	**3**	**4**	**5**	**6**
PM	0.4462	0.2257	0.0675	0.5953	-0.5525	-0.2928
PR	0.5311	0.2222	0.0043	-0.0168	0.0706	0.8144
PC	0.4268	-0.2323	0.0888	-0.7327	-0.4262	-0.1936
PG	0.3477	-0.4740	0.6253	0.2013	0.4523	-0.1357
PJ	0.4239	0.4083	-0.3766	-0.1333	0.5509	-0.4364
PT	0.1898	-0.6740	-0.6744	0.2240	0.0008	0.0682

In PC2, jasmine shows the highest positive loading, whereas tuberose and gladiolus have strong negative loadings, indicating an inverse relationship. Overall, rose emerges as the most influential crop in the composite index, followed by marigold, chrysanthemum, and jasmine, significantly influencing district-wise rankings in Chhattisgarh's floriculture sector as shown in Fig2

Fig 2. PCA Biplot (PC1 Vs PC2)



The Flower Production Index (FPI) shows clear district-wise variation in floriculture across Chhattisgarh. Mahasamund ranked first (1.000), followed by Mungeli (0.5955) and Surajpur (0.4688). Korba, Bilaspur, and Raigarh also performed well, indicating their potential as major flower production hubs. In contrast, Raipur, Sarguja, and Mohla-Manpur Ambagarh Chowki ranked lowest, reflecting poor performance. Using the 75th percentile (0.194) as a threshold, districts like Mahasamund, Mungeli, Surajpur, Korba, Bilaspur, Raigarh, Durg, Dhamtari, and Gaurella-Pendra-Marwahi were classified as high production zones, while others fell into the low production category. These differences highlight the influence of factors such as climate, irrigation, infrastructure, and adoption of floriculture practices. The ranking helps identify leading and lagging districts, providing a useful basis for policymakers to design targeted strategies for balanced floriculture development in the state.

Table4.Flower Production Index of Chhattisgarh

DISTRICT	FPI	RANK
MAHASAMUND	1.0000	1
MUNGELI	0.5955	2
SURAJPUR	0.4688	3
KORBA	0.4602	4
BILASPUR	0.3989	5
RAIGARH	0.2952	6
DURG	0.2782	7
DHAMTARI	0.2768	8
GAURELLA-PENDRA-MARWAHI	0.1943	9
BALRAMPUR	0.1869	10
KONDAGAON	0.1328	11
BALODA BAZAR	0.1216	12
BASTAR	0.1129	13
BEMETARA	0.1108	14
GARIYABAND	0.1066	15
BIJAPUR	0.1059	16
MAHNENDRAGAH-CHIRMIRI-BHARATPUR	0.1043	17
BALOD	0.1040	18
DANTEWADA	0.1009	19
KOREA	0.0939	20
KANKER	0.0881	21
RAJNANDGAON	0.0874	22
JANJGIR-CHAMPA	0.0866	23
NARAYANPUR	0.0837	24
SAKTI	0.0831	25

SUKMA	0.0805	26
JASHPUR	0.0804	27
KHAIRAGARH-CHHUIKHADAN-GANDAI	0.0791	28
KABIRDHAM	0.0787	29
SARANGARH-BHILAIGARH	0.0768	30
MOHLA-MANPUR-A. CHOWKI	0.0754	31
SARGUJA	0.0617	32
RAIPUR	0	33

CONCLUSION

The Secondary data on production of Rose, Marigold, Chrysanthemum, Gladiolus, Jasmine and Tuberose of 33 district of Chhattisgarh for the year 2023-24 were analyzed and it was observed that correlation between production of Rose with Marigold and Jasmine was significant at p value 0.05. The Flower Production Index (FPI) for each district was constructed to identify and group them into two categories High and Low on the basis of constructed FPI. The categorization of districts was done on the basis of percentile value of FPI. The 75th percentile value were found to be 0.194 respectively. The Mahasamund district ranked first followed by Mungeli and Surjpur and the districts like Sarguja, Raipur and Manpur-Mohla-Ambagarh Chowki were grouped into category with low in production of flower crops under study.

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