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RESPONSE OF CAULIFLOWER (*BRASSICA OLERACEA* L. VAR. BOTRYTIS) CULTIVARS TO VARYING PHOSPHORUS LEVELS. A CASE STUDY OF NORTHERN PUNJAB

Abdul Waheed[1], Saima Nazar[2], Sajid Ali[3], Naveed Iqbal Khan[4], Arif Husain[5], Muhammad Shoaib Aslam[6], Saeed Ur Rehman[7], Sher Afzal[6]*, Nadeem Raza[8], Bashir Ahmad[9], Raja Abad Raza[1], Taimoor Tahir Cheema[10], Allah Nawaz[11], Abdul Ghaffar Khan[12], Wajiha Anum[13], Abid Ali[13]

[1]**Soil & Water Testing Laboratory,** Rawalpindi, Pakistan
[2]**Soil & Water Testing Laboratory,** Hafizabad, Pakistan
[3]**Soil & Water Testing Laboratory,** Jhang, Pakistan
[4]**Soil &Water Testing Laboratory,** Muzaffargarh, Pakistan
[5]**Department of Soil And Environmental Sciences,** Ghazi University, Dera Ghazi Khan, Pakistan
[6]**Soil & Water Testing Laboratory,** Jhelum, Pakistan
[7]**Soil & Water Testing Laboratory,** Bahawalpur, Pakistan
[8]**Soil Fertility Section,** Ayub Agricultural Research Institute, Faisalabad, Pakistan
[9]**Soil & Water Conservation Research Station,** Fateh Jang, Attock, Pakistan
[10]**Department of Agricultural Engineering,** University of Agriculture, Faisalabad, Pakistan
[11]**Soil Chemistry Section,** Ayub Agricultural Research Institute, Faisalabad, Pakistan
[12]**Soil Fertility Research Institute,** Punjab, Lahore, Pakistan
[13]**Regional Agricultural Research Institute**, Bahawalpur, Pakistan

***Corresponding Author:** Sher Afzal. E. mail:sherafzal78@yahoo.com

Abstract

Cauliflower is one of the most widely produced vegetables in almost everywhere in the world; however, achieving higher yields per hectare remains a significant challenge for Pakistani farmers. Cultivation of high-yielding varieties necessitates the use of proper rate and balance of fertilization. Therefore, it is imperative to investigate the appropriate and balanced dose of fertilization to achieve the yield potential. The aim of this study is to investigate the response of different cauliflower varieties to various phosphorus levels at the farmers' field in district Attock during 2019-20.The research utilized a randomized complete block design with a split-plot arrangement, considering two factors: phosphorus levels (0, 50, 100, 150 kg ha^{-1}) and cauliflower varieties (Malaika, Glacier, Garma and Snow ball), with three replications. The results indicated that the response of varieties and phosphorus levels was significant and affected growth and yield parameters. At a phosphorus level of 150 kg P_2O_5 ha^{-1}, the maximum number of leaves per plant (23.292), days to curd initiation (103.38), curd diameter (29.357 cm), Head weight(29.5 Kg)and yield per hectare (32.373 tons) were recorded. Control plots showed the lowest values for all parameters. Among the varieties, Garma exhibited the highest metrics, with 23.125 leaves per plant,108.79 days to curd initiation, a curd diameter of 30.043 cm, Curd weight 28.833 Kg and a yield of 32.129 tons per hectare. It was also observed that the variety Snow ball took least no. of days to attain maturity(106.62days).The study examining the interaction between phosphorus levels and crop varieties found that the highest yield (32.373 tons/ha) was obtained with the application of phosphorus at 150 kg/. Therefore, it is recommended that farmers in the Northern Punjab region use 150 kg/ha of phosphorus along with the Garma variety to achieve the best results.

Keywords: *Attock, Brassica oleracea L., Cauliflower, Phosphorus, Yield*

INTRODUCTION

Cauliflower (*Brassica oleracea* L. var. botrytis), commonly known as Phool Gobi in Pakistan and some parts of India as well, belongs to the Brassicaceae family. This cool season annual vegetable grows best in environments with daytime temperatures between 17°C and 18°C, while temperatures exceeding 20°C during

maturity negatively affect its growth. The most suitable soil conditions for cauliflower include sandy and clayey soils; additionally, due to its sensitivity to acidity, it prefers neutral to slightly acidic soils (pH 6.0-6.8) (1).

Cauliflower (*Brassica oleracea* var. botrytis) is the second most commonly consumed cruciferous vegetable, following potatoes in popularity. It is a substantial source of key minerals, such as potassium, sodium, iron, phosphorus, calcium, and magnesium. Furthermore, it contributes notable amounts of vitamin A. Cauliflower's high protein content and its exceptional stability of ascorbic acid (vitamin C), which remains relatively intact following thermal processing, is its particular characteristic (2).

Cauliflower exhibits a compact, thickened stem that supports a rosette of leaves, and is distinguished by a branched taproot system. The primary shoot apex is modified into a shortened shoot, with the apical portions developing into the convex surface of the floral structure known as the "curd." This morphological adaptation contributes to its unique structure and culinary value. Cauliflower is utilized in a variety of food preparations, including frying, drying, soups, and pickles (3).

The edible portion of cauliflower is nutritionally dense, providing a wide range of essential nutrients. On a per-100 g basis, it contains: vitamin A (51 IU), vitamin C (56 mg), riboflavin (0.10 mg), thiamine (0.04 mg), nicotinic acid (1.0 mg), calcium (33 mg), phosphorus (57 mg), potassium (138 mg), moisture (90.8 g), carbohydrates (4.0 g), protein (2.6 g), fat (0.4 g), fiber (1.2 g), and iron (1.5 mg). These nutritional constituents contribute to its status as an important food source in human diets (3). It is low in fat but high in dietary fiber, foliate, water, vitamin-C and possessing a high nutritional density (4, 5) also reported about the presence of different minerals in cauliflower.

Historically, cauliflower is believed to have been domesticated from wild cabbage in the Mediterranean region approximately 2,000 years ago. It is native to the coastal areas of Europe and Africa, and the first recorded cultivation occurred in India in 1822 (6). Pakistan ranks among the top ten countries in cauliflower production (7). Total cultivated area of Pakistan under Caulifloweris12653 hectares, yielding 27.42 tons per hectare and a total production of 346929tons during the 2022-23 seasons. In the Punjab province, cauliflower production reached 277071 tons from 6986 hectares, resulting in an average yield of 39.66 tons per hectare. While in 2021-22 average yield of cauliflower in Punjab province was about 214785 ton from 6076 ha with average production of 35.35tonha-1 (8). The increase in yield per hectare can be attributed to various factors, particularly the adoption of improved specialized production practices. However, the average yield in the Northern Punjab region remains significantly lower than in other parts of the country, likely due to imbalanced fertilizer applications and insufficient use of low-yielding cultivars.

The application of nitrogen phosphorus (P) along with other essential nutrients at varying rates has been shown to significantly impact the growth and yield of cauliflower. It was reported that applying 225 kg N ha^{-1} and 80 kg P ha^{-1} positively influenced growth and yield-related traits (9). Similarly, some scientists (10) recommended the use of 120 kg P_2O_5 ha^{-1} to enhance plant height, leaf length, number of leaves per plant, net curd weight, and marketable curd yield compared to lower nutrient levels. Additionally, observed a significant increase in growth and yield when 250 kg N ha^{-1} and 60 kg P ha^{-1}were applied, surpassing the effects of lower nitrogen and phosphorus levels (11).

The use of chemical fertilizers in Pakistan is totally imbalanced. The farmers prefer to apply nitrogenous fertilizers in the field in vigorous weightage. The use of Phosphate fertilizers in accordance with the recommendations of Soil Fertility Research Institute, Lahore, Punjab, has never been followed by the farming community which is an alarming situation and this matter should be handled scientifically. Nitrogen share in total nutrients off take was 82.5 per cent during 2022-23 (76.7 per cent during 2021-22), phosphate had 16.8 per cent share (21.8 per cent during 2021-22) and potash 0.7 per cent (1.4 per cent during 2021-22). The N to P ratio in 2021-22 was 3.51 which further widened to 4.91 in 2022-23, leading to imbalance fertilizer use (12).

This research aims to systematically evaluate the responses of selected cauliflower cultivars to different phosphorus levels in terms of growth and yield. Therefore, determining optimal phosphorus levels and promoting the adoption of high-yielding cultivars is crucial for enhancing overall productivity.

MATERIALS AND METHODS

The comprehensive study on cauliflower (*Brassica oleracea* L. var. botrytis) cultivars' response to varying phosphorus levels was conducted in two tehsils (Hazro & Attock) Attock district of Northern Punjab during the 2019-2020 growing season. This research aimed to investigate the effects of different phosphorus applications on various cauliflower cultivars to offer the valuable insights for agricultural practices in the region for future cropping. The experimental design employed was a Randomized Complete Block Design (RCBD) with a split-plot arrangement, replicated three times. Main plot treatments consisted of different phosphorus levels, while subplots contained various cauliflower cultivars, allowing for a comprehensive assessment of both factors. The experimental layout was meticulously planned to ensure optimal growing conditions and accurate data collection. The spacing: 60 cm, Plant-to-plant distance: 30 cm, Subplot area: 9 m^2 were the implemented specifications.

These measurements were carefully selected to provide adequate space for plant growth and development while maximizing land use efficiency. Fertilizer application was a crucial aspect of the study, with the following regimen implemented:

1. Urea: 120 kg/ha 50% applied at transplantation & 50% applied 45 days after transplantation

This split application of urea was designed to ensure a steady supply of nitrogen throughout the growing season, promoting optimal plant growth and development.

2. Potash (SOP): 100($Kgha^{-1}$) Potassium sulfate (SOP) was applied to provide essential potassium nutrients, which play a vital role in plant metabolism, water regulation, and overall crop quality.

3. Phosphorus (Single Super Phosphate - SSP): Levels: 0, 50, 100, and 150 Kg ha^{-1}.

The varying levels of phosphorus application were the primary focus of the study, allowing researchers to assess the impact of different phosphorus concentrations on cauliflower growth, yield, and quality. Four distinct cauliflower cultivars (Malaika, Glacier, Garma and Snow ball) were tested in this experiment. These cultivars were selected based on their popularity among local farmers and their potential adaptability to the region's climate. By including multiple cultivars, the study aimed to identify any genotype-specific responses to phosphorus application, providing valuable information for cultivar selection and breeding programs. The research methodology involved regular monitoring of plant growth parameters, including plant height, leaf area index, and days to curd initiation. At harvest, data on curd diameter, curd weight, and overall yield were collected. Additionally, qualitative assessments of curd color, compactness, and marketability were conducted to evaluate the commercial potential of each cultivar under different phosphorus regimes.

This comprehensive approach to studying cauliflower cultivars and their response to phosphorus levels is expected to generate valuable insights for farmers, agronomists, and policymakers in the Attock district and similar agro ecological zones. The findings from this research have the potential to optimize fertilizer use efficiency, improve crop yields, and enhance the economic viability of cauliflower production in the region.

Table I. Soil characteristics of the experimental fields

Farmer	GPS Coordinates	Texture	E.C(dS/m)		pH		O.M (%)		Available P (mg/Kg)		Available K (mg/Kg)	
			0-15(cm)	15-30(cm)	0-15(cm)	15-30(cm)	0-15(cm)	15-30(cm)	0-15(cm)	15-30(cm)	0-15(cm)	15-30(cm)
Shah Nawaz	33.888736 72.328835	Loam	0.69	0.79	7.5	7.51	0.6	0.25	4.7	2.8	100	120
Ali Hussain	33.889823 72.318397	Loam	0.65	0.66	7.55	7.56	0.5	0.25	5.5	3.2	80	100
Munir Ahmed	33.906527 72.425567	Loam	1.32	1.3	7.2	7.3	0.45	0.39	4.5	4.7	120	100
Muhammad Siddiq	33.905905 72.425567	Loam	0.73	0.72	7.7	7.63	0.55	0.4	5.8	0.2	100	100

NURSERY PROPAGATION, SEEDLING TRANSPLANTATION, AND LOSSES DUE TO TRANSPLANTATION

The seeds of all four cauliflower cultivars were sown separately in nursery in June 2019 and June2020. Prior to sowing, well-rotted farmyard manure was added to the soil and thoroughly mixed in. During the three to four leaf stage of the seedlings, watering was reduced to twice a week. The seedlings were then transplanted from the nursery beds to the field in the second week of July. Healthy and uniform-sized seedlings were selected for transplantation. The seedlings were planted on one side of the ridge, spaced 60 cm apart between rows and 30 cm apart within rows. One week after transplantation, any dead seedlings were replaced with fresh ones to ensure a uniform stand.

PARAMETERS STUDIED

NUMBER OF LEAVES PER PLANT

The number of leaves per plant was determined by counting the leaves of five randomly selected plants, and the average number of leaves per plant was calculated.

DAYS TO CURD INITIATION

The plants were regularly monitored to assess the performance of different cultivars in terms of curd initiation. Data were obtained from randomly selected five plants by counting the number of days from the date of transplanting to the appearance of curd, presented in days.

CURD DIAMETER (CM)

The diameter of the cauliflower curd was measured in five randomly selected plants of each cultivar. The diameter was recorded in centimeters, and the average curd diameter per plant in each subplot was noted. Measurements were taken at the point of maximum width from two different sides.

YIELD (TONS/HA)

To estimate the yield per hectare, the yield of each subplot was converted to yield per hectare.

STATISTICAL ANALYSIS

The recorded data were analyzed statistically using the Randomized Complete Block Design (RCBD) with a split-plot arrangement, utilizing the Statistix 8.1 statistical package (13).

RESULTS AND DISCUSSIONS

These experiments were conducted to determine the response of cauliflower cultivars to phosphorus levels, and the results obtained are discussed below.

NUMBER OF LEAVES PER PLANT

Data regarding the number of leaves per plant are presented in Table II. The highest average number of leaves per plant (23.292) was recorded in plants treated with 150 kg/ha of phosphorus, while the lowest number of leaves (16.083) was observed in the control group. Among the cultivars, the highest number of leaves (23.125) was found in the Garma variety, which was statistically different from the others, followed by Snow ball variety with an average of 20.375 leaves.

Table II. Effect of different phosphorus levels on number of leaves per plant

Treatment	Fertilizer N-P_2O_5-K_2O (Kg/ha)	Location 1 Shah Nawaz (Malaika)	Location 2 Ali Hussain (Glacier)	Location 3 Munir Ahmed (Garma)	Location 4 M. Siddiq (Snow Ball)	Mean
1	120-0-100	13.667	14.333	20.500	15.833	16.083 D
2	120-50-100	14.000	16.167	23.167	20.000	18.333 C
3	120-100-100	16.333	21.833	23.000	22.833	21.000 B
4	120-150-100	22.667	21.833	25.833	22.833	23.292 A
Mean		16.667 D	18.542 C	23.125 A	20.375 B	

LSD for fertilizer=0.80, LSD for location=1.39, LSD for interaction=1.97

The interaction between cauliflower cultivars and phosphorus levels did not have a significant effect on the number of leaves. The maximum number of leaves per plant (25.833) was recorded in case of Garma variety where plants receiving 150 kg/ha of phosphorus, while the minimum number of leaves (13.6667) was noted in those of T1receiving 0 kg/ha in case of Malaika variety. The same was observed by previous researchers as well (14, 15).These differences may be attributed to the relationship between leaf number and internodal length, as each cultivar possesses its own genetic background.

Significant variability in leaf number was observed among different treatment combinations. Phosphorus had a substantial impact on the number of leaves per plant. It was observed that higher doses of phosphorus positively affected the leaf count. The results also showed that 150 kg/ha of phosphorus is essential for achieving the maximum number of leaves in cauliflower. Additionally, other studies have reported that applications of nitrogen, phosphorus, and potassium significantly enhance vegetative growth in plants (15). The results of this study suggest that increased vegetative growth supports the synthesis of necessary compounds essential for protein and carbohydrate metabolism. These compounds are crucial for the growth of cauliflower curds.

DAYS TO CURD INITIATION

Data analysis indicates that both phosphorus levels and cultivars significantly affected the days to flowering ($p < 0.01$); however, their interaction was found to be non-significant (Table III). The longest time period (125.67 days) for curd initiation was recorded in the Malaika cultivar with a phosphorus application of T1 (Control) 0Kgha^{-1} followed by 120.67 days in case of T2 of the same variety. Among the cultivars, Snow ball showed the best performance with an average of 106.62 days, which was statistically different from the others. The control group had the longest flowering time, recorded at 117.96 days. It was noticed that Glacier and Garma cultivars were statistically at par with one another taking almost 108 days on an average base to initiate curd. The same results were quoted by other scientists (1, 16).

Table III. Effect of Phosphorus levels on days to curd initiation of cauliflower

Treatment	Fertilizer $N\text{-}P_2O_5\text{-}K_2O$ (Kg/ha)	Location 1 Shah Nawaz (Malaika)	Location 2 Ali Hussain (Glacier)	Location 3 Munir Ahmed (Garma)	Location 4 M.Siddiq (Snow Ball)	Mean
1	120-0-100	125.67	118.67	114.17	115.67	118.54 A
2	120-50-100	120.67	113.17	115.50	111.83	115.29 B
3	120-100-100	114.83	100.83	101.83	99.83	104.33 C
4	120-150-100	110.67	100.00	103.67	99.17	103.38 C
Mean		117.96 A	108.17 BC	108.79 B	106.62 C	

LSD for fertilizer=1.67, LSD for location=1.69, LSD for interaction=3.35

Furthermore, these findings suggest that phosphorus may slow vegetative growth, helping plants transition more quickly to the reproductive stage. Similar studies have indicated that the application of phosphorus accelerates the transition of crops to the reproductive stage, aligning with the results of the current study

CURD DIAMETER (CM)

The data analysis on curd diameter revealed a significant effect of different phosphorus levels and cultivars. However, the interaction between cultivars and phosphorus was found to be non-significant (Table IV). The largest curd diameter (29.357 cm) was recorded with the application of 150 kg/ha phosphorus, which was statistically different from the other treatments. The control group exhibited the smallest curd diameter. There were notable differences in curd diameter among the various cauliflower cultivars. The best result was observed in the Garma cultivar (30.043cm), while the lowest diameter (23.979 cm) was recorded in Malaika.

The interaction between phosphorus and cultivars significantly affected the curd diameter of cauliflower. The largest diameter (29.357 cm) was found in plants fertilized with 150 kg/ha of phosphorus, whereas the smallest diameter (23.920 cm) was noted in the control conditions. The maximum curd diameter achieved with fertilizer levels of 120, 150, and 100 kg NPK/ha is likely attributed to an increase in water

content and the accumulation of storage substances in the leaves due to enhanced availability of N, P, and K. These results are consistent with findings from (16), which reported maximum head diameter in cauliflower at high fertilizer levels. The diameter of cauliflower curds is critical for market yield (17). The increase in curd diameter resulting from optimal fertilizer doses and improved nutrient availability in the soil promotes plant growth and enhances leaf production.

Table IV. Effect of phosphorus levels on curd diameter (cm) of cauliflower cultivars

Treatment	Fertilizer $N\text{-}P_2O_5\text{-}K_2O$ (Kg/ha)	Location 1 Shah Nawaz (Malaika)	Location 2 Ali Hussain (Glacier)	Location 3 Munir Ahmed (Garma)	Location 4 M. Siddiq (Snow Ball)	Mean
1	120-0-100	20.623	23.840	27.470	23.745	23.920 D
2	120-50-100	22.705	24.943	29.720	23.962	25.332 C
3	120-100-100	25.138	23.942	29.873	27.912	26.716 B
4	120-150-100	27.450	29.418	33.108	27.450	29.357 A
Mean		23.979 C	25.536 B	30.043 A	25.767 B	

LSD for fertilizer=1.10, LSD for location=0.91, LSD for interaction=2.11

CURD WEIGHT (KG)

All phosphorus treatments differ significantly (no overlapping letters), confirming phosphorus critically impacts yield. It is very clear from the table IV that Maximum Head weight was observed in case of Maximum P dose of 150 $kgha^{-1}$,i.e, 29.5 Kg while lowest in case of minimum P dose i.e, 17Kg. Similarly, Variety Garma proved to be the best having average head weight of 28.833 Kg from an area of $9m^{2.}$ These results could be verified by the findings of some other researchers (18, 19).

Table IV. Effect of phosphorus levels on Curd Weight (Kg) of cauliflower cultivars

Treatment	Fertilizer $N\text{-}P_2O_5\text{-}K_2O$ (Kg/ha)	Location 1 Shah Nawaz (Malaika)	Location 2 Ali Hussain (Glacier)	Location 3 Munir Ahmed (Garma)	Location 4 M. Siddiq (Snow Ball)	Mean
1	120-0-100	13.333	14.667	20.000	20.000	17.000 D
2	120-50-100	20.000	22.667	28.667	26.667	24.500 C
3	120-100-100	23.333	26.667	32.667	29.667	28.083 B
4	120-150-100	24.667	28.000	34.000	31.333	29.500 A
Mean		20.333 D	23.000 C	28.833 A	26.917 B	

LSD for fertilizer=0.72, LSD for location=0.74, LSD for interaction=1.4

YIELD PER HECTARE (TONS PER HECTARE)

Data regarding yield per hectare is presented in Table V. The analysis shows that the maximum yield (32.373 tons per hectare) was achieved in plants receiving 150 kg of phosphorus, which is statistically significant. This was followed by a yield of 30.313 tons per hectare in the 100 kg phosphorus treatment, while the minimum yield (18.859 tons per hectare) was recorded in that plot having no P fertilizer. Different cauliflower varieties had a significant impact on yield per hectare. Among the varieties, the highest yield (32.129 tons per hectare) was recorded in the Garma variety, which is statistically significant. This was followed by the Snow ball variety with a yield of 29.452 tons per hectare, while the lowest average yield (22.553 tons per hectare) was found in the Malaika variety.

The primary objective of any agricultural study is to maximize production, which is influenced by numerous factors from sowing to harvest. Key factors affecting yield include environmental conditions, genetic makeup, and soil structure. The results of this study indicate that higher phosphorus levels lead to increased diameter and weight of the curds. Phosphorus plays an important role in metabolism and photosynthesis and is a critical component of phospholipids and nucleic acids. Research has shown that the addition of nutrients to the soil can enhance plant growth, which in turn improves photosynthetic and digestive processes. For instance, one study examined the effects of nitrogen and phosphorus levels on broccoli and found that applying 140 kg of P_2O_5 per hectare yielded the highest biological yield per plant

and per hectare (20) found that P helps in increment of photosynthesis and proper curd formation. It was also mentioned in a research study that yield and chemical composition are related with P level. Elahi *et al.*, (2015) found that vigorous growth of the plant is correlated with proper nutrition (1). Uddain *et al.*, (2008) also confirmed similar results in broccoli experiments (21).

Table VI. Effect of Phosphorus levels on Yield (Ton ha^{-1}) of cauliflower cultivars

Treatment	Fertilizer N-P_2O_5-K_2O (Kg/ha)	Location 1 Shah Nawaz (Malaika)	Location 2 Ali Hussain (Glacier)	Location 3 Munir Ahmed (Garma)	Location 4 M. Siddiq (Snow Ball)	Mean
1	120-0-100	14.485	16.315	22.407	22.230	18.859 D
2	120-50-100	22.230	25.289	31.981	29.641	27.285 C
3	120-100-100	25.967	26.000	36.322	32.963	30.313 B
4	120-150-100	27.530	31.185	37.804	32.974	32.373 A
Mean		22.553 D	24.697 C	32.129 A	29.452 B	

LSD for fertilizer=951.88, LSD for location=1638.1, LSD for interaction=2315.8

These findings align with other studies that demonstrate a direct relationship between adequate nutrition and vigorous growth in terms of yield. Yield is significantly affected by optimal phosphorus levels, which are essential for the overall health and vigor of plants. Sufficient phosphorus availability promotes root development; increases stem length and improve flower formation (22).

CONCLUSION

The conclusion drawn from experiments conducted in farmers' fields in Attock district provides valuable insights for optimizing the appropriate P rates for various cauliflower cultivars. Due to severe deficiency of P in study area, 150 kg P ha^{-1} was considered best to achieve the realistic crop yield potential. This specific quantity has been determined to be the most effective in promoting robust plant development and maximizing crop output. Phosphorus plays a crucial role in energy transfer, photosynthesis, and the formation of nucleic acids, all of which are essential for healthy plant growth. These findings offer a comprehensive approach to enhance crop productivity and quality, which can significantly benefit local farmers. We also recommend that it is crucial to apply recommended doses of other nutrients alongside phosphorus. This balanced approach ensures that the plants to receive a complete spectrum of necessary elements for their growth and development. The key recommendations are as follows:

1. Phosphorus application: A dosage of 150 kg per hectare is recommended for optimal growth and yield.
2. Other essential nutrients: A well-rounded nutrient profile can enhance plant resistance to diseases, improve fruit quality, and increase overall yield. 3. Variety selection: The Garma variety is suggested for maximum yield in the Attock District. This variety has demonstrated superior performance under local conditions, exhibiting desirable traits such as adaptability to the region's climate, resistance to common pests and diseases, and high yield potential

FUTURE RECOMENDATIONS

By implementing these recommendations and pursuing further research, stakeholders can work towards developing a more robust, sustainable, and profitable cauliflower cultivation system in the Attock District and potentially beyond. This holistic approach to agricultural development can contribute to improved livelihoods for farmers, enhanced food security, and sustainable land use practices in the region.

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Conflict of interest:

There is no conflict of interest among authors regarding this article.

Authors` contribution:

AW, SN, SA & MSA conducted the research work; SA composed the paper; NIK performed proof reading and editing; AH conceptualized and supervised the research work; SUR & NR critically reviewed the manuscript; BA, RAR & TTR conducted the analysis of soil samples; AN & AGK technically reviewed the paper; WA & AA analyzed the data statistically.

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