International Research Journal of Pure & Applied Chemistry

21(24): 300-307, 2020; Article no.IRJPAC.64650
ISSN: 2231-3443, NLM ID: 101647669

Growth, Yield and Quality of Cauliflower as Influenced by Different Sources of Nutrients and Mulching in Indo- Gangatic Plains of Western Uttar Pradesh

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Authors' contributions

This work was carried out in collaboration among all authors. Author AK designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors MK, BS, MKS and SPS managed the analyses of the study. Authors RS and RK managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IRJPAC/2020/v21i2430367
Editor(s):
(1) Dr. Wolfgang Linert, Vienna University of Technology, Austria.
Reviewers:
(1) Fikreyohannes Gedamu, Haramaya University, Ethiopia.
(2) Kibreselassie Daniel Auge, Hawassa University, Ethiopia.
Complete Peer review History: http://www.sdiarticle4.com/review-history/64650

Original Research Article

Received 25 October 2020
Accepted 30 December 2020
Published 31 December 2020

ABSTRACT

A field experiment was carried out at Horticulture Research Center of Sardar Vallabhbhai Patel University of Agriculture & Technology Meerut, (UP) India during *rabi* season 2018-19 and 2019-20 respectively with entitled "Effect of different sources of nutrients and mulching on sustainable production of Cauliflower (*Brassica oleracea* var. botrytis L.) cv. Pusa Ashwani". The experiment was laid out in randomized block design with three replications and eleven treatments. The results showed that plants treated with integrated application of inorganic fertilizer, Vermicompost,

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Azotobacter, PSB (Phosphate Solubilizing Bacteria), Black mulch (2.5 mm) proved significantly better over the recommended practice 100% RDF (Recommended doses of fertilizer) and control. However, plants treated without organic manures and inorganic fertilizers resulted in significant reduction for various growth, yield and quality parameters. Among the treatments, plants fortified with application of 50% RDF + 15 t/ha Vermicompost + *Azotobacter* (5 kg/ha) + PSB (5kg/ha) + Black mulch (2.5 mm) was found to better growth, yield and quality for both years.

Keywords: Cauliflower; RDF; PSB; mulching; bio-fertilizers and vermicompost.

1. INTRODUCTION

Cauliflower (*Brassica oleracea* var. botrytis L.) is an important member of cole crops. It is grown for its white tender curd which is used as a vegetable, soup and for pickling. Cauliflower has high quality proteins and peculiar in stability of vitamin C after cooking. It is rich in minerals and one of the important vegetable crops with having high nutritional values. Cauliflower fresh curd is highly nutritive and contains moisture 90.8g, protein 2.6g, fat 0.4g, minerals 1.0g, fiber 1.2g, carbohydrates 4.0g, energy 30 kcal, calcium 33 mg, phosphorus 57 mg, Iron 1.5 mg, carotene 30 mg, thiamine 0.04 mg, riboflavin 0.10 mg, niacin 1.0 mg and vitamin-C 56.0 mg per 100 g of edible portion Jood and Khetrapaul [1].

India is second the second largest producer of cauliflower in the world with a total production of (7,887,000 MT) while China is the largest producer of cauliflower with a total production of (9,100,000 MT). In India, cauliflower is specially grown in West Bangal, Andhra Pradesh, Bihar, Gujarat, Haryana, Karnataka, Maharashtra, Madhya Pradesh, Orissa, Uttarakhand and Himachal Pradesh NHB [2] Major cauliflower growing states in India are West Bengal, Madhya Pradesh, Haryana, Odisha. The total area of production of cauliflower in India is about 453000 hectare and total productivity 1939.48 million tones, respectively. The total area of cauliflower in Uttar Pradesh is 17.53 000 million hectare with production 400.81 000 MT NHB [2]. Various factors are responsible for better growth and yield of cauliflower. Among these, soil health (chemical, biological and physical) plays a very vital role in nutrient uptake from soil which is responsible for better growth, development and finally marketable yield of cauliflower. Among the nutrients, nitrogen being a major food for plants is an essential constituent of protein (build from amino acids that involves in catalization of chemical responses and transportation of electrons) and chlorophyll (enable the process of photosynthesis) present in the plant system. Nitrogen plays a most important role in physiological processes *viz.,* dark-green color, promotes leaves, stem and other vegetative part's growth and development, moreover, it also stimulates the root growth. Nitrogen produces rapid early growth, improves fruit quality, enhances the growth of leafy vegetables, and increases protein content of fodder crops. It encourages the uptake and utilization of other nutrients including potassium, phosphorous and controls overall growth of plant.

Cauliflower is a heavy feeder of mineral elements, it removes large amount of micro and macronutrients from the soil. Heavy manuring has been recommended for proper growth and good yield of cauliflower by different workers in India Roy [3], and Randhawa and Khurana [4]. It has been reported that continuous use of inorganic fertilizers deteriorates the environment and soil fertility. Therefore, organic and inorganic fertilizers are used for better growth and yield of vegetable crops. Organic fertilizers are primarily cost effective, easily available from locality products than chemical fertilizers. Microbial fertilizers are distinctly environment friendly, non-bulky, cost effective which plays a significant role in plant nutrition. In the other hand, inorganic fertilizers are known for their high cost and their negative environmental effects if managed poorly.

Beside nutrients, mulching also play a significant role in organic farming and are used for many beneficial reason in the agriculture sector such as for soil temperature modification, weed control and for soil conservation but water conservation and erosion control are the most important objectives. Besides this, mulching also add essential plant nutrient into the soil after decomposition which improve the soil physical, chemical and biological properties and leads to increase both the quality as well as quantity of the crop Bhardwaj [5]. Therefore, the present study has been carried out to assess the effect of integrated sources of nutrients and mulching on sustainable production of cauliflower.

2. MATERIALS AND METHODS

The experimental site is located at the Sardar Vallabhbhai Patel University of Agriculture & Technology, Modipuram, Meerut, (UP). Meerut is situated on the Delhi- Dehradun Highway and geographically, it is located at 29^0 40′ north and longitude of 77^0 42′ east and at an altitude of 237 meters above the mean Sea level. The soil of experimental field was sandy loam in texture, neutral in reaction, low in N and medium in P and K. The variety of cauliflower Pusa Ashwani was tested in randomized block design (RBD) with three replication and eleven treatments namely T_1- Control, T_2- 100% RDF + Black mulch (2.5mm), T_3- 100% RDF + Paddy straw mulch, T_4- 100% RDF+ 5 t/ha VC + Black mulch (2.5mm), T_5- 100% RDF + 10 t/ha FYM + Paddy straw mulch, T_6- 75% RDF + 10 t/ha VC + Black mulch (2.5mm), T_7- 75% RDF + 10 t/ha VC + Paddy straw mulch, T_8- 50% RDF + 15 t/ha VC + Azotobacter (5kg/ha) + PSB (5kg/ha) + Black mulch (2.5mm), T_9- 50% RDF + 15 t/ha VC + Azotobacter (5kg/ha) + Paddy Straw mulch, T_{10}- 25% RDF + 20 t/ha VC + Azotobacter (6kg/ha) + Black mulch (2.5mm) and T_{11}- 25%RDF + 20 t/ha VC + Azotobacter (7kg/ha) + Paddy Straw mulch during *rabi* season 2018-19 and 2019-20, respectively. The seedlings were transplanted in experimental field on 1^{st} week of October in both years. All the cultural practices were followed according to this region. Observations were recorded on randomly selected three plants with various growth and yield parameters. Collected data were statistically analyzed using the described methods of Gomez [6] and Panse [7] and Sukhatme (1984) and using online software OPSTAT.

3. RESULTS AND DISCUSSION

3.1 Growth and Yield Parameters

The data presented in Table 1 showed that integrated sources of nutrients and mulching significantly affected growth parameters of cauliflower.

3.1.1 Plant height (cm)

Among the treatments, the maximum plant height (27.44 and 28.52 cm) of cauliflower was recorded under the treatment T_8 (50% RDF + 15 t/ha VC + *Azotobacter* (5kg/ha) + PSB (5kg/ha) + Black mulch (2.5mm) which was statistically at par with T_9 (50% RDF + 15 t/ha VC + *Azotobacter* (5kg/ha) + Paddy Straw mulch) during both the years of study while, shortest plant (19.66 and 21.61 cm) was recorded under T_1 (Control). The increase in plant height could be due to enhanced biological nitrogen fixation by *Azotobacter* which ultimately showed positive effect on vegetative growth of plant Sharma et al [8]. Thus, sufficient nutrient availability required for better growth of plants which in turns leads to increase in height of plants. The results of present investigation in terms of plant height are in concordance with the findings reported earlier by Salim et al. [9] in cauliflower, Kachari and Korla [10] in cauliflower, Shree et al. [11] Another reason may be due to mulching which help in improving the microclimatic condition of the soil which might have provided a suitable condition for better plant growth. Similar results reported by Singh and Singh [12] in cauliflower.

Table 1. Effect of different sources of nutrients and mulching on growth parameters of cauliflower

Treatments	Plant height (cm)		Number of Leaves plant $^{-1}$		Spread area of plant		Average weight of Curd (gplant^{-1})	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
T_1	19.66	21.61	18.29	20.46	29.34	30.43	445.54	535.15
T_2	20.53	22.32	19.04	20.64	30.38	31.52	658.44	692.14
T_3	25.52	24.75	20.15	21.09	34.40	35.28	598.08	699.87
T_4	23.41	25.45	21.69	21.07	31.75	32.78	516.32	742.06
T_5	24.44	28.29	20.80	23.08	33.65	34.55	652.18	686.46
T_6	25.51	26.82	24.31	21.79	35.13	36.25	740.40	719.71
T_7	22.52	24.30	25.72	26.20	34.45	35.62	680.00	715.76
T_8	27.44	28.52	29.90	31.01	48.25	49.37	888.50	971.94
T_9	27.11	28.49	27.73	28.75	38.13	39.40	790.63	821.12
T_{10}	22.55	23.47	27.32	27.77	31.19	31.31	728.93	707.35
T_{11}	26.11	27.43	26.46	28.58	36.06	39.39	628.52	709.36
SE(m) ±	0.41	0.42	0.28	0.49	0.54	0.21	19.42	32.88
C.D. at 5%	1.22	1.24	0.84	1.45	1.50	0.62	57.71	97.67

3.1.2 Number of leaves plant $^{-1}$

Plant receiving T_8 (50% RDF + 15 t/ha VC + *Azotobacter* (5kg/ha) + PSB (5kg/ha) + Black mulch (2.5mm) exhibited maximum number of leaves plant $^{-1}$ (29.90 and 31.01) during both the years of experimentation and it was significantly superior to rest of treatments. However, the treatment fortified with T_9 (27.73 and 28.75 leaves plant^{-1}) was statically at par while, the treatments T_1 (Control), T_2 (100% RDF + Black mulch (2.5mm), T_3 (100% RDF + Paddy straw mulch) and T_4 (100% RDF+ 5 t/ha VC + Black mulch (2.5mm) were statistically on par with each other during both the years of study. The minimum number of leaves plant^{-1} was found in T_1 (control). This might be attributed to timely supply of nutrients particularly nitrogen which is required for vegetative growth of plant in this treatment. These finding are in close conformity with result of Moniruzzaman et al. [13], Salim et al. [9] in cauliflower, Easmin et al. [14] in chinease cabbage Pawar et al. [15] in cauliflower. The increase in number of leaves was due to sufficient soil moisture near root zone and minimized the evaporation loss due to mulching. It may also be due to extend retention of moisture and availability of moisture also leading to higher uptake of nutrient for proper growth and development of plants, resulted higher growth of plant, as compared to control. Similar findings have also been obtained by Hallidri [16] in cucumber.

3.1.3 Spread area of plant (cm)

The maximum plant spread (48.25 and 49.37 cm) was registered under the treatment T_8 (50% RDF + 15 t/ha VC + *Azotobacter* (5kg/ha) + PSB (5kg/ha) + Black mulch (2.5mm) followed by, (38.12 and 39.40 cm) in treatment T_9 (50% RDF + 15 t/ha VC + *Azotobacter* (5kg/ha) + Paddy Straw mulch however, minimum plant spread (29.34 and 30.43 cm) was observed with T_1 (control) during both the years of study. The increase in leaf length under different treatments can be attributed to the increase in plant spread. This is probably due to the facts that nitrogen might have contributed towards an increase in leaf buds and finally increased plant spread. The present results are close conformity with Nakaande [17] in cabbage, Shree et al. [11] In cauliflower, Kumar et al. [18] in cabbage. Increase in spread of plant might be due to black polythene mulches provide favorable environmental conditions as compared to paddy straw for better growth and development of plant. Similar results have also been reported by Samaila et al. [19] in tomato.

3.1.4 Average weight of curd (g plant^{-1})

Plants fortified with T_8 (50% RDF + 15 t/ha VC + *Azotobacter* (5kg/ha) + PSB (5kg/ha) + Black mulch (2.5mm) showed maximum average weight of curd (888.50 and 971.94 g) followed by, T_9 (790.30 and 821.12 g), T_6 (740.40 and 719.71 g) and T_{10} (728.93 and 707.35 g). while minimum curd weight (445.54 and 535.15 g) was recorded under control T_1 (control) during the course of investigation. The increase in curd weight might be due to the more photosynthesis from larger area of the leaves and the translocation of photosynthates to the sink which is ultimately the curd. The increase in the curd weight at this level might also be due to the increase in the length and width of the leaves and plant spread cited by Runham et al. [20] in celery, Kanwar et al. [21], Singh and Singh [22], Singh and Mir [23] in cabbage. Additionally, mulching also show positive effect on weight of curd which may be due to the efficient use of available soil moisture, inhibition of weed growth, protection of surface soil erosion, reduction in nutrient. These results are in line with the findings of Kabir et al. [24] in garlic.

3.1.5 Fresh weight (g plant^{-1}) at initiation stage

Among the different sources of nutrients, significantly maximum fresh weight (124.97 and 127.15 g plant^{-1}) at curd initiation was recorded in T_8 (50% RDF + 15 t/ha VC + *Azotobacter* (5kg/ha) + PSB (5kg/ha) + Black mulch (2.5mm) followed by, T_9 (103.07 and 104.17gplant^{-1}), while the minimum fresh weight(72.90 and 70.68 gplant^{-1}) at curd initiation was recorded in T_1 (control) during the course of experimentation. The application of organic manure in combination of bio-fertilizer improved the soil structure and as well as biological activity of soil. This would have reduced the losses of nitrogen by increasing cation and anion exchange capacity of soil. These comprehensive changes in soil improve the plant weight at curd initiation stage. The results are conformity with the findings of Sharma et al. [8] in sprouting broccoli, Sable and Bhamare [25] in cauliflower. It may also be due to mulching which ensure efficient use of available soil moisture, inhibition of weed growth, protection of surface soil erosion, reduction in nutrient hence increased in fresh weight of plant.

3.2 Quality Parameters

Integrated sources of nutrients and mulching showed variable results in quality parameters of cauliflower (Table 2).

3.2.1 Fresh weight of curd at harvest (g plant^{-1})

Application of nutrients by different sources, significantly maximum fresh weight (1090.59 and 1077.74 g plant^{-1}) at harvesting stage was recorded in T_8 (50% RDF + 15 t/ha VC + *Azotobacter* (5kg/ha) + PSB (5kg/ha) + Black mulch (2.5mm) followed by in treatment T_9 (954.30 and 1001.39 gplant^{-1}), T_4 (865.13 and 948.81 gplant^{-1}), while minimum fresh weight (611.40 and 591.21 gplant^{-1}) at harvest stage was registered with T_1 (control) during the course of study. Increased the weight of plant at curd harvesting stage due to increased plant height number of leaves diameter of stem and curd weight, which is might have increased the photosynthesis surface and lead to more synthesis and translocation of photosynthets toward the curd formation similar results were also reported by Rather et al. [26] and Bahadur et al. [22] and Terefe et al. [27] in cabbage. Increased in fresh weight of curd at harvesting stage might be due mulching which have positive effect on yield attributes by the efficient use of available soil moisture, inhibition of weed growth, protection of surface soil erosion, reduction in nutrient loss from soil by crop.

3.2.2 Dry weight of plant at curd initiation (g)

Integrated nutrient management practices significantly affected dry weight of plant at curd initiation stage (Table 2). The maximum dry weight of plant (68.54 and 70.93 g plant^{-1}) at curd initiation was recorded in T_8 (50% RDF + 15 t/ha VC + *Azotobacter* (5kg/ha) + PSB (5kg/ha) + Black mulch (2.5mm) fallowed by T_7 (50.92 and 42.48 g plant^{-1}), T_9 (49.32 and 50.44 g plant^{-1}) and T_{11} (46.25 and 47.66 g plant^{-1}) during 2018-19 and 2019-20, respectively though, the minimum dry weight (32.38 and 34.49 g plant^{-1}) at curd initiation was recorded in T_1 (control. This was due to mulching significantly increased the soil organic carbon (SOC) as well as available nutrients (N, P, K, Ca & SO_4^{2-}-S), suppress the weed problem, conserve moisture and maximize the flora and fauna in soil similar results were reported by Kumar at al. [28].

3.2.3 Dry weight (g plant^{-1}) at curd harvest

The nutrient management practices, significantly maximum (308.42 and 316.06 g plant^{-1}) at harvest was recorded in T_8 (50% RDF + 15 t/ha Vermicompost + *Azotobacter* (5 kg/ha) + PSB (5 kg/ha) + Black mulch (2.5 mm) followed by T_3 (288.12 g plant^{-1}), T_9 (276.78 g plant^{-1}) and T_{11} (272.78 gplant^{-1}) during first year while during second yearT_9 (279.08 g plant^{-1}), T_5 (278.76 g plant^{-1}) and T_4 (275.65 g plant^{-1}) while, minimum dry weight (168.87 and 181.52 g plant^{-1}) at harvest stage was recorded in T_1 (control) during experimentation.

3.3 Yield Attributes and Yield

Data presented in (Table 3) showed variations among the yield attributing traits by integrated sources of nutrients and various type of mulching.

3.3.1 Equatorial curd diameter (cm)

The equatorial diameter of cauliflower was significantly varied with the application of different sources of nutrients. Among the treatments, significantly maximum equatorial curd diameter (20.42 and 21.26cm) was recorded in treatment T_8 (50% RDF + 15 t/ha Vermicompost + *Azotobacter* (5kg/ha) + PSB (5kg/ha) + Black mulch (2.5mm) followed by, T_9 (17.31 and 18.50 cm), T_6 (17.70 and 17.37 cm), T_3 (17.27 and 16.63 cm) and T_{11} (17.03 cm during 2019-20). However, the minimum equatorial curd diameter (11.06 and 12.21 cm) was recorded in T_1 (control) during both the years of study.

3.3.2 Marketable curd weight (g plant^{-1})

The marketable curd weight (g plant^{-1}) of cauliflower was significantly maximum (988.00 and 992.18 g) in T_8 (50% RDF + 15 t/ha VC + *Azotobacter* (5kg/ha) + PSB (5kg/ha) + Black mulch (2.5mm) followed by T_9 (876.40and 874.29 g), T_6 (752.49 and773.35 g) and T_5 (746.21 and 865.64 g). However, minimum marketable curd weight (472.98 and 464.96 g) was recorded in T_1 (control) during 2018-19 and 2019-20, respectively.

3.3.3 Net curd weight (g plant^{-1})

Among the nutrient management practices, significantly maximum net curd weight (661.06 and 664.95 gplant^{-1}) was recorded in T_8 (50% RDF + 15 t/ha VC + *Azotobacter* (5kg/ha) + PSB

(5kg/ha) + Black mulch (2.5mm) followed by, T_9 (575.37 and 582.34 g plant^{-1}), T_5 (573.03 and 581.84g plant^{-1}) and T_4 (573.53 and 559.43 g plant^{-1}) while, minimum net curd weight (282.76 and 262.71 g plant^{-1}) recorded under T_1 (control) during both the years of study.

3.3.4 Marketable curd yield (q ha^{-1})

The marketable curd yield of cauliflower was significantly affected by different sources of nutrients. Maximum marketable yield (175.44 and 182.74 q ha^{-1}) was obtained from the treatment T_8 (50% RDF + 15 t/ha VC + *Azotobacter* (5kg/ha) + PSB (5kg/ha) + Black mulch (2.5mm) followed by, T_9 (171.44 and 174.00q ha^{-1}), T_5 (169.28 and 172.88q ha^{-1}) and T_4 (168.30 and 172.52q ha^{-1}) and minimum marketable curd yield (152.65 and 153.86 q ha^{-1}) registered with control during the course of study. Increment in curd yield and its attributing traits of cauliflower was due to reduce the losses of nitrogen (nitrification and denitrification) by increasing cation and anion exchange capacity of soil thereby, enhancing the curd yield attributing traits of cauliflower. Further improving the structure of soil by more aggregation, holding capacity and air permeability was increased. Increased in marketable curd weight (g plant^{-1}) could be attributed due to increase in plant height, number of leaves and diameter of curd which might have increased the photosynthetic surface and lead to more synthesis and translocation of photosynthetase toward the curd formation. Soil application by mulch is also beneficial in minimize water losses through

Table 2. Effect of different sources of nutrients and mulching on growth parameters of cauliflower

Treatments	Fresh weight (g plant^{-1}) at initiation stage		Fresh weight of curd at harvest (g plant^{-1})		Dry weight of plant at curd initiation (g)		Dry weight (g plant^{-1}) at Harvest	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
T_1	72.90	70.68	611.40	591.21	32.38	34.49	168.87	181.52
T_2	83.78	80.44	789.17	753.66	34.27	36.35	227.87	254.38
T_3	75.48	75.76	802.48	860.71	33.28	35.59	288.12	255.76
T_4	83.35	78.81	865.13	948.81	45.16	45.79	263.31	275.65
T_5	82.81	85.59	765.79	919.47	44.16	47.68	272.78	278.76
T_6	86.86	88.57	792.03	692.33	46.12	46.52	252.79	247.12
T_7	89.15	99.42	737.74	756.00	50.92	42.48	246.80	243.53
T_8	124.97	127.15	1090.59	1077.74	68.54	70.93	308.42	316.06
T_9	103.07	104.17	954.30	1001.39	49.32	50.44	276.78	279.08
T_{10}	91.54	91.79	758.75	837.25	36.43	37.44	256.0	263.26
T_{11}	97.94	101.63	783.35	850.35	46.25	47.66	241.79	258.87
SE(m)±	1.91	1.97	37.83	36.43	0.35	3.10	6.02	2.33
C.D. at 5%	5.67	5.87	112.37	108.23	1.04	9.20	17.88	6.93

Table 3. Effect of different sources of nutrients and mulching on yield parameters of cauliflower

Treatments	Equatorial diameter of curd (cm)		Marketable curd weight (g plant^{-1})		Net curd weight (g plant^{-1})		Marketable curd yield (q ha^{-1})	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
T_1	11.06	12.21	472.98	464.96	282.76	262.71	152.65	153.86
T_2	15.12	15.96	574.03	628.52	447.73	340.99	165.62	165.53
T_3	17.27	16.63	554.81	640.13	573.53	410.63	166.72	168.78
T_4	15.38	16.15	665.55	659.18	570.48	559.43	168.30	172.52
T_5	15.43	16.62	746.21	865.64	573.03	581.84	169.28	172.88
T_6	17.70	17.37	752.49	773.35	366.91	378.93	166.52	171.41
T_7	16.58	16.59	725.47	702.45	348.75	344.32	168.04	165.55
T_8	20.42	21.26	988.00	992.18	661.06	664.95	175.44	182.74
T_9	17.31	18.50	876.40	874.29	575.37	582.34	171.44	174.00
T_{10}	16.43	16.90	680.17	685.13	446.85	485.68	166.69	168.26
T_{11}	15.65	17.03	668.16	670.37	467.66	497.96	166.46	166.98
SE(m) ±	0.54	0.61	13.94	15.92	12.78	68.91	1.64	0.63
C.D. at 5%	1.59	1.81	41.42	47.29	37.97	204.70	4.86	1.87

evaporation, enhance soil organic carbon status in soil, minimizing the nitrogen loss by nitrification and denitrification from soil Similar results were also reported by Sable and Bhamare [25] in cauliflower.

4. CONCLUSION

On the basis of present study, it may be concluded that plants treated with T_8 (50% RDF + 15 t/ha VC + *Azotobacter* (5kg/ha) + PSB (5kg/ha) + Black mulch (2.5mm) and T_9- 50% RDF + 15 t/ha VC + *Azotobacter* (5kg/ha) + Paddy Straw mulch which was recorded statistically at par while, the minimum was recorded under T_1 (Control) during both the years of study. It might be due to application of mulch with different sources of nutrient enhance growth, quality and yield of cauliflower due to mulch play a very vital role in minimize evaporation losses of water, suppress weed problem which was responsible for more uptake of nutrients and timely available of water for better crop production.

ACKNOWLEDGEMENTS

This work was carried out in collaboration among all authors. Author AK designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Co-authors; MK, BS, MKS and SPS managed the analyses of the study. Author RS and RK managed the literature searches. All authors read and approved the final manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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