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SHORT COMMUNICATION

Nutrient uptake and yield of cauliflower (*Brassica oleracea* L. var. *botrytis* L.) as affected by inorganic and bio-fertilizers

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Cauliflower (*Brassica oleracea* L. var. *botrytis* L.) is an important cole crop grown in an area of 1.36 million hectares with an annual production of 25.5MT at a global level (FAO, 2020). In contrast, in India, cauliflower occupies an area of 459 thousand ha with a production of 8840 thousand MT and productivity of 19.17 t/ha, sharing 34.67% of global production (NHB, 2021-22). Globally, cauliflower grows best between the latitudes 11 to 60° N with average temperatures ranging from 5 to 8°C to 25 to 28°C, which may tolerate temperatures from –10°C to 40°C for a few days during the vegetative growth period (Singh *et al*., 2017). In Himachal Pradesh, it is cultivated over an area of 5.56 thousand hectares having a total production of 135.11 thousand tonnes and productivity is 23.56 tonnes per hectare, which is higher than that of the national scenario sharing 1.46% of the total production of India (NHB, 2021-22). Intensive use of chemical fertilizers is believed to be responsible for declining soil health, besides hazardous effects on humans and other flora and fauna on the planet. Hence, nature-friendly fertilizers like bio-fertilizers need to be promoted to maintain balance in nature. Bio-fertilizers are naturally formulated preparations containing living microbes that are applied on seeds, surfaces of plants, or soil that contain microorganisms, which mobilize nutritive elements from non-usable forms to usable forms through a different biological process, thus keeping soil sustainable for future use. These are also eco-friendly and sustainable sources of fertilizer that enhance the growth and quality of crops by producing plant hormones. Bio-fertilizers also act as bio-control agents by preventing many plant pathogens and harmful microorganisms from attacking the crop (Asokan et al., 2000). Vermicompost is prepared with the help of earthworms and farm waste or bio-degradable waste. The level of nutrients in vermicompost depends upon the source of the raw material and the species of earthworm. A fine worm cast is rich in N (0.50%), P (0.30%), and K (0.24%) besides other nutrients *viz*., Ca (0.17%), Mg (0.06%). Its C/N ratio, organic matter and organic carbon content are 11.64, 20.46, and 11.88%, respectively. Nutrients in vermicompost are in readily available form and are released within a month of application. However, these findings needed to be verified for mid-hills where cauliflower is a cash crop, but sole use of chemical fertilizers for nutrient supplementation requires to be replaced with integrated nutrient management (INM), which can help sustain soil health for the future. Vermicompost, along with bio-fertilizers, can be a good alternative to supplement some part of the plant's nutrient requirements, as besides meeting the nutrient requirements of the plant, these also make the nutrients readily available for uptake. As such, this study was visualized to standardize suitable doses of chemical fertilizers when combined with vermicompost along with bio-fertilizers.

The experiment was carried out at the Vegetable Research Farm of the Department of Vegetable Science, Dr. YS Parmar University of Horticulture and Forestry, Solan, Himachal Pradesh. The Experimental Farm is situated at 30°51'47» NL and 77°10'13» EL at an elevation of 1276 m amsl. The experiment was laid out in Randomized Block Design (RBD) with three replications comprising of eight treatment combinations having three levels of inorganic fertilizers (100, 80 and 60%) and two types of bio-fertilizers (*Bacillus licheniformis* and *Pseudomonas aeruginosa*) *viz*., T_1 (Recommended dose of nutrients + vermicompost), T_2 (80% RDN + vermicompost + *Pseudomonas aeruginosa*), T_3 (80% RDN + vermicompost + *Bacillus licheniformis*), T_4 (80% RDN + vermicompost + *Pseudomonas aeruginosa* + *Bacillus licheniformis*), T_5 (60% RDN + vermicompost + *Pseudomonas aeruginosa*), T_6 (60% RDN + vermicompost + *Bacillus licheniformis*), T_7 (60% RDN + vermicompost + *Pseudomonas aeruginosa* + *Bacillus licheniformis*), T_8 (RDN + FYM). The seedling of cauliflower cv. 'PSB K-1' was transplanted on 9th October, 2021. The plot size was 2.4 × 2.25 m with a spacing of 60 × 45 cm. Roots of seedlings were dipped for one hour in concentrated *Pseudomonas aeruginosa* @ 500 seedlings per liter and immediately transplanted. For second dose of *Pseudomonas aeruginosa*, diluted in the ratio of 1:1 (one part bio-fertilizer and one part water), was applied to the root zone of seedlings @ 50 mL per seedling 15 days after transplanting. Drenching of *Bacillus licheniformis* (1:5) solution was applied to the root zone of seedlings @ 50 mL per seedling. The first treatment was given just after transplanting, and the second at 15 days after transplanting. Soil analysis, including microbial count before planting and after the termination of the experiment, was done as per the procedure. Plant analysis includes N, P, and K uptake by above-ground plant parts of cauliflower at harvest using standard procedures.

The marked effect in 50% marketable curd maturity (Table 1) was recorded when inorganic fertilizer was applied in conjunction with bio-fertilizers over control. The maximum number of days (131.40) to 50% marketable curd maturity under treatment T_4 was statistically at par with T_3 (129.58 days) and T_2 (128.76 days). The minimum days were recorded under T_5, which took 119.57 days for 50% marketable curd maturity and was statistically at par with T_6 (120.18) and T_7 (122.64). Jana and Mukhopadhyay (2001) found a significant effect of fertilization on 50% maturity in cauliflower. This might be ascribed to enhanced availability of nutrients (nitrogen, phosphorous and potassium) because of the addition of bio-fertilizers, which act as an important constituent of chlorophyll and protein and might have resulted in luxurious growth of the plant, which led to increased vegetative period and delayed curd maturity. Delayed curd maturity is desired in a late group of cauliflower to avoid market glut.

The maximum plant height (55.38 cm) was recorded under treatment T_4. However, T_2 and T_3, with a plant height of 54.57 and 54.78 cm, respectively, were at par with T_4 (Table 1). While the minimum plant height (48.32 cm), was recorded under T_5. The number of leaves, stalk length and curd size were also remarkably influenced by fertilizers. Treatment T_4 recorded the maximum number of leaves (30.81), stalk length of 5.83 cm and curd size of 152.91 cm^2, which may be ascribed to increased activity of microbial saprophytes, which might have resulted in increased nutrient availability and uptake. Plant height unveiled a remarkable response to bio-fertilizers in conjunction with inorganic fertilizers. Subedi et al. (2019) in cauliflower observed the beneficial effect of conjoint use of biofertilizers and chemical fertilizers in their respective studies.

The weight of the plant is the chief yield-contributing attribute in cauliflower. A combination of inorganic and bio-fertilizers exhibited significant outcomes for gross curd weight (kg), net curd weight and yield of cauliflower during the study period (Table 1). The maximum gross curd weight (1.89 kg), net curd weight (800.14 g), and yield (276.74 q/ha) were recorded under the treatment of T_4 but were statistically at par with T_2 and T_3. The minimum gross curd weight (1.54 kg), net curd weight (635.44 g) and yield (255.48 q/ha) were recorded under treatment T_5 but were statistically at par with T_6 and T_7. This might be because of the increased availability and uptake of nutrients, which resulted in a larger area of leaves with more chlorophyll contents, which further led to high photosynthesis and production of photosynthates and then its translocation to the sink, which ultimately increased gross weight of curd. Another reason behind these outcomes might be due to the increased availability of nutrients in soil with the application of bio-fertilizers as *Bacillus* associates with the rhizosphere and develops biofilm to promote plant growth and *Pseudomonas* helps in the synthesis of plant growth-promoting hormones, which might have led to more uptake and effective utilization of nutrients for enhanced metabolism and synthesis of carbohydrates, more

Table 1: Effect of treatments on growth and yield parameters of cauliflower

Sr. No.	*50% marketable curd maturity*	*Plant height (cm)*	*Number of leaves per plant*	*Leaf size (cm²)*	*Stalk length (cm)*	*Curd size (cm²)*	*Gross curd weight (kg)*	*Net curd weight (g)*	*Yield (q/ha)*
T_1	126.52	51.93	29.78	1,154.95	4.96	144.65	1.76	700.33	265.65
T_2	128.76	54.57	30.00	1,193.43	5.66	149.81	1.81	767.67	272.47
T_3	129.58	54.78	30.16	1,195.99	5.72	151.06	1.84	778.59	272.63
T_4	131.40	55.38	30.81	1,204.46	5.83	152.91	1.89	800.14	276.74
T_5	119.57	48.32	28.44	1,122.09	4.48	137.76	1.54	635.44	255.48
T_6	120.18	48.52	28.65	1,124.32	4.53	138.38	1.57	648.48	255.66
T_7	122.64	49.45	29.30	1,134.31	4.63	139.84	1.62	666.81	259.81
T_8	125.73	50.71	29.62	1,142.79	4.77	143.28	1.74	685.15	263.31
Mean	125.52	51.71	29.60	1159.04	5.07	144.72	1.72	710.33	265.22
$CD_{(0.05)}$	3.38	1.28	0.35	12.72	0.17	4.57	0.11	32.85	5.04

vegetative growth and subsequent translocation from leaf (source) to curd (sink) which ultimately enhanced the weight of curd (Kumar et al*.,* 2021).

Data on N, P & K-uptake (Table 2) differ substantially in the above-ground part of cauliflower. The inorganic fertilizers, in conjunction with bio-fertilizers, had significant influence on N, P & K-uptake. The maximum nitrogen (159.56 kg/ha), phosphorus (31.10 kg/ha), and potassium (167.24 kg/ha) uptake were recorded in the treatment T_4. The minimum nitrogen (139.23 kg/ha), phosphorus (15.00 kg/ha), and potassium (145.85 kg/ha) uptake were recorded under treatment T_5.

The amplified nitrogen, phosphorus and potassium uptake in cauliflower (leaves and curd) was reported under treatments having inorganic fertilizer in conjunction with bio-fertilizers. This might be due to the ready availability of soil nutrients with the application of *Bacillus* and *Pseudomonas* as it helps in enhancing the plant-available forms of nutrients in rhizospheres and also synthesizes growth-stimulating plant hormones. *Pseudomonas* spp., synthesizes growth-stimulating plant hormones and also solubilizes phosphorous which might have improved P bioavailability. As phosphorous is associated with several vital functions, such as the proper distribution of sugar and starch and its consumption, better photosynthesis activity and root growth are achieved. Better root growth might have resulted in better uptake of nutrients. Our results are consistent with that of Chatterjee and Bandhopadhyay (2014).

Both inorganic and bio-fertilizers had a significant influence on available N, P & K (kg/ha) in soil. Substantial minimum available nitrogen (374.55 kg/ha), phosphorus (25.30 kg/ha) and potassium (414.95 kg/ha) were recorded in the treatment T_4. The maximum available nitrogen (385.95 kg/ha), phosphorus (38.34 kg/ha), and potassium (426.31 kg/ha) were recorded under control (T_8). Biofertilizers maximized availability. Both inorganic and bio-fertilizers had a significant influence on available N, P & K (kg/ha) in soil. Substantial minimum available nitrogen (374.55 kg/ha), phosphorus (25.30 kg/ha) and potassium (414.95 kg/ha) were recorded in the treatment T4. The maximum available nitrogen (385.95 kg/ha), phosphorus (38.34 kg/ha) and potassium (426.31 kg/ha) were recorded under control (T8).

Biofertilizers maximized the availability of nutrients to the rhizosphere, and more uptake occurred, resulting in less availability of N, P and K in the soil. These findings are similar to cabbage. Such contrast in the nutrient status of the post-harvest soil was on account of the dissimilarities in the nutrient-supplying power of the different applied INM treatments and the nutrient uptake by the crop. These findings closely align with the results of Suman et al. (2017), who recorded the above outcome in tomatoes.

Significant differences were reported for the viable microbial count in the soil after the final harvest of the crop (Table 2). Both inorganic and bio-fertilizers had a significant influence on viable microbial count in soil. The maximum viable bacterial count (131.07 × 106 cfu g^{-1} of soil), actinomycetes count (54.76 × 104 cfu g^{-1} of soil) and fungal count (17.50 × 104 cfu g^{-1} of soil) were recorded in the treatment T4. The minimum viable bacterial count (109.90 × 106 cfu g^{-1} of soil), actinomycetes count (35.67 × 104 cfu g^{-1} of soil) and fungal count (6.20 × 104 cfu g^{-1} of soil) were recorded under control (T8). According to Fitriatin et al. (2021), bio-fertilizers and organic ameliorants increased soil biological properties significantly.

In modern agriculture, the adoption of technology can only be practicable and sustainable to the farmer if it is economically viable. The maximum expenditure for cultivation amounting to Rs. 2,84,727 was incurred in T4, whereas the lowest expenditure for cultivation (Rs.1,59,043) was recorded in control (Table 3). The maximum gross return per hectare amounting to Rs. 4,15,110 was recorded

Table 2: Effect of treatments on soil and plant analysis

S. No.	*N, P, K-Uptake by above-ground plant parts (Leaves and curd)*			*Available N, P, K in soil after harvesting*			*Soil microbial count after harvesting*		
	N-uptake	*P-uptake*	*K-uptake*	*Available N (kg/ha)*	*Available P (kg/ha)*	*Available K (kg/ha)*	*Bacterial count (10^6)*	*Actinomycetes Count (10^4)*	*Fungi Count (10^4)*
T_1	150.10	24.33	159.51	385.13	36.95	424.81	113.00	40.82	8.90
T_2	155.52	27.95	163.36	376.68	28.13	416.71	119.33	50.85	11.60
T_3	156.55	28.38	164.37	376.09	27.02	416.50	121.20	52.11	12.10
T_4	159.56	31.10	167.24	374.55	25.30	414.95	131.07	54.76	17.50
T_5	139.23	15.00	145.85	381.54	33.73	421.57	114.20	44.15	10.20
T_6	140.66	15.47	147.27	380.80	33.02	420.99	115.80	45.37	10.50
T_7	144.77	18.11	151.13	379.59	31.75	419.35	118.00	48.59	10.80
T_8	147.82	21.08	155.77	385.95	38.34	426.31	109.90	35.67	6.20
Mean	149.23	22.72	156.81	380.04	31.78	420.15	117.81	41.97	10.98
$CD_{(0.05)}$	2.13	2.28	2.11	2.71	2.57	2.23	2.93	5.45	1.90

Table 3: Effect of treatments on economics of cauliflower

S. No.	*Yield (q/ha)*	**Gross return (₹/ha)*	*Cost of cultivation (₹/ha)*	*Net return (₹/ha)*	*B:C ratio*
T_1	265.65	3,98,475	2,07,793	1,90,682	0.92
T_2	272.47	4,08,705	2,55,097	1,53,608	0.60
T_3	272.63	4,08,945	2,36,727	1,72,218	0.73
T_4	276.74	4,15,110	2,84,727	1,30,383	0.46
T_5	255.48	3,83,220	2,53,358	1,29,862	0.51
T_6	255.66	3,83,490	2,34,988	1,48,502	0.63
T_7	259.81	3,89,715	2,82,988	1,06,727	0.38
T_8	263.31	3,94,965	1,59,043	2,35,922	1.48

*Sale price @ ₹15/- per kg of cauliflower.

from treatment T4, whereas the minimum (Rs. 3,83,220/ha) was recorded from treatment T5. However, the highest net return (Rs. 2,35,922/ha) was obtained in control, while the lowest (Rs. 1,06,727/ha) was recorded in T7. Overall, the maximum B: C ratio of 1.48 was recorded under control, while the minimum (0.38) was recorded under treatment T7. Treatment T8 (control) recorded the maximum B: C ratio due to the minimum cost of cultivation but sufficient yield, which resulted in the highest net return. Sharma and Suryavanshi (2020) observed comparable results.

From the study, it can be concluded that the use of vermicompost in conjunction with bio-fertilizers can reduce the use of 20% chemical fertilizers, besides improving soil health by increasing viable soil microbial count, which has an important role in making the nutrients available to the plants. Yield, quality characteristics, and gross returns were significantly higher under INM treatments, but the BC ratio was better under control, signifying a higher cost of cultivation under biofertilizers. The study, therefore, can provide a significant basis for future studies on biofertilizers for concluding real benefits.

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