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Effect of Integrated Nitrogen Management on Macronutrient Availability under Cauliflower (*Brassica oleracea* var. *botrytis* L.)

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A B S T R A C T

This study investigates the effect of integrated nitrogen management (INM) on yield and soil properties under cauliflower (*Brassica oleracea* var. *botrytis* L.) cv. Nuzi Snow White at Students' Research Farm, P.G. Department of Agriculture, Khalsa College, Amritsar during Rabi season of 2017-18. For INM studies, organic manures *viz*., vermicompost (VC), farmyard manure (FYM) and recommended dose of nitrogenous fertilizers (RDNF) was employed. The experiment was laid out in Randomized Block Design (RBD) with eight treatments comprised of T_1: Control, T_2: 100 % RDF, T_3: 75% RDNF + 25% N (VC), T_4: 50% RDNF + 50% N (VC), T_5: 75% RDNF + 25% N (FYM), T_6: 50% RDNF + 50% N (FYM), T_7: 50% RDNF + 25% N (VC) + 25% N (FYM), T_8: 75% RDNF + 12.5% N (VC) + 12.5% N (FYM). The availability of macro and micronutrients were significantly improved by integrated use of nutrient sources. Maximum values of available N, P, K and S were observed to be 255.90 kg ha^{-1}, 25.18 kg ha^{-1}, 308.65 kg ha^{-1} and 11.97 kg ha^{-1}, respectively in a treatment where 50% recommended nitrogen was supplied through VC (T_4). Similarly, available micronutrients (Zn, Fe, Cu and Mn) were also found highest in treatment T_4. Exchangeable Ca and Mg in soil varied from 58.47 to 33.47 mg kg^{-1} and 6.73 to 11.87 mg kg^{-1}, respectively. Values regarding plant growth parameters, yield as well as nutrient uptake were noticed highest in T_2 (100% NPK through inorganic fertilizers) which was at par with T_3 in which 25% N was substituted through VC. Integrated application of organic inputs along with 25% reduced chemical fertilizers proved to enhance the soil health while sustaining crop productivity.

Introduction

Cauliflower (*Brassica oleracea* var. *botrytis*) is one of the most important vegetable crops belonging to the family Brassicaceae. It is widely cultivated all over world for its nutritive values, high productivity and wider adaptability under different ecological conditions. Cauliflower contains various kinds of vitamins, especially vitamin C. It also contains minerals like potassium, sodium, calcium, iron, phosphorus and magnesium (Ogbede *et al.*, 2015). Cauliflower is a heavy feeder of mineral elements, it removes a large amount of macronutrients from the soil, especially nitrogen. The use of nitrogenous fertilizers upsurges tremendously in order to fulfil growing food needs since the green revolution. Applicability of nitrogen-containing fertilizer at or below than optimum levels help in proper build up of organic nitrogen in the soil whereas excessive and imbalance use of synthetic nitrogen sources cause loss of native nitrogen that ultimately makes soil devoid of good structure as well as soil biomass (Singh, 2018). Nitrogen applied through fertilizers of ammonical nature produce acidic conditions in the soil (Fageria *et al.,* 2010). The annual consumption of fertilizers increased from about 255.36 LMT in 2012-13 to 259.49 LMT in 2016-17 (Anonymous, 2017). In general agriculture, the use of chemical fertilizers cannot be ruled out completely. However, there is a need for the integrated application of different sources of nutrients for sustaining the required crop productivity by integrated nutrient management. The concept of integrated nutrient management requires the optimum use of organic, inorganic and bio-sources of plant nutrients (Tekasangla *et al.,* 2015). Organic manures like FYM, poultry manure, vermicompost have traditionally used by farmers in different regions of Punjab. In the past, the integrated use of organic materials and inorganic nitrogenous fertilizers have received notable attention to meet the farmer's economic need as well as maintaining ecological conditions on the long-term basis (Kumar *et al.,* 2007). Keeping the above in view, the present work was undertaken to study the impact of different combination of nutrient sources on macronutrient availability under cauliflower.

Materials and Methods

The field experiment was conducted during Rabi season (Aug to Dec) of 2017 at Students' Research Farm, Khalsa College, Amritsar, India on sandy loam, moderately alkaline (pH 8.22), medium in organic carbon (0.45 %), available P (20.53 kg ha^{-1}) and available K (261.36 kg ha^{-1}) and low in available N (198.21 kg ha^{-1}) soil. Organic manures *viz*., farmyard manure (FYM), vermicompost (VC) containing various macro and micronutrients (Table 1) and recommended dose of nitrogenous fertilizers (RDNF) were applied according to the treatments. Organic wastes used for vermicomposting includes waste vegetables, cow dung, green weeds etc. having high nitrogen content. FYM was prepared from cow dung and other farm waste.

The experiment was laid out in Randomized Block Design (RBD) with the three replications. A total of eight treatments; T_1 - Control, T_2 - 100% recommended NPK through fertilizers, T_3 - 75% RDNF + 25% N through VC, T_4 - 50% RDNF + 50% N through VC, T_5 - 75% RDNF + 25% N through FYM, T_6 - 50% RDNF + 50% N through FYM, T_7 - 50% RDNF + 25% N through VC + 25% N through FYM, T_8 - 75% RDNF + 12.5% N through VC + 12.5% N through FYM were evaluated for nutrient management. Organic manures were incorporated in soil 15 days before transplanting. Cauliflower seedlings of the cultivar Nuzi Snow White were procured from KVK, Amritsar. Seedlings were transplanted in 2.7 m × 2.7 m plots with both ways spacing of 45 cm. Fertilizers used were urea (46% N), single superphosphate (16% P) and muriate of potash (60% K). All the dose of P, K and half dose of N was applied as basal dressing and the remainder of N was top-dressed after 4 weeks of transplanting as recommended in the package of practices for cultivation of vegetables published by Punjab Agricultural University, Ludhiana.

Soil samples were taken from all the replications before starting the experiment and after the harvest of cauliflower from each treatment. Soil Samples were air dried and ground to pass through a 2 mm sieve. Soil samples were analysed for pH and EC in 1:2 soil: water suspension, organic carbon

(Walkley and Black, 1934), cation exchange capacity (Jackson, 1987), available N (Subbiah and Asija, 1965), available P (Olsen, 1954), available K, exchangeable Ca and exchangeable Mg (Merwin and Peech, 1951), available S (Chesnin and Yien, 1950) and DTPA-extractable Zn, Fe, Cu and Mn by the method of Lindsay and Norvell (1978). Total N, P (Chapman and Pratt, 1961; Jackson, 1987) and K (Jackson, 1987) uptake in plant samples was analyzed after the harvest. Agronomic nitrogen use efficiency (Dilz, 1988) and apparent nitrogen recovery were calculated as described by Novoa and Loomis (1981).

Results and Discussion

Use of organic manures and inorganic fertilizers showed significant impact on yield and other attributes of cauliflower. Highest plant height (at 45 DAT - 32.81 cm and at harvest - 76.82 cm), plant spread (at 45 DAT - 159.37 cm and at harvest - 215.24 cm), no. of leaves plant^{-1} (19.45) and leaf area (1132.00 cm^2) was recorded under application of 100% NPK through inorganic fertilizers which was statistically at par with treatment T_3 in which 25% N was applied through VC (Table 1).

This could be attributed to higher dose of inorganic nitrogen which is associated with increase in protoplasm, cell division and cell enlargement resulting in taller plants (Kumari, 2017). There was increase in number of leaves with the increase in nitrogen doses because nitrogen promotes the apical branching and hence more number of leaves appeared on plant (Kebrom, 2017).

Higher leaf area was also related to addition of nitrogen in different doses and nitrogen mediates cell expansion (Chaudhary *et al.,* 2015). Significant increase in plant growth in vermicompost treated plots over FYM treated plots may have been due to its faster mineralization of nutrients from vermicompost (Joshi *et al.,* 2015) (Table 2).

The observation on stalk length, girth of stem, dry matter accumulation and yield showed an increasing trend with higher level inorganic nitrogen doses (Table 3). The highest stalk length (14.63 cm) and girth of stem (12.47 cm) was recorded with application of 100% RDF alone which was at par with treatment T_3. Stalk length as well as girth of stem was increased due to less retention in the roots and more translocation of nutrients to aerial parts for synthesis of protoplasmic protein and other metabolites (Rather *et al.,* 2018).

Dry matter accumulation varied from 18.23 q ha^{-1} to 34.49 q ha^{-1}. Treatments T_7 and T_6 in which 50% N was applied through VC and FYM were at par and inferior to all treatments except the control. The weight gain of plant or plant organs indicated that the plant growth and development occurred by increasing the size and volume of the cell due to release of nutrients (Kumari, 2017). Yield of cauliflower ranged from 378.86 q ha^{-1} to 202.58 q ha^{-1} in all the treatments. The effect of combined use of organic manures have not resulted significant influence on yield of cauliflower and highest yield was found under 100% RDF treated plots, however it was statistically at par with T_3 treatment. Nitrogen being the major constituent of chlorophyll, amino acids and proteins as well as phosphorus being the component of energy compounds *viz*., ATP, NADP and potassium regulates the activity of various enzymes involved in photosynthesis and CO_2 fixation (Ohyama, 2010). It could have promoted satisfactory plant growth, yield structure and finally to cauliflower yield under adequate and balanced supply of nutrients at maximum level.

Application of 100% RDF resulted in highest N (82.12 kg ha^{-1}), P (12.94 kg ha^{-1}) and K (60.21 kg ha^{-1}) uptake by cauliflower which was found to be statistically similar to treatment T_3 in which 25% N was substituted through VC (Table 4). Least N, P and K uptake was found in control due to less growth of plants in such plots. The increase in uptake of nitrogen with application of inorganic fertilizers as well as in combination of organic manures was consistent with the findings of Bozkurt *et al.,* (2011) who concluded that this nitrogen was further utilized for metabolism of various substances required for growth of plants which produced more dry matter. The ability of a plant to take up phosphorus is largely due to its root distribution relative to phosphorus as it is relatively immobile in the soil. Application of organic manures might have improved the soil environment, which encouraged proliferous root system resulting in better absorption of water and nutrients from lower layers and thus resulting in higher yield and nutrient uptake (Devi *et al.,* 2017). Higher potassium uptake in all plots over the control might be due to the enhanced number of small root hairs resulting from more growth of plant which in turn increased the absorbing ability (Reza *et al.*, 2016).

Likewise, Maximum agronomic nitrogen use efficiency was recorded under 100% RDF (141.02 kg ha^{-1}) and minimum value of agronomic nitrogen use efficiency in treatments T_4, T_7 and T_6 in which 50% N was applied through VC and FYM was due to lower yield in such treatments (Table 5). Similar trend was observed for apparent nitrogen recovery (%). Kumar and Mukhopadhyay (2017) also reported an increase of agronomic nitrogen use efficiency and apparent nitrogen recovery with yield of cauliflower with same dose of nitrogen applied.

Apart from all, there was no significant difference in soil pH and soil EC among different treatments was observed (Table 6).

Maximum organic carbon (0.56%) and CEC [11.51 cmol (p^+) kg^{-1}] was recorded in treatment T_6 [50% RDNF + % 50% N (FYM)] that was at par with treatments T_7 [50% RDNF + 25% (VC) + 25% (FYM)] and T_4 [50% RDNF + 50% (VC)]. The increase in soil organic carbon content with the application of FYM and VC may be attributed due to direct incorporation of these organic materials in the soil and the subsequent decomposition of these materials result in enhanced organic carbon content of the soil. Similar trend was also reported by Merentola *et al.,* (2012). Application of organic inputs increased the organic carbon stock in soil which, ultimately resulted in higher cation exchange capacity (CEC). The findings are well supported by those reported by Scotti *et al.,* (2015).

Available N, P, K and S mean values were lower in control plots (T_1) and it increased significantly with the application of chemical fertilizers and organic manures (Table 7). Maximum available N, P, K and S was observed in treatment T_4 which was at par with treatments T_7 and T_6. Higher availability of nitrogen was observed in case of treatments that received combined application of organic manures and inorganic fertilizers might be partly due to release of native soil nitrogen and partly due to mineralization of nutrients from organic manures (Singh, 2018). Available P varied from 13.42 kg ha^{-1} under control to 25.18 kg ha^{-1}. The conjunctive use of inorganic and organic sources increased the phosphorus availability by reducing the fixation of water soluble P and by increasing mineralization that resulted in more availability of phosphorus (Singh *et al.,* 2015). Available potassium was improved in INM plots over the control. This might be due to the organic acids released during decomposition of manures mobilize the native or non-exchangeable forms of potassium, so that it will be readily available Chander *et al.,* (2010).

Table.1 Nutrient composition of vermicompost and farmyard manure

Source	Macronutrients						Micronutrients			
	Per cent				mg kg^{-1}		mg kg^{-1}			
	N	P	K	S	Ca	Mg	Zn	Fe	Cu	Mn
VC	1.68	1.05	1.21	0.57	64.30	19.97	22.14	76.32	4.08	121.16
FYM	0.87	0.49	0.77	0.42	47.43	16.81	15.43	67.83	2.97	103.84

Table.2 Effect of integrated nitrogen management on plant height, plant spread, no of leaves plant^{-1} and leaf area

Symbol	Treatments	Plant height (cm)		Plant spread (cm)		No. of leaves plant^{-1}	Leaf Area (cm^2)
		45 DAT	At Harvest	45 DAT	At Harvest		
T_1	Control	20.08	41.62	100.67	123.28	9.35	594.67
T_2	100% RDF	32.81	76.82	159.37	215.24	19.45	1132.00
T_3	75% RDNF + 25% N (VC)	30.47	73.91	148.10	200.26	18.27	1081.00
T_4	50% RDNF + 50% N (VC)	27.31	64.59	132.22	175.33	16.23	978.00
T_5	75% RDNF + 25% N (FYM)	29.17	69.49	142.96	189.47	17.31	1028.33
T_6	50% RDNF + 50% N (FYM)	25.27	58.79	127.90	166.27	15.15	917.00
T_7	50% RDNF + 25% N (VC) + 25% N (FYM)	26.30	61.40	130.38	171.80	15.77	948.00
T_8	75% RDNF + 12.5% N (VC) + 12.5% N (FYM)	29.86	70.60	146.29	195.55	17.72	1057.00
	CD (p=0.05)	2.51	5.94	12.15	16.43	1.42	64.9

Table.3 Effect of integrated nitrogen management on stalk length, girth of stem, dry matter and yield

Symbol	Treatments	Stalk Length (cm)	Girth of stem (cm)	Dry Matter (q ha^{-1})	Yield (q ha^{-1})
T_1	Control	8.17	7.17	18.23	202.58
T_2	100% RDF	14.63	12.47	34.49	378.86
T_3	75% RDNF + 25% N (VC)	13.61	11.76	32.79	357.28
T_4	50% RDNF + 50% N (VC)	12.05	10.42	28.90	319.18
T_5	75% RDNF + 25% N (FYM)	12.94	11.28	30.57	346.74
T_6	50% RDNF + 50% N (FYM)	11.43	10.04	26.65	311.78
T_7	50% RDNF + 25% N (VC) + 25% N (FYM)	11.67	10.29	28.04	315.07
T_8	75% RDNF + 12.5% N (VC) + 12.5% N (FYM)	13.22	11.42	31.94	349.24
	CD (p=0.05)	1.10	0.95	2.52	29.45

Table.4 Effect of integrated nitrogen management on N, P and K uptake by cauliflower

Symbol	Treatments	N uptake (kg ha^{-1})	P uptake (kg ha^{-1})	K uptake (kg ha^{-1})
T_1	Control	36.15	6.37	27.61
T_2	100% RDF	82.12	12.94	60.21
T_3	75% RDNF + 25% N (VC)	76.64	12.06	57.50
T_4	50% RDNF + 50% N (VC)	66.63	10.24	51.49
T_5	75% RDNF + 25% N (FYM)	70.74	11.13	54.40
T_6	50% RDNF + 50% N (FYM)	60.85	9.36	48.25
T_7	50% RDNF + 25% N (VC) + 25% N (FYM)	64.84	9.75	49.42
T_8	75% RDNF + 12.5% N (VC) + 12.5% N (FYM)	73.41	11.62	56.12
	CD (p=0.05)	6.06	0.96	3.76

Table.5 Effect of integrated nitrogen management on agronomic nitrogen use efficiency and apparent nitrogen recovery

Symbol	Treatments	Agronomic nitrogen use efficiency (kg yield kg^{-1} N applied)	Apparent nitrogen recovery (%)
T_1	Control	---	---
T_2	100% RDF	141.02	36.78
T_3	75% RDNF + 25% N (VC)	123.77	32.39
T_4	50% RDNF + 50% N (VC)	93.28	24.38
T_5	75% RDNF + 25% N (FYM)	115.33	27.67
T_6	50% RDNF + 50% N (FYM)	87.36	19.76
T_7	50% RDNF + 25% N (VC) + 25% N (FYM)	89.99	22.95
T_8	75% RDNF + 12.5% N (VC) + 12.5% N (FYM)	117.33	29.81
	CD (p=0.05)	---	---

Table.6 Effect of integrated nitrogen management on soil pH, EC, organic carbon and cation exchange capacity

Symbol	Treatments	pH	EC (dS m^{-1})	Organic carbon (%)	CEC cmol (p^+) kg^{-1}
T_1	Control	8.21	0.31	0.44	10.20
T_2	100% RDF	8.19	0.31	0.45	10.47
T_3	75% RDNF + 25% N (VC)	8.18	0.32	0.49	10.73
T_4	50% RDNF + 50% N (VC)	8.16	0.33	0.53	11.25
T_5	75% RDNF + 25% N (FYM)	8.16	0.32	0.51	10.98
T_6	50% RDNF + 50% N (FYM)	8.14	0.33	0.56	11.51
T_7	50% RDNF + 25% N (VC) + 25% N (FYM)	8.15	0.33	0.55	11.38
T_8	75% RDNF + 12.5% N (VC) + 12.5% N (FYM)	8.18	0.32	0.50	10.86
	CD (p=0.05)	N.S	N.S	0.03	0.28

Table.7 Effect of integrated nitrogen management on available and exchangeable macronutrients

Symbol	Treatments	Available macronutrient (kg ha^{-1})				Exchangeable Macronutrients (mg kg^{-1})	
		N	P	K	S	Ca	Mg
T_1	Control	178.30	13.42	246.58	7.43	33.47	6.73
T_2	100% RDF	222.76	19.94	278.75	9.07	46.60	7.37
T_3	75% RDNF + 25% N (VC)	238.28	22.77	293.48	10.33	52.70	10.53
T_4	50% RDNF + 50% N (VC)	255.90	25.18	308.65	11.97	58.47	11.87
T_5	75% RDNF + 25% N (FYM)	230.11	21.43	285.95	9.83	49.53	10.03
T_6	50% RDNF + 50% N (FYM)	245.76	23.76	299.94	11.17	55.80	11.23
T_7	50% RDNF + 25% N (VC) + 25% N (FYM)	249.19	24.39	304.20	11.43	56.73	11.60
T_8	75% RDNF + 12.5% N (VC) + 12.5% N (FYM)	234.99	22.21	289.23	10.03	51.53	10.33
	CD (p=0.05)	10.44	1.50	9.47	0.90	3.34	0.87

Table.8 Effect of integrated nitrogen management on available micronutrients

Symbol	Treatments	Available micronutrients (mg kg^{-1})			
		Zn	Fe	Cu	Mn
T_1	Control	0.99	2.29	0.46	7.47
T_2	100% RDF	1.21	2.43	0.52	8.53
T_3	75% RDNF + 25% N (VC)	2.63	3.81	0.63	10.86
T_4	50% RDNF + 50% N (VC)	2.95	4.28	0.72	12.44
T_5	75% RDNF + 25% N (FYM)	2.44	3.53	0.58	10.14
T_6	50% RDNF + 50% N (FYM)	2.76	3.98	0.67	11.68
T_7	50% RDNF + 25% N (VC) + 25% N (FYM)	2.86	4.14	0.69	11.95
T_8	75% RDNF + 12.5% N (VC) + 12.5% N (FYM)	2.54	3.65	0.60	10.55
	CD (p=0.05)	0.21	0.31	0.05	0.85

Table.9 Effect of integrated nitrogen management on economic analysis

Symbol	Treatments	Total input cost (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
T_1	Control	110732	202577	91845	0.82
T_2	100% RDF	117918	378857	260939	2.21
T_3	75% RDNF + 25% N (VC)	124685	357283	232598	1.87
T_4	50% RDNF + 50% N (VC)	132236	319177	186941	1.41
T_5	75% RDNF + 25% N (FYM)	120108	346737	226629	1.89
T_6	50% RDNF + 50% N (FYM)	121537	311777	190240	1.57
T_7	50% RDNF + 25% N (VC) + 25% N (FYM)	127735	315067	187332	1.47
T_8	75% RDNF + 12.5% N (VC) + 12.5% N (FYM)	120955	349243	228288	1.89

In integrated nutrient management treatment available sulphur was recorded higher because organic manures enhance the activity of soil microorganisms and they apparently utilize organically bound sulphur.

They further convert it into sulphur containing amino acids like cystine and methionine, which are then converted in to inorganic sulphate by the action of microorganisms and increase the availability of sulphur in soil (Blum *et al.,* 2013). Similarly, exchangeable calcium and magnesium was found significantly higher 58.47 mg kg^{-1} and 11.87 mg kg^{-1}, respectively in 50% RDNF + 50% N (VC) applied treatment (Table 7). However, vermicompost was well known for improving soil properties by release of Ca and Mg from exchangeable sites (Uz *et al.*, 2016).

Application of 50% RDNF + 50% N (VC) also documented with significant higher availability of cationic micronutrients (Zn, Fe, Cu and Mn) and at par with treatments (T_7 and T_6) in which 50% N was substituted through FYM and VC (Table 8). The increase in availability of cationic micronutrients may be attributed to decomposition of organic sources, which increased the availability of micronutrients by preventing fixation, oxidation, precipitation and leaching (Rai *et al.*, 2018).

Economic analysis

The highest benefit: cost ratio of 2.21 was recorded in treatment T_2 in which 100% recommended dose of nutrients was applied through fertilizers (Table 9). While, minimum benefit: cost ratio of 0.82 was observed in T_1 (control). In T_2 benefit: cost ratio was recorded highest due to reason that maximum yield was obtained with least investment as compared to other treatments in which only inorganic fertilizers were used in combination with organic manures.

It is concluded that with the use of organic inputs through integrated nutrient management in the present study had marked effect in improving soil health and economic yield of cauliflower. Available macronutrients and cationic micronutrients (Zn, Fe, Cu and Mn) were observed highest in plots where 50% N was substituted through FYM and VC. However, crop yield was highest in chemically fertilized plots (T_2). Application of 75% RDNF + 25% N through VC (T_3) resulted in improved soil properties over entirely chemically fertilized plots without significant decrease in yield. Therefore, this treatment is recommended as beneficial for farmers on long term basis, as it resulted in saving 25% inorganic fertilizers for better net returns.

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