

Research Article

Effects of integrated nutrient management in early season cauliflower production and its residual effects on soil properties

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Received: July 20, 2020; Accepted: September 21, 2020; Published: October 30, 2020

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ABSTRACT

This experiment was conducted in the farmer's field at Ajagadhawa, Gadhawa-4, Dang, Nepal to evaluate the effect of integrated nutrient management on growth and yield of cauliflower as well as their residual effects on soil properties. The cauliflower variety silvercup-60 was grown under eight different treatments; T1: 50% N through RDF + 50% N through FYM; T2: 50% N through RDF + 50% N through PM; T3: 50% N through RDF + 50% N through VC; T4: 50% N through RDF + 25% N through FYM + 25% N through PM; T5: 50% N through RDF + 25% N through VC + 25% N through PM; T6: 50% N through RDF + 25% N through VC + 25% N through FYM; T7: 50% N through RDF + 25% N through VC + 25% N through FYM; T8: 50% N through RDF + 50% N through FYM, VC and poultry manure. The experiment was laid out in RCB design with three replications. The result revealed that the highest plant height (36.40 cm), number of leaves (15), plant spread (31.72 cm), leaf area (526.5 cm²), curd weight (207.3g) and curd yield (12.85 t/ha) were found under 50% N through RDF + 50% N through VC. The root length, root diameter and root density were better under all INM treatments as compared to 100% N through RDF. INM treatments showed lesser bulk density, lesser particle density, greater infiltration rate and greater organic matter content than application of 100% N through RDF. Soil total nitrogen was increased in all INM treatments while soil available phosphorus decreases in all treatments except 100% N through RDF and 50% N through RDF + 50% N through PM. Thus, farmers are suggested to apply 50% N through VC along with 50% N through RDF to increase cauliflower yield.

Keywords: Cauliflower, curd yield, growth parameters, integrated nutrient management, residual soil properties

Correct citation: Neupane, B., Aryal, K., Chhetri, L.B., & Regmi, S. (2020). Effects of integrated nutrient management in early season cauliflower production and its residual effects on soil properties. *Journal of Agriculture and Natural Resources*, 3(2), 353-365. DOI: <https://doi.org/10.3126/janr.v3i2.32548>

INTRODUCTION

Cauliflower (*Brassica oleracea* L. var. *botrytis*) native to Mediterranean region is a temperate vegetable crop belonging to crucifer family. It is most popular for its white tender curd and extensively cultivated throughout the world. It is regarded as indispensable group of food as it contains vitamin A (51 IU), vitamin C (56 mg), riboflavin (0.10 mg), thiamin (0.04 mg), nicotinic acid (1.0 mg), calcium (33mg), 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) per

100 g of edible portion of cauliflower (Fageria *et al.*, 2012). Moreover, it has medicinal value and has been found effective in inhibition of carcinogenesis as it contains high concentration of glucothiocyanate and indol-3-Carbinol with anti-inflammatory properties (Basnet & Shakya, 2016).

Diverse agro-ecological conditions of Nepal favours the year-round cultivation of cauliflower and it is available throughout the season in the market. So, it is one of the most preferable vegetable in the Nepalese kitchen. It is consumed as cooked, fried, boiled as well as making pickle. According to MoALD (2019), cauliflower ranked first in terms of area under cultivation and production among all other vegetables in Nepal whose cultivation covers about 35764ha with total production of 574795 mt and productivity of 16.07 mt/ha.

Cauliflower demands greater amount of plant nutrients as it is one of the heavy feeder plant. Constant supply of manures and fertilizer in higher doses is required to obtain good yield (Subedi *et al.*, 2019). Farmers apply chemical fertilizers haphazardly without considering the initial soil nutrient status and the crop demand which ultimately degrades the soil health. Besides locally available organic sources of nutrients like FYM, poultry manure, vermicompost etc. were not emphasized. Use of organic manures and biological fertilizers cannot alone enhance the production of this heavy feeder crop in spite of sustaining soil health. Sustainable and cost-effective approach both for higher yield and management of soil fertility is required and hence INM (Integrated Nutrient Management) can be the better nutrient management approach at the present context.

INM concept encourage integrated applications having judicious combination of mineral fertilizer with organic and biological sources of nutrients which results higher crop productivity due to their combined and synergistic effect in improving soil physical, chemical and biological properties (KC & Bhattarai, 2012). Keeping the above fact in view, this experiment was conducted to evaluate the effect of different INM treatments on the growth and yield parameters of cauliflower as well as its effect on residual soil properties.

MATERIALS AND METHODS

Experimental site

The field experiment was carried out during late monsoon (September) to early winter (November) of 2019 in the farmer's field at Ajagadhawa, Gadawa-4, Dang which is part of inner Terai of Nepal with humid sub-tropical climate. Geographically it is situated at 27°48' North latitude and 82°34' East longitude. Its height above mean sea level is about with 263 m. The soil of the experimental site was clay loam having slightly acidic pH (6.41), low organic matter content (1.9%), low total nitrogen (0.09%) and very high available phosphorus (126 kg/ha).

Experimental design and treatment details

The experiment was laid out in randomized complete block design (RCBD) with eight treatments (Table 1.) and was replicated thrice. Gross area of experimental plot was 284.35m². The area of each treatment plot was 6.075 m² (2.7m × 2.25m) with 0.5m spacing between the treatment plots and 1m in between the replication. There were 5 rows and 6 columns in each plot adapting spacing of 0.45m×0.45m and 30 seedlings.

Table 1. Treatment details of the experimental field.

Treatments Symbol	Treatment details
T1	100% N through recommended dose of chemical fertilizer (RDF) (RDF: 200:120:80 NPK kg/ha)
T2	50%N through RDF + 50% N through FYM
T3	50% N through RDF + 50% N through poultry manure(PM)
T4	50%N through RDF + 50% N through vermicompost (VC)
T5	50%N through RDF + 25% N through FYM + 25% through poultry manure(PM)
T6	50%N through RDF +25% N through vermicompost (VC) + 25% N through poultry manure(PM)
T7	50%N through RDF + 25% N through vermicompost (VC) + 25% N through FYM
T8	50%N through RDF + 50% N through FYM, Vermicompost and poultry manure (1:1:1) ratio

Planting materials and cultural practices

For the experiment, Silvercup60, an extra early maturing hybrid variety of cauliflower supplied by Syngenta seed company, Japan mostly used for off season cultivation in Nepal was used for the study. The variety is recommended for Mid hill and Terai domain of Nepal (MoALD, 2019/20). The cauliflower seed was collected from local agrovet of Lamahi and the germination percentage and purity percentage of the variety as mentioned in the label was 85% and 99% respectively.

The seedlings required for the experiment was grown in bubble tray using the growing media (Cocopeat, sterilized soil and well decomposed FYM in the ratio 1:1:1). Irrigation on the seedlings was done two to three times a day depending upon the dryness of media. Fungicide (Bavistin) was sprayed at 15 days after sowing (DAS) at concentration of 0.1% after emergence of seedlings. Amounts of fertilizers for each treatment were calculated based on recommended dose of fertilizer for cauliflower i.e. 200:120:80 NPK kg/ha (MoALD, 2019/20) and N content of the respective organic fertilizer (Table 2.) The treatments were designed with the different composition or ratio of chemical and organic fertilizers and were applied in such a way that their combination meets the recommended dose of nitrogen required by the crop. Required dose of organic manures were applied 15 days before transplanting. $\frac{1}{2}$ dose of Nitrogen through urea and DAP, full dose of Phosphorus through DAP and full dose of Potassium through MOP were applied as a basal dose. Remaining $\frac{1}{2}$ dose of N was applied at 30 days of transplanting (DAT). Healthy uniform seedlings of 25 days old were transplanted on a ridge at spacing of 45×45cm to reduce effect of rainfall in growing season. Light irrigation was given immediately after transplanting. Further irrigation was done subsequently at 8 days interval.

Table 2. Nutrient content of the different fertilizers used in the experiment.

S.N.	Fertilizers	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Source
1	Urea	46	-	-	Local Agrovet, Lamahi
2	DAP	18	46	-	Local Agrovet, Lamahi
3	MOP	-	-	60	Local Agrovet, Lamahi
4	FYM	1.54	NA	NA	Local Farmers, Ajgadawa
5	Vermicompost	2.5	NA	NA	Local Agrovet, Chitwan
6	Poultry Manure	2.08	NA	NA	Local Farmers, Ajgadawa

Manual weeding was done at 15 and 30 days after transplanting to protect the crop from weed infestation. After transplanting SAAF fungicide (mancozeb and carbendazim) @ 2mL/L was

used after each heavy rainfall within time interval of 10-15 days to protect cauliflower from fungal disease and neem oil-based insecticides was used on weekly basis to decrease insect infestation in experimental plots as different lepidopteran larva was observed at 20 days after transplanting(DAT).The harvesting of curds was done at proper maturity stage, when curds are compact and upper leaves start turning back. The harvesting of tender curds was done with the help of sickle at 60 days after transplanting.

Data collection and analysis

Plant parameters

Randomly ten plant samples were selected and tagged to record the data of crop growth parameters such as plant height (cm), number of leaves, plant spread (cm), leaf area (cm²). Similarly, other five plants were selected randomly to collect the root growth parameters such as root length (cm), root diameter(cm) and root density(g/cm³) and observations were recorded at 45 days after transplanting(DAT). Yield parameters such as curd diameter (cm), curd depth(cm), curd weight(g) and marketable yield(t/ha) were recorded at harvest.

Soil parameters

Soil samples from the depth of 0-15 cm were collected in z- pattern from each treatment plots before and after harvesting of the crop. Sub-samples from each treatment plots were mixed to form composite sample. The samples were processed and analyzed for the following soil parameters using standard procedure at soil lab of Prithu Technical College as shown in Table 3.

Table 3. Methods to analyse soil samples for different selected soil parameters.

S.N	Soil Parameters	Method Used
1	Soil texture	Field-Feel method
2	Soil Infiltration Rate (cm/hr)	Double ring infiltrometer (ASTM, 2003)
3	Soil Bulk density (g/cm ³)	Core Sampler Method (Blake and Hartge, 1986)
4	Soil Particle Density (g/cm ³)	Pycnometer (Reischauer and Gay Lussac, 1802)
5	Soil pH	Potentiometric 1:2 (Jackson, 1973)
6	Organic Matter (%)	Walkley and Black (Walkley and Black, 1934)
7	Total Nitrogen (%)	OM×0.05 (A & L Canada Laboratory, 2013)
8	Available Phosphorous (kg/ha)	Modified Olsen's method (Olsen <i>et al.</i> , 1954) using spectrophotometry.

The data collected in the experiment were statistically analyzed with R-STAT using Agricolae tool package. Analysis of variance (ANOVA) was done on every measured parameter to determine the significance of differences between means of treatments. Means for each parameter were separated by the Duncan's multiple range test (DMRT) and the treatment means were compared by the Least Significant Difference (LSD) test at 5% level of significance(Gomez & Gomez, 1984; Shrestha, 2019).

RESULTS AND DISCUSSION

Effect of INM on growth parameters of cauliflower

Plant height

Although no significant difference was observed in this parameter, use of 50% N through RDF+ 50% N through VC showed highest value (36.4cm) for plant height over other treatments. However, minimum value for it was recorded (31.24cm) with 100% N through RDF.The results of present investigation in terms of plant height corroborate the findings of Shree *et al.* (2014) Rakesh *et al.* (2006) and Mitiku *et al.* (2014) who reported increased plant

height due to compound application of organic and inorganic fertilizers. The result may pertain to adding organic manures to soil in combination with inorganic fertilizers which increases the availability of nutrients considerably result in positive effect on growth parameters.

Number of leaves

There was no significant difference in number of leaves but application of 50% N through RDF+ 50% N through VC and application of 50% N through RDF and 50% N through FYM+ VC+ PM showed the highest number of leaves i.e, 15 and the lowest number of leaves was recorded with 100% N through RDF. The results obtained were corroboratory with the findings of Singh *et al.* (2018) who reported the maximum number of leaves on Half Dose of NPK/ha + Vermicompost @ 2.5 t/ha + Azospirillum @ 5 kg/ha+ VAM @ 5 kg/ha. Kumar *et al.* (2013) also reported maximum number of leaves in broccoli under integrated application of inorganic fertilizers and vermicompost. These effects could be attributed to the character of organic manures, the addition of which has solubilizing effects on the soil nutrients as well as chelating effects on metal ions and hence increased availability of nutrients to the plants.

Plant spread

Plant Spread showed significant difference with treatments. Maximum plant spread (31.72cm) was also recorded with 50% N through RDF + 50% N through VC which was statistically at par with other integrated treatments.

Table 4. Effect of different treatments on plant growth parameters of cauliflower at 45 DAT in Dang, Nepal, 2019

Treatments	Plant height (cm)	No. of leaves	Plant Spread (cm)	Leaf area (cm ²)
T1	31.24	13.20	24.79 ^b	313.8 ^c
T2	33.16	13.33	28.33 ^a	351.1 ^{bc}
T3	35.80	13.93	30.48 ^a	462.6 ^{ab}
T4	36.40	15.00	31.72 ^a	526.5 ^a
T5	34.72	14.13	29.93 ^a	431.8 ^{abc}
T6	35.85	14.93	30.67 ^a	443.2 ^{ab}
T7	36.39	14.93	30.89 ^a	454.4 ^{ab}
T8	35.87	15.00	30.48 ^a	426.6 ^{abc}
Grand Mean	34.93	14.31	29.66	426.00
SEM(±)	1.50	0.86	1.07	37.6
LSD (P<0.05)	NS	NS	3.25	113.9
F-test	NS	NS	*	*
CV(%)	7.4	10.4	6.3	15.3

Treatments means followed by the common letter or letters within the column are not significantly different among each other based on DMRT at 5% level of significance. LSD = Least significant difference, CV = Coefficient of variation, NS= Non significant and *= Significant

Minimum canopy diameter was recorded 100% N through RDF. Similar finding was observed in research conducted by Devi *et al.* (2018) in cauliflower. The rationale behind this trend of plant spread may be due to balanced C:N ratio and abundant supply of available nutrients from the soil comparatively less retention in the roots and more translocation to aerial portion for synthesis of protoplasmic proteins and other metabolites enabling expansion of photosynthetic area, hence plant spread.

Leaf area

Integrated use of 50% N through RDF and remaining 50% N through VC showed significant difference in leaf area which was statistically equivalent to other integrated treatment

combinations except integrated use of 50% N through RDF + 50% N through FYM and minimum value was observed with 100% N through RDF.

Similar result was also revealed by experiment performed by Devi *et al.* (2018) which revealed highest leaf area with treatment integrating vermicompost with inorganic fertilizers. This may be attributed to numerous humic acid contained in vermicompost, which enhances the growth of leaves.

Effect of INM on root growth parameters of cauliflower

Root length

The average root length was found to be non- significant in response to treatment combinations. However, higher root length was observed in T3 (50%N through RDF +50%N through PM) while lowest in T1 (100% N through RDF). Similar finding was also observed in research performed by Gadi *et al.* (2017) in green gram. This may be attributed to improved soil properties like bulk density and WHC encouraged by organic manures and better availability of nutrient which promote root length and proliferation.

Root diameter

No significant difference among the treatments was observed on root diameter. T3 (50%N through RDF + 50%N through PM) and T5 (50%N through RDF + 25%N through FYM +25%N through PM), showed the highest value of root diameter (1.0 cm) and T2(50%N through RDF + 50% N through FYM) showed the lowest (0.73cm).

Table 5. Effect of different treatments on root growth parameters of cauliflower at 45 DAT in Dang, Nepal, 2019

Treatments	Root length (cm)	Root diameter (cm)	Root density (g/cm ³)
T1	18.67	0.80	0.63
T2	19.67	0.73	0.51
T3	21.73	1.00	0.69
T4	20	0.90	0.63
T5	20.07	1.00	0.65
T6	20.33	0.87	0.63
T7	19.07	0.87	0.66
T8	19.67	0.93	0.67
Grand Mean	19.90	0.89	0.63
SEM(±)	2.14	0.11	0.05
LSD(0.05)	NS	NS	0.15
F-test	NS	NS	NS
CV(%)	18.6	21.6	13.8

*Treatments means followed by the common letter or letters within the column are not significantly different among each other based on DMRT at 5% level of significance. LSD = Least significant difference, CV = Coefficient of variation, NS= Non significant and *= Significant*

Our finding represents better root development under integrated treatment combinations during growing days which was supported by result obtained from Khatri *et al.* (2019) in radish. This may be resulted from integration of organic manure which lowers mechanical resistance, better aeration and lower bulk density of the surface soil that promoted better root proliferation resulting proper growth and development of root.

Root density

Root density was found to be insignificant among all the treatments, however, T3(50%N through RDF + 50%N through PM) had the highest root density (0.69 g/cm³) and T2(50%N through RDF + 50% N through FYM) had the lowest root density (0.51 g/cm³). The small

diameter and low root density are supposed to have better nutrient root absorption efficiency (Fitter, 2002).

Effect of INM on yield parameters of cauliflower

Curd depth

Significance differences in curd depth, an indicator of curd size was observed in response to different treatment combinations. Average curd depth was found maximum (9.90cm) in T6 (50%N through RDF + 25%N through VC + 25%N through PM) and lowest curd depth (5.40 cm) was found in T1 (100% N through RDF). The result maybe attributed to beneficial role of organic manures in improving soil physical, chemical and biological properties which in turn help in better nutrient absorption by plants resulting in better development of the curd.

Curd diameter

The average curd diameter influenced by the treatment T6 (50%N through RDF + 25%N through VC + 25%N through PM) had the highest significant difference (13.5 cm) among other treatment combinations and had lowest curd diameter (7.93 cm) in T1 (100% N through RDF). The result obtained was in conformity with the findings of Devi *et al.* (2018) in cauliflower and Mohanata *et al.* (2018) in sprouting brocolli. This might be due to increase in photosynthetic activity of plant with overall growth and by increasing chlorophyll content. The increased chlorophyll content produced more photosynthesis which was diverted for the growth of curd and as a result in better nourishment of the curd.

Average curd weight

Curd weight is found to have increased under the influence of integrated supply of nutrients through organic and inorganic sources. Average curd weight was found maximum (207.3 g) in T4 (50% N through RDF + 50%N through VC) which were at par with T3 and T6. The lowest curd weight (147.5 g) was obtained in T1 (100% N through RDF). The results obtained were in concordance with the findings of Bhanushalini *et al.* (2002), Gosh *et al.* (2009) and Dalal *et al.* (2010) who reported highest curd weight in application of vermicompost in conjunction with chemical fertilizers. The increase in curd size in integrated treatment with vermicompost could be due to added supply of nutrients and proliferous root system enabling better absorption of water and nutrient along with the physical environment.

Marketable curd yield

Curd yield showed significant differences among the treatments. The treatment T4 (50% N through RDF + 50% N through VC) produced the highest yield (12.85 t/ha) while the lowest yield (7.28 t/ha) was obtained in T1 (100% N through RDF). The result was in agreement with the findings of Bhattra and Mishra (2012) that the maximum yield was recorded by the application of 1/2NPK+ 2t/ha vermicompost. Similarly, Lamichhane *et al.* (2015); Kumar *et al.* (2013) and Mohanata *et al.* (2018) also found highest curd yield in VC integrated treatments. The contribution of VC to increase in yield can be attributed to the balanced C:N ratio and enhanced availability of essential plant nutrients throughout the growing season, hence increased rate and efficiency of metabolic activities resulting in high assimilation of metabolites. The beneficial effects of added organic matter in improving soil physical, chemical and biological properties is well known which in turn helps in better nutrient absorption by plants resulting in better yield.

Table 6. Effect of different treatments on yield parameters of cauliflower at 60DAT in Dang, Nepal, 2019

Treatments	Curd Depth (cm)	Curd Diameter (cm)	Average Curd weight (g)	Marketable curd Yield (t/ha)
T1	5.40 ^d	7.93 ^d	147.5 ^c	7.28 ^f
T2	8.06 ^{abc}	11.5 ^{abc}	195.2 ^{ab}	11.02 ^{bc}
T3	7.50 ^{bcd}	10.63 ^{abcd}	206.4 ^a	9.91 ^{cd}
T4	8.90 ^{ab}	12.1 ^{ab}	207.3 ^a	12.85 ^a
T5	6.97 ^{bcd}	10.23 ^{bcd}	175.2 ^{abc}	8.65 ^{def}
T6	9.90 ^a	13.5 ^a	205.8 ^a	12.50 ^{ab}
T7	6.27 ^{cd}	8.9 ^{cd}	174 ^{abc}	9.41 ^{cde}
T8	7.03 ^{bcd}	9.23 ^{bcd}	157.6 ^{bc}	7.78 ^{ef}
Grand Mean	7.50	10.50	183.6	9.93
SEM(±)	0.68	0.88	11.55	0.53
LSD(0.05)	2.06	2.67	35.05	1.62
F-test	**	*	*	**
CV(%)	15.7	14.5	10.9	9.4

Treatments means followed by the common letter or letters within the column are not significantly different among each other based on DMRT at 5% level of significance. LSD = Least significant difference, CV = Coefficient of variation, NS= Non significant and * = Significant

Effects of Integrated Nutrient Management on residual soil properties

Soil pH

The research showed that all the treatments do not have significant effect on soil pH. However, soil receiving the INM treatments was found to increase the soil pH closer to neutrality. Treatment having only inorganic fertilizer reduces the soil pH. This reflects that application of inorganic fertilizer tends to make the soil acidic while integrating organic and inorganic fertilizer helps to balance the soil pH. Similar result was observed in experimentation done by Kafle *et al.* (2019) under integrated application of organic and inorganic fertilizers. This may be attributed to the buffering capacity of the organic manures, which resists change in pH values, however, addition of organic manures tend to increase the pH value and leads to neutrality.

Organic matter

The research depicted that integrated supply of organic and inorganic fertilizers increases the soil organic matter than that of application of sole inorganic fertilizer. Soil having the treatment T2 (50%N through RDF + 50% N through FYM) had highest soil organic matter (2.66) after harvest while T1 had the lowest (1.69). Higher amount of organic matter in the soil receiving integrated supply of chemical fertilizer and FYM might be attributed to the application bulk volume of FYM on equivalent basis. Citak and Sonmez (2011) reported FYM and PM application had positive effects on soil organic matter (SOM) more than the other organic manures. Ojha *et al.* (2019) and Kafle *et al.* (2019) also reported that organic residues of plant and animal waste are the parent materials of organic matter and humus, which make up the nutrient supplies of microorganisms and plant root.

Bulk density

No significant difference was observed in soil bulk density in response to the treatments applied. However, INM treatments were found to have lower bulk density and treatment having only inorganic fertilizer had higher bulk density. T2 (50%N through RDF + 50% N through FYM) showed the lowest value and T1 (100% N through RDF) showed the highest value of soil bulk density. The lower value of soil bulk density in integrated treatments might be

attributed to the higher proportion of soil organic matter. The findings are in agreement with Kafleet *et al.* (2019) and Chaudhary *et al.* (2003).

Particle density

The treatments do not have significant effect on particle density. However, INM treatments were found to have lower particle density, while treatment having only inorganic fertilizer had higher particle density. Integration of organic fertilizers along with inorganic fertilizers have decreased the PD to the greater extent because of addition of soil organic matter. Similar results were revealed by the studies of Cercioğlu *et al.* (2008) using Farmyard manure.

Table 7. Effect of different treatments on residual soil properties in Dang, Nepal, 2019

Treatments	Soil pH	Organic matter (%)	Bulk density (g/cm)	Particle density (g/cm ³)	Infiltration rate(cm/hr)
T1	6.33	1.69 ^b	1.34	2.47	4.67
T2	6.61	2.66 ^a	1.18	2.23	5.88
T3	6.47	2.23 ^{ab}	1.29	2.26	5.29
T4	6.53	2.06 ^{ab}	1.30	2.29	5.72
T5	6.58	2.04 ^{ab}	1.28	2.24	4.87
T6	6.39	1.71 ^b	1.31	2.32	4.67
T7	6.65	2.30 ^{ab}	1.32	2.36	5.35
T8	6.49	2.51 ^a	1.30	2.31	5.25
Grand Mean	6.51	2.15	1.29	2.31	5.21
SEM(±)	0.15	0.19	0.04	0.06	0.58
LSD(0.05)	NS	0.60	NS	NS	NS
F-test	NS	*	NS	NS	NS
CV(%)	4.1	16	5.9	4.6	19.4

Treatments means followed by the common letter or letters within the column are not significantly different among each other based on DMRT at 5% level of significance. LSD = Least significant difference, CV = Coefficient of variation, NS= Non significant and *= Significant

Infiltration rate

The treatments do not have significant effect on infiltration rate. However, INM treatments had higher infiltration rate, while, treatment having only inorganic fertilizer had lower infiltration rate. T2 (50%N through RDF + 50% N through FYM) had highest infiltration rate (5.88 mm/hr) and T1 (100% N through RDF) and T6 (50%N through RDF + 25%N through VC + 25%N through PM) both had lowest infiltration rate (4.67 cm/hr).The result may be attributed to integration of organic manures which are bulky source of nutrients having high organic matter contained in it. Similar type of result was observed in experiment conducted by Ojha *et al.* (2019) where the highest infiltration rate (0.522 mm/sec) was obtained from FYM whereas the lowest was obtained from control plot.

Total nitrogen

Data pertaining to the total nitrogen in soil analysed after harvesting of the crop clearly shows no significance in differences among different treatment combinations. However, INM treatments were found to increase the total soil nitrogen (%) except T4 (50% N through RDF + 50%N through VC). The increased total nitrogen may be attributed to slow release of the mineral nutrients while the low total nitrogen might be attributed to the loss of the mineral nutrients or due to efficient utilization of mineralized nitrogen in short growing period. Similar results was obtained by Devi *et al.* (2018) and Choudhary *et al.*(2012).

Available phosphorus

The research showed that all the treatments do not have significant effect on available phosphorus. However, INM treatments were found to decrease the soil available phosphorus except T3 (50%N through RDF + 50%N through PM) where phosphorus content had increased due to slow decomposition of Poultry manure. Treatment having inorganic fertilizer increases the soil available phosphorus. The result was in light with Devi *et al.* (2018) who observed the addition of organic manure like FYM with inorganic fertilizer had a beneficial effect in increasing the phosphate availability thus reducing phosphorus accumulation in soil. Decrease in phosphorus content in INM treatments could be due to the efficient utilization of phosphorus by the plant.

Table 8. Effect of integrated nutrient management on residual soil properties in Dang, Nepal, 2019

Treatments	Total Nitrogen (%)	Available Phosphorus (kg/ha)
T1	0.08	146.1
T2	0.12	118.0
T3	0.11	137.8
T4	0.10	108.0
T5	0.10	128.8
T6	0.08	116.1
T7	0.11	119.1
T8	0.12	112.7
Grand Mean	0.10	123.3
SEM±	0.01	10.57
LSD(0.05)	NS	NS
F-test	NS	NS
CV(%)	17.6	14.8

*Treatments means followed by the common letter or letters within the column are not significantly different among each other based on DMRT at 5% level of significance. LSD = Least significant difference, CV = Coefficient of variation, NS= Non significant and *= Significant*

CONCLUSION

INM system showed better performance on crop growth parameters, root growth parameters and residual properties of soil rather than applying chemical fertilizers alone. Among the integrated nutrient management combinations 50% N through RDF + 50% N through VC showed greater plant height, number of leaves, plant spread, leaf area, curd length, curd diameter, curd weight and marketable curd yield. Similarly, root length, root diameter and root density was found better in INM treatments. The residual soil properties such as pH, bulk density, particle density, infiltration rate, total nitrogen and available phosphorus were found better under integration of FYM. Thus we conclude that vermicompost in combination with chemical fertilizers can be used for satisfactory yield of cauliflower without deteriorating soil health.

ACKNOWLEDGEMENTS

The authors express their warmest appreciation towards Prithu Technical College, IAAS for providing platform and support.

Authors' contributions

B. Neupane and S. Regmi designed and performed experiment, recorded data, analyzed data and wrote the paper. K. Aryal and L.B Chhetri supervised the experiment and edited the paper.

Conflict of Interest

The authors declare no conflict of interest regarding the publication of this manuscript.

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