Nepalese Horticulture 16 : 45-54, 2022
ISSN : 2092-1122 | Print : 2542-2936 (Online)
DOI : https://doi.org/10.3126/nh.v16i1.44967

Research Article

OPEN ACCESS

Effect of Integrated Nutrient Management Approach on Growth, Yield, and Economics of Cauliflower (*Brassica oleracea* L. *var botrytis*).

Prakash Gyawali[1*], Kanhaiya Prasad Singh[1], Rukmagat Pathak[1] and Bishnu Prasad Bhattarai[2]

[1]*Institute of Agriculture and Animal Science, Tribhuvan University, Kathmandu, Nepal.*

[2]*National Tea and Coffee Development Board, Kathmandu, Nepal.*

[*]Corresponding Author's Email: prakashgyawali1992@gmail.com

[*]Orcid ID: https://orcid.org/0000-0001-9312-566X

Received on: 26 November, 2021 **Revised on:** 7 April, 2022 **Accepeted on:** 6 May, 2022

Abstract

The integrated nutrient management approach addresses the issues arising from the irrational use of chemical fertilizers such as soil quality degradation, and the unsustainability of productivity and profitability. In this study, we evaluated the effect of the integrated nutrient management approach on the growth, yield, and economics of cauliflower (Brassica oleracea L. var botrytis cv. Khumal Jyapu), through a field experiment in Randomized Complete Block Design with three replications and seven treatments- 50% NPK + 6.90 Mt ha-^{1} vermicompost, 75% NPK + 3.45 Mt ha-^{1} vermicompost, 50% NPK + 3.75 Mt ha-^{1} poultry manure, 75% NPK + 1.88 Mt ha-^{1} poultry manure, 50% NPK + 20.80 Mt ha-^{1} farmyard manure, 75% NPK + 10.40 Mt ha-^{1} farmyard manure and 100% recommended NPK, 200:120:80 kg NPK ha-^{1} as the control. Among the tested treatments, organic and inorganic nutrient sources, in combination, recorded a significant influence on growth and yield-attributing characters as compared to sole inorganic treatment. 50% NPK + 6.9 Mt ha-^{1} vermicompost recorded highest height (63.33 cm), earliest harvest (73.67 days), largest curd diameter (16.83 cm), highest curd weight (680.53 g), biomass (1384.79 g), curd yield (25.2 Mt ha-^{1}), gross margin (NRs.10,08,000 ha-^{1}), net return (NRs. 6,91,944 ha-^{1}) and B:C ratio (3.19). Desirable growth parameters, higher yield, cost-effectiveness, and profitability from 50% NPK + 6.90 Mt ha-^{1} vermicompost show that the use of vermicompost is economically viable. Results also show that farmers can reduce chemical fertilizer costs by up to 50% using vermicompost without affecting profitability.

Keywords: organic manure, production, profitability, vermicompost

Introduction:

Among different vegetables, Cauliflower (*Brassica oleracea* L. *var botrytis*) is a cole crop, belongs to the family Cruciferae, and is one of the most important winter vegetable crops grown throughout the world. Cauliflower is a rich source of vitamins A and C along with minerals such as Potassium, Sodium, Calcium, Iron, Phosphorus, and Magnesium (Tekasangla et al., 2015). In 2016, the worldwide production of cauliflower with broccoli was 25.2 million Mt (FAOSTAT, 2017). In Nepal, cauliflower ranked the first vegetable in terms of cultivated area (35,764 ha), which is 12% of the total area under vegetable crops and has the highest contribution in terms of production (5,74,795 Mt) as well (MOAD, 2018). In Kalimati Fruits and Vegetables Market, the major and most preferred commercial vegetables are cauliflower, cabbage, and tomato and their price has been increasing significantly every year from August to November (Bhattarai et al., 2015).

Cauliflower needs a constant supply of large amounts of nutrients for growth and yield and such nutrient supplement has been provided through chemical fertilizer. However, the irrational, continuous, unbalanced, and heavy supply of chemical fertilizer causes hazards to public health, soil health, and the environment (Bashyal, 2011). The Ministry of Agriculture and Livestock has been allocating a significant portion of the total annual budget to subsidize chemical fertilizer imports. However, there is no chemical fertilizer plant in Nepal, and supplements of chemical fertilizer are used with imports from India, China, Egypt, and Turkey (Pant, 2018). The gap between nutrient removal by the crop and nutrient supply or availability in soil has possessed a serious challenge to the sustainability of crop production in the long run (Mukherjee, 2017). Recently, there is an increasing concern about the sustainability of the cropping system due to stagnant and declining production, challenging the appropriateness of the green revolution that encourages chemical fertilizer application (Mahajan & Gupta, 2009).

Approaches should have been directed towards optimum harvest without compromising sustainable soil health status through the judicious use of organic and inorganic plant nutrients (Jat et al., 2015). Adoption of the integrated nutrient management approach, climate-smart agriculture technologies, low external input sustainable agriculture, organic agriculture, permaculture, integrated pest management, etc. are some approaches that might lead to sustainability. The integrated nutrient management approach adopts the joint application of both organic and inorganic plant nutrient sources and has the potential to secure higher crop productivity which also enhances both human health as well as soil health (Bhattarai et al., 2012). The integrated nutrient management approach for large-scale vegetable production could be a remedy to the waste disposal problem and enriches the supplementation of organic matter in the soil (Chatterjee et al., 2017).

In Nepal, there has been an increasing seasonal and off-seasonal vegetable production area. Farmers have been using both organic and inorganic plant nutrient sources either in combination or alone without any scientific basis due to the lack of crop-specific recommended doses of combined organic and inorganic nutrient sources. There is also a constraint in the availability of sufficient data regarding crop performance based on integrated nutrient management. Therefore, this research was conducted with the following objectives:

a. To study the effect of integrated nutrient management on growth-attributing characters of cauliflower.

b. To study the effect of integrated nutrient management on yield-attributing characters of cauliflower.

c. To analyze the economics of cauliflower production based on integrated nutrient management.

Materials and Methods:

A field experiment was conducted at Dakshinkali Municipality-2 Kathmandu, Nepal from August 2017 to December 2017. The experimental site was at 27°38'N latitude and 85°16' E longitude with an elevation of 1423 m above sea level. The experimental site was characterized by a mild, warm, and subtropical climate. The average annual temperature was 16.5°C and the average rainfall was 1645 mm. A composite soil sample was taken from the field and then analyzed in Soil Management Directorate, Hariharbhawan.

Table1. An analysis report of the soil sample from the experimental field before the field experiment

Particulars	Mean
pH	6.80
Organic matter (%)	2.67
Available Nitrogen (%)	0.11
Available Phosphorus(kg ha-1)	255.11
Available potassium (kg ha-1)	197.30

Source: Laboratory test in Soil Management Directorate, 2017

The soil of the experimental plot was nearly neutral (pH 6.8) containing medium level organic matter (2.67%), medium level of total Nitrogen (0.11%), very high available Phosphorus (255.11 kg ha-1), and a medium level of available Potash (197.30 kg ha-1) with loamy texture. The Nitrogen content of vermicompost, poultry manure, and FYM was analyzed in Soil Management Directorate, Hariharbhawan, and found to be 1.45%, 2.67%, and 0.48% respectively as shown in Table 2. The experiment was carried out in Randomized Complete Block Design (RCBD) consisting of 3 replications and 7 treatments as shown in Table 3.

Table 2. Nitrogen content of organic manures used for the field experiment

Organic manure	Nitrogen content (%)
Vermicompost	1.45
Poultry manure	2.67
FYM	0.48

Source: Laboratory test in Soil Management Directorate, 2017

Table 3. Treatments combination used for the field experiment

Treatment symbol	Treatment combination
T_1	50% NPK + 6.90 Mt ha-^{1} vermicompost
T_2	75% NPK + 3.45 Mt ha-^{1} vermicompost
T_3	50% NPK + 3.75 Mt ha-^{1} poultry manure
T_4	75% NPK + 1.88 Mt ha-^{1} poultry manure
T_5	50% NPK + 20.80 Mt ha-^{1} FYM
T_6	75% NPK + 10.40 Mt ha-^{1} FYM
T_7	Control (100% recommended NPK i.e. 200:120:80kg NPK ha-^{1})

Source of recommended NPK for Cauliflower: MOAD, 2016

Each replication had 7 plots of size 2 m × 2.5 m and plots were separated by 0.5 m. The distance between the two blocks was 1 m. Plants were spaced at 60 cm between rows and 45 cm between plants. Each plot consisted of 16 plants. Khumal Jyapu, a newly registered early to mid-season variety of cauliflower was selected for the experiment.

The first ploughing was carried out on 20th August 2017 followed by the second ploughing on 23rd August 2017, and the third ploughing on 26th August 2017 to make the soil well pulverized and friable suitable for crop establishment. Well decomposed FYM, poultry manure, and vermicompost were placed according to the treatment combination. The sources of chemical fertilizers were urea, DAP (Diammonium Phosphate), and MOP (Muriate of Potash). The whole dose of Phosphorus and potassium and half dose of Nitrogen per plot as per treatment was applied before transplanting of seedling through the placement method and the remaining dose of Nitrogen was side-dressed at 25 days after transplanting (DAT) and 50 DAT, respectively, in the form of urea. The 25 days old healthy seedlings having 5-6 leaves grown in the nursery block of Vegetable Crops Development Center, Khumaltar, Lalitpur, were transplanted on 8th September 2017. Daily irrigation was given for 15 days to establish the seedlings and then given at 2 days intervals for the next 15 days. After that, the plots were irrigated at 5 days intervals up to 45 DAT. First manual weeding and hoeing were done at 25 DAT and second weeding and hoeing were done at 50 DAT.

From among sixteen plants per plot, five plants were randomly selected and tagged for recording observations. The data were recorded for growth and yield attributing characteristics such as plant height, number of leaves, leaf length, leaf breadth, plant spread, days to curd initiation, days to the first harvest, curd weight, curd diameter, curd depth, biomass, and curd yield. Plant height was measured from the point of ground level up to the tip of the longest leaf. Plant spread was measured as an average of the longest axis and shortest axis. All the leaves of each plant were counted separately excluding the smallest young leaves at the growing point. The average number of leaves of five plants gave the number of leaves per plant. Leaf length was measured from the base of the petiole to the tip of the leaf of each plant with a meter scale. Leaf breadth was measured from the widest central and two terminal portions of the lamina with a meter scale and average breadth was recorded. Leaf area was calculated by multiplying leaf length and leaf breadth in cm^2. The number of days was counted from transplanting to initiate curd in all tagged plants. The numbers of days were recorded carefully from curd initiation to the first harvest for each plot. Curd diameter was recorded in several directions with a meter scale at the matured stage and the curd depth was measured as the height (cm) of the curd recorded from the junction of the last upper leaves (up to the tip of curd) at the matured stage. Biomass was calculated for each harvested tagged plant as the weight of curd with its leaves. Curd was weighted from five randomly selected plants and each curd was measured separately. The curd yield per hectare was calculated in tons by converting the total curd yield Mt ha-^{1}.

Likewise, economic parameters such as gross income, the net return, and the benefit-cost ratio were calculated. The farm gate price was NRs. 40 per kg at the time of harvest. Gross income was calculated by multiplying curd yield with the farm gate price. Total cost includes the cost incurred in field preparation, seedling, labor, fertilizers, manures, irrigation, intercultural operations, harvesting, grading, etc. Net return was calculated by deducting the total cost incurred from gross income. Finally, the benefit-cost ratio was calculated by dividing the net return by the total cost.

The mean value of each parameter was calculated in Microsoft Excel 2007 and Analysis of Variance (ANOVA) was done by Statistical Tool for Agriculture Research (STAR), version: 3.2.1 to calculate the significance level of the treatment effect. Means of each other within the parameter were measured by Duncan's Multiple Range Test (DMRT) at a 5% significance level.

Results:

The results obtained concerning the various growth and yield and economic characteristics have been presented and discussed with possible explanations and pieces of evidence to find out the cause-and-effect relationship among different treatments.

Growth attributing characters

Observations on growth attributing characters at harvest as influenced by integrated nutrient management, showed a significant effect among different treatments as shown in Table 4.

Plant height

Observations taken at harvest showed a significant difference in plant height of cauliflower under various treatments. The tallest plants (63.33 cm) were observed from T_1 (50% NPK + 6.90 Mt ha-^{1} vermicompost), which was statistically similar to other combined treatments. The shortest plants (56.60 cm) were observed from treatment T_7 (100% NPK).

Number of leaves

Observation taken on the number of leaves at harvest showed plants grown under treatment T_5 (50% NPK + 20.80 Mt ha-^{1} FYM) contain the highest number of leaves (22.70) which was statistically similar to other combined treatments. The lowest number of leaves (19.57) was observed in T_7 (100% NPK).

Leaf area

Observation taken on leaf area at harvest showed a significant difference among different treatments. The crop grown under T_5 (50% NPK + 20.80 Mt ha-^{1} FYM) showed highest leaf area (1176.11 cm^2) followed by T_2 (75% NPK + 3.45 Mt ha-^{1} vermicompost) which was at par with T6 (75% NPK + 10.40 Mt ha-^{1} FYM) and T_3 (50% NPK + 3.75 Mt ha-^{1} poultry manure). Treatment T_7 (100% NPK) showed the lowest leaf area (892.93 cm^2).

Plant spread

Observation taken on plant spread at harvest showed a significant effect among different treatments. The crop grown under T_3 (50% NPK + 3.75 Mt ha-^{1} poultry manure) has maximum plant spread (71.87 cm) which was at par with T_1 (50% NPK + 6.90 Mt ha-^{1} vermicompost), T5 (50% NPK + 20.80 Mt ha-^{1} FYM) and T_2 (75% NPK + 3.45 Mt ha-$_1$ vermicompost). Crop grown under T7 (100% NPK) showed minimum plant spread (62.33 cm).

Days to Curd initiation

Observation taken on days to curd initiation showed significant effect among different treatments. All the integrated treatments of inorganic and organic fertilizers showed a minimum time to curd initiation than the sole inorganic one. The crop grown under T_3 (50% NPK + 3.75 Mt ha-^{1} poultry manure) initiated curd formation earliest (63.67 DAT) which was statistically at par with all combined treatments. Crop grown under sole inorganic treatment T_7 (100% NPK) took the longest time (70.00 DAT) for curd initiation.

Days to the first harvest

Observation taken on days taken to the first harvest showed a significant effect among different treatments. All the integrated treatments showed earlier harvest while 100% NPK fertilizer application showed late harvest. The cauliflower curds from the T_1 (50% NPK + 6.90 Mt ha-^{1} vermicompost) treatment harvested earliest (73.67 DAT) which was at par with all combined treatments. The cauliflower curds grown under T_7 (100% NPK) were harvested late (80.33 DAT) among all treatments. This showed that all the integrated treatments had earlier curd initiation while sole inorganic treatment had late curd initiation. A similar trend was seen in curd maturity as well.

Table 4. Effect of integrated nutrient management on growth attributing characters at harvest of Cauliflower var. Khumal Jyapu

Treatments	Plant height (cm)	Leaf number	Leaf area (cm²)	Plant spread (cm)	Curd initiation (DAT)	First harvest (DAT)
T_1	63.33[a]	22.63[a]	1002.55[bc]	70.60[ab]	64.33[b]	73.67[b]
T_2	61.30[a]	21.57[a]	1139.83[ab]	67.70[ab]	64.00[b]	75.33[b]
T_3	63.32[a]	21.63[a]	1095.81[ab]	71.87[a]	63.67[b]	74.33[b]
T_4	61.23[a]	22.23[a]	1008.40[bc]	66.77[b]	64.33[b]	76.67[b]
T_5	61.83[a]	22.70[a]	1176.11[a]	68.93[ab]	65.67[b]	75.67[b]
T_6	61.83[a]	22.03[a]	1115.65[ab]	67.20[b]	64.33[b]	75.67[b]
T_7	56.60[b]	19.57[b]	892.93[c]	62.33[c]	70.00[a]	80.33[a]
SEM (±)	1.24	0.53	6397.87	1.77	1.48	1.59
LSD (0.05)	2.69[**]	1.15[**]	142.29[*]	4.02[**]	3.22[*]	3.46[*]
CV (%)	2.47	2.96	7.53	3.20	2.77	2.56
Grand mean	61.37	21.77	1061.61	67.87	65.19	75.95

Note: Means followed by the same letter(s) in the column are not significantly different at a 5% significance level as determined by Duncan's Multiple Range Test (DMRT). cm=Centimeter; DAT=Days after transplanting; SEM=Standard error of mean; LSD=Least significant difference; CV=Coefficient of variation

Yield attributing characters

Observation taken on yield-attributing characters at harvest as influenced by integrated nutrient management, showed a significant effect among different treatments except for curd depth as shown in Table 5.

Curd diameter

Observation taken on curd diameter showed a significant effect among different treatments. Plants grown under T_1 (50% NPK + 6.90 Mt ha-^{1} vermicompost) produced largest curd (16.83 cm) followed by T_3 (50% NPK + 3.75 Mt ha-1 poultry manure) which was statistically similar with T_4 (75% NPK + 1.88 Mt ha-^{1} poultry manure) and T_6 (75% NPK + 10.40 Mt ha-^{1} FYM). The lowest diameter (13.57 cm) curds were produced from T_7 (100% NPK).

Curd depth

Observation taken on curd depth showed no significant effect among different treatments.

Curd weight

Observation taken on curd weight showed a significant effect among different treatments. The highest curd weight (680.53 g) was observed from T_1 (50% NPK + 6.90 Mt ha-^{1} vermicompost) which was followed by T3 (50% NPK + 3.75 Mt ha-^{1} poultry manure). The lowest curd weight (500.03g) was observed in treatment having T_7 (100% NPK).

Biomass

Observation taken on biomass showed a significant effect among different treatments. The highest biomass (1384.79 g) was observed in treatment having T_1 (50% NPK + 6.90 Mt ha-^{1} vermicompost) which was at par with T5 (50% NPK + 20.80 Mt ha-^{1} FYM) and T_3 (50% NPK + 3.75 Mt ha-^{1} poultry manure). The lowest biomass (990.70 g) was observed in treatment having T_7 (100% NPK).

Curd yield

Observation taken on curd yield showed a significant effect among different treatments. The highest curd yield (25.20 Mt ha-^{1}) was observed from T_1 (50% NPK + 6.90 Mt ha-^{1} vermicompost) which was followed by T_3 (50% NPK + 3.75 Mt ha-^{1} poultry manure). The lowest curd yield (18.52 Mt ha-^{1}) was observed in treatment having T_7 (100% NPK).

Table 5. Effect of integrated nutrient management on yield attributing characters at harvest of Cauliflower var. Khumal Jyapu

Treatments	Curd diameter (cm)	Curd depth (cm)	Curd weight (g)	Biomass (g)	Curd yield (Mt ha-1)
T_1	16.83^{a}	9.67	680.53^{a}	1384.79^{a}	25.20^{a}
T_2	15.17^{b}	7.08	593.91^{abc}	1232.83^{ab}	22.00^{abc}
T_3	16.13^{ab}	7.83	622.69^{ab}	1335.23^{a}	23.06^{ab}
T_4	16.12^{ab}	8.25	606.29^{abc}	1082.21^{bc}	22.46^{abc}
T_5	15.33^{b}	7.60	559.86^{bc}	1361.67^{a}	20.74^{bc}
T_6	15.89^{ab}	8.25	523.04^{bc}	1243.13^{ab}	19.37^{bc}
T_7	13.57^{c}	7.75	500.03^{c}	990.70c	18.52^{c}
SEM (±)	0.57	0.96	46.36	83.39	1.72
LSD (0.05)	1.23**	ns	101.02*	181.68**	3.74*
CV (%)	4.48	14.51	9.73	8.28	9.73
Grand mean	15.57	8.06	583.77	1232.94	21.62

Note: Means followed by the same letter(s) in the column are not significantly different at a 5% significance level as determined by Duncan's Multiple Range Test (DMRT). cm=Centimeter; g=gram; Mt=metric ton; ha=hectare; SEM=Standard error of mean; LSD=Least significant difference; CV=Coefficient of variation; ns=non-significant

Economic analysis

During crop harvesting, the farm gate price of cauliflower was NRs. 40 at Dakshinkali, Kathmandu. Our calculation showed the highest gross income (NRs. 10,08,000 ha-^{1}) and the highest net return (NRs. 6,91,944 ha-^{1}) recorded in treatment having T_1 (50% NPK + 6.90 Mt ha-^{1} vermicompost) while the lowest gross income (NRs. 7,40,800 ha-^{1}) and the lowest net return (NRs. 4,82,688 ha-^{1}) recorded in treatment having T_7 (100% NPK). The highest benefit-cost ratio (3.19) was recorded in T_1 (50% NPK + 6.90 Mt ha-^{1} vermicompost) and lowest benefit-cost ratio (2.86) was recorded in T_5 (50% NPK +20.80 Mt ha-^{1} FYM) and T_6 (75% NPK + 10.40 Mt ha-^{1} FYM). The total cost of cultivation was varied among seven different treatments and presented in Table 6.

Table 6. Treatment cost of cauliflower cultivation in a hectare

Treatments	Organic manure		Urea (kg)	DAP (kg)	MOP (kg)	Cost of fertilizer (NRs.)	Cost of application (NRs.)	Treatment cost (NRs.)	General cost (NRs.)	Total cost (NRs.)
	Quantity (Mt.)	Price (NRs.)								
T_1	6.90	69000	168.50	125.00	66.67	85323.50	5000	90323.50	197000	287323.50
T_2	3.45	34500	252.75	187.50	100.00	58985.00	2500	61485.00	197000	258485.00
T_3	3.75	67500	168.50	125.00	66.67	83823.50	5000	88823.50	197000	285823.50
T_4	1.88	33750	252.75	187.50	100.00	58235.00	2500	60735.00	197000	257735.00
T_5	20.80	40000	168.50	125.00	66.67	56323.50	10000	66323.50	197000	263323.50
T_6	10.40	20000	252.75	187.50	100.00	44485.00	5000	49485.00	197000	246485.00
T_7	0	0	337.00	250.00	133.33	32646.50	5000	37646.50	197000	234646.50

Note: All calculations are based on local market price and wage rate at research time. NRs=Nepali rupees; Mt=Metric ton; kg=kilogram

Gross returns, net returns, and B: C ratio of cauliflower were varied about the application of seven different treatments and presented in Table 7.

Table 7. Effect of integrated nutrient management on the economics of cauliflower var. Khumal Jyapu

Treatments	Total cost (NRs. ha-1)	Interest	The total cost of production (NRs. ha-1)	Curd yield (Mt ha-1)	Gross income (NRs. ha-1)	Net return (NRs.)	B:C ratio
T1	287323.50	28732.35	316055.85	25.20	1008000	691944.15	3.19
T2	258485.00	25848.50	284333.50	22.00	880000	595666.50	3.09
T3	285823.50	28582.35	314405.85	23.06	922400	607994.15	2.93
T4	257735.00	25773.50	283508.50	22.46	898400	614891.50	3.17
T5	263323.50	26332.35	289655.85	20.74	829600	539944.15	2.86
T6	246485.00	24648.50	271133.50	19.37	774800	503666.50	2.86
T7	234646.50	23464.65	258111.15	18.52	740800	482688.85	2.87

Note: All calculations are based on market price NRs. 40 kg-1 and interest rate 10%. NRs=Nepali rupees; Mt=Metric ton; B: C=Benefit-cost ratio; ha=Hectare

Discussion:

Growth attributing characters

Growth and development are the function of genetic, environmental, and crop management factors along with their interaction that directs crop growth and development. In recent times, the combination of organic manures with chemical fertilizers draw attention as a nutrient source in vegetable crop production because of rising costs, rapid nutrient depletion, and environmental hazards of chemical fertilizers. In vegetable production, many researchers reported that integration of both organic manures and inorganic fertilizers has shown a positive influence on growth attributing characters compared to the application of chemical fertilizer alone. Our results of the effect of integrated nutrient management on growth attributing characters also depict fully or partially a similar trend. All integrated nutrient treatments have a superior effect on all growth attributing characters as compared to the sole application of inorganic fertilizers.

All integrated nutrient treatments showed tall plants as compared to inorganic fertilizers. This finding is consistent with Alam (2006), who reported that the treatment which has a combination of organic manures and chemical fertilizers responded to the tallest plant height of cabbage. This is due to the sufficient and continuous availability of essential nutrients from an integrated combination of organic manures and chemical fertilizers as organic manures are rich in growth-promoting substances and contain various essential nutrients.

All integrated nutrient treatments had more leaf numbers per plant as compared to inorganic fertilizers. This finding is consistent with Ghuge et al. (2007) who also reported that the integration of FYM and inorganic fertilizer produced the maximum number of leaves in cabbage.

The sufficient number of active photosynthetic leaves present in plants has contributed to the overall growth of plants. They serve as the source of food materials for the entire plant. The desirable number of leaves intact with curd after harvest helps in post-harvest storage life and quality. But a very large number of leaves development might hamper the growth of other plant parts.

The T_5 (50% NPK + 20.80 Mt ha-^{1} FYM) showed the largest leaf area followed by other integrated nutrient treatments. KC & Bhattarai (2011) found that adequate and continuous provision of essential nutrients to the plant from the combined application of organic manures plus inorganic fertilizer enhances the metabolic activity in the early growth phase which promotes overall growth afterward. The optimum leaf area ensures leaves capture enough sunlight which ultimately helps in photosynthesis. But very large leaves intact with curd after harvest are undesirable as they transpire more water decreasing post-harvest life and quality deteriorating their economic value.

The crop grown under T_3 (50% NPK + 3.75 Mt ha-^{1} poultry manure) had a maximum plant spread. Continuous supply and higher Nitrogen content of poultry manure might promote the vegetative growth of cauliflower. A higher positive influence on overall vegetative growth parameters might lead to a higher spread of the plant. Plant spread determines the space covered by the plant within the field which ultimately ensures a desirable number of plants in the field. Yadav et al. (2004) also observed the judicious application of organic manures and Nitrogen levels significantly increase in plant height, number of branches per plant, and leaf area.

As an early to mid-season variety, the lower days taken to curd initiation has paramount importance considering economic and marketing point of view. Early curd initiation and subsequent early harvest are crucial for farmers expecting off-season prices in the market. Combined treatments showed early harvest, which is a very important parameter to be considered for commercial growers as it fetches a higher price. Ghosh et al. (2009) observed that the plants treated with 50% vermicompost + 50% NPK were early in head initiation and also first to reach harvestable maturity. The continuous availability of essential nutrients from organic manures and inorganic fertilizers may have a synergistic effect on overall growth parameters which ultimately leads to timely maturity and harvest. Singh et al. (2005) found that higher doses of inorganic fertilizer especially Nitrogen led to delayed maturity in tomatoes.

Yield attributing characters

Curd yield and biomass are the outcomes of a crop that generally rely on the development of yield attributing characters. An enhancement in overall growth attributing characters because of the increased uptake of Nitrogen and translocation of assimilates from source to sink increased most of the yield attributing characters. All integrated nutrient treatments have a superior effect on all yield attributing characters as compared to the sole application of inorganic fertilizers except curd depth. Among integrated treatments, T_1 (50% NPK + 6.90 Mt ha-^{1} vermicompost) had a superior effect on all yield attributing characters except curd depth.

Being an economic part, curd diameter is a very important parameter to be considered. T_1 (50% NPK + 6.90 Mt ha-^{1} vermicompost) produced the largest curd diameter and curd weight. Dalal et al. (2010) reported that 50% Nitrogen from urea with 50% Nitrogen from vermicompost increases the diameter of the plant head and the yield of cabbage. All treatments have a similar effect on curd depth which was against the findings of Kumar et al. (2013) who found a higher curd depth from the combined treatment of inorganic and organic manures than inorganic alone.

Bhattarai et al. (2015) reported that optimum-sized curd is desirable by the consumer for family purposes. This preference might be due to decreasing family size. The curd weight has economic importance for farmers which determines the economic yield and income. This result is in agreement with the findings of Kanwar et al. (2002) who reported that the integration of organic manure with a 50% NPK level significantly increases curd weight.

All 50% organic manure and 50% inorganic fertilizers had the highest biomass as compared to other treatments but curd yield was highest from the T_1 (50% NPK + 6.90 Mt ha-^{1} vermicompost). The superiority of vermicompost plus inorganic combinations in improving the yield could be attributed to the positive effect in different growth parameters such as height, a number of leaves, days to curd initiation and days to first harvest, continuous and balanced supply of essential elements throughout the growing season of the crop that promotes yield attributes such as curd diameter, curd weight, biomass and curd yield, the supply of food material and its subsequent partitioning in the sink. Vermicompost provides all the essential macro and microelements required for plants to complete their lifecycle. The availability of these elements ensures a better source-sink relationship for proper growth and development. Furthermore, KC & Bhattarai (2011) reported that the solubilization effect of available plant nutrients enhanced by vermicompost facilitates the uptake of NPK which in turn increases the curd yield. This finding is consistent with the findings of Choudhary et al. (2011), Devi et al. (2003), Manivannan & Singh (2004), Maurya et al. (2008), Shree et al. (2014), and Wani et al. (2011) reported the highest values of yield attributing characters through vermicompost combined with a half dose of recommended inorganic fertilizers.

Economic analysis

The highest gross income, net return, and benefit-cost ratio indicate that economic viability with the use of vermicompost could be attained subjected to their cost-effective availability in a specific location. Results showed we could reduce the 50% cost of chemical fertilizer easily by using vermicompost without compromising yield which is consistent with the finding of Tekasangla et al., (2012).

Conclusion:

The integrated nutrient management system is an emerging approach to tackle the degrading soil health and long-run crop productivity issues. In this study, we studied the effect of integrated nutrient management on the growth, yield, and economics of cauliflower. The findings suggest that the judicious application of organic and inorganic plant nutrient sources, in combination, produced significantly higher yield and profitable production as compared to inorganic fertilizer alone. Among all integrated treatments, most of the growth-attributing parameters and yield-attributing parameters were found to be appropriate from 50% NPK + 6.90 Mt ha-1 vermicompost. Treatment with 50% NPK + 6.90 Mt ha-1 vermicompost gave the highest gross income, net return, and benefit-cost ratio. The superiority of 50% NPK + 6.90 Mt ha-1 vermicompost is economically viable due to superior yield, higher gross income, net margin, and benefit-cost ratio. Resource-poor farmers who are unable to apply a full dose of recommended fertilizer may apply 50 % of the recommended dose of fertilizers along with vermicompost in a balanced way to maximize the yield of the crop.

Declaration of conflict of interest and ethical approval:

P. Gyawali was involved in designing the experiment, data collection, laboratory work, data analysis, and writing the manuscript. K.P. Singh, B.P. Bhattarai and R. Pathak provided guidance and participated in designing the experiment, data analysis, and writing the manuscript. All authors declare that there are not any types of competing interests in the published materials.

References:

Alam, M. N. (2006). Effect of vermicompost and some chemical fertilizers on yield and yield components of selective vegetable crops. Ph.D. Thesis, Faculty of Agriculture, University of Rajshahi, Bangladesh, 122-176.

Bashyal, L.N. (2011). Response of cauliflower to nitrogen fixing biofertilizer and graded levels of nitrogen. *J. Agr. Environ, 12*, 41–50.

Bhattarai, D. R., & Budhathoki, K. (2005). Effect of organic manures on postharvest physiology and consumer's acceptability of cauliflower. *Nepal Journal of Science and Technology, 6*, 11–14.

Bhattarai, D. R., Poudyal, K., & Pokhrel, S. (2012). Effect of Azotobacter and Nitrogen levels on fruit yield and quality of bell pepper. *Nepal Journal of Science and Technology, 12*, 29-34.

Bhattarai, D. R, Pradhan, N. G., Chalise, B., & Piya, S. (2015). Selection of early cauliflower variety for income generation. *Nepal Journal of Science and Technology, 15*(1), 1-6.

Chaudhary, R. S., Das, A., Patnaik, U. S., & Das, A. (2003). Organic farming for vegetable production using vermicompost and FYM in Kokriguda watershed of Orissa. *Indian Journal of Soil Conservation, 31*(2), 203-206.

Chatterjee, R., Gajjela, S., Thirumdasu, R. K. (2017). Recycling of organic wastes for sustainable soil health and crop growth. *Int J Waste Resour 7*: 296. https://doi: 10.4172/2252-5211.1000296.

Dalal, V. V., Bharadiya, P. S., & Aghav, V. D. (2010). Effect of organic and inorganic sources of Nitrogen on growth and yield of cabbage (Brassica oleracea var. capitata). *Asian Journal of Horticulture, 5*(2), 291-293.

Devi, H. J., Maity, T. K., & Paria, N. C. (2003). Effect of different sources of Nitrogen on yield and economics of cabbage. *Environment Ecology, 21*(4), 878-880.

FAOSTAT. (2017). Crop production Statistical Database. Food and Agriculture Organization of the United Nations.

Ghosh, C., Mandai, J., & Chattopadhyaya, G. N. (2009). Effect of vermicompost on growth and yield of cabbage (*Brassica oleracea* var. *capitata* L.). International Conference on Horticulture.

Ghuge, T. D., Gore, A. K., & Jadhav, S. B. (2007). Effect of organic and inorganic nutrient sources on growth, yield, and quality of cabbage (*Brassica oleracea* var. *capitata* L.). *Journal of Soils and Crops, 17*(1), 89-92.

Hsieh, C. F., Huieh, C. F., & Hsu, K. N. (1996). An experiment on the organic farming of broccoli. *Bull. Taich. Dist. Agr. Impr. Sta, 53*, 35-40.

Jat, L., Singh, Y., Meena, S., Meena, S., Parihar, M., Jatav, H., Meena, R., & Meena, V. (2015). Does integrated nutrient management (INM), enhance agricultural productivity? *Journal of Pure and Applied Microbiology, 9*(2),1211-1221.

KC, P., & Bhattarai, B. P. (2011). Effect of integrated nutrient management on the growth, yield, and soil nutrient status in tomato. Himalayan College of Agricultural Science and Technology, Gaththaghar, Bhaktapur. *Nepal Journal of Science and Technology, 12*, 23 – 28.

Kanwar, K., Paliyal, S. S., & Nandal, T. R. (2002). Integrated nutrient management in cauliflower (Pusa Snowball K-1). *Research on Crops, 3*(3), 579-589.

Kumar, M., Das, B., Prasad, K. K. & Kumar, P. (2013). Effect of integrated nutrient management on growth and yield of broccoli (*Brassica oleracea* var. *italica*) under Jharkhand conditions. *Vegetable Science, 40*(1), 117-120.

Mahajan, A., & Gupta, R. (2009). *Integrated Nutrient Management (INM) in a Sustainable Rice—Wheat Cropping System.* https://doi.org/10.1007/978-1-4020-9875-8.

Manivannan, M. I., & Singh, J. P. (2004). Effect of biofertilizers on the growth and yield of sprouting broccoli (*Brassica oleracea* var. *italica* Pelnck) under Allahabad Agro-Climatic conditions. *Bioved, 15*(1/2), 33-36.

Maurya, A. K., Singh, M. P., Singh, Y. V., Singh, D. K., Singh, S., & Singh, P. K. (2008). Effect of organic manures and inorganic fertilizers on growth characters, yield, and economics of sprouting broccoli cv. fiosta. *Indian Journal of Horticulture, 65*(1), 116- 118.

MOAD. (2018). Statistical Information on Nepalese Agriculture. Agri-business Promotion and Statistics Division, Ministry of Agricultural Development, Singha Durbar, Kathmandu, Nepal.

Mukherjee, A. K., Pati, S., Bag, A. G., Chatterjee, N., Pal, B., & Padhan, D. (2017). Integrated nutrient management for sustainable agriculture. *Innovative Farming, 2*(1): 37-40.

Panta, H. (2018). Supply chain of subsidized chemical fertilizers in Nepal. *Journal of the Institute of Agriculture and Animal Science, 35*(1), 9-20. https://doi.org/10.3126/jiaas.v35i1.22509

Pasricha, N. S, Singh, Y., Singh, B., & Khind, C. S. (1996). Integrated nutrient management for sustainable crop production. *Journal Research of Punjab Agricultural University, 33*, 101-107.

Sherchan, D., & Karki, K. (2006). Plant nutrient management for improving crop productivity in Nepal. Food and Agriculture Organization, Improving Plant Nutrient Management for Better Farmer Livelihoods, Food Security and Environmental Sustainability. https://www.researchgate.net/publication/292223238.

Shree, S., Singh, V. K., & Kumar, R. (2014). Effect of integrated nutrient management on yield and quality of cauliflower (Brassica oleracea var. botrytis L.). *The Bioscan, 9*(3), 1053-1058.

Singh, A. K., Gupta, M. J., Srivastava, R., & Behera, T. K. (2005). Effect of NPK levels on growth and yield of tomato hybrids under multi-span polyhouse. *62*(1), 91-93.

Tekasangla, S., Kanaujia, P., & Singh, P. K. (2015). Integrated nutrient management for quality production of cauliflower in acid Alfisol of Nagaland. *Karnataka J. Agric. Sci., 28*(2): 244-247.

Wani, A. J., Narayan, R., Ahmed, N., Singh, A. K., Chattoo, M. A., & Narayan, S. (2011). Influence of organic and inorganic sources of nutrients on growth, yield, and quality of cauliflower (*Brassica oleracea* var *botrytis* L.). *Environ. Ecol., 29*(4), 1941-1947.

Yadav, P., Singh, P., Yadav, R. L., & Lal, R. (2004). Ameliorative potential of organic manures and Nitrogen levels on okra cv. Varsha Uphar. *Haryana J. Hort. Sci., 33*(1&2), 124-126.