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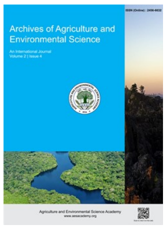

ORIGINAL RESEARCH ARTICLE

CrossMark

Effect of integrated nutrient management on growth, yield, and soil nutrient status in okra (*Abelmoschus esculentus* cv. Arka Anamika)

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ABSTRACT

Okra (*Abelmoschus esculentus* cv. Arka Anamika) is one of the most widely grown vegetable crops in the tropics during the spring, summer, and Kharif seasons. One of the major constraints of low productivity of okra and soil deterioration is due to the inappropriate and sole use of synthetic fertilizer. So, to address the yield gap, an experiment was conducted in Gokuleshwor, Baitadi Nepal from 23rd March to 15th July 2021 to study the effect of integrated nutrient management (INM) on growth, and yield and soil nutrient status in okra". The experiment was laid out in a randomized complete block design (RCBD) with 8 treatments and 3 replication T_8 gave maximum plant height (37.21 cm), stem diameter (4.04 cm), numbers of leaves (14.33), and a number of pods (8.07) and minimum plant height (23.18 cm) and a number of leaves (9.00) were observed in T_3 whereas minimum steam diameter (2.87cm) a and number of pods (2.87) were observed in T_6. It was observed that treatment T_8 produced a maximum yield (2.10 kg) and treatment T_3 produces the minimum yield (1.24 kg). Highest post-harvest available nitrogen (0.1167%), phosphorus (85.20 kg/ha), potassium (229.61 kg/ha), organic matter (2.31%) and pH (6.25) was found in treatment T_8. This study suggests integrating vermicompost and synthetic fertilizer as a potential source for better growth, and high yield of okra thus more experiments on dosage optimization and SSNM should be focused onwards for long term sustainability.

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INTRODUCTION

Okra is one of the most widely grown vegetable crops in the tropics during the spring, summer, and Kharif seasons. It belongs to the genus *Abelmoschus*, family Malvaceae with two species as *Abelmoschus esculentus* and *Abelmoschus caillei*. It is one of the most popular vegetables in all sections of people because of its richness in nutrition, taste, and medicinal and industrial value. Okra which is grown for its immature fruits and young leaves also known as lady's finger or bhindi and originated in tropical Africa (Sachan *et al*., 2017). It is an erect, herbaceous, annual plant of 1-2m in height. Globally, it is mainly grown in India, Nigeria, Sudan, Pakistan, Ghana, Egypt, Benin, Saudi Arabia, Mexico and Cameroon. In an integrated nutrient management (INM) system, organic manure is used alongside chemical fertilizer which is significant from the standpoint of crop productivity and quality (Sachan *et al*., 2017). Okra is a very good source of dietary fiber, Magnesium, Manganese, potassium, vitamin k and vitamin C. Okra seed oil is rich in unsaturated fatty acids which are essential for human nutrition. Moreover, it is beneficial for diabetes and some cancers. Okra mucilage from the immature pods was found to be suitable for industrial and medicinal applications. Okra production was 122,101.6 metric tons across the country (Nepal), covering 10,781.4 hectares with the productivity of 11.3 tons per hectare (MoAD, 2015-2016). Okra production in Baitadi District is 504 MT. covering

42ha with the productivity of 12mt/ha (Statistical Information on Nepalese agriculture, 2019/2020).

Okra is a heavy feeder of both macro and micronutrients for optimal economic yields which play a key role in okra production, both in terms of quality and quantity. However, indiscriminate use of inorganic fertilizers has led to the low nutrient uptake, poor quality of vegetable and depleted soil health (Agarwal, 2003). In light to this problem, integrated nutrient management (INM) system is now evolving as a promising method to improve crop yield, and has long sustainable effects on soil health and soil microbial diversity; Organic manure is used alongside with chemical fertilizers which is significant from the standpoint of crop productivity and quality (Sachan *et al*., 2017). INM helps to provide balanced nutrition to crops & minimizes the antagonistic effects resulting from hidden deficiencies & nutrient imbalance where the actual demand of nutrients by the plants is supplied by organic inputs along with inorganic fertilizers which lower the amount of chemicals fed to the soil.

INM refers to the maintenance of soil fertility & of plant nutrient supply at an optimum level for sustaining the desired productivity through optimization of the benefits from all possible sources of organic, inorganic, and biological components in an integrated manner. It synchronizes the nutrient demand for crops with nutrient supply from native and applied sources. The requirements of fertilizer in okra are important for early growth and total production of fruit yield. Integrated use of organic and inorganic fertilizers can improve crop productivity (Mal *et al*., 2013). Only through the interaction of organic and inorganic sources of nutrients, long term sustainability of productivity can be achieved (Hedge *et al*., 1992). Thus, in this study, we aimed on assessing the role of different dosages of fertilizers in sole and integrated management using chemical and organic sources; aiming for obtaining high yields with sustainable management practices.

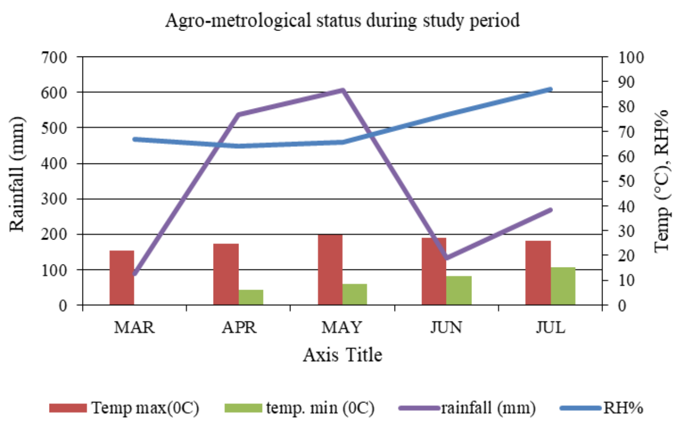

Figure 1. *Agro-metrological status during study period.*

MATERIALS AND METHODS

Study area and agro-climatic conditions

An experiment was conducted at the experimental farm, Department of soil science, Gokuleshwor Agriculture and Animal Science College, Dilasaini, Baitadi during March to July 2021, situated at 29.6880°N latitude and 80.5494°E longitude at an elevation of 850 masl. It falls under subtropical and temperate climatic zone with the average summer and winter temperatures of 21.1°C and 7.7°C respectively. The agro-climatic features of the research field are presented in Figure 1 (Data was made available from the agrometeorological station of Gokuleshwor Agriculture and animal science college, Baitadi).

Design of experiment and treatment details

The experiment was carried out in a Completely Randomized Block Design (RCBD) with 8 treatments replicated three times. The treatments used in the study were T1 (Recommended dose of NPK 200:180:60 (kg/ha), T2 (RDF +25% of NPK), T3 (FYM @ 20 ton/ha), T4 (Full dose of FYM+ 50% of RDF), T5 (50% FYM+50% of RDF), T6 (Single dose of vermicompost @15ton/ha), T7 (50% of VC + 50 % of RDF) and T8 (Full dose of VC + 50% of RDF). The plot size was 1.6m x 1.2m and the planting geometry was 40cm x 20cm.

Soil physiochemical properties of research plot

Before applying the treatments, the soil of the experimental field was tested in the laboratory of Sundurpur soil research center, Kanchanpur, Mahendranagar such that it aids in effective decision making for selection of treatment which have positive impact on plant growth and yield and improving soil physio-chemical attributes. The physiochemical properties along with their determination method are given in Table 1.

Table 1. Initial soil physico-chemical properties before sowing okra in the field.

S.N.	Parameters	Initial Result	Method of determination
1	Organic manure	2.25 %	Walkley-Black method (Matus *et al*., 2009)
2	pH	6.77	Deluxe pH meter
3	Total nitrogen	0.1125 %	Kjeldahl method (Haynes, 1980; Stewart & Porter, 1963)
4	Available phosphorous	58.27 kg/ha	Modified Olsen method (Etchevers Claudia Hidalgo Moreno Gina P Nilo & Bernaldo Florfina P Sanchez, n.d.; Olsen & Dean, 1965)
5	Available potassium	104.40 kg/ha	Flame photometer (Pauline & Hald, 1946; Pratt, 1965)

Land preparation and agronomic practices

The land was prepared to a fine tilth by repeated plowing and harrowing. After preparing a proper layout of the experimental field entire dose of (FYM) was applied 1 week prior to sowing. Vermicompost, phosphorus, potassium, and half dose of nitrogen as per treatment combination per plot were applied at the time of sowing as basal dose. The remaining half dose of nitrogen was applied after 4 weeks of sowing and at the flowering period. In this experiment "Arka Anamika" variety was used as the test crop. Seed sowing was done manually by dibbling @ 2 seeds per hill and was thinned out immediately after plant emergence allowing only one plant per hill. Recommended seed rate was 500gm per ropani. Intercultural operation was conducted at 20, 35, and 45 days after sowing (DAS) for optimum growth and yield of Okra.

Data collection techniques

Five plants were tagged randomly at 25 DAS for collecting various quantitative traits at 30, 40, and 50 DAS. Plant height was measured from base to tip of a plant at 30, 40, and 50 DAS on five selected plants using a measuring scale 60cm long. Stem diameter was measured using a Vernier caliper, and leaf number and pod number were counted on respectively tagged plants.

Statistical analysis

Data was entered in MS-excel 2016 and analysis was done using the open-source software package R-studio v. 4.0.1. Analysis of variance was computed and the Least significant difference (LSD) at 0.05 Level of Significance (LOS). Duncan's multiple range test (DNMRT) was done to compare the set of means between the treatment which are significantly different.

RESULTS AND DISCUSSION

Effect of nutrient management on plant architectural traits

Plant height is an important yield-attributing trait having a direct effect on biomass accumulation and fruit yield (Khandaker *et al*., 2017). Okra plant height was recorded for each treatment on 30, 40, and, 50 DAS. It is apparent from the data presented in Table 2 that different levels of nutrients significantly influenced the plant height at 40 DAS and the treatment effect was found to be non-significant among the treatments at 30, 40, and 50 DAS. Application of full dose VC and Half dose of NPK (T_8) attained the maximum plant height (37.21cm) at 50 DAS among all the treatments followed by 33.72 cm, 33.32cm, 32.91cm, 30.05cm, 29.37cm, 27.44cm, 23.18cm in T_7 (50%VC +50%NPK), T_2 (RDF+25% of NPK), T_5 (50%FYM +50%NPK), T_1(Recommended dose of NPK (200:180:60), T_4 (Full dose of FYM +Half dose of NPK), T_6 (Single dose of vermicompost(15ton/ha), and T_3 (FYM @20 ton/ha) respectively. This might be due to 2^{nd} dose of nitrogen fertilizer application of 30 DAS which have significant impact on plant growth and development in later periods. From the table, it is evident that different levels of fertilizer played a vital role in the growth and development of the plant. The use of chemical fertilizers alone at the recommended dosage (RD) or more than RD and organic fertilizers alone cannot lead to the maximum growth and development of the plant as observed under the combined effect of both. The combined effect of chemical fertilizer and organic fertilizer not only improves plant growth but also reduces the amount of chemical fertilizer incorporated to the soil. A similar result of increased plant height with 50% NPK has been reported by (Khanal *et al*., 2020). Similarly, Rana *et al.* (2020) also concluded that the integrated nutrient management (INM) in okra gave maximum plant height.

Table 2. Effect of nutrient management on plant height, no. of leaves and stem diameter at 30, 40, 50 DAS.

Treatments	Plant height (cm)			No. of leaves			Stem diameter (cm)		
	30DAS	40DAS	50DAS	30 DAS	40DAS	50DAS	30DAS	40DAS	50DAS
Recommended dose of NPK 200:180:60 (kg/ha)	8.26	19.24^{abc}	30.05	4.87	7.00	11.67^{abcd}	1.39^{bc}	2.28	3.61
RDF +25% of NPK	8.13	19.19^{abc}	33.32	5.67	8.00	10.67^{bcd}	1.51^{ab}	2.77	3.69
FYM @ 20 ton/ha	7.49	16.50^{bc}	23.18	5.33	7.00	9.00^{d}	1.31^{bc}	2.14	2.94
Full dose of FYM+ 50% of RDF	9.19	17.90^{bc}	29.37	5.00	8.33	12.00^{abcd}	1.27^{c}	2.31	3.37
50% FYM+50% of RDF	9.29	20.64^{ab}	32.91	5.67	8.67	13.33^{ab}	1.46^{abc}	2.54	3.61
Single dose of vermicompost (15ton/ha)	8.91	16.44^{c}	27.44	5.00	7.00	10.00^{cd}	1.32^{bc}	2.11	2.87
50% of VC + 50 % of RDF	10.21	20.55^{abc}	33.72	5.33	8.67	12.67^{abc}	1.68^{a}	2.49	3.85
Full dose of VC + 50%of RDF	10.73	23.19^{a}	37.21	6.33	9.33	14.33^{a}	1.65^{a}	2.64	4.09
Grand mean	9.03	19.21	30.90	5.40	8.00	11.71	1.45	2.41	3.50
P value	0.1803	0.0496	0.0621	0.0975	0.2516	0.0484	0.0101	0.3187	0.0322
LSD at 0.05	Ns	4.1574	Ns	Ns	Ns	3.2087	0.2304	Ns	0.7236
CV (%)	15.75	12.36	15.17	10.39	16.17	15.65	9.09	14.97	11.80

The different levels of NPK, VC, and FYM significantly influenced the diameter of the stem at 30 DAS and the treatment effect was found to be non-significant among the treatments at 40 and 50DAS. The maximum diameter (4.09 cm) was found under a Full dose of VC + Half dose of NPK(T_8) which was followed by T_7(Full dose of VC +Half dose of NPK), T_2(RDF +25% of NPK), T_5 (50%FYM +50%NPK), T_1(Recommended dose of NPK (200:180:60)), T_4 (Full dose of FYM +Half dose of NPK), T_3 (FYM @20 ton/ha), andT_6 (50%VC +50%NPK) respectively. This result of maximum plant diameter in T_8 was supported by (Meena and Meena, 2018) on okra. A similar kind of result having a maximum stem diameter in radish was obtained by Guragain *et al.* (2021). The different level of organic and inorganic fertilizers significantly influences the leaf numbers at 50DAS. The maximum number of leaves (14.33cm) was observed with a Full dose of VC +Half dose of NPK (T_8) followed by 50%FYM +50%NPK (T_5), 50%VC +50%NPK (T_7), Full dose of FYM +Half dose of NPK (T_4), Recommended dose of NPK (200:180:60) (T_1), 125% of NPK(T_2), Single dose of vermicompost(15ton/ha) (T_6) and FYM @20 ton/ha (T_3) which was supported by the findings of Rana *et al.* (2020) and further highlights the essence of organic and inorganic nutrients to influence the yield attributing traits.

The higher vegetative growth in treatments T_8 (Full dose of VC +Half dose of NPK) might be attributed to vermi-compost application, which increases microbial activity in the soil (improves soil health) and solubilizes native nitrogen, phosphorus, potassium, and trace nutrients Orozco *et al.* (1996) and Sharma *et al.* (2022).

Effect of nutrient management on the number of pods per plant and fruit yield

Results from Table 3 revealed that the application of organic and inorganic fertilizer or in combination were non-significant among the treatments at 40 DAS. However, a significant influence was observed in the number of pods at 50DAS and the treatment effect was found to be maximum at T_8 (Full dose of VC +Half dose of NPK) followed by T_7(50%VC +50%NPK), T_5 (50%FYM +50%NPK), T_2 (125% of NPK), T_4 (Full dose of FYM +Half dose of NPK), T_1 (Recommended dose of NPK (200:180:60), T_6 (Single dose of vermicompost (15ton/ha), T_3 (FYM @20 ton/ha) respectively. The differences in the plant growth and yield are also affected by the time of application where after the application of the second dosage of nutrient significant influence can be recorded showing a clear difference in nutrient availability and plant growth. This result was further supported by (Sachan *et al.*, 2017; Meena and Meena, 2018), and (Singh and Tiwari, 2019). The increased number of pods might be due to the higher growth at T_8 (Full dose of VC +Half dose of NPK) allowing for more photosynthetic space for the accumulation and translocation of photosynthates to the sink, i.e., fruit.

A critical look at data presented in Table 3 revealed that maximum yield (2.10 kg) was recorded in T_8 (Full dose of VC +Half dose of NPK) followed by 1.90 Kg in T_2 (125% of NPK). The minimum yield was recorded in 1.24, 1.32, 1.34, 1.55, 1.75, and 1.83 in T_3 (FYM @20 ton/ha), T_6 (Single dose of vermicompost (15ton/ha), T_5(50%FYM +50%NPK), T_7(50%VC +50%NPK), T_5 (50%FYM +50%NPK), T_1(Recommended dose of NPK (200:180:60), T_7(50%VC +50%NPK), and T_4 (Full dose of FYM +Half dose of NPK), respectively and the treatment effect was found to be significantly different among treatments. The function of vermicompost in improving the physical, chemical, and biological aspect of soil, is well established, which help plants better monitor nutrients resulting in increased yield which further explains that rather than the singular application of fertilizer integrated application shows promising yield. This result is closely confined to the findings of (Damar *et al.*, 2021). The importance of vermicompost in improving the physical, chemical, and biological properties of soil is widely established, which helps plants in better observation of nutrients, resulting in higher yields (Dutta *et al.*, 2020).

Table 3. Effect of nutrient management on number of pods at 40, 50 DAS and mean yield (KG).

Treatments	No. of pods		Mean yield (kg) per plot
	40DAS	50DAS	
Recommended dose of NPK 200:180:60 (kg/ha)	3.33	5.53^{bcd}	1.75^{bc}
RDF +25% of NPK	4.00	6.80^{abcd}	1.90^{ab}
FYM @ 20 ton/ha	3.33	5.20^{cd}	1.24^{d}
Full dose of FYM+ 50% of RDF	3.27	6.00^{bcd}	1.83^{b}
50% FYM+50% of RDF	3.13	7.07^{abc}	1.34^{d}
Single dose of vermicompost (15ton/ha)	2.80	5.13^{d}	1.32^{d}
50% of VC + 50 % of RDF	3.60	7.27^{ab}	1.55^{cd}
A full dose of VC + 50%of RDF	3.73	8.07^{a}	2.10^{a}
Grand mean	3.40	6.38	1.63
P value	0.8672	0.0364	0.057
LSD at 0.05	ns	1.8698	0.49
CV%	28.89	16.73	22.29

Table 4. Soil nutrients status after harvest.

Treatments	Organic matter	pH	N (%)	P (kg/ha)	K (kg/ha)
Recommended dose of NPK 200:180:60 (kg/ha)	2.18	5.90^{cd}	0.1100	62.14^{bc}	157.44^{cd}
RDF +25% of NPK	1.89	5.56^{d}	0.0967	42.41^{d}	118.61^{e}
FYM @ 20 ton/ha	2.21	6.15^{ab}	0.1133	67.47^{b}	153.49^{cd}
Full dose of FYM+ 50% of RDF	1.99	6.25^{a}	0.0967	53.75^{bcd}	180.77^{bc}
50% FYM+50% of RDF	1.68	6.22^{ab}	0.0833	47.88^{cd}	132.87^{de}
Single dose of vermicompost (15ton/ha)	2.24	6.25^{a}	0.1133	53.74^{bcd}	191.92^{b}
50% of VC + 50 % of RDF	1.96	6.20^{bc}	0.0967	52.81^{bcd}	132.56^{de}
Full dose of VC + 50%of RDF	2.31	5.89^{c}	0.1167	85.20^{a}	229.61^{a}
Grand mean	2.06	6.03	0.1033	58.18	162.61
P value	0.2824	0.0001	0.1961	0.0017	0.0001
LSD at 0.05	Ns	0.2271	Ns	16.08	32.0047
CV%	15.26	2.15	15.15	15.79	11.27

Soil nutrient status after harvest of yield

Total Nitrogen: The initial nitrogen content of the field before the application of treatment was (0.1125 %) as shown in Table 1. Post-harvest available nitrogen content in soil was found to be non-significant. However, the maximum available nitrogen was observed in T_8 (full dose of VC +Half dose of NPK) followed by T_6 (Single dose of vermicompost (15ton/ha) and T_3 (FYM @20 ton/ha). The minimum nitrogen content was found in T_5 (50% FYM +50%NPK) followed by T_2, T_4, and T_7 with the same value (0.0967) as mentioned in Table 4. (Mishra *et al.*, 2020) reported higher post-harvest availability of nitrogen in INM treatment (25% N through FYM + 25% N through vermicompost + 25% N through poultry manure + 25% N through neem oil cake).

Organic matter: Examination of data in Table 1 indicates that the initial OM content in the soil before treatments was found to be 2.25%. The post-harvest available OM content in soil was found maximum in T_8 (full dose of VC +Half dose of NPK) followed by T_6 (Single dose of vermicompost (15ton/ha) and T_3 (FYM @20 ton/ha). The minimum OM content was found in T_5 (50%FYM +50%NPK) followed by T_2, T_4, and T_7 as mentioned in Table 4. The result was found similar to the Nitrogen content.

Available phosphorous: Initial value of available Phosphorous was found to be 58.27 kg/ha as given in Table 1. Data presented in Table 4 revealed that maximum phosphorous depletion was shown in RDF + 25% of NPK (T_2) and minimum depletion was shown in T_8 followed by T_3 and T_1 which are statistically significant. This may be due to the high content of phosphorous in vermicompost and FYM and the slow release of nutrients.

Available potassium: Initial value of available potassium was found to be 104.40 kg/ha as shown in Table 1. A critical look at data (Table 4) shows that available potassium in the soil after harvest of the crop was significantly higher in T8 and lowest in T_2.

PH: Initial value of pH was found to be 6.77 as given in Table 1. In Table 4, all the values of pH in different treatments were significantly low than initial one's due effect of treatments. The minimum pH was found in T_2 due to the increasing number of acidic substances in RDF +25 % of NPK. The maximum value of pH is found in T_6 and T_4 (6.25).

Conclusion

From the above findings, it is concluded that the treatment T_8 (Full dose of VC +Half dose of NPK) was observed to be best concerning most of the parameters examined in this research i.e., plant height, stem diameter, number of leaves, number of pods, and yield. The maximum available nitrogen, phosphorus, and potassium were also observed in T8 (full dose of VC + Half dose of NPK). The post-harvest is available OM content in soil was found maximum in T_8(full dose of VC +50% of RDF) and in T_5(50%FYM +50% of RDF). Similarly, after post-harvest analysis lowest acidic soil was found in T_4 and T_6 and the highest acidic soil was found in T_2. Thus, this study infers that for optimum plant growth and yield in comparison to the recommended dose of fertilizers, we can use vermicompost as a substitute which not only enhances the crop yield attributes and yield but also improves the soil's physical and chemical links with soil microbial activity. Thus, Integrated Nutrient Management in crop production shows a positive effect on crop growth and yield which has a dual effect on economic yield and improved soil health.

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