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Response of organic, inorganic fertilizers and integrated nutrient management on growth, yield and quality of okra (*Abelmoschus esculentus* (L.) Moench)

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Abstract
The experiment was conducted at the instructional farm of Krishi Vigyan Kendra Jajpur, Odisha during 2016 to study the "Response of organic, inorganic fertilizers and integrated nutrient management on growth, yield and quality of okra" variety-Pusa A4. From the experiment it was observed that application of RDF (75%) + (25%) N through neem oil cake (T_7) produced maximum plant height (136.41 cm), internode length (8.20cm), fruit length (12.13cm), maximum number of fruits per plant (15.02), individual fruit weight (15.11g) and yield per ha. (10.49 ton) where RDF was 110:50:80 NPK kg/ha. Whereas, maximum number of nodes per plant (23.32), maximum fruit girth (5.87cm) were found in (T_5) where RDF (75%) + (25%) N through vermicompost were applied. Application of RDF (75%) + (25%) N through neem oil cake (T_7) recorded high protein content (15.92%). Highest chlorophyll content in leaves (1.48mg/g) was found in T_2 (100% RDF + FYM 1.5t/ha). High Ascorbic acid content (15.12mg/100g) was found in T_{12} (25% N through FYM + (25%) N through vermicompost + (25%) N through poultry manure + (25%) N through neem oil cake+sea weed extract (15kg/ha) which was at par with T_7 (14.66 mg/100g). Low crude fibre content (10.61%) was observed in T_1 (100% RDF) followed by T_7 (10.94%) and T_5 (11.12%). High TSS content (3.72^{0}Brix) was found in T_2 receiving RDF (100%) and FYM (1.5kg/ha).

Keywords: INM, growth, yield, quality, neem oil cake, vermicompost and okra

Introduction
Okra, (*Abelmoschus esculentus* (L). Moench) is one of the most important vegetable crop grown in tropical and subtropical region of the world belongs to family Malvaceae (2n= 130). It is commonly known as Bhindi, Gumbo and Lady's finger. It is a popular fruit vegetable grown round the year and fetches premium price in the market. Besides the utility of its tender green fruits as vegetable, it is used in soups and curries. Okra fruits are canned green or dried for use by army at high altitudes and are also exported helping in earning foreign exchange. In Odisha okra is grown all the thirty districts as a main crop in summer and rainy season and to some extent also in winter and also fetches premium prices in the market. The production of okra is comparatively low due to injudicious application of inorganic and organic fertilizers and high incidence of disease and pest. Nutritional imbalances in the soil cause instability in productivity and hidden hunger of nutrient besides resulting in poor nutritional quality of vegetable. The maintenance of sustainability in production through integrated use of different sources of nutrients also help to maintain the fertility of soil and avoids depletion of soil organic matter and plant nutrients besides suppression of some insect, pest and diseases. Integrated nutrient management (INM) system envisages use of organic manures, green manures, bio-fertilizers along with chemical fertilizers. From the stand point of crop yield and quality, nutrient supply from both organic and inorganic sources is important. Integrated nutrient management (INM) help to store and sustain soil fertility and crop productivity. It may also help to check the emerging deficiency of nutrient other than N, P and K. In the present Indian Agriculture, keeping in view the inadequate availability of organic sources of nutrients and expected yield decline at least in the initial years, complete substitution of chemical fertilizer is not necessarily warranted. Rather organic sources should be used as partial replacement of the chemical fertilizer. Thus, a strategy for judicious combination of both organic and inorganic sources of nutrient is the most viable option for nutrient management in okra. It will be economically viable and also help in attaining sustainability in production and maintaining soil health and environment. The use of organic amendments applied to soil not only enhances its nutrient status but also reduces the incidence of pest. (Adilakshmi *et al*., 2008) [1].

Materials and methods

The experiment was conducted at the instructional farm of Krishi Vigyan Kendra Jajpur, Odisha during 2016 to study the "Response of organic, inorganic fertilizers and integrated nutrient management on growth, yield and quality of okra" variety-Pusa A4.The experiment was laid out in randomized block design (RBD) with three replications and twelve treatments. Treatments involved were T_1 (100% RDF), T_2 (100% RDF + FYM 1.5 t / ha), T_3 (RDF (75%) +*Azotobacter* +*Azospirillum* + PSB (2kg/ha each), T_4 (RDF (75%) + (25%) N through FYM), T_5 (RDF (75%) + (25%) N through vermicompost), T_6 (RDF (75%) + (25%) N through poultry manure), T_7 (RDF (75%) + (25%) N through neem oil cake), T_8 (RDF (50%) + (25%) N through FYM + (25%) N through vermicompost), T_9 (RDF (50%) + (25%) N through FYM + (25%) N through poultry manure), T_{10} (RDF (50%) + (25%) N through FYM + (25%) N through neem oil cake), T_{11} (25% N through FYM + 25% N through vermicompost + 25% N through poultry manure + 25% N through neem oil cake), T_{12} (25% N through FYM + 25% N through vermicompost + 25% N through poultry manure+25% N through neem oil cake + sea weed extract 15kg/ha), where RDF was recommended dose of fertilizers (110:50:80 NPK kg/ha.)The land was brought to a fine tilth through ploughing and tillage. Irrigation channels and bunds were prepared according to layout. The seeds were soaked overnight and sown in the field directly. Light irrigation was given just after sowing of seeds. Organic manures were applied one week before sowing. Full dose of phosphorus, potassium and half dose of nitrogen as per treatments were applied just before sowing. The remaining half dose of nitrogen was applied twentyfive days after sowing. All cultural practices were followed regularly during crop growth and observations were recorded on yield and yield attributing characters. The data on these parameters were subjected to statistical analysis to draw logical conclusions.

Growth parameters

Plant height (cm)

Maximum plant height was observed in T_7 (136.41 cm) where 75% RDF and 25% N through neem oil cake were applied and was at par with T_5 (134.62cm) and T_{10} (132.82cm). The plant height was found lowest in T_{11}(102.35 cm) where 25% N through FYM + 25% N through vermicompost + 25% N through poultry manure + 25% N through neem oil cake were applied. Increase in plant height observed in T_7 was due to supply of 75% RDF through chemical fertilizer and 25% N through neem oil cake which resulted in less incidence of sucking pest and disease occurrence for which the source-sink relation and photosynthesis was some what normal resulting in increase in plant height. Initial requirement of N met from the inorganic source and subsequent requirement of N from organic source assuring continuous N supply throughout growing period favours consistent N uptake by plant at different growth stage favouring increase in height. The present findings corroborate with the findings of Das *et al*. (2014) [9], Choudhury *et al*. (2015) and Anand *et al*. (2016) [3],

Internode length (cm)

Length of internode was maximum in T_7 (8.20 cm) and minimum in T_{11} (6.82 cm). T_7 (8.20 cm) and T_5 (8.01 cm) were at par for this character and differed significantly from other character. This might be attributed due to less incidence of disease and pest, synergetic effect of organic and inorganic fertilizer combinations which could make available different nutrients in the soil to the plant and enhanced steady supply of essential nutrient to the crop and favourable soil physical environment. Similar results were obtained by Adilakshmi *et al*. (2008) and Sharma *et al*. (2014) [1, 20].

Number of nodes per plant

It was observed that number of nodes per plant was maximum (23.32) in T_5 followed by T_7 (21.62) and T_{10} (21.22) respectively. However, minimum number of nodes per plant was observed in T_{11} (16.12). T_5 produced significantly higher nodes per plant as compared to other treatments. This is due to better availability and uptake of plant nutrients, more specially N, P, K resulting in better photosynthesis and protein synthesis. Thus, these increased amount of NPK nutrients in plants, lead to increase plant metabolites that help to build up plant tissues of okra (Prabhu *et al*., 2003) [16]. The present finding is in accordance with same type of results obtained by Barani and Amburani (2004) [5], Bairwa *et al*. (2009) [4] and Kumar *et al*. (2013) [11].

Fruit length and Girth of fruit (cm)

Fruit length was maximum in T_7 (12.13 cm) followed by T_5 (11.84 cm), T_6 (11.68 cm) and T_{10} (11.67cm) respectively. Minimum fruit length of 9.21 cm was observed in T_{11}. All the treatments were found at par except treatments T_{11} (9.21cm), T_{12}(9.68 cm), T_3 (10.56 cm). Girth of fruit was maximum in T_5 (5.87 cm) followed by T_7 (5.85 cm), T_{10} (5.83 cm) and T_2 (5.81 cm) respectively. All the treatments were found at par except treatments T_{11} (5.49cm), T_{12} (5.74 cm), T_3 (5.52 cm) and T_9 (5.58 cm) respectively. This might be attributed to the synergistic effects of organic manures which make more nutrients available to the plants by improving the soil physical condition and solubilizing the nutrients in soil..The increased vegetative growth, balanced C/N ratio and increased synthesis of carbohydrates help in increasing the fruit size. Similar findings were reported by Bodamwal *et al*. (2006) [6], Bairwa *et al*. (2009) [4] and Shelar *et al*. (2011) [22].

Fruit number

Maximum number of fruits was with T_7 (15.02) followed by T_5 (14.69), T_{10} (14.45), respectively whereas, minimum number of fruits per plant was recorded in T_{11} (10.72). T_7 (15.02), T_5 (14.69) and T_{10} (14.45) were at par and were significantly differed from all other treatments..The increased in number of fruits per plant might be due to the better availability and uptake of nutrients by plants. Integrated use of 75% RDF through chemical fertilizer + 25% N through neem oil cake or vermicompost improved the physical properties of soil and thereby improved the water and nutrient holding capacity of soil as well as soil fertility condition (Subba Rao and Shankar, 2001) [24]. Availability of nutrients helps the plant to bear more number of flower and reduces the chances of flower drop resulting in more number of fruits per plant. The present findings corroborate with the findings of Bodamwal *et al*., (2006) [6], Munikrishnapa and Tirakannanavan, (2009) and Bairwa *et al*. (2009) [4].

Fruit weight (g)

Highest fruit weight of 15.11 g was recorded T_7 and lowest of 12.82 g was observed in T_{11}. It was observed that T_7 (15.11 g), T_5 (14.96 g) and T_{10} (14.49 g), T_2 (14.21 g), T_6 (13.86 g) and T_1 (13.70 g) were at par for this character. Combined application of organic and inorganic fertilizer increase the availability and uptake of more plant nutrients resulting in

luxuriant vegetative growth. The increased photosynthetic area and translocation of photosynthetics in plants subsequently accelerated the formulation of more number of large sized fruits with more number of seeds per fruits resulting in increase in fruit weight. Similar results for okra were also reported by Bairwa *et al*. (2009) [4], Shelar *et al*. (2011) [22], Wagh *et al*. (2014) [26] in okra.

Table 1: Response of organic, inorganic fertilizers and integrated nutrient management on yield and yield attributing characters of okra

Treatment	Plant height (cm)	Inter node length (cm)	Number of nodes	Fruit length (cm)	Fruit girth (cm)	Fruit number	Fruit weight (g)	Yield/ha. (ton.)
T_1	118.32	7.32	18.68	11.18	5.74	12.96	13.70	8.72
T_2	121.30	7.35	20.46	11.54	5.81	13.61	14.21	9.52
T_3	107.23	6.94	16.92	10.56	5.52	11.45	13.28	8.27
T_4	116.24	7.56	17.56	10.94	5.62	12.48	13.45	8.58
T_5	134.62	8.01	23.32	11.84	5.87	14.69	14.96	9.85
T_6	119.2	7.56	19.26	11.68	5.78	13.21	13.86	8.99
T_7	136.41	8.20	21.62	12.13	5.85	15.02	15.11	10.49
T_8	121.45	7.45	17.95	11.02	5.68	12.86	13.56	8.62
T_9	112.22	7.24	17.12	10.78	5.58	12.20	13.33	8.35
T_{10}	132.82	7.65	21.22	11.67	5.83	14.45	14.49	9.65
T_{11}	102.35	6.82	16.12	9.21	5.49	10.72	12.82	7.30
T_{12}	105.29	7.00	16.56	9.68	5.74	11.15	12.94	7.49
SE(m)±	4.18	0.18	0.56	0.53	0.07	0.38	0.51	0.31
CD(0.05)	12.25	0.52	1.64	1.54	0.22	1.12	1.50	0.91

Fruit yield

Maximum yield per hectare was obtained in T_7 (10.49 t/ha) and minimum (7.30 t/ha) in T_{11}. T_7 (10.49 t/ha), T_5 (9.85 t/ha) and T_{10}(9.65 t/ha) were found to be at par. Other treatments like T_2, T_6, and T_1 recorded 9.52 t/ha, 8.99 t/ha and 8.72 t/ha per ha fruit respectively. It was evident from the present study that application of neem oil cake proved to be very significant in

reducing incidence of disease and pest. The efficacy of neem cake in reducing incidence of pest in okra reported by Godase and Patel, 2001 [10], Mallick and Lal, 1989 [14] and *et al*., 2009 [25]. Application of neem oil cake along with chemical fertilizer significantly increased the number of fruits per plant, fruit weight which result in increasing yield. This is due to the better availability and uptake of plant nutrients for a longer time of crop growth due to neem cake as compared to other combination of fertilizer.. Similar type of results were also reported by Bairwa *et al*. (2009) [4], Prasad and Naik (2013) [17], Mal *et al*. (2014) [13], Das *et al*. (2014) [9], Choudhary *et al*. (2015) [7], Anand *et al*.(2016) [3] and Kumar *et al*.(2017) [12] in okra.

Quality parameters

Leaf chlorophyll

Leaf chlorophyll content was influenced by combined application of inorganic fertilizers along with organic manures in the form of neem oil cake, poultry manure, vermicompost, FYM, biofertilizer and sea weed extract. Year leaf chlorophyll content was maximum in T_2 (1.48 mg/g) and was minimum in T_{12} (1.28 mg/g). Treatments T_2 (1.48 mg/g), T_9 (1.47 mg/g), T_3 (1.46 mg/g), T_5 (1.46 mg/g), T_7 (1.45mg/g) and T_{10} (1.43 mg/g) were at par. Similar result were obtained by Shanti and Vijayakumari (2005) [19], Bairwa *et al*., (2009) [4] and Sharma and Choudhary (2011) [7, 21].

Ascorbic acid content

The present investigation revealed that ascorbic acid content in okra varied significantly with treatments. Maximum ascorbic acid content was found in T_{12} (15.12 mg/100 g) and found at par with T_8 (14.48 mg/100 g), T_{11} (14.37 mg/100 g) and T_7 (14.66 mg/100 g) and was minimum in T_6 (12.34 mg/100 g). Similar findings of increased ascorbic acid content of okra fruits with combined application of organic and inorganic fertilizers were also reported by *et al.* (2009) [25], Ciba *et al*. (2017) [8] and Singh *et al*.(2018) [23] in okra.

Crude protein

Crude protein content was maximum in T_7 (15.92%) and was minimum in T_{11} (13.56%). T_7 (15.92%) T_5 (15.58%) were at par. Variation in protein content in okra fruit due to different INM practices were also reported by Raj and Geethakumari (2001) [18] and Wagh *et al*. (2014) [26] in okra.

Table 2: Response of organic, inorganic fertilizers and integrated nutrient management on quality of okra

Treatment	chlorophyll (mg/g)	Ascorbic acid (mg/100g)	Crude protein (%)	Crude fibre (%)	TSS (ºBrix)
T_1	1.35	12.64	14.64	10.61	2.92
T_2	1.48	13.43	14.94	12.94	3.72
T_3	1.46	13.81	13.82	12.32	3.18
T_4	1.38	12.64	14.22	11.78	2.46
T_5	1.46	13.28	15.58	11.12	2.74
T_6	1.36	12.34	14.86	11.96	3.18
T_7	1.45	14.66	15.92	10.94	3.24
T_8	1.35	14.48	14.42	12.92	2.82
T_9	1.47	13.24	13.98	12.64	2.96
T_{10}	1.43	13.36	15.12	11.36	3.46
T_{11}	1.34	14.37	13.56	11.86	3.24
T_{12}	1.28	15.12	13.68	12.12	3.17
SE(m)±	0.02	0.42	0.15	0.41	0.08
CD (0.05)	0.05	1.23	0.44	1.20	0.22

Crude fibre content

Crude fibre content is one of the important criteria to judge the quality of okra pod. Crude fibre% in fruit was maximum in T_2 (12.94%) and was minimum in T_1 (10.61%). T_1 (10.61%), T_7 (10.94%), T_5 (11.12%), T_4 (11.78%), T_{10} (11.36%) were at par with each other. The crude fibre content increased with the advancement of crop growth. It might be due to reduced succulence resulting from the cell wall thickening and reduced uptake of nitrogen with advancement of crop growth. The present findings corroborate with Wagh

et al. (2014) [26], Ciba *et al*. (2017) [8] and Amiry *et al*. (2018) [2] in okra.

Total soluble solid (TSS)

Total soluble solid **(**TSS) of fruit was found maximum in T_2 (3.72ºBrix) followed by T_{10} (3.46 ºBrix), T_{11} (3.24 ºBrix), T_7 (3.24 ºBrix) and was minimum in T_4 (2.46 ºBrix).. This result was in conformation with Singh *et al*. (2018) [23] and Amiry *et al*. (2018) [2] in okra.

Conclusion

From the experimental result it was observed that integrated application of 75% RDF in the form of chemical fertilizers and 25% through neem oil cake was found best in producing more plant height. Internode length, number of nodes per plant,fruit length, fruit girth, number of fruits per plant, fruit weight with higher yield and also increased quality of fruit in okra.

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