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Effect of integrated nutrient management on growth, yield, and quality of okra (*Abelmoschus esculentus* (L). Moench) cv. Arka Anamika

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Abstract
A field experiment was conducted at the Experimental Farm, Department of Horticulture, Assam Agricultural University, Jorhat during March to July 2016 to study the effect of "Integrated Nutrient Management in Okra [*Abelmoschus esculentus* (L.) Monech]. Organic manures, inorganic fertilizers were applied in different combinations along with biofertilizers. One treatment consisted of recommended dose of fertilizers (RDF). Among the treatments highest plant height (118.52 cm), least numbers of days taken to first flowering (46.20 days) and fruiting (47.33 days), number of fruits per plant (16.00) and yield (12.70 t ha^{-1}) were recorded in T_1 (RDF) followed by T_2 [75% RD of NPK + Vermicompost @ 1 t ha^{-1} (mixed with microbial consortium)]. In case of quality parameters of fruit lowest moisture content (90.58%) and highest ash content (9.07%) were recorded in T_3 followed by T_4 and T_2. Soil parameters like organic carbon (1.40%), available N (211.29 kg ha^{-1}), P (64.05 kg ha^{-1}) and K (143.20 kg ha^{-1}) were also recorded highest in T_3 followed by T_4 and T_2. The perusal of result revealed that most of the growth, yield and yield attributes were found highest in treatment receiving RDF. However, INM treatments exhibited superior value regarding quality and soil parameters as compare to the treatment receiving RDF.

Keywords: INM, RDF, Microbial consortium, vermicompost, FYM.

Introduction
Okra belongs to genus *Abelmoschus* and species *esculentus* of family Malvaceae. It is also known as lady's finger or bhindi and originated in tropical Africa. Because of its richness in nutrition, taste, medicinal and industrial value okra is one of the most popular vegetables in all section of people. Immature okra fruits commonly consumed as a vegetable. The fruit composition is enriched with about 88 IU of vitamins and as high as 300 mg of different minerals per 100 g edible portion (Aykroyd, 1963) [1]. The green revolution of previous decades and the intensive agriculture has depleted the soil nutrient status and increased the deficiency of micro-nutrients. To maintain sustainability in quality production through the proper use of different sources will also help to maintain the fertility of the soil (Palaniappan and Annadurai, 2000) [8]. From several experiments, it has been observed that no single source of nutrients, be it organic manure, chemical fertilizer or biofertilizers can meet the nutrient needs for modern intensive farming. Integrated nutrient management (INM) is a holistic, approach that considers all the available farm resource that can be used as plant nutrients. Nutrients added through combined inorganic and organic sources are better utilized than inorganic alone, besides reducing cost of production and maintaining the soil health (Sarvanan *et al.*, 1986) [12]. Moreover, long term sustainability of productivity could be achieved only through the interaction of inorganic and organic sources of nutrients (Hedge *et al.*, 1992 and Singh and Yadav, 1992) [4, 14].

Materials and Methods
A field experiment was conducted at the Experimental Farm, Department of Horticulture, Assam Agricultural University, Jorhat during March to July 2016. The experiment was laid out with Randomized Block Design and replicated three times. There were seven treatments consisting of T_1 [RDF (50:50:50 kg NPK ha^{-1} + FYM @ 10 t ha^{-1})], T_2 [75% RD of NPK + Vermicompost @ 1 t ha^{-1} (mixed with microbial consortium)], T_3 [50% RD of NPK + (mixed Vermicompost @2 t ha^{-1} with microbial consortium)], T_4 [75% RD of NPK + Microbial

consortium as seed coat + Vermicompost @ 1 t ha^{-1}], T_5 [50% RD of NPK + Microbial consortium as seed coat + Vermicompost @ 2 t ha^{-1}], T_6 [FYM @ 10 t ha^{-1} (mixed with microbial consortium)] and T_7 [Microbial consortium as seed coat + FYM @ 10 t ha^{-1}]. Organic manures, inorganic fertilizers and biofertilizers were applied at different doses as per the treatment requirement. FYM was applied @ 10 t ha^{-1}, and vermicompost was applied @ 1 t ha^{-1} and 2 t ha^{-1} after final land preparation. Microbial consortium was applied through inoculation in two ways *i.e* with seed and with organic manures (FYM and vermicompost). Consortium applied at the rate of 500 g per 10 kg of seed as a seed treatment and along with organic manures at the rate of 3.5 kg ha^{-1}. Inorganic fertilizers *i.e.* Urea, SSP, and MOP were applied three days before sowing as a basal application. Half of Urea, full dose of SSP and MOP was applied as basal. The second half of Urea was applied at 30 days after sowing.

Results and Discussion

Growth and yield parameters

Growth and yield attributes were accentuated and differ significantly by different treatments (Table 1). The perusal of result indicated that okra plants fertilized with RDF (NPK @ 50:50:50 kg ha^{-1} + FYM 10 t ha^{-1}) recorded the highest plant height (118.52 cm), least days took to 1st flowering (46.20 DAS) and fruiting (47.33 DAS), highest number of fruits per plant (16.00) and yield (12.70 t ha^{-1}) followed by INM treatment T_2 [75 % RD of NPK + Vermicompost 1 t ha^{-1} (mixed with microbial consortia)]. This might be due to the fact that N in readily available form vigorously activated the vegetative development of plants (Patel *et al.,* 2009) [9]. Also, application of NPK showed synergistic effect upto 100 per cent RDF by extracting the synthesis of chlorophyll and amino acid which are associated with major plant process. These results are accordance with Sharma *et. al* (2014) [13], Ghuge *et al*. 2015 [3] and Lal and Kumar (2016) [5]. The beneficial effect of application of organic manures along with inorganic and bio fertilizer increasing the vegetative growth and yield of plant can be attributed to the joint application of manures, biofertilizers and chemical fertilizers that might have acted complementary and supplementary to each other and resulted into adequate slow but steady supply of nutrients. Moreover, the organic manures are also significant sources of major and micronutrients much needed by the plants as reported by Rafi *et al* (2002) [10]. The lowest vegetative growth and yield was recorded with the treatment receiving only organic manures and bio fertilizers.

Quality parameters

There was significant variation among the treatments regarding moisture and ash content of the fruit (Table 1). The highest moisture content (91.64%) was recorded in treatment T_1 (RDF (NPK @ 50:50:50 kg ha^{-1} + FYM 10 t ha^{-1}) which was significantly superior to all other treatments receiving organic manures either alone or in combination with inorganic fertilizers and biofertilizers. It might be due to the fact that higher levels of nitrogen leads to much more moisture uptake and ultimately increased the water content in fruits. Also, fertilization is generally less intense in organic agriculture and therefore organic fruits and vegetables are smaller and thus contains less water (Basker, 1992) [2].

Ash content represented the total amount of non-combustible substance *i.e.,* minerals present in the plant product. In the present study, highest ash content of 9.07 % in fruit was found in T_3 [50% RD of N, P, K + Vermicompost @ 2 t ha^{-1} (mixed with microbial consortium)]. This might be due to improvement in quality parameters of fruits. Application of biofertilizers in this treatment along with the manure might have resulted in increased secretion of many growth promoting compounds that influenced the plants to absorb more macro and micro nutrient from soil leading to increase in mineral content of fruits.

Table 1: Effect of INM on growth, yield and quality parameters of okra

	Growth and yield					Quality	
Treatments	**Plant height (cm)**	**Days to 1st flowering**	**Days to 1st fruiting**	**No. of fruits plant^{-1}**	**Yield (t ha^{-1})**	**Moisture (%)**	**Total Ash (%)**
T_1	118.52	46.20	47.33	16.00	12.70	91.64	7.27
T_2	103.40	51.20	52.33	14.90	11.75	90.99	8.37
T_3	91.89	52.75	54.35	13.20	9.87	90.58	9.07
T_4	102.18	51.98	53.18	14.60	11.24	90.90	8.31
T_5	90.17	53.05	54.71	13.00	9.62	90.43	8.98
T_6	76.12	55.27	56.30	11.00	7.48	89.64	7.67
T_7	74.96	55.40	56.41	10.95	7.38	89.51	7.58
S.Ed (±)	1.01	0.26	0.21	0.34	0.40	0.36	0.12
CD at 5%	2.20	0.56	0.46	0.74	0.87	0.79	0.27

Soil parameters

The chemical properties of soil were influenced by different sources of soil nutrients (Table 2). The content of organic carbon increased from the initial status, in all the treatments. Higher organic carbon under INM treatments might be due to the direct application of carbon input (Ros *et al.* 2003) [11], which could be enhanced further through root exudates, root residue of okra and biofertilizers application (Singh and Pathak 2003) [15]. Manna *et al*. (2005) [6] reported that integrated nutrient management, including NPK improved soil organic carbon as well as crop productivity in different agro-ecosystems.

Availability of major plant nutrients like N, P and K were also affected by application of different nutrients (Table 2). In all cases the nutrient availability increased and the highest availability of N, P and K was found in T_3 [50% RD of NPK + Vermicompost @ 2 t ha^{-1} (mixed with microbial consortium)]. Such a build up of available N could be attributed to the ability of biofertilizers to fix atmospheric N in the rhizosphere throughout the cropping period. Organically managed soil exhibited great of biological activity of inoculated microorganism as well as their potential nitrogen fixation (Melero *et al.,* 2006) [7].

The increase in available P might be acrebited to the phosphate solubilising and mineralising abilities of organism from the insoluble form of phosphorus source. Microorganism capable of solubilising and mineralising phosphorous pool in soil are considered vital in promoting P availability (Tao *et al.,* 2008) [17].

The increase in available P might be due to mineralization of insoluble compounds through the action of organic acids released during the decomposition of organic manures or produced by bio-fertilizers. The positive influence of organic manure on the available soil potassium was earlier reported by Srikant *et al.*, (2000) [16].

The results of the present investigation revealed that application of recommended dose of fertilizers in production system gave the highest yield among the all treatments. However, considering the negative effect of inorganic fertilizer on soil it is not recommendable to use inorganic fertilizers in higher amount. Combine use of inorganic, organic and biofertilizers (INM practices) not only improved the quality of fruit and soil health, but it can also produc better vegetative growth and yield of okra. Therefore, treatment T_2 [75% RD of NPK + Vermicompost @ 1 t ha^{-1} (mixed with microbial consortium)] has been inferred as farmer's friendly for sustainable production, higher net return and good quality which is considered to be the best treatment that can be adopted under field cultivation.

Table 2: Effect of INM on soil parameters of okra

Treatments	Organic carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T_1	1.03	176.86	44.21	129.75
T_2	1.24	198.21	55.58	145.41
T_3	1.40	211.29	64.05	154.27
T_4	1.21	194.53	52.24	143.20
T_5	1.36	206.93	61.60	153.41
T_6	1.13	187.31	47.01	137.34
T_7	1.11	182.78	46.73	135.43
S.Ed(±)	0.02	2.50	2.36	2.05
CD at 5%	0.05	5.45	5.13	4.46
Intinal	0.91	168.52	40.77	110.09

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