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Effects of Bio-fertilizers, Chemical Fertilizers, and Farmyard Manure on Growth and Yield of Okra (*Abelmoschus esculentus* L.)

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Abstract

A field experiment was carried out to compare the effects of different fertilizers on growth and yield of okra (*Abelmoschus esculentus* L.). The randomized complete block design experiment had five treatments with four replications. Besides a control, the experiment included bio-fertilizer Multiplex Annapurna, bio-fertilizer Spic Surabi, FYM, and chemical fertilizer treatments. Bio-fertilizers were applied at the rate of 297 kg ha^{-1} while FYM and NPK chemical fertilizers were applied at the rate of 4,000 kg ha^{-1} and 100:150:50 kg ha^{-1} respectively. Plant height, stem diameter, plant canopy, and number of leaves were measured at 42, 54, 66, and 78 days after sowing (DAS). Yield and yield components (yield, no of fruits per plants, fruit length, and fruit weights) were assessed at the time of harvest. Fertilizer treatment had a significant effect on growth and yield of okra ($p < .05$). Spic Surabi gave the highest yield (11.77 t ha^{-1}) and the lowest (9.63 t ha^{-1}) was from control treatment. The experiment indicated that the application of bio-fertilizer, mainly Spic Surabi, increases growth and yield of okra.

Key words: Bio-fertilizer, chemical fertilizer, growth, okra, yield

Introduction

Okra (*Abelmoschus esculentus* L.) belongs to Malvaceae family and is commonly called as lady's finger (Akanbi *et al.*, 2010). Okra is also known by many local names in different parts of the world. It is called lady's finger in England, gumbo in the United States of America (USA) and bhindi in India (Olaniyi *et al.*, 2010). Okra requires high day and night temperatures with soil temperature in the range of 24 to 32 °C and pH of 6.5–7.5. Countries leading in okra production are Afghanistan, Bangladesh, Brazil, Burma, Cyprus, Ethiopian, Ghana, India, Nigeria, and the south United States (Akanbi *et al.,* 2010). India ranks first in the world with 6.0 million tons (70% of the world production) production followed by Nigeria with 1.1 million tons (FAO, 2013).

Okra has been called "a perfect villagers vegetable" because of its robust nature, dietary fibers, and distinct seed protein balanced in both lysine and tryptophan amino acid (unlike the protein of cereals and pulses) it provides (Kumar *et al*., 2010). It is considered a nutritional powerhouse used for both medicinal and culinary purposes. Okra promotes healthy pregnancy, helps in diabetes and kidney disease, supports colon health, helps with respiratory issues like asthma, and promotes healthy skin (Kumar, 2013). The nutritional composition of okra includes calcium, protein, oil and carbohydrates, iron, magnesium, and phosphorus (Omotoso and Shittu, 2007).

In Bhutan, okra is considered a minor crop and its cultivation is yet to receive importance. In few areas of southern Bhutan, okra is cultivated in farmers' kitchen garden for home consumption. With the ongoing construction of hydro-power projects in the country, the demand for such vegetables will increase, requiring use of fertilizers to increase their production. Chemical fertilizer is a major facet of green revolution's package of increasing crop yield (Mann, 1999). According to Potter *et al*. (2009), continuous use of chemical fertilizers leads to deterioration of soil chemical, physical and biological properties, and soil health. Use of fertilizers has also resulted in

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decline of crop yield and contributed to environmental pollution in the long run. The negative impacts of chemical fertilizers coupled with escalating prices have led to growing interests in use of organic fertilizers as a source of crop nutrients.

Bio-fertilizer is a substance containing living micro-organisms such as bacteria, fungi, and blue green algae. Bio-fertilizers are applied to seed, plant surface, and soil, which colonize the root rhizophere that promotes growth and development of plants through biological activity (Isfahani and Besharati, 2012). According to Ullah *et al*. (2008), bio-fertilizers and Farm Yard Manure (FYM) are low cost, effective, and renewable sources of plant nutrients to supplement chemical fertilizers and are environment friendly method for boosting agriculture productivity. Multiplex Annapurna and Surabi are natural organic fertilizers which provide most nutrients required by plants besides improving soil quality with natural micro-organism environment (Savic, 2012).

This study was conducted with the objective to compare the effects of chemical fertilizer, FYM, and bio-fertilizers on growth and yield of okra crop. The study is also an attempt to create awareness on the use of bio-fertilizers for sustainable farming and to promote okra as one of the potential vegetable crops in the Bhutanese farming system.

Materials and Method

Study site

The experiment was conducted in the agriculture farm of the College of Natural Resources in Lobesa in between June to September, 2014. The experiment site is located approximately at 1480 metre above sea level. Temperature of the site ranges between a maximum mean of 23.2 °C to minimum mean of 9.9 °C with an average of 17.7 °C. The site receives an annual precipitation of 883 mm. Soil type is sandy clay and the vegetation primarily consists of dry shrubs and chirpine (*Pinus roxburghii* Sarg.) trees.

Experimental design and treatments

An experiment with a Randomized Complete Block Design (RCBD) with five treatments and four replications was conducted. The experiment spanned over a total area of 90 m^2 comprising of 20 plots. Plot size was 4.5 m^2 (3 x 1.5 m). Each plot accommodated 32 plants with a planting distance of 0.30 m (plant to plant) and 0.45 m (row to row). The fertilizer treatments and application rates were i) Control – no inputs, ii) Multiplex Annapurna – 133.43 g per plot (297 kg ha^{-1}), iii) Spic Surabi – 133.43 g per plot (297 kg ha^{-1}), and iv) FYM – 3.89 kg per plot (4,000 kg DM ha^{-1} FYM). Chemical fertilizer rates were, Urea (basal application) – 144.49 g N per plot, Urea (top dressing) – 72.51 g N per plot, Single superphosphate (SSP), (basal application) – 486 g P per plot, and Muriate of Potash (MOP) (KCL) (basal application) – 72 g K per plot. An additional urea of 30 kg ha^{-1} was applied as a top dressing at 40 days after sowing (DAS).

Data collection

Eight plants from each plot were randomly selected and tagged for measuring growth and yield. The growth parameters were plant height, stem diameter, number of leaves and plant canopy. These parameters were measured at an interval of 42, 54, 66, and 78 DAS. The yield parameters were number of fruits per plant, fresh and dry weight of fruit, fruit length, and fruit diameter. These parameters, along with the number of lateral roots and length of tap root, were measured at the time of harvest. Soil test was done twice, before (pre-test) the cultivation of okra and after harvesting of okra (post-test). Soil samples were randomly collected from 0–30 cm soil depth using soil auger. Soil was tested for soil texture, soil pH – water (1:1.25 soil water suspension), total N (Semi micro Kjeldahl), available P (Bray), available K ($CalCl_2$ extraction), CEC by Ammonium acetate, total OM, and texture by hand.

Data analysis

Data were analyzed using statistics8 (analytical software, 2003). Differences among the treatments were tested using one way ANOVA.

Results and Discussion

Soil nutrients

The total amount of available P and exchangeable K in plots applied with Spic Surabi at harvest were very low (P = 5.36 mg kg^{-1} and K = 37.23 mg kg^{-1}). Low soil nutrient level may be the result of high amount of P and K uptake by plants in plots treated with Spic Surabi, which might have contributed to higher pod yield. Control plots lacked sufficient level of nutrients especially NPK supply during plant growth stages, which resulted in poor plant growth and low yield. The pH levels in plots treated with Spic Surabi, Multiplex Annapurna, and FYM were neutral. However, the plots treated with chemical fertilizer had decreased pH level of 1% leading to soil acidity. The total percentage of C and N level increased in plots treated with Spic Surabi, Multiplex Annapurna, and FYM; whereas the C and N level decreased in chemical and control treatment plots. Comparison of soil test before and at harvest time (Table 1 and Table

2) showed that the bio-fertilizers and FYM contributed in improving the soil pH and total CN ratio compared to that in chemical fertilizer treatment plots.

Akande *et al*. (2010) and Law-Ogbomo (2013) reported that improvement of soil pH was due to enrichment of soil with living micro-organism in the bio-fertilizers, improving the physical and chemical properties of the soil. There was enhanced available P and K uptake by plants during growth and therefore there was depletion of these nutrients in the soil fertilized with Spic Surabi.

Yield of okra

There was a significant effect ($p < .05$) of treatments on pod yield (Figure 1). The overall mean yield was 10.93 t ha^{-1}. Spic Surabi bio-fertilizer gave the highest yield (11.77 t ha^{-1}) followed by chemical fertilizer (11.44 t ha^{-1}), Multiplex Annapurna (11.28 t ha^{-1}), and FYM (10.52 t ha^{-1}). The lowest yield (9.63 t ha^{-1}) was recorded in control plots. The highest pod yield in Spic Surabi could be attributed to high available P and K, which has greater influence on growth, development, and yield. Mal *et al*. (2013) recorded the highest yield of okra in plot treated with bio-fertilizer followed by chemical fertilizers. Chattoo *et al.* (2011) also reported similar results in okra with highest yield from plots treated with organic fertilizer. Spic Surabi bio-fertilizer also enhance yield in cabbage (Yeshi, 2014) and bio-fertilizer is reported to provide high grain yield in rice (Alam and Seth, 2012). These studies reveal that bio-fertilizers give better plant growth and yield.

Table 1. Effect of treatments on soil properties (pH, Carbon, and Nitrogen)

Treatments	Before experiment (2013)			After experiment (2014)		
	pH	C%	N%	pH	C%	N%
Control	6.98	0.93	0.07	7.16	0.6	0.05
Multiplex Annapurna	6.85	0.87	0.1	7.09	0.9	0.08
Spic Surabi	6.75	0.75	0.06	7.07	1	0.11
FYM	6.78	0.88	0.07	7.18	0.85	0.11
Chemical Fertilizer	6.97	0.73	0.06	6.96	0.8	0.1

Table 2. Effect of treatments on soil properties (available Phosphorus and Potassium)

Treatment	Before experiment (2013)		After experiment (2014)	
	P (mg kg^{-1})	K (mg kg^{-1})	P (mg kg^{-1})	K (mg kg^{-1})
Control	18.39	157.78	6.01	76.05
Multiplex Annapurna	33.63	94.37	27.12	67.63
Spic Surabi	31.98	104.95	5.36	37.23
FYM	33.14	119.99	20.88	64.92
Chemical Fertilizer	21.66	140.42	11.77	92.76

Fruit dry matter (t ha^{-1})

The effect of different fertilizers on dry matter accumulation of okra fruit was significant ($p > .05$) (Figure 2). Chemical fertilizer (urea) treated plots gave the highest dry mater accumulation (2.63 t ha^{-1}) and control plots gave the lowest (1.54 t ha^{-1}). High dry matter accumulation in plots treated with chemical fertilizer may be due to more availability of N. Nitrogen has a significant effect on dry matter production and increase in soil fertility results in high dry matter yield (Department of Environment Primary Industries, 2010). The result agrees with that of Galavi

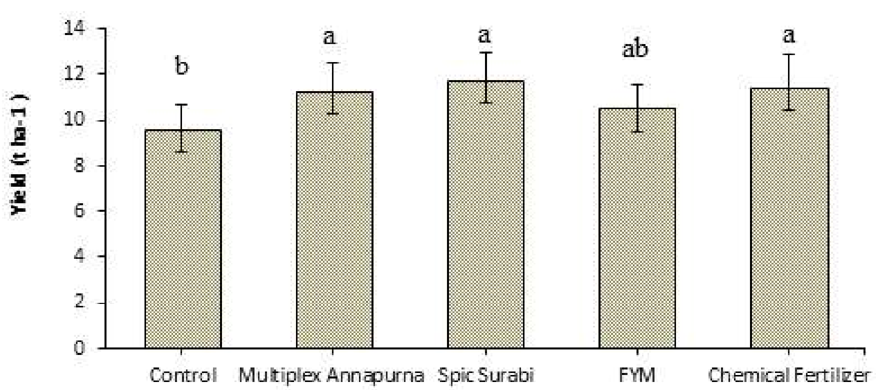

Figure 1. Effect of different fertilizer treatments on fruit yield of okra

et al. (2011) who reported highest dry matter accumulation in maize as a result of chemical and organic fertilizer application. Similar results on okra have also been reported by Omotoso and Shittu (2007) and Akanbi *et al.* (2010).

Fruit number, length, weight and diameter

The number of fruits is a significant factor that indicates the yield of okra. Fertilizer treatment had significant effect on the number of fruits per plant (Table 3) compared to no significant difference amongst chemical fertilizer, FYM, and bio-fertilizers. Highest number of fruit per plant (10.5) was found in plots treated with chemical fertilizer followed by Spic Surabi (10.09), Multiplex Annapurna (9.93), and control plots (7.87). The result agrees with those of Menash (2013) and Akande *et al*. (2010) who obtained highest number of fruit per plant from chemical and bio-fertilizer application over control treatment. There was no significant difference ($p >$ .05) in number of fruit per plant between chemical and bio-fertilizers.

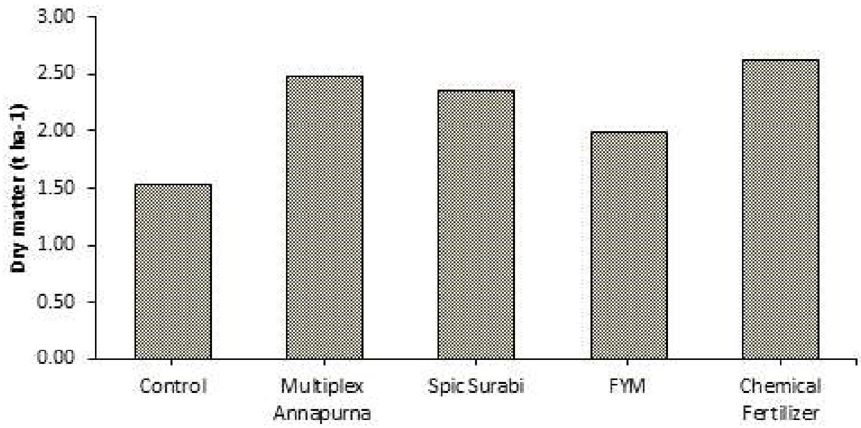

Figure 2. Effect of different fertilizer treatments on fruit dry matter

There was no significant difference ($p > .05$) in fruit length among the treatments (Table 3). Overall mean fruit length was 18.03 cm. The longest fruit length (18.80 cm) was in plot applied with Spic Surabi and the shortest (17.33 cm) in FYM plot. Long fruit length contributed to high fruit weight and yield, which could be due to increased available P and exchangeable K in Spic Surabi (Table 2). The result is in agreement with that of Ukai *et al*. (2013) who reported that there was no significant difference in fruit length of eggplant treated with chemical fertilizers, bio-fertilizers, and FYM.

Fruit diameter and fresh weight per plant differed significantly among the treatments (Table 3). Chemical fertilizer application produced bigger fruit (17.26 mm) followed by Multiplex Annapurna (16.02 mm), Spic Surabi (15.56 mm), FYM (13.93 mm), and the smallest fruit size was recorded in control treatment (13.19 mm). However, the result showed that there was no significant difference on fruit size among the fertilizer treatments ($p < .05$). Highest mean fresh weight of individual fruit was found in Spic Surabi (34.82 g) and lowest in control (28.42 g). Higher number of fruits of bigger size and weight in bio-fertilizers, Spic Surabi and Multiplex Annapurna could be attributed to enhanced uptake of essential plant nutrients including NPK in bio-fertilizer, which contributes to growth and formation of fruits. Subrahmanvam *et al.* (2011) reported greater number of fruits per plant, fruit diameter, and total yield when okra plants were treated with bio-fertilizer and organic fertilizer. Saeed *et al*. (2015) obtained maximum fruit weight and size of tomato under bio-fertilizer than chemical fertilizer application. Similar results were also reported by Isfahani and Besharati (2012) for cucumber.

Table 3. Effect of different fertilizer treatments on yield components of okra

Treatments	No. of fruits/plant	Fruit length (cm)	Fruit dia. (mm)	Fruit wt. (g)
Control	7.87^{b}	18.45	13.191^{c}	28.42^{b}
Multiplex Annapurna	9.93^{a}	17.96	16.02^{ab}	31.22^{ab}
Spic Surabi	10.09^{a}	18.80	15.56^{ab}	34.82^{a}
FYM	9.43^{a}	17.33	13.93^{bc}	31.05^{ab}
Chemical Fertilizer	10.56^{a}	17.63	17.26^{a}	33.16^{ab}
Significance	**	*ns*	*	*
CV (%)	20.72	23	22.8	25.5

* = significant at $p < .05$, ** = significant at $p > .01$, *ns* = not significant

Plant height

Fertilizer treatment had a significant effect on plant height ($p < .05$) (Table 4). Plots treated with chemical fertilizer produced the tallest plants. However, at 78 DAS, the plants were tallest in plots applied with Multiplex Annapurna. The shortest plant height was recorded in control. The tallest plants under chemical fertilizer application could be due chemical fertilizers containing plant nutrients in soluble form which are readily available to plants, whereas in bio-fertilizers release of plant nutrients is slower (Akande *et al*. 2010). Bio-fertilizers release N and P at later stages of plant growth when compared with chemical fertilizers. Similar results were reported by Baharvand *et al*. (2014) on corn cultivars. Plant growth performance is better at initial stage under the application of chemical fertilizers, but at later stages the growth performance picks up with bio-fertilizers (Alam and Seth, 2012). This might explain why plants applied with Multiplex Annapurna were taller at 78 DAS.

Table 4. Effect of different fertilizer treatments on plant height (cm)

	Plant height Days After Sowing (DAS)			
Treatments	42	54	66	78
Control	33.45^{b}	71.75^{c}	134.19^{a}	159.92^{b}
Multiplex Annapurna	34.06^{b}	73.25b^{c}	137.05^{a}	173.89^{a}
Spic Surabi	32.93^{b}	74.75b^{c}	133.56^{a}	172.86^{a}
FYM	38.03^{a}	76.47^{b}	134.91^{a}	168.94^{a}
Chemical Fertilizer	40.34^{a}	83.96^{a}	140.28^{a}	173.19^{a}
Significance	**	**	*ns*	*
CV (%)	20.5	11.32	11.38	9.15

* = Significant at $p < .05$, ** = Significant at $p < .01$, *ns* = not significant

Stem diameter

There was a significant effect of fertilizer treatment on stem diameter (Figure 4). At 54 and 66 DAS the biggest stem diameter was observed in plots applied with FYM (16.07 mm and 16.98 mm) and the smallest was observed in control (14.63 mm and 14.75 mm). At 78 DAS, the biggest stem diameter was observed in Spic Surabi (18.44 mm) and the smallest was in control (17.25 mm). At the later stages of plant growth, bigger stem diameter was observed in bio-fertilizer and FYM treated plots. This result is in agreement with those of Ukai *et al*. (2013) who reported that mineral fertilizer, bio-fertilizer, cow dung, and poultry droppings improve stem diameter of okra.

Number of leaves

Effect of fertilizer treatment on leaves number is presented in Table 5. Fertilizer treatment had a significant effect on the number of leaves ($p < .05$), where the total number of leaves per plant ranged from 9.96 to 12.59 at 42 DAS, 14.16 to 18.35 at 54 DAS, 21.12 to 25.12 at 66 DAS, and 26.93 to 30.59 at 78 DAS. Maximum number of leaves was recorded in plots treated with chemical fertilizer (30.59) in all four stages of plant growth. Lowest leaves number was in control plots (26.93). The number of leaves increased with growth and development of plants peaking at about 26-30 per plant. According to Ansari and Sukhraj (2010), higher amount of nitrogen in

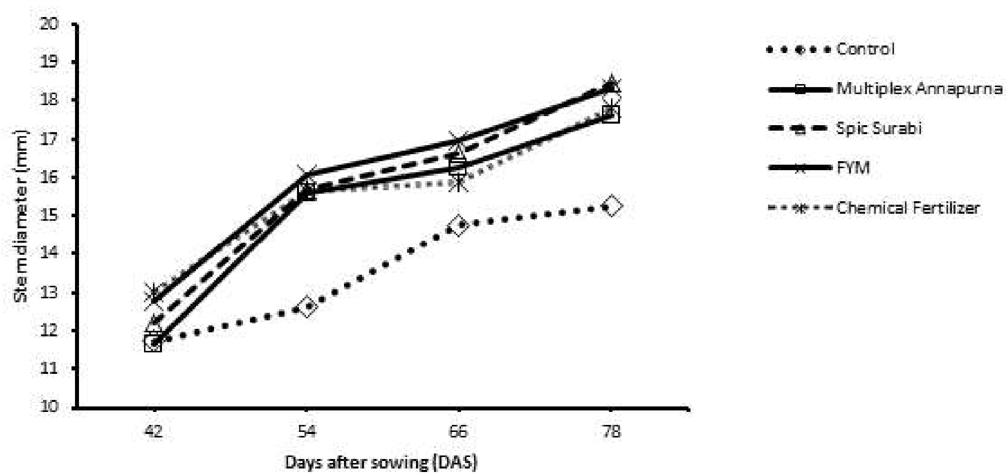

Figure 4. Effect of different fertilizer treatments on Stem Diameter at different stages of plant growth

chemical fertilizers results in maximum numbers of leaves and rapid growth of plant. However, there was no significant difference between chemical and bio-fertilizers at the later stages of plant growth in this study. This may be because of the mobilization and release of nutrients at later stages by bio-fertilizers.

Table 5. Effect of different fertilizer treatments on number of leaves

Treatments	Days After Sowing (DAS)			
	42	54	66	78
	No. of leaves	No. of leaves	No. of leaves	No. of leaves
Control	10.46^{bc}	14.16^{c}	21.12^{b}	26.93^{b}
Multiplex Annapurna	9.96^{c}	16.23^{b}	23.81^{a}	29.31^{a}
Spic Surabi	10.96^{bc}	18.35^{a}	25.12^{a}	30.15^{a}
FYM	11.21^{b}	17.07^{ab}	23.65^{a}	29.90^{a}
Chemical Fertilizer	12.59^{a}	17.57^{ab}	25.00^{a}	30.59^{a}
Significance	*	**	*	*
CV(%)	19.8	20.57	15.4	11.78

* = Significant at $p < .05$, ** = Significant at $p < .01$

Conclusion

Fertilizer treatments improved the growth and yield of okra. However, Spic Surabi gives better results among the fertilizers tested and should be promoted in extension programmes. The okra crop performed well when Spic Surabi is applied at the rate of 296 kg ha^{-1}. Bio-fertilizers are readily available and are environment friendly therefore awareness on their use in vegetable crops should be initiated. A future research is recommended to investigate chemical composition of okra fruits for medicinal value and health benefits, resulting from organic production.

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