Original Research Article

Studies on Foliar Application of Bio-enhancers and Nano-fertilizers on Red Okra (*Abelmoschus esculentus* L.)

ABSTRACT

Horticultural crops are confined to various climate and environmental conditions that influence their whole life cycle and their activities. Providing proper amount of relevant nutrients is also a factor from them. One major vegetable crop of India is okra that is grown on large area. In this study, a field experiment conducted on red okra during summer season 2023 at Experimental Farm, Kharora, Mata Gujri College, Sri Fatehgarh Sahib, Punjab, India to "Studies on Foliar Application of Bio-enhancers and Nano-fertilizers on Red Okra (*Abelmoschus esculentus* L.)" under Randomized Block Design and plants were treated with various treatments. The investigation found superior results from the treatment T6 (Nano Urea @0.4% + Panchagavya @3%) in which crop response best toward growth attributes like plant height (121.40 cm), number of secondary branches plant^{-1} (31.01), and harvest duration (41.57) while, minimum number of days were recorded days to first flowering (47.27), days to first fruiting (50.67) and days to first picking (53.13). Treatment T6 showed significant results among the yield parameters such as pod weight (9.74 g), pod yield (9.82 q ha^{-1}), length of pod (10.44 cm), pod diameter (1.89 cm), number of pods plant^{-1} (18.44), biological yield (18.82 kg ha^{-1}) and harvest index (52.63%). Moreover, plants represent best in yield that results in higher B:C ratio (2.94) and net retuns (₹ 399286.93 ha^{-1}) respectively.

Comment [1]: Not necessary

Keywords: High Yield, Jivamrita, Nano Urea, Panchgavya, Red Okra

1. INTRODUCTION

Red okra or Lady finger (*Abelmoschus esculentus* L.) is an annual, fast growing, erect, herbaceous plant cultivated as vegetable crop throughout the world. It is originated from Ethiopia (Naveed *et al.* 2009 and Simmone *et al.* 2009). It belongs to family Malvaceae or also known as mallow family. Okra holds highest chromosome no. (2n=130) among the vegetable crops. It is commonly known as bhindi or bhendi in India, gumbo in United States of America, ochoro in South eastern parts of Asia. This crop demands a long warm and humid climate. Seeds of okra fail to germinate if temperature goes below 20 °C and optimum temperature for seed germination is 29 °C (Anonymous, 2021). India ranks on 1st position for production of okra in the world (Anonymous, 2023).

Abelmoschus esculentus L. is a rich source of numerous of nutrients. It is consumed as raw vegetable, used as salads, soups and stews, fresh or dried, boiled or fried (Ndunguru and Rajabu, 2004). In contrast of nutrients, lady finger contains mucilage content which is thick and slimy substance found in fresh as well as dried pods. After cutting the pod, gummy liquid appears in form of mucilage. Mucilage has some medicinal properties, includes the use as a serum albumin (Miller *et al.*, 1993), as tablet binder (Ofoefule *et al.*, 2001) and also used in Asian medicines as a protective food additive against irritating and inflammatory gastric diseases (Lengsfelf *et al.*, 2004).

Colour of red okra is due to the presence of anthocyanin and phenolics (Anonymous, 2018). Anthocyanins are pigments present in vascular parts of plants. It possess antidiabetic,

anticancerous, anti-inflammatory, antimicrobial and anti-obesity and also prevention of cardiovascular diseases (Khoo *et al.*, 2017).

Bio-enhancers are the organic manures, it is the bio-products in powder or liquid form. Best replacement as fertilizers against chemical fertilizers, if used at proper rate and proper time. Organic fertilizers have dual benefits, it increases the productivity of soil as well as crop productivity. Commonly bio enhancers are the active fermentation of residues of plant materials and animals waste which are major source of microbial consortia, macronutrients (NPK), micronutrients and plant growth promoting substances including immunity enhancers (Pathak and Ram, 2013). A single Indian cow dung and cow urine is enough to meet 12 hectares of land for organic cultivation (Aulakh *et al.*, 2013).

Panchagavya, a bio-enhancer which is a mixture of five ingredients of cow waste *viz*. cow dung, cow urine, cow curd, cow ghee and cow milk. Additionally, jaggery and ripened banana also added. These ingredients are properly mixed and kept covered for 30 days period and thereafter it is ready as fermented solution which has positive impact on crops. Mixture stirred twice in a day as clock and anticlockwise for 15 minutes everyday. The prepared product is rich in plant growth nutrients *viz*. gibberellins, auxins and microbial fauna and it acts as tonic to enrich soil, induce vigour in plant with production of good quality yield (Swarnam *et al.*, 2016 and Natrajan, 2003). The effective micro organisms in panchagavya are the mixed solution of naturally occurring beneficial microbes, mostly lactic acid bacteria (*Lactobacillus*), yeast (*Saccharomyces*), actinomycetes (*Streptomyces*), photosynthetic bacteria (*Rhodopsuedomonas*) and certain fungi (*Aspergillus*), some of which are nitrogen fixers and some of them are phosphorus solubilizers (Sreenivasa *et al.*, 2011), considered as an ideal organic growth promoter (Pathak and Ram, 2013).

Jivamrita is a liquid bio-enhancer, made up of organic waste material such as cow dung, urine, jaggery, pulse flour and virgin soil. Prepration of bio formulation done within 5-7 days period, that requires stiring thrice a day in clockwise direction. It helps to enhance the microbial activities in the soil and increase in population of microorganisms (Borairah *et al.*, 2017).

Nano-fertilizers are the nanotechnology based chemical fertilizers which are available in market in the form of liquid nano sized particles. It is a new approach for sustainable agriculture in modern era with efficient use of per drop of fertilizer. Nano-fertilizers are extremely soluble, provided in precise concentration and slow release of nutrients due to greater surface area. Nano urea is a nano-fertilizer which fulfill the nitrogen requirement of the plants. It has been notified under Fertilizer Control Order, 1985 (FCO, 1985) Government of India. As per specifications of IFFCO Nano urea – liquid, the particle size is less than 100 nm. It contains 4% N and has a shelf-life of about 2 years. India has become the first country which globally starts commercial production of Nano Urea (Lakshman *et al.*, 2022). With the help of nano urea, the reduction of carbon footprints upto 50 % (IFFCO). Nano urea performs smart delivery system means it performs action on specific area due to its high surface area as well as high absorption rates (Kumar *et al.* 2021). Nano nitrogen improves metabolic activities in plant results in more apical growth and increase in photosynthetic area (Lakshman *et al.* 2022).

The objective of this study is to investigate the effect of bio-enhancers and nano-fertilizers on growth, yield and fruit quality of red okra and to compute the economics of different treatments applied to crop.

2. MATERIALS AND METHODS

The experiment was successfully conducted at Experimental Farm, Mata Gujri College, Kharora, District Sri Fatehgarh Sahib, Punjab, India during summer season 2023. The experimental site falls in south eastern part of Punjab at an elevation of 246 m above from the sea level at 76°- 24' 15.8184'' E East longitude and 30°- 33' 45.18 N'' North latitudes. Number of soil samples were collected randomly from different spots at a depth of 15 cm before laying out an experiment. The texture of soil was sandy loam estimated using (Piper, 1996) with a pH value (7.8) neutral to slightly basic soil calculated using (Jackson, 1973). The experiment was laid out in Randomized Block Design (RBD) consists of nine treatments with three replications was represented in table .1. The dimensions of each plot size were measured as 2.4 m×2.4 m. Sowing was done manually on 24th February, 2023 with spacing of 45×15 cm. The cultivar used was Kashi Lalima (VROR-157) which was purchased from Indian Institute of Vegetable Research, Varanasi, Uttar Pradesh, India. Package of practices for vegetable crops was followed as per the recommendations of Punjab Agricultural University, Ludhiana, Punjab, India. All the intercultural operations was done manually according to need such as weeding, hoeing and pruning of damaged plants. Crop was irrigated at 10-12 days period during the growing season.

2.1 Panchgavya

Panchgavya used on experimental site was prepared manually at experimental site. Initially fresh cow dung @1.5kg and cow ghee @1.5kg and mix thoroughly. Then, add fresh cow urine @1.5 l along with 5 l of water. By mixing all the ingredients properly, allowed for fermentation process and daily stirring twice in both clock and anti clockwise and add cow milk @1 l along with 6 bananas and stirred for 1 month to decompose properly. The dose of panchgavya @3% was used to treat the plots at 30, 45 and 60 days of sowing. Solution of panchgavya @3% was made by mixing of 30 ml of panchgavya in 1000 ml of water.

Table .1 Detail of Treatments

Treatment	Treatments Combination
T0	Control
T1	Nano Urea @0.2%
T2	Nano Urea @0.4%
T3	Panchgavya @3%
T4	Jivamrita @10%
T5	Nano Urea @0.2% + Panchgavya @3%
T6	Nano Urea @0.4% + Panchgavya @3%
T7	Nano Urea @0.2% + Jivamrita @10%
T8	Nano Urea @0.4% + Jivamrita @10%

2.2 Jivamrita

Jivamrita was also prepared on the experimental site manually. In this procedure fresh cow dung @10 kg along with cow urine @10 l mixed with jaggery solution properly. Then pulse flour @2kg was mixed in solution with @1kg live soil. Daily stir twice and kept for fermentation for 7 days and solution is ready to use. The dose of Jivamrita @10% was used in treatment as foliar application at 30, 45 and 60 days after sowing. Jivamrita solution was formed by mixing 100 ml of Jivamrita in 1000 ml of water.

2.3 Nano-urea

IFFCO nano urea bottle was purchased from local market and dose used @0.2% and @0.4% respectively to treat the plots at 30, 45 and 60 days after sowing. Solution was prepared @0.2% and @0.4% by mixing 2 ml and 4 ml of nano urea in 1000 ml of water.

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

3.1.1 Days to first flowering

The data recorded from various treatments shows significant effect on days to first flowering showed minimum number of (47.27 days) to first flower emerge in the T6 treated plot and represented in table 2. This may be due to formation of florigen which promotes early flowering in plants (Swain *et al.*, 2015). Additionally, nano urea also impact flowering by providing strength to plant and results in flower emergence (Midde *et al.*, 2022). Similar observations were recorded by Gunasekar *et al.* (2018), Yadav *et al.* (2019) and Panda *et al.* (2020).

3.1.2. Days to first fruiting

Number of days to first fruiting was recorded minimum in T6 that was (50.67 days) represented in table 2 Such observation might be due to nano nitrogen application it plays role in flowering as well as fruit setting in plant by fulfill the needs of carbohydrates that are necessary for flower bud formation to complete fertilization (Davarpanah *et al.*, 2017). Similar results were found by (Chauhan and Deepanshu, 2023) in chilli.

3.1.3 Number of secondary branches plant^{-1}

Observed data revealed that the maximum number of secondary branches plant^{-1} were recorded in T6 at 60 and 90 days that was (11.31) and (31.01) and represented in table 2. It might be attributed by panchgavya due to activation of cell division and cell elongation in the axilliary buds that promotes the branches (Patel *et al.*, 2013). Nano urea impacts on branch formation due to its slow release action and complete the nutritional needs of plant. Similar findings were observed by Sridhar *et al.* (2001), Alagesan *et al.* (2009) Swain *et al.* (2015) and Mahmoodi *et al.* (2018).

3.1.4 Number of leaves plant^{-1}

The maximum number of leaves plant^{-1} (17.70) and (33.93) was recorded in T6 at 60 and 90 days, respectively which is represented in table 2 This might be due to hormonal effects produced by panchgavya on plant health. Similar findings were observed by Sridhar *et al.* (2001), Alagesan *et al.* (2009), Gopakkali and Sharanappa (2014), and (Madhvi *et al.*, 2022).

3.1.5 Plant height (cm)

Data recorded on plant height show significant results at 60 and 90 days that was (71.56 cm) and (121.40 cm) respectively and represented in table 3 Increase in plant height may be due to panchgavya that contains essential plant growth regulators such as auxin which promotes the plant height while nano urea helps to target delivery of required nutrient that enhanced the plant growth and development. Similar findings were observed by Kumar *et al.* (2011), Rakesh *et al.* (2017), Arivazhagan *et al.* (2019), Midde *et al.* (2022) and Subramani *et al.* (2023).

3.1.6 Days to first Picking

Days to first picking showed significant effect of various treatments and results revealed that minimum days to first picking (53.13 days) was recorded in the treatment T6 and represented in table 3. Number of days to first picking may be due to early flowering in plants that influence the fruiting period by nano urea as well as panchgavya increased the cytokinin and auxin formation in plants that results in fruit formation and early picking of pods. Similar findings were observed by Parmar *et al.* (2020) and Chauhan and Deepanshu (2023).

3.1.7. Harvest Duration (days)

The data recorded on harvest duration was significantly recorded maximum in T6 that was (41.67 days) and represented in table 3.. This was due to more number of harvesting given by a plant in its lifecycle. Similar findings were observed by Parmar *et al.* (2020).

Table 2 Growth parameters of red okra

Treatments	Days to first flowering	Days to first fruiting	Number of secondary branches Plant^{-1}			Number of leaves plant^{-1}		
			At 30 days	At 60 days	At 90 days	At 30 days	At 60 days	At 90 days
T0	55.93	59.50	3.43	5.14	23.47	3.20	10.33	22.40
T1	53.47	57.23	3.20	6.93	25.81	4.60	12.13	25.80
T2	51.23	55.85	3.57	7.23	27.53	4.50	12.80	26.20
T3	52.61	56.51	3.47	7.05	26.77	3.80	12.60	25.73
T4	54.33	58.92	3.20	6.07	24.53	3.80	12.07	25.40
T5	49.43	52.75	2.97	10.53	30.33	2.93	16.87	30.97
T6	47.27	50.67	2.91	11.31	31.01	3.13	17.70	33.93
T7	51.11	55.22	3.83	8.97	28.80	3.43	14.50	27.13
T8	50.10	54.33	3.70	9.70	29.53	3.90	15.80	29.27
SEm (±)	0.97	0.76	NS	0.30	0.67	NS	0.61	1.00
$CD_{(0.05)}$	2.91	2.29		0.89	2.02		1.84	2.99

Comment [2]: T2 and T3 are non significant please check data properly for others too

Table 3. Growth parameters of red okra

Treatments	Plant height (cm)			Days to first picking	Harvest duration (days)
	At 30 days	At 60 days	At 90 days		
T0	8.07	40.43	73.21	61.90	35.00
T1	7.63	53.44	82.31	61.05	37.33
T2	8.24	56.10	90.12	59.57	37.67
T3	6.46	54.77	86.46	60.45	39.33
T4	3.44	52.25	79.55	58.33	37.67
T5	5.75	70.32	112.78	55.50	40.33
T6	6.73	71.56	121.40	53.13	41.67
T7	4.09	66.47	95.06	58.26	38.00
T8	6.48	68.44	103.38	56.01	38.67
SEm (±)	NS	1.37	1.40	0.91	0.45
$CD_{(0.05)}$		4.10	4.21	2.74	1.36

Comment [3]: T4 and t7 are NS, interpret properly

3.2 Yield Parameters

3.2.1 Average pod length (cm)

The maximum length of pods (cm) was found in T6 treated plots in which average value of pods was (10.44 cm) recorded and represented in table 4. Increase in length of pods might be due to nano urea it helps to stretch and built the strength of cell walls that is beneficial for fruit to shape modification. Panchgavya application helps in growth due to hormonal production. Similar results were found by Panda *et al.* (2020), Subramani *et al.* (2023) and Balyan *et al.* (2024).

3.2.2 Average pod diameter (cm)

Average pod diameter (cm) recorded maximum in T6 that was (1.89 cm) shown in table 4 which may be resulted by impact of nano urea on enzymatic activity which is responsible for synthesis of organic acids and convert the energy for fruit growth and development. Similar results were found by Panda *et al.* (2020) and Meena *et al.* (2023).

3.2.3 Average pod weight (g)

The data pertaining to average pod weight (g) was significantly influenced by T6 treated plot that showed maximum weight (9.74 g) and represented in table 4 The effect of panchgavya on pod weight due to increased translocation of photosynthetic activity to economic parts which was due to more chlorophyll formation that is responsible for translocation of more number of carbohydrate towards fruit (Yadav *et al*., 2019). While nano urea helps to increase pod weight due to availability of nitrogen which is responsible for growth of plant parts. Similar results were found by Vennila and Jayanthi (2008), Adeyeye *et al.* (2017), Davarpanah *et al.* (2017), Devanda *et al.* (2021) and Madhvi *et al.* (2022).

3.2.4 Number of pods plant^{-1}

Data recorded on number of pods plant^{-1} showed significant results with application of T6 that was (18.44) respectively and shown in table 4. Such observation may be due application of panchgavya that accumulates the cytokinins and auxin in plants which may produce more number of fruits plant^{-1} (Swain *et al*., 2015). Nano urea responds to cell growth due to better absorption that leads to accumulation and translocation of nutrients to whole plant. Similar findings were observed by Vennila and Jayanthi (2008), Kumawat *et al.* (2011), Bhawariya *et al.* (2022) and Mirji *et al.* (2023).

3.2.5 Pod yield

The superior results for pod yield was found in treatment T6 in which maximum pod yield (130.99 g plant^{-1}), (9.82 kg plot^{-1}) and (174.59 q ha^{-1}) recorded and represented in table 4. It is reported that yield of plant may be effected due to panchgavya that increase photosynthetic activity which results in better source-sink relationship (Swain *et al*., 2015) while nano urea helps to proper photosynthesis accumulation and increased microbial activity which helps the plant to gives more yield (Sharada and Sujathamma 2018). Similar findings were observed by Swaminathan *et al.* (2007), Padmapriya *et al.* (2008), Shivaprasad and Chittapur (2009), (Lekshmi *et al*., 2022) and (Ojha *et al.*, 2023).

3.2.7 Biological yield

Biological yield was recorded maximum under the treatment T6 in which data showed (18.82 kg plot^{-1}) respectively and shown in table 4. This may be affected due to easy translocation of nutrients and growth regulators such as IAA and Ga to plants by foliar application of panchgavya (Choudhary *et al.*, 2017). Similar findings were observed by Kumawat *et al.* (2013).

3.2.8 Harvest index (%)

The data recorded showed maximum harvest index (52.63%) in the treatment T6 and represented in table 5. The harvest index obtained with the help of panchgavya efficiency to increase photosynthesis and there hormonal features and nano nitrogen improves the transportation due to need based supply trough foliar application. Similar findings were observed by Shivaprasad and Chittapur (2009), Midde *et al.* (2022) and Reddy *et al.* (2022).

Table 4 Yield Parameters of red okra

Treatments	Average Pod length (cm)	Average Pod Diameter (cm)	Average. Pod Weight (g)	No. of Pods Plant^{-1}
T0	7.40	1.37	6.45	12.30
T1	8.12	1.61	6.69	14.64
T2	9.47	1.67	7.40	15.38
T3	8.49	1.62	7.15	14.96
T4	7.61	1.53	6.68	13.95
T5	9.90	1.78	9.19	18.10
T6	10.44	1.89	9.74	18.44
T7	9.34	1.68	7.72	16.11
T8	9.71	1.70	8.10	17.46
SEm (±)	0.31	0.04	0.27	0.66
$CD_{(0.05)}$	0.93	0.11	0.80	1.98

Table 5 Yield Parameters of red okra

Treatments	Pod Yield (g plant^{-1})	Pod Yield (kg plot^{-1})	Pod Yield (q ha^{-1})	Biological Yield (kg plot^{-1})	Harvest Index (%)
T0	82.45	6.18	109.92	16.79	37.10
T1	100.01	7.49	132.94	16.97	44.17
T2	110.61	8.29	147.50	17.20	48.22
T3	108.04	8.10	144.13	17.08	47.45
T4	94.94	7.12	126.58	16.93	41.95
T5	127.14	9.53	169.88	18.70	50.95
T6	130.99	9.82	174.59	18.82	52.63
T7	115.59	8.66	154.09	17.61	49.19
T8	121.09	9.11	161.46	17.78	50.82
SEm (±)	1.38	0.28	1.66	0.12	0.67
$CD_{(0.05)}$	4.14	0.85	4.97	0.36	2.01

3.3 Economic Parameters

Among all the parameters there is one important parameter of economic value of crop in market. The red okra pods were sold in market with gross returns (₹ 523770.83 ha^{-1}) and cost of cultivation (₹ 135501.17 ha^{-1}). Total net returns (₹ 399286.93 ha^{-1}) was recorded maximum in treatment T6 and the highest benefit: cost ratio (2.94) was also acquired in the treatment T6. While in case of T0 it was recorded minimum amount of net returns (₹ 206992.24 ha^{-1}) as compare to T6 represented in table 6

Table 6 Economic Parameters of red okra

Treatments	Cost of Cultivation (₹ ha^{-1})	Gross Income (₹ ha^{-1})	Net Returns (₹ ha^{-1})	Benefit: Cost ratio
T0	121102.88	329760.12	206992.24	1.70 (R.D.F)
T1	123552.63	398820.37	275602.74	2.23
T2	127002.39	442500.61	318830.22	2.51
T3	129600.95	432390.05	308806.10	2.38
T4	125586.96	379740.04	255982.08	2.03
T5	134050.66	509640.34	385606.68	2.87
T6	135501.17	523770.83	399286.83	2.94
T7	131036.81	462270.19	338062.38	2.57
T8	131486.59	484380.41	359722.82	2.73

4. CONCLUSION

From the above study, it is suggested that treatment T6 was suggested for cultivation at farmer field due to higher net returns as well as higher B:C ratio. It is beneficial to reduce the nitrogen losses in environment and to maintain ecological balance with site specific nitrogen management. Additionally, adoption of home based products such as panchgavya that is a boon for organic production of vegetable crops with minimal charges.

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Comment [4]: Maintain the format

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