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EFFECT OF NUTRIENT MANAGEMENT PRACTICES ON OKRA (*ABELMOSCHUS ESCULENTUS* L.) UNDER A BAEL-BASED AGRI-HORTI SYSTEM IN SEMI-ARID EASTERN PLAIN ZONE OF UTTAR PRADESH INDIA

Biswapriya Mallik[1*], J. S. Bohra[2], Akash Ghosh[1], Meghnath Pan[1], Debabrati Roy[3] and Somava Mondal[4]
[1]Department of Agronomy, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal (741 252) India
[2]Department of Agronomy, Banaras Hindu University, Varanasi, Uttar Pradesh (221 005) India
[3]Department of Agricultural Entomology, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal (741 252) India
[4]Department of Horticulture, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal (741 252) India
*Corresponding author E-mail: dattamallik@gmail.com
ORCID: 0009-0003-7783-5612
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ABSTRACT

The present investigation was conducted during the *spring* season (February) of 2021 at the Agricultural Research Farm of the Rajiv Gandhi South Campus, Banaras Hindu University, Uttar Pradesh. The study aimed to examine the effect of in nutrient management on okra grown under a bael-based agri-horti system. The experiment was laid out in a Randomized Block Design with three replications where treatments were comprised at 100 % and 75 % recommended dose of inorganic fertilizer separately along with different sources and quantity of organic fertilizer like vermicompost at 2.5 t ha^{-1}; poultry manure at 2.5t ha^{-1} and FYM at 5t ha^{-1}, respectively with eight different combinations. The growth of 'Okra' was significantly influenced by the different nutrient management practices. Specifically, significantly higher dry matter production was observed when 75% RDF was combined with either 2.5 t ha^{-1} of vermicompost, 2.5 t ha^{-1} of poultry manure, or 5 t ha^{-1} of FYM. The maximum number of fruits and fruit yield $plant^{-1}$, along with the highest overall fruit yield (t ha^{-1}), was recorded with 100% RDF+2.5 t ha^{-1} of vermicompost. Overall, integrating the three organic manures (vermicompost, poultry manure, and FYM) with both 75% and 100% RDF proved more effective than the sole application of inorganic fertilizers. For achieving higher yield and profit, application of 100% RDF+ 2.5 t ha^{-1} of vermicompost was proved to be better under a bael-based agri-horti system in the Vindhyan region of India.
***Key words*: RDF, FYM, vermicompost, poultry manure, okra, agri-horti system, yield, economics.**

Introduction

Agroforestry is a method of managing land that intentionally combines trees or other long-lived woody plants with traditional crop cultivation or livestock raising. Agroforestry systems (AFS) prioritize resource-efficient and environmentally responsible agricultural methods to promote both higher productivity and greater environmental sustainability on a local, small-scale farming level (Anonymous., 2022). The system also offers substantial environmental advantages, including fostering a better local microclimate, reducing nutrient loss, minimizing soil erosion and improved water retention, ultimately strengthening the farm's productive potential (Muhie., 2022). The Bael (*Aegle marmelos*) is valued as a medicinal plant. The fruit is packed with nutrients, including various minerals (such as phosphorus, potassium, calcium, and iron), fiber (like pectin, cellulose, hemi-cellulose), protein, carbohydrates, fats, and essential vitamins. It also contains numerous vital amino acids (e.g., threonine, methionine, valine, lysine) and fatty acids (Sharma *et al*., 2022). The presence of bioactive compounds, including polyphenols, flavonoids, alkaloids, and carotenoids, is linked to a host of health benefits, such as antioxidant, antimicrobial, antidiabetic, anti-ulcerative, and anti-cancer effects, in addition to providing cardioprotective, gastroprotective, and hepatoprotective properties (Jagetia *et al*., 2023). Okra (*Abelmoschus esculentus* L.) is highly valued for both its versatility in cuisine and its nutritional content, making it a worthy addition to the diet (Anonymous., 2023). This value is reflected in global agriculture; in 2023, worldwide harvest volumes surpassed 9.96 mt, driven by major contributions from India (6.18 mt), USA and Nigeria, which highlights its status as an essential staple vegetable (Anonymous, 2023). The primary macronutrients like nitrogen, phosphorus, and potassium are required for okra to achieve optimal growth and maximize their harvest. In any agricultural setting, plants naturally compete for essential resources such as sunlight, physical space, and soil nutrients across varying climatic conditions. To alleviate nutrient shortages, the application of fertilizers becomes necessary. Strategic management of these inputs is key to maximizing the overall production density obtained from a specific unit of land (Singh *et al*., 2012). Vermicompost serves a dual role by both promoting and safeguarding plant growth. Additionally, vermicompost significantly enhances the physical attributes of soil and provides elevated concentrations of readily accessible essential nutrients. These components collectively influence plant growth and yield in a manner comparable to synthetic inorganic soil fertilizers (Singh *et al*., 2008). Poultry manure represents an excellent organic resource, offering a viable substitute for synthetic chemical fertilizers and shown to significantly boost soil fertility (Shanti *et al*., 2015). Poultry manure increased soil nitrogen content by more than 53%, moving from 0.09% to 0.14%, and also enhanced exchangeable cation levels (Boateng *et al.*, 2006). Farmyard manure (FYM) directly boosts crop yields by either accelerating respiratory functions, enhancing cell permeability, and stimulating hormonal growth, or by integrating these processes. Moreover, they significantly improve soil physicochemical attributes, a gradual release of nutrients, an elevated cation exchange potential, and enriched soil flora and fauna (Singh *et al*., 2018) including, boosts the soil microbial population, and minimizes nitrogen losses due to its slow-release nutrient profile (Tadesse *et al*., 2013). Mishra *et al*., 2025, observed that intercropping with tree resulted higher height, yield and other growth attributes compared to pure crop cultivation. Integrating inorganic and organic nutrient sources like vermicompost, FYM and chemical fertilizers enhance crop growth and soil health (Sarvade *et al*., 2025). Considering the above fact and findings a balanced strategy utilizing both organic and inorganic nutrient management practices in bael based agroforestry system with okra as a companion crop in agri-horti system for better resource utilization efficiency. Thus, the study aimed to examine the effect of in nutrient management on okra grown under a bael-based agri-horti system.

Materials and Methods

The experiment was carried out during *spring* season (February) of 2021 at the Agricultural Research Farm, Rajiv Gandhi South Campus, Banaras Hindu University, Uttar Pradesh which lies at 25.146° N latitude and 82.569° S longitude, and stands at an elevation of 128.93 m above mean sea level. Geographically, this part falls within Agro-climatic zone III-A, comprised semi-arid eastern plain zone. The experimental soil was sandy loam in texture with organic carbon was 0.33% and available Nitrogen, phosphorus and potassium were 163.12 kg ha^{-1}, 20.34 kg ha^{-1} and 230.47 kg ha$^{-1,}$ respectively. The experiment was conducted in a randomized block design (RBD) with three replications comprising eight number of treatments viz., T_1: 75% RDF, T_2: 100% RDF, T_3:75% RDF+2.5 t ha^{-1} of vermicompost, T_4:75% RDF+2.5 t ha^{-1} of poultry manure, T_5: 75% RDF+5 t ha^{-1} of FYM, T_6: 100% RDF+2.5 t ha^{-1} of vermicompost, T_7:100% RDF+2.5 t ha^{-1} of poultry manure, T_8: 100% RDF+5 t ha^{-1} of FYM.. The variety of okra ‘‘PAN 2199’’ was sown as an intercrop with 60×50 cm^2 spacing in between the spacing of 5×5 m^2 of bael plantation. Ten Plants were chosen from each plot, and the height (in centimeters) between the ground, and the tip of the highest point of the tagged plants was recorded. Dry Matter accumulation in above-ground plant parts using destructive sampling Methods during harvesting time to follow the oven-dry weight method. Number of Branches, leaf length and breadth were counted and measured, respectively, from Ten tagged plants from each treatment. The initial flowering date was noted following the induction of the first flower in a plot and the 50% flower in a plant. Fruit diameter was measured using slide callipers from the 10 tagged plants in each treatment, and fruit length was measured from base to tip. From the ten tagged plants, the number of fruits was counted, and the average value was recorded. Fruit yield, both in individual plants and from net plot area was recorded and was expressed in g plant^{-1} and t ha^{-1}, respectively. Production economics were calculated considering the parameters of gross return, net return, total cost, and finally, the benefit per rupee invested. The subsidiary crop, okra, was cultivated following standard agro-techniques.

Results and Discussion

Crop Growth

The vertical growth of the okra crop showed a continuous upward trend from sowing until maturity. Statistical analysis indicated that applying the full recommended dose of fertilizer (100% RDF) resulted in significantly taller plants compared to the 75% RDF treatment at all recorded intervals (30 DAS, 45 DAS, and at harvest). Regarding Nutrient Management, the addition of organic amendments like vermicompost (2.5 t ha^{-1}), FYM (5 t ha^{-1}) and poultry manure (2.5 t ha^{-1}) proved more effective in promoting plant height when combined with 100% RDF rather than 75% RDF. However, there was no significant statistical difference in performance between the different organic sources themselves at either fertilizer level. Treatment T_6 achieved the highest plant height, while treatment T_1 (75% RDF) recorded the lowest crop growth. These similar finding was corroborated with earlier studies reported by Santhy *et al.*, 2001, which also highlighted the synergistic benefits of combining organic and inorganic nutrient sources. The onset of branching was observed following 30 days after sowing (DAS) and maximum number of branches was recorded in the treatment T_6 which was statistically at par with T_7 and T_8. Compared to applying both organic and inorganic fertilizer, using only inorganic fertilizer resulted in smaller number of branches and organic combination with 100% RDF outperformed the 75% RDF. Number of leaf plant^{-1}, plant length and breadth increased with increasing doses of inorganic fertilizer and it was increased further with the supplementation of organic fertilizers and significantly higher numbers of leaf plant^{-1} was recorded in the treatment T_6 (Table 1) which was statistically on par with T_7 and T_8 but significantly superior to rest of the treatments. The exponential growth of the leaves might be due to uptake of higher nutrients especially, higher nitrogen supplementation also accelerated the process of cell division and differentiation (Barani *et al.*, 2004).

Aerial dry matter accumulation was greatly influenced by nutrient supplementation and increasing rate was observed with incremental doses of inorganic fertilizer. From the Table 1 it was found that dry matter accumulation gradually increased with increasing doses of nutrient supplementation either solely from inorganic sources or in combinations of both organic and inorganic sources. RDF 100% showed the maximum dry matter accumulation to 75% of RDF but the supplementation of organic fertilizer either through vermicompost or FYM or poultry manure further increased the dry matter and higher dry matter was exhibited in the treatment T_6 viz., 100% RDF+2.5 t ha^{-1} Vermicompost which was statistically at par with T_7 (100% RDF+ 2.5 t ha^{-1} poultry manure) and T_8 (100% RDF+5 t ha^{-1} FYM). But all these treatments (T_6, T_7 and T_8) were significantly superior to rest of the treatments. From the above stated results, it was found that higher doses of inorganic fertilizer were beneficial for maximum accumulation of dry matter and its further deviations of doses, decreased the dry matter considerably. Increased dry matter accumulation and subsequent migration from the source to the sink influence the yield attributes which ultimately reflected in yield. This finding was an agreement with the Cai *et al.*, 2001 who stated that two main physiological mechanisms influencing the production of crop yields were dry matter accumulation and partitioning. Treatment T_6 (100% RDF+2.5 t ha^{-1} vermicompost) proved most effective for inducing early flowering, recording the fewest days to reach first flower appearance and 50% flowering. According to Gurjar *et al.*, 2022, the earliest onset of flowering was achieved using 75% RDF+25% vermicompost. This evidence demonstrated that vermicompost played an important role for increasing okra growth.

Yield Attributes

Yield attributes of okra were greatly influenced by nutrient management practices and integrated management of nutrients significantly contribute the yield attributes over sole application of inorganic fertilizer. Data depicted in the Table 2 stated that all yield attributes viz., Fruit length, fruit diameter, number of fruits plant^{-1}, single fruit weight etc. were responded significantly by application of fertilizer (Figure 1). Incremental doses of inorganic fertilizer increased steadily the yield attributes and finally reflected in fruit yield. Supplementation of organic fertilizer further enhanced the yield attributes and higher value was recorded in the treatment T_6 (100% RDF+2.5 t ha^{-1} of vermicompost), except number of fruits plant^{-1} where it was higher in the treatment T_8 (100% RDF+5 t ha^{-1} of FYM) (Bamboriya *et al.*, 2018). From the Table 2, it was also revealed that adding all three organic fertilizer sources with 75% RDF resulted in an increasing trend for all yield parameters compared to using only inorganic fertilizer sources with 75% RDF (Jat *et al.*, 2000). Fruit yield plant^{-1} was also affected by application of inorganic fertilizer and maximum fruit yield was found in the treatment T_2 (180.5) and the yield was further enhanced when organic sources of fertilizer was added with inorganic fertilizer either 75% or 100% of RDF. Among all three sources of organic fertilizers, the vermicompost at 2.5 t ha^{-1} was found more beneficial and outperformed more yield under 100% of RDF as compared to 75% of RDF and none of the other sources could not surpass the fruit yield. The beneficial effect of combining organic and inorganic fertilizers on increasing yield attributes due to adequate fertilization enhanced the rate of photosynthesis including a sufficient amount of chemical fertilizer stimulated superior metabolic and enzymatic activities within the plant, alongside boosting the photosynthetic rate during crucial early growth and developmental stages (Sharma *et al*., 2014).

Yield

Fruit yield of okra under bael based agroforestry system influenced with different nutrient management practices. Inorganic fertilizer application was essentially required to boost up the growth and yield of the crop, However, different sources of nutrient supplement for the crop was further beneficial for sustaining good growth and yield of the crop and also restored the productivity enhancement of the crops and the soil. Data depicted in the Table 3, it was found that the fruit yield increased with increasing doses of inorganic fertilizer and was found maximum under 100% of RDF (7.1 t ha^{-1}) which was significantly higher than 75% of RDF (5.7 t ha^{-1}). This finding was an agreement with Singh *et al*., 2012, who stated that yield rises incrementally with NPK levels. From Figure 2, the fruit yield of okra further increased with supplementation of organic fertilizer and was found maximum (9.7 t ha^{-1}) in the treatment T_6 (100 % RDF+2.5 t ha^{-1} of vermicompost) followed by T_8 viz., 100% RDF+5 t ha^{-1} of FYM (9.6 t ha^{-1}) and T_7 viz., 100% RDF+2.5 t ha^{-1} of poultry manure (9.2 t ha^{-1}). The treatment T_6 was statistically at par with T_8 and T_7 and the yield enhancement was recorded a tune of 1.04–5.43. % among the organic fertilizer treatments (T_6 Vs. T_8 and T_6 Vs. T_7). But the yield enhancement was higher a tune of 33.80% when organic fertilizer was added with 100% of RDF (Average value of T_6, T_7 and T_8 Vs. T_2). Reducing of RDF at 25% ,yield was reduced a tune of 24.56% (T_2 vs.T_1) but supplementation of organic fertilizer the yield enhancement was recorded a tune of 47.89% (Average value of T_3,T_4 and T_5 vs. T_1).So from the above stated results it was clearly found that the supplementation of organic fertilizer was beneficial rather only inorganic fertilizer application (Vennila *et al.*, 2008) and had the greater impact on fruit yield of okra under bael based agri-horti system. A similar pattern was also seen in stover yield after the final picking of okra. The use of organic fertilizer especially, vermicompost was recognized for its significant role in enhancing quality of soil. It significantly increased the activity of soil enzymes like urease, catalase and β-glucosidase which were critical for nutrient cycling (Ramazanoglu, 2024). Consequently, research indicated that combining fertilizer with vermicompost (integrated application) was more effective in boosting yields than using fertilizer alone, a finding that aligned with other studies (Damar *et al.*, 2021).

Economics

Organic sources and their degree of application were the primary causes of the cultivation costs' variation in the treatments. Vermicompost thus led to increased expenses for both 75% and 100% RDF (T_3 and T_6). The application of 100% RDF+2.5 t ha^{-1} vermicompost (T_6) recorded the highest gross return (□ 2,81,080 /-), however the application of 100% RDF+5 t ha^{-1} FYM (T_8) recorded the maximum net return. This could be attributed to the comparatively cheap cost of cultivation in$T_{8.}$ This also resulted in a higher B:C ratio (2.3), which was significantly higher than all of the treatments (Figure 3).

However, in terms of gross return, net return, and B:C ratio, the application of 100% RDF outperformed 75% RDF among the two inorganic fertilizer treatments. These results were consistent with Mishra *et al*., 2009.

Conclusion

Applying of 100% RDF to okra resulted in notable increases in both crop yield and profit compared to a 75% RDF in a bael+okra agri-horti system. Supplementation of organic fertilizer with 100% RDF either with vermicompost at 2.5 t ha^{-1} or FYM at 5 t ha^{-1} further enhanced the fruit yield of okra and was more remunerative to okra grown under a bael-based agri-horti system in Vindhyan region of Mirzapur under semi-arid eastern plain zone.

Table 1: Effect of nutrient management on growth attributing characters and flowering pattern of okra under a beal-based-agri-horti system.

Treatments	Plant height (cm) at harvest	No. of leaf plant^{-1} at harvest	No. of branches plant^{-1} at harvest	Leaf length (cm) at harvest	Leaf breadth (cm) at harvest	Dry matter production (g plant^{-1}) at harvest	Days to 1st flowering	Days to 50% flowering
T_1	54.0	18.0	2.1	8.8	15.9	14.5	45.1	48.5
T_2	63.7	23.2	2.7	10.3	17.3	17.5	44.7	48.2
T_3	75.4	24.4	3.2	10.7	17.7	16.6	44.2	44.7
T_4	72.2	21.9	3.0	9.8	17.4	16.0	41.4	45.3
T_5	74.3	23.2	3.1	10.3	17.5	16.4	41.0	47.7
T_6	84.6	29.8	3.6	11.3	19.0	20.6	37.2	41.2
T_7	80.4	28.3	3.4	10.8	18.4	19.9	40.5	44.2
T_8	83.5	29.3	3.5	11.0	18.8	20.5	40.5	44.7
SEm (+)	1.69	0.73	0.08	0.40	0.08	0.38	0.19	0.54
CD at p=0.05	5.14	2.22	0.23	1.20	0.23	1.15	0.57	1.63

T_1 : 75% RDF
T_2 : 100% RDF
T_3 : 75% RDF+2.5 t ha^{-1} of vermicompost
T_4 : 75% RDF+2.5 t ha^{-1} of poultry manure
T_5 : 75% RDF+5 t ha^{-1} of FYM
T_6: : 100% RDF+2.5 t ha^{-1} of vermicompost
T_7 : 100% RDF+2.5 t ha^{-1} of poultry manure
T_8: : 100% RDF+5 t ha^{-1} of FYM
RDF: Recommended dose of fertilizer

Table 2: Effect of nutrient management on yield attributes of okra under a bael-based-agri-horti system

Treatments	**Fruit length (cm)**	**Fruit diameter (cm)**	**Fresh fruit weight (g)**	**No of fruits plant^{-1}**	**Fruit yield plant^{-1} (g ha^{-1})**
T_1	6.9	1.2	8.3	11.8	147.2
T_2	8.7	1.5	9.9	14.7	180.5
T_3	10.6	1.8	12.1	17.9	219.9
T_4	10.1	1.7	11.5	17.1	209.9
T_5	10.4	1.8	11.9	17.6	216.4
T_6	11.9	2.0	13.6	19.8	248.4
T_7	11.4	1.9	12.9	19.2	235.3
T_8	11.8	2.0	13.5	19.9	245.0
SEm (+)	0.27	0.05	0.34	0.47	5.62
CD at p=0.05	0.83	0.14	1.03	1.41	17.04

T_1 : 75% RDF
T_2 : 100% RDF
T_3 : 75% RDF+2.5 t ha^{-1} of vermicompost
T_4 : 75% RDF+2.5 t ha^{-1} of poultry manure
T_5 : 75% RDF+5 t ha^{-1} of FYM
T_6: : 100% RDF+2.5 t ha^{-1} of vermicompost
T_7 : 100% RDF+2.5 t ha^{-1} of poultry manure
T_8: : 100% RDF+5 t ha^{-1} of FYM
RDF: Recommended dose of fertilizer

Table 3: Effect of nutrient management on yield, harvest index and economics of okra+bael under a bael-based-agri-horti system

Treatments	Fruit yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest Index (%)	Gross return (□ ha^{-1})	Net return (□ ha^{-1})	Total cost of cultivation (□ ha^{-1})	B:C ratio
T_1	5.7	2.6	31.33	219069	142741	76328	1.9
T_2	7.1	3.3	31.73	240609	162364	78245	2.1
T_3	8.6	3.9	31.20	264078	171850	92228	1.9
T_4	8.2	3.8	31.67	258153	172550	85603	2.0
T_5	8.5	3.9	31.45	261983	179295	82688	2.2
T_6	9.7	4.4	31.21	281080	186935	94145	2.0
T_7	9.2	4.2	31.34	273293	185773	87520	2.1
T_8	9.6	4.3	30.94	279034	194429	84605	2.3
SEm (+)	0.22	0.12	-	3339	3339	-	0.04
CD at *p*=0.05	0.67	0.37	-	10127	10127	-	0.12

T_1 : 75% RDF
T_2 : 100% RDF
T_3 : 75% RDF+2.5 t ha^{-1} of vermicompost
T_4 : 75% RDF+ .5 t ha^{-1} of poultry manure
T_5 : 75% RDF+5 t ha^{-1} of FYM
T_6: : 100% RDF+2.5 t ha^{-1} of vermicompost
T_7 : 100% RDF+2.5 t ha^{-1} of poultry manure
T_8: : 100% RDF+5 t ha^{-1} of FYM
RDF: Recommended dose of fertilizer

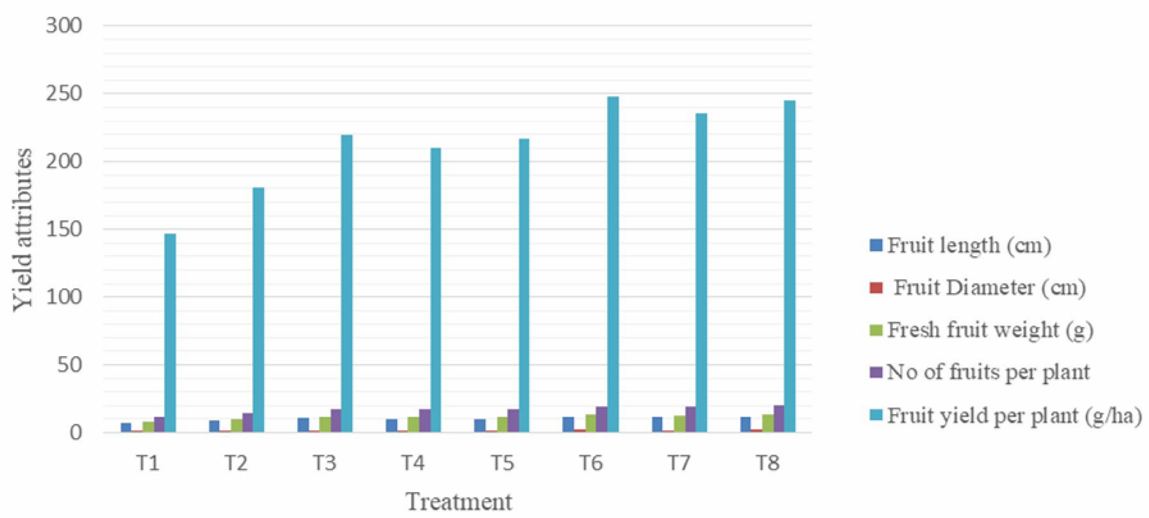

Fig 1: Effect of nutrient management on yield attributes of okra under a bael-based-agri-horti system

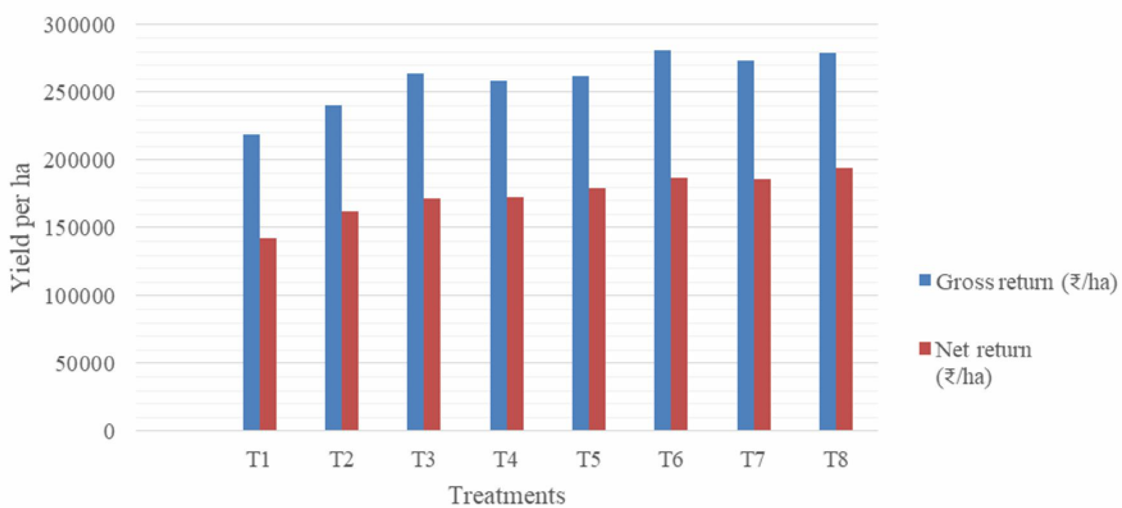

Fig:2 : Effect of nutrient management on fruit yield per hectare(t) and stover yield per hectare(t) of okra

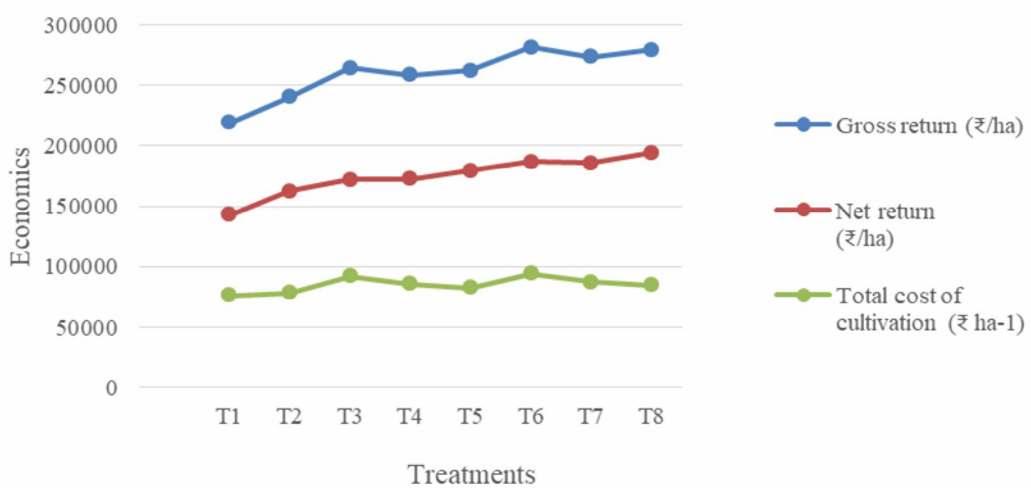

Fig:3 Economics of okra + bael agri horti system as influenced by nutrient management

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