Production efficiency, water productivity and monetary efficiency of Okra under organic manure and biofertilzers application

Abstract

Field experiment was conducted during the *kharif* seasons of 2017 at Sri Karan Narendra Agriculture University, Jobner (Jaipur) to assess the effect of biofertilizers and organic manures on production efficiency, water productivity and monetary efficiency of okra. The study had four organic manures and four biofertilizer treatments that were replicated thrice in factorial randomized block design. Vermicompost application @ 6 t ha^{-1} resulted into the maximum production efficiency (201 kg $ha^{-1}day^{-1}$) and water productivity (54 kg $ha^{-1}mm^{-1}$) whereas poultry manure (@ 8 t ha^{-1}) reported greatest monetary efficiency (Rs. 3013 $ha^{-1}day^{-1}$). Among the biofertilizers, dual seed treatment with both *Azosprillum* + PSB recorded 39%, 40% and 55% higher production efficiency, water productivity and monetary efficiency than control. Fourth picking yielded the greatest tonnes of fruit and yield declines after it. Application of organic manures and biofertilizer enhanced okra yield up to 5.9 and 3.8 t ha^{-1}, respectively. Therefore, poultry manure and double inoculation with biofertilizer is advisable for okra production under poorly fertile soils.

Key words: *Azosprillum;* Farm yard manure; Phosphorous solubilizing bacteria; Poultry manure; Vermicomposts and Water productivity.

Introduction

Organic nutrition for vegetable is especially important for providing health security to vast vegetarian population in the country. As the vegetables are mostly consumed as fresh or cooked, they should be devoid of residual effect of inorganic chemicals. Use of organic manures in vegetable crops not only resulted in increasing the productivity but also in maintaining certain level of organic manure in the soil, which has an important role in improving soil physico-chemical conditions (El-shinawy, 2003). The application of organic manures will lead to the production of some vegetables that are safe sources of required nutrients by plant, human and environment (El-shinawy, 2003).

The effect of vermicompost in combination with other mineral fertilizer and/soil is quite hearten for better crop growth and harvest of yield. Even at the lower dose than that of recommended dose of mineral fertilizers, vermicompost has shown better results for projection and crop yield, which is not only in expensive but also favourable with soil improvement point of view (Bajracharya and Rai, 2009). The organic fertilizer can improve soil fertility, provide comprehensive nutrition for long-term crops, improve soil physical and chemical properties, enhance soil water storage capacity, and improve crop quality (Lu *et al*., 2011). Recently, there has been an erratic rainfall distribution pattern in terms of the on-set and amount in the north-west part of Rajasthan consequently affecting grain yield. Application of manure is known to enhance crop growth as it improves the soil's ability to hold water and also improves other soil properties leading to improved crop growth (Vanlauwe, 2004; Javaid, 2009; Javaid and Mahmood, 2010). Currently, grain production is moving towards the efficient use of resources and sustainable yield increases with low environmental costs. Organic farming resulted in better economic returns due to improved productivity and lower cost of cultivation compared to chemical farming (Javaid and Mahmood, 2010; Jiago *et al*., 2016). Thus, the efficient and sustainable management of fertilizer use must be explored (Fan *et al*., 2018).

Keeping in view the importance of organic manures and biofertilizers a study was designed to hypothesize that production efficiency, water productivity and monetary efficiency of okra could be improved with the use of inorganic manures and biofertilizers.

Material and method

Experimental site

A field experiment was conducted at Horticulture Farm, SKN college of Agriculture, Jobner during *kharif* season 2017. The experimental site is located 26^0 5“ North latitude, 75^0 28” East longitudes and an altitude of 427 meters above mean sea level. This region comes under Semi-Arid Eastern Plain agro climatic zone. Due to semi-arid climate the region faces extreme hot and cold during summer and winter season, respectively. It receives 400-500 mm rainfall annually especially during monsoon season. The soil was sandy loam in texture having with 8.1 pH, 124.7 kg ha^{-1} available N, 18.8 kg ha^{-1} available P_2O_5 and 147.5 kg ha^{-1} available K.

Treatment description

The experiment was laid out in factorial randomized complete block design and replicated trice. Total 16 treatment combinations of organic manure (control, FYM 20 tha^{-1}, vermicompost 6 t ha^{-1} and poultry manure 8 t ha^{-1}) and biofertilizer (control, PSB, *Azospirillum* and *Azospirillum* + PSB) were tested. Organic manures were applied as per treatment before sowing and spread uniformly. According to the treatments, seed were inoculated with *Azospirillum* 25 g kg^{-1} seed) and PSB (*Bacillus megaterium* var. *phosphoticum* 5 g kg^{-1} seed) following the standard procedure.

Table 1. Treatment details of the experimental research

Treatment	Symbol
A. Organic manures	
1.Control	M_0
2.FYM @ 20 t ha^{-1}	M_1
3.Vermicompost @ 6 t ha^{-1}	M_2
4.Poultry manure @ 8 t ha^{-1}	M_3
B. Bio-fertilizers	
1.Control	B_0
2.Azosprillum	B_1
3.PSB	B_2
4.Azosprillum + PSB	B_3

FYM= Farm yard manure; PSB= phosphorous solubilizing bacteria

Crop raising

Okra variety 'Arka Anamika' was sown at 60×45 cm spacing using 15 kg ha^{-1} seed on July 28, 2017. One pre-sowing irrigation and three in-season irrigation was given whenever needed. Thinning was carried out at 22 days after sowing. For weeds management hand weeding was done at 30 and 50 days after sowing. Imidacloprid 17.5 SL (0.25%) and Dimethoate 30 EC (0.03%) were sprayed to protect the crop from attack of Jassid and whitefly. The crop was ready for picking 50 days after sowing. Consequent picking was done when green tender fruit attained marketable size. Total seven picking were done at an interval of 2-3 days.

Statistical analysis

Statistical analysis was done using analysis of variance technique. To test the significance of variation among different treatment means CD (critical difference) was calculated at 5% probability level.

Water productivity, monetary efficiency and production efficiency was computed using the following formula:

$$\text{Irrigation water productivity (kg ha}^{-1}\text{ mm}^{-1}\text{)} \quad \frac{\text{Fruit yield (kg ha}^{-1}\text{)}}{\text{Irrigation applied (mm)}}$$

$$\text{Monetary efficiency (Rs. ha}^{-1}\text{ day}^{-1}\text{)} \quad \frac{\text{Net returns (Rs. ha}^{-1}\text{)}}{\text{Crop duration (days)}}$$

$$\text{Production efficiency (kg ha}^{-1}\text{ day}^{-1}\text{)} \quad \frac{\text{Fruit yield (kg ha}^{-1}\text{)}}{\text{Crop duration (days)}}$$

Results and Discussion

Yield per picking

Across the organic manure treatments, fruit yield per picking was 0.91 t ha^{-1} during foremost picking that reached to pick level (2.5 t ha^{-1}) at fourth picking and declined there after (fig. 1a). From the graph it is clearly visible that at every picking, the lowest yield was observed at control followed by FYM @ 20 t ha^{-1}. Application of vermicompost @6 t ha^{-1} recorded the highest fruit yield at each picking. Poultry manure @ 8 t ha^{-1} was found poor yielder than vermicompost @ 6 t ha^{-1} at every harvesting whereas it was out yield than FYM @ 20 t ha^{-1} except at 4^{th} and 5^{th} picking when both have equal yield. Total fruit yield was ranges between 8.13 to 14.3 t ha^{-1} with a mean of 11.8 t ha^{-1} (fig. 1b). The vermicompost application (@ 6 t ha^{-1}) had 0.75, 2.17 and 5.91 t ha^{-1} higher yield over poultry manure (@ 8 t ha^{-1}), FYM (@ 20 t ha^{-1}) and control, respectively. Vermicompost is rich in plant macro and micronutrients and beneficial soil microbes and plant growth promoting compounds like growth hormones therefore its application in agriculture enhance plant growth and yield (Coulibaly *et al.*, 2021). Beside these, vermicompost also improves soil physical (soil bulk density, water holding capacity) and soil chemical properties (pH, and electrical conductivity) than conventional compost (Doan *et al.*, 2015). Ahirwar and Hussain (2015) and Rahman and Hasan (2016) also reported that the addition of vermi-compost improved yield of vegetable crops.

The per picking yield under various biofertilizer were also followed the similar trend as noticed in the case of organic manures (fig. 1c). The lowest and highest yield per fruit picking was found at 1^{st} and 4^{th} picking, respectively. Seed treatment with both *Azosprillum* + PSB resulted into highest yielded per picking. The lowest per picking yield was seen at control at every occasion. Sole *Azosprillum* and sole PSB performed equally as not clear cut difference was seen in their performance across the pickings. The total yield varied between 9.6-13.4 t ha^{-1} under various biofertilizer treatments (fig. 1d). Compared to control, sole *Azosprillum,* sole PSB and *Azosprillum* + PSB had 2.68, 2.52 and 3.82 t ha^{-1} higher okra yield. Biofertilizers augment nutrient availability, produce growth promoting substances and suppress the plant pathogen attack therefore enhance crop productivity (Anisa *et al.*, 2016). Choudhary *et al.* (2015) and Anisa *et al*. (2016) also reported that application of biofertilizer provided enhanced yield of okra.

Irrigation water productivity

Various organic manure treatments had significant effect on irrigation water productivity. On an average, okra produced 45 kg fruit by consuming one ha-mm water. Plot that did not get any kind of organic manure (control) was found least efficient in water use (31.3 kg ha^{-1} mm^{-1}) (fig. 2a). The highest water productivity was observed at vermicompost (54.0 kg ha^{-1} mm^{-1}) and it was at par with both poultry manure (51.1 kg ha^{-1} mm^{-1}). Therefore, application of organic manure enhanced the water productivity by 46-73%. This addition of organic matter under manure plots favoures soil faunal activity that improve the soil aggregation and porosity and thus improve infiltration rates and water productivity (Assefa and Tadesse, 2019**)**. Moreover, organic matter addition also increase water retention capacity and favour root growth for higher water uptake. The cumulative action of all these factors enhances water productivity. Ye *et al*. (2020) also reported enhanced water use efficiency with addition of organic manures.

The irrigation water productivity varied between 36.9-51.5 kg $ha^{-1}mm^{-1}$ under biofertilizer application (fig. 2b). Co-inoculation with *Azosprillum* + PSB was found most efficient in water use with the greatest water productivity (51.5 kg $ha^{-1}mm^{-1}$) and it was at par with *Azosprillum* (47.2 kg $ha^{-1}mm^{-1}$) and sole PSB (46.5 kg $ha^{-1}mm^{-1}$). Compared to un-inoculated plot, biofertilized plots produced 9.6-14.6 kg higher fruits by using one mm irrigation water. This may be attributed to the organic matter which indirectly contributes to soil texture via increased soil faunal activity leading to improve the soil aggregation and porosity which ultimately increased the number of macro-pores and thus, infiltration rates.

The organic matter was found contributing to the stability of soil aggregates and pores through the binding properties of organic material. The higher water productivity in biofertilizer inoculated plots might be associated with yield increment in these treatments.

Monetary efficiency

The fig. 3(a) depicted that cultivation of okra can generate Rs. 1,683 to 3,013 per day net benefit from one ha area during its crop cycle. Monetary efficiency increased 1.5-1.8 folds when organic manures were applied against control (RS. 1683 $ha^{-1}day^{-1}$). Among the various organic manures, poultry based manure proved more profitable (RS. 3033 $ha^{-1}day^{-1}$) followed by vermicompost (RS. 2967 $ha^{-1}day^{-1}$) whereas FYM was least beneficial (Rs. 2576 $ha^{-1}day^{-1}$). Organic manures are locally and easily available and low-priced nutrient source which reduce the dependence on costly chemical fertilizer thus enhance farm profitability (Bajeli *et al*., 2016). The better net returns and benefit cost ratio by integrated application of organic, inorganic and biofertilizer were also stated by Rao *et al.* (2020).

Biofertilizer also enhanced the monetary efficiency from RS. 1927 (control) to 2996 (double inoculation (fig. 3a). In another words, biofertilizer treated plot gave Rs. 762 to 1069 $ha^{-1}day^{-1}$ higher economical advantages than untreated plots. Lower cost of organic manures and biofertilizers and higher prices of organically produced okra generated more net returns. Wali-Asal (2010) also reported that biofertilizer are cost effective sources of plant nutrients therefore must be used to sustain crop production.

Production efficiency

Different manure treatment had positive effect on okra production efficiency. Vermicompost application @ 6 t ha^{-1} resulted into the highest production efficiency (210 kg ha^{-1} day^{-1}) followed by vermicompost (190 kg ha^{-1} day^{-1}) and FYM (170 kg ha^{-1} day^{-1}), whereas control recorded the least production efficiency (116 kg ha^{-1} day^{-1}) (fig.3b). Compared to un-manured plot, production efficiency increased up to 72% in manured plots.

The fig. 3(b) indicated that double inoculation with *Azosprillum* + PSB had higher production efficiency (191 kg ha^{-1} day^{-1}) over control (137 kg ha^{-1} day^{-1}) and single inoculation with either *Azosprillum* (175 kg ha^{-1} day^{-1}) or PSB (173 kg ha^{-1} day^{-1}). This might be due to more availability of nitrogen and phosphorus nutrients from the beneficial effects accrued due to *Azotobacter* and phosphate solubilizing bacteria (PSB) inoculation. It may also be due to production of amino acids, vitamins and growth promoting substances like indole acetic acid and gibberellic acid by these introduced beneficial microorganisms which resulted in enhanced nutrient uptake, translocation and synthesis of photosynthate assimilates thus increased yield (Suke *et al*., 2011)

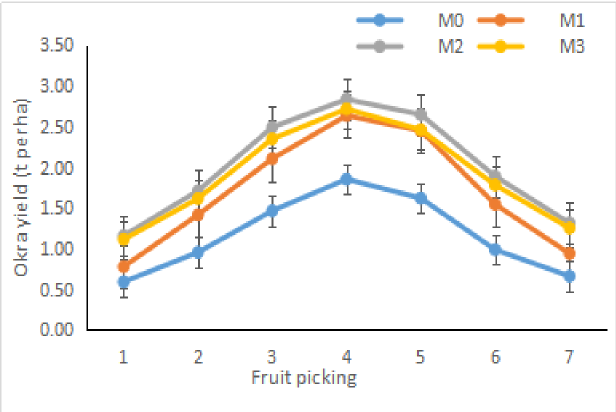

Fig. 1(a) Picking wise yield of okra under organic manures

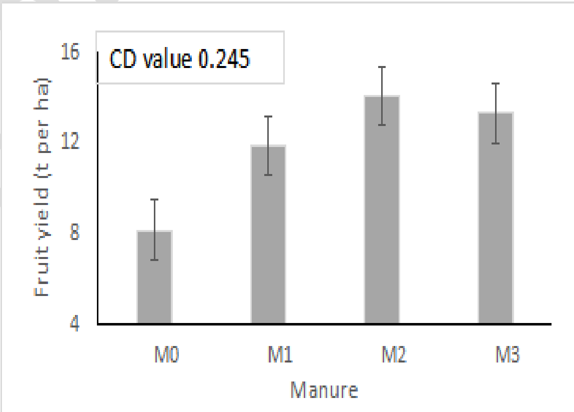

Fig. 1(b) Total yield of okra with organic manure

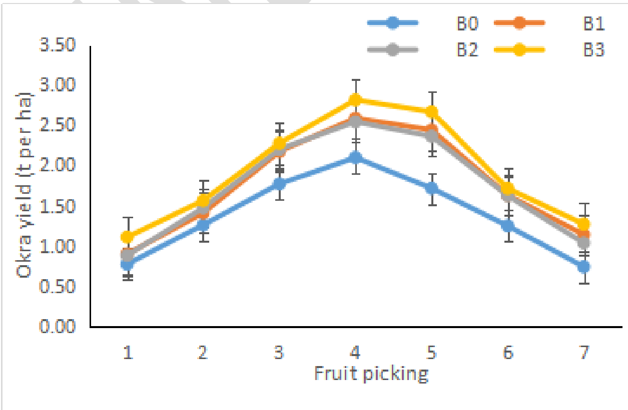

Fig. 1(c) Picking wise yield of okra under biofertilizers

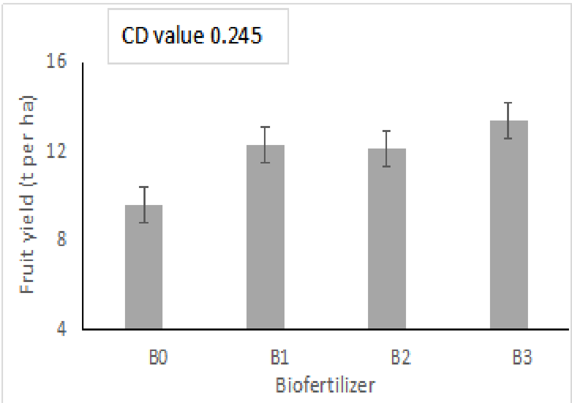

Fig.1 (d) Total yield of okra with biofertilizers

Here, M_0=Control; M_1= FYM @ 20 t ha^{-1}, M_2=Vermicompost @ 6 t ha^{-1}, M_3= Poultry manure @ 8 t ha^{-1}; B_0= Control; B_1= *Azosprillum; B*$_2$= PSB; B_3=*Azosprillum* + PSB

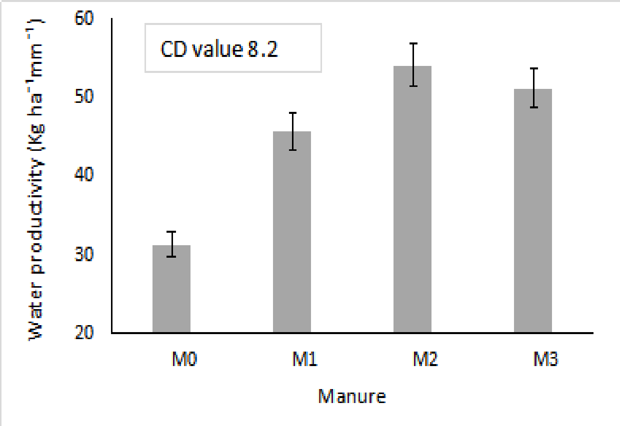

Fig. 2(a) Effect of organic manures on irrigation water productivity of okra

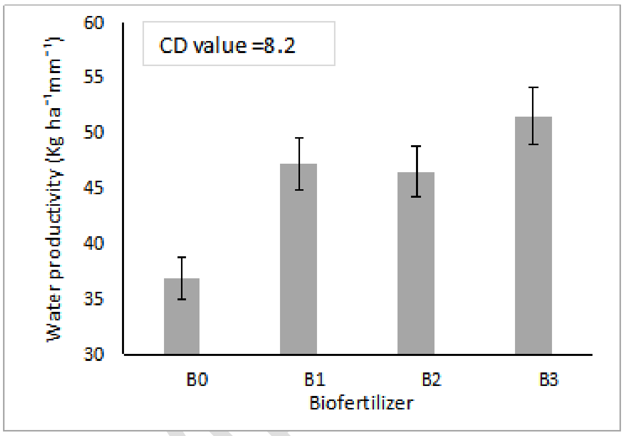

Fig. 2(b) Effect of biofertilizers on irrigation water productivity of okra

Here, M_0=Control; M_1= FYM @ 20 t ha^{-1}, M_2=Vermicompost @ 6 t ha^{-1}, M_3= Poultry manure @ 8 t ha^{-1}; B_0= Control; B_1= *Azosprillum; B*$_2$= PSB; B_3=*Azosprillum* + PSB

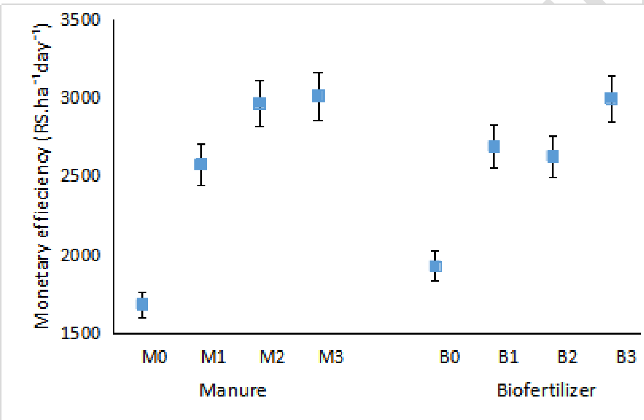

Fig. 3(a) Effect of organic manures and biofertilizers on monetary efficiency of okra

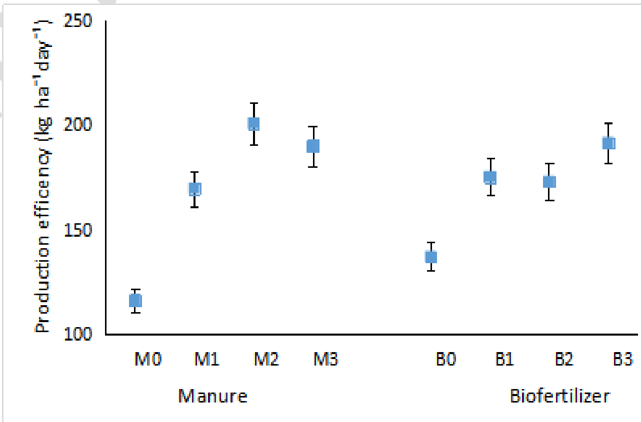

Fig. 3(b) Effect of organic manures and biofertilizers on production efficiency of okra

Here, M_0=Control; M_1= FYM @ 20 t ha^{-1}, M_2=Vermicompost @ 6 t ha^{-1}, M_3= Poultry manure @ 8 t ha^{-1}; B_0= Control; B_1= *Azosprillum; B*$_2$= PSB; B_3=*Azosprillum* + PSB

Conclusion

In nutshell, the present investigation showed that compared to FYM (20 t ha^{-1}), vermicompost application @ 6 t ha^{-1} found good for getting higher fruit yield however poultry manure (@ 8 t ha^{-1}) proved the highest economical advantages. Beside this double inoculation of seed with biofertilizer like *Azosprillum* + PSB was most productive and profitable than single inoculation with either of the strain.

References

Ahirwar CS, Hussain A. Effect of vermicompost on growth, yield and quality of vegetable crops. International Journal of Applied and Pure Science and Agriculture. 2015; 1(8):49-56.

Anisa NA, Markose BL, Joseph S. Effect of biofertilizers on yield attributing characters and yield of okra (*Abelmoschus esculentus* (L.) Moench). International Journal of Applied and Pure Science and Agriculture. 2016;2(2):57-60.

Assefa S, Tadesse, S. The principal role of organic fertilizer on soil properties and agricultural productivity –A review. Agricultural Research and Technology. 2019;22(2):e556192.

Bajeli J, Tripathi, S, Kumar A, Tripathi A, Upadhyay RK. Organic manures a convincing source for quality production of Japanese mint (*Mentha arvensis* L.). Indian Crop Production. 2016;83:603-606.

Bajracharya SK, Rai SK. Study on the effects of vermicompost on the nodulation and the yield of chickpea. Nepal Agriculture Research Journal. 2009;9:49- 55.

Choudhary K, More SJ, Bhanderi DR. Impact of bio-fertilizers and chemical fertilizers on growth and yield of okra (*Abelmoschus esculentus* L. Moench). The Ecosan. 2015;9(1&2): 67-70.

Coulibaly S, Toure M, Kouame A, Kambou I, Soro S, Yeo K, Kone S, Zoro B. Vermicompost as an alternative to inorganic fertilizer to improve okra productivity in Côte d’Ivoire. Open Journal of Soil Science. 2021;11:1-12.

Doan TT, Henry-des-Tureaux T, Rumpel C, Janeau JL, Jouquet P. Impact of compost, vermicompost and biochar on soil fertility, maize yield and soil erosion in Northern Vietnam: A three-year mesocosm experiment. The Science of the Total Environment. 2015;514:147-154.

El-shinawy E. The use of organic and biological fertilizers in the production of some vegetable crops for export. Faculty of Agriculture, Ain Shams University, Egypt; 2003.

Fan YB, Wang CG, Nan ZB. Determining water use efficiency of wheat and cotton: a meta-regression analysis. Agriculture Water Management. 2018;199:48-60.

Javaid A. Growth, nodulation and yield of black gram [*Vigna mungo* (L.) Hepper] as influenced by biofertilizers and soil amendments. African Journal of Biotechnology. 2009;8(21):5711-5717.

Javaid A, Mahmood N. Growth, nodulation and yield response of soybean to biofertilizers and organic manures. Pakistan Journal of Botany. 2010;42(2):863-871.

Javaid A, Bajwa R. Effect of effective microorganism application on crop growth, yield and nutrition in *Vigna radiata* (L.) Wilczek in different soil amendment systems. Communications in Soil Science and Plant Analysis. 2011;42(17):2112-2121.

Jiago X, Lyu Y, Wu X, Li H, Cheng L, Zhang C, Yuan L, Jiang R, Jiang B, Rengel Z, Zhang F, Davies WJ, Shen J. Grain production versus resource and environmental costs: towards increasing sustainability of nutrient use in China. Journal of Experimental Botany. 2016;67(17):4935-4949.

Lu WT, Jia ZK, Zhang P, Cai TY, Li R. Effects of organic fertilization on winter wheat photosynthetic characteristics and water use efficiency in semi-arid areas of southern Ningxia. Plant Nutrition and Fertilizer Science. 2011;17(5):1066-1074.

Rahman M, Hasan MZ. Potential of vermicompost prepared from organic wastes on the growth, yield and nutrient status of Okra (*Abelmoschus esculentus* L.). Research Journal of Agriculture and Biological Sciences. 2016;12(1):9-16.

Rao BM, Mishra GC, Mishra G, Maitra S, Adhikari R. Effect of integrated nutrient management on production potential and economics in summer sweet corn (*Zea mays* L. var. Saccharata). International Journal of Chemical Studies. 2020;8(2):141-144.

Suke SN, Deotale RD, Hiradeve P, Deogirkar M, Sorte SN. Effect of nutrients and biofertilizers of chemical and biochemical parameters of maize (*Zea mays* L.). Journal of Soil and Crops. 2011;21(1):107-112.

Vanlauwe B. "Integrated soil fertility management research at TSBF: the framework, the principles, and their application," in Managing Nutrient Cycles to Sustain Soil Fertility in Sub-Saharan Africa, ed A. Bationo (Nairobi: Academy Science Publishers) 2004;25-42.

Wali Asal MA. The combined Effect of mineral organic and bio-fertilizers on the productivity and quality of some wheat cultivars. Ph. D. Thesis, Faculty of Agricultural Alex. University Egypt; 2010.

Ye S, Liu T, Niu Y. Effects of organic fertilizer on water use, photosynthetic characteristics, and fruit quality of pear jujube in northern Shaanxi. Open Chemistry. 2020;18:537–545.