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Priyanka Sahu
PhD Scholars, Department of Vegetable Science, College of Agriculture, Bhubaneswar, Odisha, India

P Tripathy
Professor, Department of Vegetable Science, College of Agriculture, Bhubaneswar, Odisha, India

GS Sahu
Professor, Department of Vegetable Science, College of Agriculture, Bhubaneswar, Odisha, India

SK Dash
Scientist, AICRP on Vegetable Crops, College of Agriculture, Bhubaneswar, Odisha, India

SK Pattnayak
Emeritus Professor, Department of Soil Science and Agriculture Chemistry, College of Agriculture, Bhubaneswar, Odisha, India

S Sarkar
Scientist, AICRP on Vegetable Crops, College of Agriculture, Bhubaneswar, Odisha, India

RK Nayak
Associate Professor and OIC, AICRP on Micronutrients, College of Agriculture, Bhubaneswar, Odisha, India

NJ Nayak
PhD Scholars, Department of Vegetable Science, College of Agriculture, Bhubaneswar, Odisha, India

S Mishra
PhD Scholars, Department of Vegetable Science, College of Agriculture, Bhubaneswar, Odisha, India

Corresponding Author:
Priyanka Sahu
PhD Scholars, Department of Vegetable Science, College of Agriculture, Bhubaneswar, Odisha, India

Efficiency of nutrient management practices on marketable fruit yield and quality and economics in cucumber (*Cucumis sativus* L.)

Priyanka Sahu, P Tripathy, GS Sahu, SK Dash, SK Pattnayak, S Sarkar, RK Nayak, NJ Nayak and S Mishra

Abstract
Field experiments were conducted at AICRP on Vegetable Crops, operating under Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India during summer season of 2017 and 2018. The objective of the investigation was to evaluate the efficacy of nutrient management practices on marketable fruit yield, quality and economics in cucumber. Twelve nutrient management treatments consisting of inorganic chemical fertilizer, organic manures FYM (F) and/or vermicompost (VC) and soil inoculation of biofertilizer consortia (BFs) including absolute control were evaluated by adopting RBD repeated thrice. The pooled results over two years revealed significant variations among the nutrient management practices on marketable fruit yield and quality in cucumber. Significantly highest marketable fruit yield was recorded by adoption of integrated application of ½ RDF + F_{10} + VC_2 + BFs (15.6 tha^{-1}) clearly followed by RDF + F_{10} + BFs (13.9tha^{-1}) whereas minimum in absolute control (4.6 tha^{-1}). Regarding, fruit quality, integrated application of ½ RDF + F_{10} + VC_2 + BFs produced cucumber fruits with highest ascorbic acid (39 $mg100g^{-1}$) and sugar content (3.7 %). However, integrated application of ½ RDF + VC_2 + BFs recorded highest TSS (5.5 ^{0}Brix) and *statistically at par* with T_4, T_7, T_8, T_{11} and T_{12}. The economics of nutrient management revealed maximum B:C ratio of 1.66 with T_{12} closely followed by T_{11}. It may be concluded that integrated application of nutrients *i.e.*, ½ RDF + F_{10} + VC_2 + BFs may be recommended for significantly highest marketable fruit yield with quality produce and highest B:C ratio in cucumber.

Keywords: Cucumber, marketable fruit yield, quality, economics, B:C ratio

Introduction

Cucumber (*Cucumis sativus* L.) is one of the most popular salad crop of the world, grown extensively in three major climates of the world, tropical, subtropical and temperate climates, both under open field and protected condition. Cucumber fruits are highly suitable for people suffering from jaundice, constipation and indigestion, besides adding cooling effect (Marogal *et al*., 2018). Cucumber as fresh consumption is rich in vitamins, minerals and antioxidants (Patel and Panigrahi, 2019) [19]. Marketability of cucumber depends on cucumber quality *i.e.*, fruit yield, shape, colour, freshness, turgidity and appearance of defects (*i.e.*, rots, cuts, bruises, scars, damaged, deformed fruits etc. (Kader, 2002) [14]. Now-a-days, cucumber production is gaining importance due to spread of awareness among consumers regarding medicinal properties leading to elevated demand and higher fruit yield and income in short period of time which is attracting more farmers to cultivate.

In most of the annual cucurbit including cucumber, nutrient management play very crucial role towards sex expression, in turn sex ratio (male: female flower) which ultimately influenced the productivity and quality of the fruits. Being monoecious nature, there will be production of both male and female flowers in the same plant but in different position. The sex expression of monoecious cucumber is significantly influenced not only by the genetic constitution of the variety but also prevailing temperature, day length, nutrient management, water management and concentration of PGRs. Nutrient management practices known to have decisive role in successful role in successful cucumber production. Moreover, cucumber is treated as a high nutrient demanding crop and performs poorly on nutrient deficient soils leading to lower fruit yield, bitter and misshaped fruits (Grubbenand and Denton, 2004; Olalekan, 2017) [13, 18]. In order to produce cucumber on a sustainable basis and meet consumer's demand, there is urgency to evaluate various sources of nutrients from inorganic chemical fertilizer, organic and biofertilizer sources. Moreover, it has already established that organic and biological sources of nutrients significantly increased the fruit quality with maintenance of soil fertility on a sustainable manner (Selim, 2020) [22]. Keeping these facts in view, the present investigation was conducted to evaluate different nutrient management practices in marketable fruit yield, fruit quality and their impact on economics of production.

Materials and Methods

The field experiment was conducted at AICRP on Vegetable Crops operating under Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India during summer season of 2017 and 2018. Twelve nutrient management modules including absolute control were evaluated by adopting RBD replicated thrice. The nutrient management practices were formulated from different sources of nutrients with inorganic chemical fertilizers, organic (FYM and/or VC) and BF consortia, consisting of *Azotobacter*, *Azospirillum* and *PSB* (1:1:1) including absolute control (Table no. 1). Cucumber variety "Seven Star" was sown on 21st of march during summer, 2017 and 2018 with a spacing of (1.5 x 1) m and plot size of (3.0 x 2.7) m. All the recommended package of practices were adopted uniformly to all the treatments except nutrient management practices. Observations on marketable fruit yield was calculated after deducting the small sized, bent necked fruits and misshaped fruits on each harvest on plot basis. Observations on fruit quality of cucumber was recorded immediately after harvest. Total Soluble Solid (TSS) determined by using digital refractometer and results were expressed in ^{0}Brix. Similarly, Ascorbic acid content of cucumber grown by different nutrient management was determined by 2,6 dichlorophenol indophenol visual titration method (Ranganna, 1995) and expressed in mg $100g^{-1}$. Similarly, sugar content of freshly harvested cucumber fruits were determined by adopting procedure of Ranganna, (1995). Cost of cultivation was calculated on the basis of treatment schedule along with constant fixed cost of production and accordingly gross return, net return and B: C ratio was calculated on the basis of marketable fruit yield. Data recorded were analysed by adopting his standard statistical procedure as suggested by Gomez and Gomez (1996) [12].

Table 1: Treatment details

Sl. No.	Treatment details	Abbreviation
1	Absolute Control	AC
2	Recommended dose of fertilizers	RDF
3	½ RDF + consortia Biofertilizer *	½ RDF + BFs
4	Vermicompost @ 4 tha^{-1}	VC_4
5	Vermicompost @ 2 tha^{-1} + consortia Biofertilizer	VC_2 + BFs
6	½ RDF + Vermicompost @ 2 tha^{-1} + consortia Biofertilizer	½ RDF + VC_2 + BFs
7	RDF + Vermicompost @ 2 tha^{-1} + consortia Biofertilizer	RDF + VC_2 + BFs
8	FYM @ 20 tha^{-1}	F_{20}
9	FYM @ 10 tha^{-1} + consortia Biofertilizer	F_{10} + BFs
10	½ RDF + FYM @ 10 tha^{-1} + consortia Biofertilizer	½ RDF + F_{10} + BFs
11	RDF + FYM @ 10 tha^{-1} + consortia Biofertilizer	RDF + F_{10} + BFs
12	½ RDF + FYM @ 10 tha^{-1} + Vermicompost @ 2 tha^{-1} + consortia Biofertilizer	½ RDF + F_{10} + VC_2 + BFs

Result and Discussion

Marketable fruit yield

A perusal of table 2 revealed significant impact of various nutrient management practices on marketable fruit yield in cucumber variety Seven Star. The pooled results over two years revealed significantly highest marketable fruit yield of 15.6 tha^{-1} with integrated application of ½ RDF + F_{10} + VC_2 + BF, while that of minimum in absolute control (4.5 tha^{-1}). However, *statistical parity* was recorded with integrated application of RDF + F_{10} + BF (13.9 tha^{-1}) with highest value, T_{12}. Adoption of T_{12} recorded about 246.6% over absolute control while 45.8% over the RDF (T_2) for total marketable fruit yield. However, invariably higher marketable fruit yield in cucumber were recorded in different nutrient management practices which varied from 77.8% (T_5) to 246.6% (T_{12}) over absolute control whereas 3.7% (T_{10}) to 45.8% (T_{12}) over T_2, the RDF values indicating the influence of nutrient management practices for marketable yield.

Table 2: Effect of nutrient sources on marketable fruit yield of cucumber variety "seven star".

Sl. No.	Treatments	Marketable fruit yield (tha^{-1})	Total fruit yield (tha^{-1})
		Pooled (2017-2018)	Pooled (2017-2018)
T_1	Absolute Control	4.5	5.5
T_2	RDF	10.7	11.8
T_3	1/2 RDF + BFs	9.5	10.6
T_4	VC_4	9.8	10.7
T_5	VC_2 + BFs	8.0	9.3
T_6	1/2 RDF + VC_2 + BFs	9.8	11.0
T_7	RDF + VC_2 + BFs	12.0	13.3
T_8	F_{20}	11.2	12.8
T_9	F_{10} + BFs	10.3	11.4
T_{10}	1/2 RDF + F_{10} + BFs	11.1	12.3
T_{11}	RDF + F_{10} + BFs	13.9	15.1
T_{12}	1/2 RDF + F_{10} + VC_2 + BFs	15.6	17.2
	Mean	10.5	11.7
	SE (m) ±	1.10	0.62
	CD (5%)	1.64	1.77
	CV (%)	8.0	8.0

The increased marketable fruit yield in cucumber due to integration of plant nutrient over their sole application might be due to creation of favorable environment for better vegetative growth, flowering behavior, fruit yield attributing traits which in turn enhanced the marketable fruit yield. By adoption of integrated nutrient management, from various sources with inorganic chemical fertilizers, organic (FYM and/or VC) and BFs significantly increased marketable fruit yield might be due to supply of steady and continuous supply of plant nutrients along with micronutrients from all the sources, resulting in higher production of marketable fruit yield. Application of organic manures (FYM and/or VC) in the present study might have attributed to more availability of nutrients continuously and subsequent uptake of nutrients by cucumber plants, thereby increased in production of good size cucumber fruits resulting in increased marketable fruit yield. Besides, organic manure (FYM and/or VC) would have provided the micronutrients such as Zn, Fe, Co, Mg in an lower concentration, enhanced the better metabolic activities which in term enhanced growth and development Singh and Mishra (2020) [24]. Enujeke (2013) [10] reported the organic manure sources as nutrient amendment reduced soil erosion, increased water holding capacity, increased moisture availability which favored the release of macronutrients for higher growth and yield. Better utilization of nutrients might be the reason towards increase in marketable fruit yield in the present study.

Further, soil inoculation of biofertilizer consortia involving *Azotobacter*, *Azospirillum* and *PSB* (1:1:1) enhanced the steady supply of balanced nutrition. The presence of *Azotobacter*, *Azospirillum* added extra nitrogen to the soil, while presence of *PSB* increased the solubility of unavailable phosphates to available form in turn enhanced marketable fruit yield in cucumber. Therefore, integration of nutrients from various sources gradually build-up of sufficient food reserves for developing sinks and better portioning towards the development of good size fruits. The findings of present study are in accordance with the reports of several scientists in cucumber (Moharana *et al*, 2017; Dash *et al*, 2018 and Singh *et al*, 2018) [8, 16, 17]. Similar reports of better efficacy of INM treatments over their sole application for enhanced fruit yield have also been reported by Sanni *et al.* (2015) [21] in cucumber and Abafita *et al.*, (2014) [1] in tomato.

On the other hand, significantly lowest marketable fruit yield was recorded in absolute control plots (4.6 tha^{-1}) without application of nutrients from any sources. Significantly decreased marketable fruit yield due to significantly reduction in growth and development of the cucumber crop, resulting low yield. According to Eifediyi and Remison (2009), cucumber crop prefers moderate to high nutrients levels so as to achieve high fruit yield. Infertile soils or soils with nutrient deficiency, as in case of absolute control results in bitter and misshaped fruits which are often rejected by consumer, thereby reducing farmer's yield.

Results also showed increased marketable fruit yield in T_{12} (45.8%), T_{11} (30.0%) and T_7 (12.1%) over the sole application of inorganic chemical fertilizers (T_2) indicating the significance of integration of nutrients from different sources rather than inorganic source alone. This might be due to supply of steady and continuous plant nutrients specifically macro, secondary and micronutrients from different sources rather than sole inorganic fertilizers, which in turn enhanced the growth and yield. The findings of present study are in agreement with Azarmi *et al.* (2009) [4]; Ghayal *et al.*, (2018) [11]; Bhattarai and Sapkota (2016) [5] in cucumber.

Fruit quality

The value of cucumber fruit is not only assessed by its yield but also by the quality of the produce. The quality of the cucumber is often determined on the basis of TSS, Ascorbic Acid and sugar content. The pooled results of two years revealed significant influence of various nutrient management practices on fruit quality of cucumber in terms of TSS, ascorbic acid and sugar content (Table 3).

Table 3: Effect of nutrient sources on quality parameters of cucumber variety "Seven Star".

	Treatments	TSS Pooled (2017-2018)	Ascorbic acid (mg $100g^{-1}$) Pooled (2017-2018)	Sugar content (%) Pooled (2017-2018)
T_1	Absolute Control	3.8	2.1	2.1
T_2	RDF	4.5	2.4	3.2
T_3	1/2 RDF + BFs	5.3	2.4	2.6
T_4	VC_4	4.8	2.7	2.9
T_5	VC_2 + BFs	4.8	2.3	2.9
T_6	1/2 RDF + VC_2 + BFs	5.5	2.5	3.0
T_7	RDF + VC_2 + BFs	5.1	3.7	3.6
T_8	F_{20}	5.0	3.2	2.7
T_9	F_{10} + BFs	4.5	2.4	3.0
T_{10}	1/2 RDF + F_{10} + BFs	4.9	3.2	3.6
T_{11}	RDF + F_{10} + BFs	5.2	3.6	3.7
T_{12}	1/2 RDF + F_{10} + VC_2 + BFs	5.4	3.9	3.9
	Mean	4.89	2.85	3.10
	SE (m)±	0.14	0.09	0.10
	CD (5%)	0.44	0.26	0.32
	CV (%)	7.0	8.0	6.0

In general, the TSS (Total Soluble Solid) value is defined as the amount of sugar and soluble solids present in fruit and vegetables. Technically, TSS of a produce includes the carbohydrate, organic acids, proteins, fats and minerals. TSS is an indicator towards produce quality. It has been established that the TSS value of fruits and vegetable crops varies according to variety, crop maturity, crop physiology or metabolism and major abiotic component of growing environment includes soil moisture, soil fertility, prevalence of light temperature etc. In the present study pooled results significantly varied among the nutrient management practices which varied from 4.6 ^{0}Brix (T_9) to 5.5 ^{0}Brix (T_6). Significantly highest TSS of 5.5 ^{0}Brix was recorded with application of ½ RDF + VC_2 + BFs (T_6) and was *statistically at par* with T_{12} (5.4 ^{0}Brix), T_{11} (5.2^{0}Brix), T_7 (5.1^{0}Brix) and T_3 (5.3^{0}Brix). In variably, either alone or in combination of organic manures (FYM and/or VC) with BFs enhanced the TSS of the cucumber fruits. This might be due to the fact that soil amendment can increase the soil organic matter or alter other soil properties, thereby creating growing conditions more conducive to crop health and quality produce as well. Increased fertility status also influenced with TSS and accumulation of more volatile compounds and flavours. There is also evidenced that nitrogen nutrition can affect ^{0}Brix level but in an indirect and complex manner. Availability of nitrogen can impact the efficacy of photosynthesis through which sugar is created and therefore possibly altered the TSS levels of the produce. The TSS of edible fruit (^{0}Brix) in cucumber was enhanced significantly due to application of inorganic fertilizers, organic manures (FYM/ and/or VC) and biofertilizer in an integrated manner either any two sources or all in combination might be due to higher accumulation of carbohydrates, proteins and captured energy by abundant supply of NPK high mineral nutrition, organic biofertilizer.

This in agreement with findings of Anjaanappa *et al*. (2012); Sharma *et al*. (2012) [23]; Sikarwar and Hardaha (2016) [24]. Soil inoculation of BFs consortia further enhanced the availability of nutrients and growth promoting substances in turn increased fruit TSS (Singh *et al.*, 2018) [17].

Regarding ascorbic acid content (mg $100g^{-1}$) of cucumber fruits, the pooled results revealed significant variations due to nutrient management practices which varied from 2.1 (T_1) to 3.9 (T_{12}). Significantly highest ascorbic acid content (mg $100g^{-1}$) of cucumber fruits were observed with adoption of INM treatments, T_{12} (3.9) closely followed by T_{11} (3.6) and T_7 (3.7) where *statistical parity* were recorded. The results clearly demonstrated that integrated application of inorganic chemical fertilizers, organic manures (FYM/and/or VC) with soil inoculation of biofertilizer consortia significantly enhanced the cucumber fruit quality with high ascorbic acid content. Similar trend was also observed in fruit sugar content (mg $100g^{-1}$) of cucumber, which varied significantly from 2.1 (T_1) to 3.9 (T_{12}). Significantly highest total sugar content (mg $100g^{-1}$) was recorded in plots received with INM practices (T_{12}) as 3.9 and was *statistically at par* with T_{11}, T_{10} and T_7. Better efficacy of integrated application of nutrients from different sources such inorganic chemical fertilizer, organic manures (FYM/and/or VC) and soil inoculation with biofertilizer in the present study might be due to steady and continuous supply of plant nutrient both nitrogen and potassium along with other important micro nutrients, thereby increased ascorbic acid content of fruits. Further when a plant exposed to increase nitrogen, it increased the production of protein and thus reduces the synthesis of carbohydrates, its levels are also reduced. In case of INM practices, usually nutrients released slowly, more specifically nitrogen released over a long period of time. Furthermore, soil microorganism affects soil dynamics and plant metabolism which ultimately results in plant composition and nutrition quality (Chouhan *et al.*, 2017) [6]. Soil inoculation of biofertilizer consortia also provides balanced nutrition as N by *Azospirillium* and *Azotobacter* while release of unavailable phosphorus to available from by *PSB* along with release of plant growth substances further enhanced the yield and quality of the produce. The findings of present study are in agreement with reports of Sharma *et al.* (2012) [23]; Thongney *et al.*, (2018) [28] in cucumber; Triveni *et al*. (2015) in bittergourd and Das *et al.*, (2015) [7] in bottle gourd.

Economics

The average results on economics of cucumber production on various nutrient management practices showed significant variations indicating the significance of results (Table No. 4). The mean data show wide variation for gross income which varied from Rs. 87515/- (T_1) to RS. 300462/- (T_{12}). Similar results was also observed for net returns which varied from Rs. -12794/- in absolute control (T_1) to Rs. 121148/- in plots received ½ RDF + F_{10} + VC_2 + BFs (T_{12}). In both the case of gross income and net income was maximum with adoption of INM treatment with integrated application of ½ RDF + F_{10} + VC_2 + BF_s indicating superiority of the treatment. Invariably, integrated application of nutrients from inorganic chemical fertilizers, organic (FYM and/or VC) coupled with soil inoculation of BFs (T_7, T_8, T_9, T_{10}, T_{11}, and T_{12}) recorded higher gross return and net returns. This was due to higher marketable fruit yield as observed in the present study.

Table 4: Economics of cucumber variety Seven Star as influenced by INM practices.

	Treatments	Total expenditure (Rs.) Mean (2017-2018)	Gross return (Rs.) Mean (2017-2018)	Net return (Rs.) Mean (2017-2018)	B:C ratio Mean (2017-2018)
T_1	Absolute Control	100309	87515	-12794	0.88
T_2	RDF	125110	206423	81313	1.64
T_3	1/2 RDF+ BFs	120937	182460	61523	1.50
T_4	VC_4	168042	188528	20487	1.12
T_5	VC_2+BFs	143641	152848	9207	1.06
T_6	1/2 RDF+VC_2+BFs	150585	188327	37742	1.25
T_7	RDF+VC_2+BFs	164303	231411	67108	1.40
T_8	F_{20}	167679	220855	53176	1.30
T_9	F_{10}+ BFs	142321	198042	55721	1.38
T_{10}	1/2 RDF+F_{10}+BFs	151944	214584	62640	1.40
T_{11}	RDF+F_{10}+BFs	160225	267110	106885	1.65
T_{12}	1/2 RDF+F_{10}+VC_2+ BFs	179314	300462	121148	1.66

Regarding net income, the results showed relatively lower values in T_7, T_8, T_{10} which might be due to higher cost of organic manures (FYM and/or VC) with relatively lower marketable yield. Similar results has also been reported by Prabhu *et al.* (2006), Kanaujia and Daniel (2016) [15], Singh *et al.* (2018) [17] in cucumber.

Benefit cost ratio calculated on the basis of gross income increased against cost of production different nutrient management practices recorded viable results ranging from minimum of 0.88 (T_1) to maximum of 1.66 (T_{11} and T_{12}). However, while recommending the nutrient management practice, as per principle, the treatment which will be provide more B:C ratio along with better growth, yield and soil fertility status should be considered simultaneously. Hence, in the present study, it may be concluded, that integrated application of ½ RDF + F_{10} + VC_2 + BF_s for higher marketable fruit yield and economics.

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