Bangladesh J. Bot. 53(1): 83-90, 2024 (March) DOI: https://doi.org/10.3329/bjb.v53i1.72230

INTEGRATED NUTRIENT MODULE: AN EFFICIENT TOOL FOR SUSTAINABLE FARMING OF CAPE GOOSEBERRY (*PHYSALIS PERUVIANA* L.)

VIVEK KUMAR, MANOJ KUNDU[1]*, HIDAYATULLAH MIR AND MAHENDRA SINGH[2]

Department of Horticulture (Fruit & Fruit Technology), Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India- 813210

Keywords: Azotobacter, Cape gooseberry, Fruit quality, KSB, PSB, Soil fertility

Abstract

Cape gooseberry is a nutrient loving crop. But excessive use of inorganic fertilizers may leads to health hazards, ecological vulnerabilities and diminution of soil physico-chemical characteristics. Hence, a trial was conducted for substituting inorganic fertilizers with biofertilizer in cape gooseberry to maintain the yield potential with soil fertility status too. The experimental plants were treated with azotobacter, phosphate and potash solubilizing bacteria (PSB and KSB) at 10 g plant^{-1} each with reduced dose of recommended fertilizer (RDF) (100- 60%) for two consecutive growing season. Total harvestable fruit plant^{-1} with highest yield was recorded in 90% RDF + Azotobacter, PSB and KSB treatment with par value in 60% RDF + Azotobacter, PSB and KSB treatment. Quality of ripe fruit with respect to TSS (15.90 °B), total sugar (11.29%), ascorbic acid (60.03 mg 100 g^{-1}) and carotenoid content (49.25 µg 100 g^{-1}) was also improved significantly in 60% RDF + Azotobacter, PSB and KSB treatment. Soil physico-chemical properties of the field was not varied significantly over initial reading. However, microbial population *viz*. bacteria, fungi and actinomycetes count was improved significantly in all the nutrient modules. Hence, it can be concluded that integrated nutrient module comprising 60% RDF of NPK + Azotobacter, PSB and KSB at 10 g plant^{-1} is the best treatment module for improving the production system of cape gooseberry in sustainable manner for long run without hampering the soil health and quality.

Introduction

Cape gooseberry (*Physalis peruviana* L.) is an important annual fruit crop of Solanaceae family. It is the rich source of vitamin A, Vit. C, Vit. B_1, B_2, B_3, P, Ca and Fe. Besides, it also contains phenols and flavonoids which also having a high degree of antioxidant properties against free radicals. These high nutrients content of the crop increases its demand significantly in fresh market as well as in processing industries. Further, the annual nature of the crop helps to give profitable return in shortest possible time which makes it a potential fruit crop to double the farmers' income. But the major drawback is the low yield of the crop in India (only 400 – 500 g plant^{-1} as compared to 700-900 g plant^{-1} in leading cape gooseberry producing countries). This is mainly due to its neglected cultivation without following any scientific package of practice. Hence, to improve the yield potentiality of the crop, it is very important to apply sufficient amount of nutrients to the crop. Due to shallow root system as well as the production of large number of berries per plant, it requires higher amount of inorganic fertilizers particularly nitrogenous and potassic fertilizers (Hazarika and Aheibam 2019). But inorganic forms of fertilizers are very short in supply and expensive too which ultimately raises the cost of production of the crop. In addition, the imbalance application of inorganic fertilizers may leads to health hazards, ecological vulnerabilities and diminution of soil health too.

*Author for correspondence: <manojhorti18@gmail.com>. [1]Department of Fruit Science, College of Horticulture & Forestry, Rani Lakshmi Bai Central Agricultural University, Jhansi, Uttar Pradesh, India- 284003. [2]Department of Soil Science & Agricultural Chemistry, College of Agriculture, Acharya Narendra Deva University of Agriculture and Technology Kumarganj, Ayodhya, Uttar Pradesh, India- 224229.

Therefore, it is the urgent necessity to think about the use of alternative nutrient sources which may boost the crop yields and quality without having any antagonistic effect on soil health and environmental hazards and also to reduce cost of cultivation. Biofertilizers are known to be environment friendly, ecologically sound and economically viable choice to reduce the rate of application of inorganic fertilizers without hampering the nutrient supply to the crop and also increase the use efficiency of natural resources. Further, biofertilizers are worked as carriers based on their formulation comprising beneficial microbes in viable condition which play significant role for improving the fertility status of the soil and also the plant growth and development (Kumar *et al.* 2019). Till date a large number of bacterial population present in the rhizosphere of the plant, has been evaluated and identified as beneficial for plant growth and developmental process with increased yield of better quality fruits (Karlıdag *et al.* 2007). These include Azotobacter, Azospirillum, Phosphate solubilizing bacteria (PSB), potash solubilizing bacteria (KSB) etc. Besides, biofertilizers are also known to have indirect effect on increasing soil microbial activities (Rana and Chandel 2003). Hence, it can be hypothesised that the combined application of lower dose of inorganic fertilizers with biofertilizers can be a promising way to reduce the threat of degradation of soil fertility status. But available literature is very scanty regarding the potentially of these N fixers as well as P and K solubilizers to the extent of substitution of inorganic fertilizers under integrated nutrient module. Therefore, an experiment was formulated to standardize the integrated nutrient module in cape gooseberry for improving yield and quality without hampering the soil fertility status.

Material and Methods

Healthy seedlings of cape gooseberry (*Physalis peruviana* L.) having uniform growth without any disease and injuries were used as the experimental materials and transplanted in the main experimental plot at Horticulture Garden, Bihar Agricultural University, Sabour, Bihar, India.

Treatment details for the experiments were: T_1= 100% Recommended Dose of Fertilizers (RDF) (N:P:K @ 2.5:2.0:1.5 g plant^{-1}); T_2= 100% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each; T_3= 90% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each; T_4= 80% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each; T_5= 70% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each; T_6= 60% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each and T_7= 50% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each. Inorganic fertilizers were supplied to the plants through urea, diammonium phosphate and muriate of potash. Full dose of N and P with half K was applied one day before transplanting while remaining half dose of K was applied 60 days after transplanting (DAT) as per the treatment details. Azotobacter, PSB and KSB were applied at the root zone during transplanting. Uniform cultural schedule was adapted to all the experimental cape gooseberry plants during the entire period of investigation. The entire experiment was laid on completely randomized block design (CRBD) with three replications.

Plant height, total number of leaves plant^{-1} and specific leaf weight was measured manually while leaf area was recorded through leaf area meter (CI-203 CA). Relative water content of matured leaf was recorded through the procedure described by Weatherley (1950). Leaf chlorophyll content was recorded by the protocol described by Barnes *et al.* (1992).

Total flowers and fruits plant^{-1}, harvesting span, yield plant^{-1} as well as average fruit weight was recorded manually. With respect to fruit quality, total soluble solids (TSS) content was estimated through hand refractometer (Atago, Tokyo, Japan) while titratable acidity was determined by titration method (Rangana 2010). Total sugar content was determined by Lane and Eynone (1923) method. Ascorbic acid and total carotenoid content of the fruit was estimated by the procedure described by Jones and Hughes (1983) and Roy (1973), respectively.

Soil samples were collected before transplanting of cape gooseberry seedlings to the main field and again after harvesting of fruits to analyze different soil physico-chemical and biological characters. A solution of soil:water was prepared at 1:2.5 ratio to collect the data of soil pH as well as electrical conductivity through pH meter and conductivity meter, respectively (Jackson 1967). The available soil organic carbon and nitrogen were assessed by Walkley and Black (1934), and Subbiah and Asija (1956) methods, respectively. Available phosphorous and potassium present in the soil were determined through the procedure described by Olsen *et al.* (1954) and Jackson (1967), respectively. Total bacterial population, actinomycetes and total fungi were counted by the method described by Thornton (1922), Jensen (1930) and Martin (1950), respectively. Data of two consecutive years were pooled to prepare average data for each and every parameter before their statistical analysis through statistical analysis software (SAS 9.3; SAS Institute, Cary, NC, USA). The mean values were compared by Duncan's multiple range test (DMRT).

Results and Discussion

Plant height, total number of leaves plant^{-1} and leaf area were recorded maximum (140.33 cm, 150.33 and 73.67 cm^2, respectively) in T_2 treatment (Table 1) with non-significant difference in T_3. However, with the further reduction of NPK doses at 60% RDF or lower along with the application of Azotobacter, PSB and KSB at 10 g plant^{-1} each, the plant height, leaf number and leaf size were decreased sharply. The increased plant height under T_2 treatment module might be due to increased availability of nitrogen at initial stage of their growth as compared to other nutrient modules because the response of Azotobacter to fix the atmospheric nitrogen and

Table 1. Impact of integrated nutrient module on vegetative and physiological growth of cape gooseberry (*Physalis peruviana* L.).

Treatment	Vegetative growth			Physiological growth		
	Plant height (cm)	No. of leaves plant^{-1}	Leaf area (cm^2)	Specific leaf weight (mg cm^{-2})	Leaf relative water content (%)	Total chlorophyll content (mg g^{-1} FW)
T_1= 100% RDF (Control)	134.67ab	140.67bc	68.00bc	20.18bc	66.33b	4.27cd
T_2= 100% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each	140.33a	150.33a	73.67a	22.26a	74.39a	4.68a
T_3= 90% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each	132.33b	149.00a	70.00ab	22.24a	72.04a	4.59ab
T_4= 80% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each	125.67c	146.33ab	69.33bc	22.01a	71.03ab	4.49abc
T_5= 70% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each	125.00c	142.00bc	66.67bc	21.65ab	70.60ab	4.48abc
T_6= 60% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each	123.33cd	138.00c	65.33cd	21.55ab	68.12abc	4.39bc
T_7= 50% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each	118.33d	128.33d	61.67d	19.72c	64.54bc	4.07d

Different letters in the same column indicate significant differences at $P \leq 0.05$ (DMRT).

mineralization of inorganic source of phosphatic as well as potassic fertilizer by PSB and KSB, respectively, is a slow process. However, as the time progress, the function of Azotobacter, PSB and KSB start to increase which ultimately helps to increase the bioavailability of N, P and K to the plants slowly but steadily resulting significant improvement of leaf number and size under T_3 and T_4 nutrient modules too. It confirms the previous research finding of Hazarika and Aheibam (2019).

Similarly, specific leaf weight and leaf relative water content was calculated maximum in T_2 treatment (22.26 mg cm^{-2} and 74.39%, respectively) with par value in the treatment comprising the reduction of NPK doses up to 60% RDF along with the application of Azotobacter, PSB and KSB (T_3 to T_6) treatment (Table 1). However, with the further reduction of NPK doses at 50% RDF (T_7), specific leaf weight and leaf relative water content reduced drastically. Similar pattern was also observed for total chlorophyll content in the leaf of experimental cape gooseberry plants. Similarly, biofertilizer application accelerated the nutrient uptake process which in turn enhances the chlorophyll and carbohydrate synthesis (Ekinci *et al*. 2014).

The highest number of flowers $plant^{-1}$ was counted in T_2 treatment with par result in T_3 (11.98 and 8.94% additional flowers over control, respectively) (Table 2). However, least number of flowers were counted in T_7 treatment (2.47% lower than the control). The improved vegetative and physiological growth in Azotobacter along with PSB and KSB inoculated plants helps to produce significantly higher amount of photosynthates in their greenly structures for longer period of time resulting significant improvement in total flower count (Kumar *et al*. 2019).

Table 2. Impact of integrated nutrient module on reproductive behaviour and yield attributes of cape gooseberry (*Physalis peruviana* L.).

Treatment	Total number of flowers $plant^{-1}$	Total number of fruits $plant^{-1}$	Duration of harvest (days)	Fruit weight (g)	Yield (g $plant^{-1}$)
T_1= 100% RDF (Control)	175.33cd	69.00cd	117.33c	7.61c	524.95c
T_2= 100% RDF + Azotobacter, PSB and KSB @ 10 g $plant^{-1}$ each	196.33a	75.00bc	122.33bc	8.75b	657.08b
T_3= 90% RDF + Azotobacter, PSB and KSB @ 10 g $plant^{-1}$ each	191.00ab	82.33a	134.33a	9.77a	804.06a
T_4= 80% RDF + Azotobacter, PSB and KSB @ 10 $gplant^{-1}$ each	184.00bc	82.00a	132.33ab	9.72a	797.23a
T_5= 70% RDF + Azotobacter, PSB and KSB @ 10 g $plant^{-1}$ each	183.33bc	81.00ab	136.33a	9.70a	785.76a
T_6= 60% RDF + Azotobacter, PSB and KSB @ 10 g $plant^{-1}$ each	178.00cd	80.33ab	136.00a	9.77a	785.89a
T_7= 50% RDF + Azotobacter, PSB and KSB @ 10 g $plant^{-1}$ each	171.00d	68.00d	114.00c	7.80c	530.32c

Different letters in the same column indicate significant differences at $P \leq 0.05$ (DMRT).

The maximum number of fruits $plant^{-1}$ was also counted in T_3 treatment (19.32% higher than the control) with at par value in T_4, T_5 and T_6 (18.84, 17.39 and 16.42% higher than the control, respectively) (Table 2) and it was reduced drastically in T_7. The increased activity of IAA, GA and cytokinins by synergistic effect of Azotobacter, PSB and KSB could help to divert the photosynthates from vegetative part to the developing flower buds resulting maximum conversion of flowers to fruits. It confirms the findings of Hazarika *et al*. (2015) and Hazarika and Aheibam (2019) in banana and lemon, respectively.

The harvesting span was extended significantly as compared to control in all different nutrient modules except the treatment comprising 50% RDF application along with Azotobacter, PSB and KSB at 10 g plant^{-1} each (T_7) where it was reduced by 3.33 days over control (117.33 days) (Table 2). On the other hand, average berry weight as well as yield plant^{-1} was measured maximum in T_3 treatment (9.77 g and 804.06 g plant^{-1}, respectively) with at par result in T_6, T_4 and T_5 treatment (Table 2). These improvement in fruit weight and yield plant^{-1} under T_3, T_4, T_5 and T_6 were associated with the increased transportation of photosynthetic assimilates from source to sink as stimulated by different growth hormones which might be synthesized in presence of different biofertilizers, applied to the plants. These observations confirm the earlier report of Kumar *et al.* (2019) in strawberry.

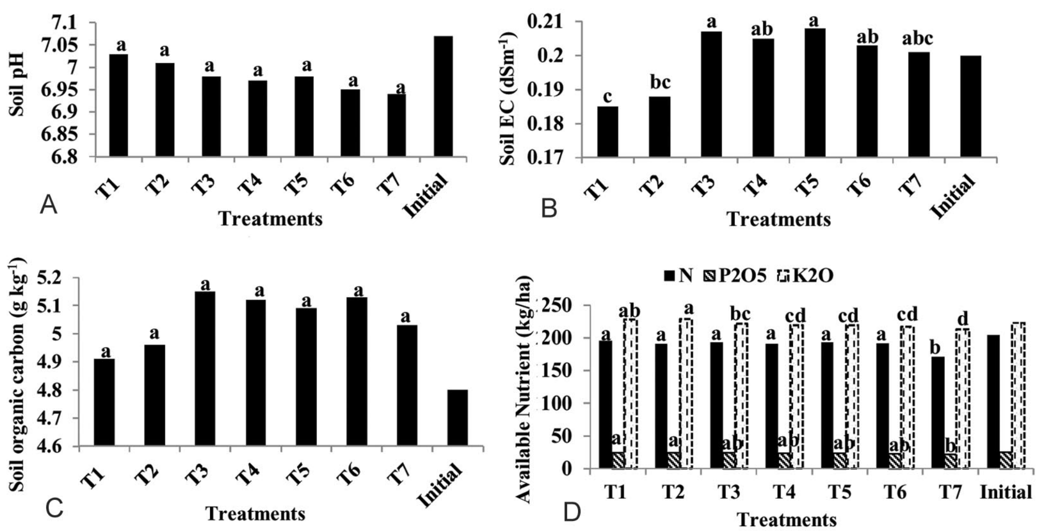
TSS and total sugar content of ripe cape gooseberry fruit was recorded maximum in the INM module comprising 80% RDF + Azotobacter, PSB and KSB at 10 g plant^{-1} each (T_4) (16.05 ºB and 11.40%, respectively) with non-significant differences in T_5 and T_6 (Table 3). However, titratable acidity was measured minimum in T_4 with marginal difference in T_3, T_5 and T_6 treatment (25.81, 22.58, 21.51 and 18.28% lower than control, respectively). The increased content of TSS and sugar in combined application of bio-fertilizers with reduced NPK doses were due to the increased production of sugars as well as other soluble compounds from protein hydrolysis and ascorbic acid oxidation (Hazarika *et al*. 2015). However, the lowest acidity in the nutrient module comprising multi-inoculation of different biofertilizers could be due to the dilution effect and increased conversion of fruit acidity to sugar and other solids (Singh and Singh 2009). On the other hand, ascorbic acid and carotenoid content of ripe cape gooseberry fruit was calculated maximum in T_4 and T_5, respectively, with statistically non-significant difference in T_6 treatment (Table 3). The increased catalytic activities of several enzymes were influenced by Azotobacter, PSB and KSB and their positive impact on ascorbic acid and carotenoid biosynthesis increased the accumulation of ascorbic acid and carotenoid content in the fruit (Dudi *et al*. 2005).

Table 3. Impact of integrated nutrient module on biochemical attributes of ripe cape gooseberry (*Physalis peruviana* L.) fruit.

Treatment	TSS (°B)	Titratable acidity (%)	Total sugar (%)	Ascorbic acid (mg 100g^{-1} FW)	Carotenoid content (µg g^{-1} FW)
T_1= 100% RDF (Control)	13.65b	0.93a	9.70c	48.05c	40.72b
T_2= 100% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each	15.15ab	0.78b	10.76ab	60.01a	50.46a
T_3= 90% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each	15.90a	0.72bc	11.28a	58.07ab	52.08a
T_4= 80% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each	16.05a	0.69c	11.40a	60.35a	51.01a
T_5= 70% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each	15.94a	0.73bc	11.32a	59.70a	52.15a
T_6= 60% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each	15.90a	0.76bc	11.29a	60.03a	49.25a
T_7= 50% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each	14.04b	0.90a	9.97bc	53.70b	46.46a

Different letters in the same column indicate significant differences at $P \leq 0.05$ (DMRT).

Soil pH, electric conductivity (EC) and available soil organic carbon (SOC) content were not differed significantly over control by different integrated nutrient modules (Fig.1A, B and C). However, as compared to the initial soil pH reading (7.07), it was marginally reduced to all the treatments with the reduction of NPK doses including control while the EC and SOC values were increased marginally over the initial reading with the reduction of NPK doses. Formation of chelate compounds or stable complexes and the cations associated with phosphate fixation (Prabhu *et al.* 2002) as well as the increased accumulation of organic acids through bacterial population (Turan *et al*. 2006) play significant role to reduce the soil pH in the biofertilizer treated plots. While the trends of electrical conductivity reduction in biofertilizer treated plots were in line with the earlier findings of Verma and Rao (2013) in strawberry. Availability of soil nitrogen and phosphorous was estimated maximum in the soil sample collected before the application of treatments (initial value) (204.56 kg ha^{-1} and 24.98 kg ha^{-1}, respectively) while minimum in T_7 (Fig.1D). Available soil potassium was recorded maximum in T_2 (229.20 kg ha^{-1}) with non-significant difference in T_1. This reduction of available soil NPK content under the treatment comprising reduced NPK content as compared to 100% RDF was due to the improved solubilisation of inorganic P and K sources by PSB and KSB and increased N fixation by Azotobacter (Singh *et al*. 2015).



T_1= 100% RDF (N:P:K @ 2.5:2.0:1.5 g $plant^{-1}$); T_2= 100% RDF + Azotobacter, PSB and KSB @ 10 g $plant^{-1}$ each; T_3= 90% RDF + Azotobacter, PSB and KSB @ 10 g $plant^{-1}$ each; T_4= 80% RDF + Azotobacter, PSB and KSB @ 10 g $plant^{-1}$ each; T_5= 70% RDF + Azotobacter, PSB and KSB @ 10 g $plant^{-1}$ each; T_6= 60% RDF + Azotobacter, PSB and KSB @ 10 g $plant^{-1}$ each and T_7= 50% RDF + Azotobacter, PSB and KSB @ 10 g $plant^{-1}$ each.

Fig. 1. Impact of integrated nutrient modules on soil pH (A); EC (B); organic carbon (C) and available nutrients (D) present in the rhizosphere of cape gooseberry (*Physalis peruviana* L.) field.

The microbial counts in the form of actinomycetes, bacteria as well as fungi in the soil of cape gooseberry field varied significantly in different treatment combinations (Table 4). The bacterial population was counted maximum in T_5 (498.33 $\times10^4$ cfu g^{-1} soil higher over control) with at par count in T_2, T_4, T_6 and T_3 treatments. Similar pattern was also observed in actenomycetes and fungi population with maximum in T_3 and T_4 treatments, respectively with non-significant difference in T_5 and T_6 treatments. Generally, the synergistic effect between beneficial microorganisms (Azotobacter, PSB and KSB), enhanced the solubilization of P and K and increased the secretion of different plant growth-promoting substances at root rhizosphere of biofertilizer treated plants which helped to increase the fungi, bacteria, actinomycetes population to the rhizosphere (Kumar *et al.* 2019).

Table 4. Impact of integrated nutrient module on soil microbial count of cape gooseberry (*Physalis peruviana* L.) field.

Treatment	Microbial count ($\times 10^4$cfu g^{-1} soil)		
	Bacterial count	Actinomycetes	Fungi
T_1 - 100% RDF (Control)	3139.00c	119.49c	7.86c
T_2 - 100% RDF + Azotobacter, PSB and KSB @ 10 g $plant^{-1}$ each	3573.33a	127.44c	8.47bc
T_3 - 90% RDF + Azotobacter, PSB and KSB @ 10 g $plant^{-1}$ each	3459.67ab	215.00a	11.17abc
T_4 - 80% RDF + Azotobacter, PSB and KSB @ 10 g $plant^{-1}$ each	3570.33a	213.23a	12.52a
T_5 - 70% RDF + Azotobacter, PSB and KSB @ 10 g $plant^{-1}$ each	3637.33a	210.78a	10.86abc
T_6 - 60% RDF + Azotobacter, PSB and KSB @ 10 g $plant^{-1}$ each	3525.33a	207.00a	11.60ab
T_7 - 50% RDF + Azotobacter, PSB and KSB @ 10 g $plant^{-1}$ each	3248.00bc	149.00b	8.04c
Initial value	3214.00	148.56	8.78

Different letters in the same column indicate significant differences at $P \leq 0.05$ (DMRT).

The current research work confirms that integrated application of 90% RDF of NPK + Azotobacter, PSB and KSB at 10 g $plant^{-1}$ each (T_3) is the suitable treatment combination for improving physiological as well as reproductive growth of cape gooseberry plants with increased yield of better quality fruits with at par result in 80% RDF of NPK + Azotobacter, PSB and KSB at 10 g $plant^{-1}$ (T_4), 70% RDF of NPK + Azotobacter, PSB and KSB at 10 g $plant^{-1}$ (T_5) and 60% RDF of NPK + Azotobacter, PSB and KSB at 10 g $plant^{-1}$ (T_6) treatments. Further, the availability of nutrients in the soil under these four treatments was statistically at par with initial reading while the viable count of microorganism was significantly higher than initial count. Hence, it can be concluded that the integrated nutrient module comprising 60% RDF of NPK + Azotobacter, PSB and KSB at 10 g $plant^{-1}$each (T_6) is the best treatment to improve the production system of cape gooseberry in sustainable manner for long run without hampering the soil health and quality.

Reference

Barnes JD, Balaguer L, Manrique E, Elvira S and Davison AW 1992. A reappraisal of the use of DMSO for the extraction and determination of chlorophylls a and b in lichens and higher plants. Environ. Exp. Bot. **32**: 85-100.

Dudi OP, Singh S, Baloda S and Singh D 2005. Effect of nitrogen and FYM on fruit quality and yield of Kinnow mandarin. Haryana J. Hortic. Sci. **34**: 224-226.

Ekinci M, Turan M, Yildirim E, Gunes A, Kotan R and Dursun A 2014. Effect of plant growth promoting rhizobacteria on growth, nutrient, organic acid, amino acid and hormone content of cauliflower (*Brassica oleracea* L. var. botrytis) transplants. Acta Sci. Pol. Hortorum Cultus **13**: 71-85.

Hazarika TK and Aheibam B 2019. Soil nutrient status, yield and quality of lemon (*Citrus limon* Burm.) cv. 'Assam lemon' as influenced by biofertilizers, organics and inorganic fertilizers. J. Plant Nutr. **42**: 853-863.

Hazarika TK, Nautiyal BP and Bhattacharyya RK 2015. Conjunctive use of bio-fertilizers and organics for improving growth, yield and quality of banana cv. Grand Naine. Indian J.Hortic. **72**: 461-465.

Jackson MS 1967. Soil chemical analysis, Prentice Hall of India Private Limited, New Delhi, India.

Jensen HL 1930. Actinomycetes in Danish Soils. Soil Sci. **30**: 59-77.

Jones E and Hughes RE 1983. Foliar ascorbic acid in some angiosperms. Phytochem. **22**: 2493-2499.

Karlıdag H, Esitken A, Turan M and Sahin F 2007. Effects of root inoculation of plant growth promoting rhizobacteria (PGPR) on yield, growth and nutrient element contents of leaves of apple. Sci. Hortic. **114**: 16-20.

Kumar S, Kundu M, Das A, Rakshit R, Siddiqui MW and Rani R 2019. Substitution of mineral fertilizers with biofertilizer: An alternate to improve the growth, yield and functional biochemical properties of strawberry (*Fragaria* × *ananassa* Duch.) cv. Camarosa. J. Plant Nutr. **42**: 1-20.

Lane JH and Eynone L 1923. Determination of reducing sugars by means of Fehling solution with methylene blue indicator as an internal indicator. J. Indian Chem. Soc. **42**: 32-36.

Martin JP 1950. Use of acid, rose bengal and streptomycin in the plate method for estimating soil fungi. Soil Sci. **69**: 215-232.

Olsen S, Cole C, Watanabe F and Dean L 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate, USDA Circular Nr 939, US Gov. Print Office, Washington DC.

Prabu T, Ismail S, Sanjindranath AK and Savithri R 2002. Effect of integrated nutrient management on yield, dry matter and nutrient content in okra. Orissa J. Hortic. **30**: 52-56.

Rana R and Chandel J 2003. Effect of biofertilizers and nitrogen on growth, yield and fruit quality of strawberry. Progress. Hortic. **35**: 25-30.

Rangana S 2010. Handbook of analysis and quality control for fruit and vegetable products, Tata McGraw-Hill Limited, New Delhi, India.

Roy SK 1973. Simple and rapid methods for the estimation of total carotenoids pigments in mango. J. Food Sci. Technol. **10**: 45-46.

Singh A and Singh JN 2009. Effect of biofertilizers and bioregulators on growth, yield and nutrient status of strawberry cv. Sweet Charlie. Indian J. Hortic. **66**: 220-224.

Singh AK, Beer K and Pal AK 2015. Effect of vermicompost and biofertilizers on strawberry I: Growth, flowering and yield. Ann. Plant Soil Res. **17**: 196-199.

Subbiah BV and Asija GL 1956. A rapid procedure for estimation of available nitrogen in soils. Curr. Sci. **25**: 259-260.

Thornton HG 1922. On development of standardised agar medium for counting soil bacteria with special regard to repression of spreading colonies. Ann. Appl. Biol. **9**: 241-274.

Turan M, Ataoglu N and Sahin F 2006. Evaluation of the capacity of phosphate solubilizing bacteria and fungi on different forms of phosphorus in liquid culture. J. Sustain. Agric. **28**: 99-108.

Verma J and Rao VK 2013. Impact of INM on soil properties, plant growth and yield parameters of strawberry cv. Chandler. J. Hill Agric. **4**: 61-67.

Walkley A and Black IA 1934. An examination of the degtjareff method for determining organic carbon in soils: Effect of variations in digestion conditions and of inorganic soil constituents. Soil Sci. **63**: 251-263.

Weatherley PE 1950. Studies in the water relations of the cotton plant. I. The field measurement of water deficits in leaves. New Phytol. **49**: 81-87.

(Manuscript received on 22 November 2023; revised on 16 March, 2024)