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Integrated nutrient module can uphold the growth and yield of Cape gooseberry (*Physalis peruviana* L.)

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Abstract
The current research work was conducted during 2019-20 in the Department of Horticulture (Fruit and Fruit Tech.), BAC, Sabour to standardize the integrated nutrient module in cape gooseberry. From the investigation, it was observed that the vegetative and physiological growth in terms of leaf size, ratio of chlorophyll a:b of the experimental cape gooseberry plants had improved significantly by 100% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each treatment. However, the reproductive growth with respect to precocity in flowering after bud break was obtained in 60% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each treatment (15.33 days) with par value in 50% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each treatment. On the other hand, highest yield acre^{-1} was recorded in 90% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each treatment with par value in the module comprising 60-80% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each. The quality attributes of ripped cape gooseberry fruit in terms of sugar: acid ratio was also improved significantly in 90% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each treatment with par value in the module comprising 60-80% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each (14.96-15.69). Hence, it can be concluded that the integrated nutrient module comprising 60% RDF of NPK + Azotobacter, PSB and KSB @ 10 g plant^{-1} is the best treatment to improve the production system of cape gooseberry.

Keywords: Cape gooseberry, INM, KSB, PSB, Yield

1. Introduction
Cape gooseberry (*Physalis peruviana* L.), belongs to the family Solanaceae, is an important annual fruit crop. It is the rich source of vitamin. A (36 IU/100g), vit. C (11 mg/100g), Vit. B1, B2, B3, P (40 mg/100 g), Ca and Fe. Besides, antioxidants, it contain phenols, flavonoids, which also exhibit a high degree of antioxidant capacity against free radical. Due to annual nature of the crop, it gives return in shortest possible time and has great demand in fresh market as well as in processing industries to prepare sauces, puddings, pies, jams, chutneys, ice cream etc. But the main drawback in the large scale cultivation of this crop is the non-availability of improved production technology resulting poor yield and quality. There are large number of low-cost production technologies are available in different fruit crops *viz*. application of recommended dose of fertilizers, micronutrients, PGRs etc (Khatoon *et al*., 2021; Nandita *et al.*, 2020; Khatoon *et al*., 2020; Kumari *et al*., 2019a; Kundu *et al*., 2013a; Kundu *et al*., 2013b; Kundu *et al*., 2013c) [12, 22, 13, 16, 18-20]. Among them adaptation of integrated nutrient module is one of the most viable option to improve the yield and quality of different crops.

For optimum plant growth, nutrients must be available in sufficient and balanced quantities (Chen, 2006) [5]. Farming regions that emphasize heavy chemical application are led to adverse environmental, agricultural and health consequences (Shehata and El-khawas, 2003) [25]. One of the possible options to reduce the use of chemical fertilizers could be use of bio and organic fertilizers. Biofertilizers are products containing living cells of different types of microorganisms which when, applied to seed, plant surface or soil, colonize the rhizosphere or the interior of the plant and promotes growth by converting nutritionally important elements (nitrogen, phosphorus) from unavailable to available form through biological process such as nitrogen fixation and solubilization of rock phosphate (Rokhzadi *et al*., 2008) [23]. Beneficial microorganisms in biofertilizers accelerate and improve plant growth and protect plants from pests and diseases (El-yazeid *et al*., 2007) [7]. To increase the availability of phosphorus and nitrogen for plant, large amounts of fertilizers are used on a regular basis soon after application of a large proportion of phosphorus fertilizer is rapidly immobilized and becomes unavailable to plants (Xiao *et al*., 2008) [28] and also, 25% of the applied nitrogen fertilizer is lost from the soil plant system through leaching, volatilization and de-nitrification (Saikia and Jain, 2007) [24]. Symbiotic nitrogen fixer and phosphate solubilizing microorganisms play an important role in supplementing nitrogen and phosphorus to the plant, allowing a sustainable use of nitrogen and phosphate fertilizers (Tambekar *et al*., 2009) [27]. The fixed phosphorus in the soil can be solubilized by phosphate solubilizing bacteria (PSB), which have the capacity to convert inorganic unavailable phosphorus form to soluble forms HPO_4^{2-} and H_2PO^- through the process of organic acid production, chelation and ion exchange reactions and make them available to plants. Therefore, the use of PSB in agricultural practice would not only offset the high cost of manufacturing phosphate fertilizers but would also mobilize insoluble in the fertilizers and soils to which they are applied (Banerjee *et al*., 2010) [3]. Biological nitrogen fixation is one way of converting elemental nitrogen into plant usable form (Gothwal *et al*., 2007) [9]. Nitrogen-fixing bacteria (NFB) transform inert atmospheric N_2 to organic compounds (Bakulin *et al*., 2007) [2]. The ability of these bacteria to contribute to yields in crops is only partly a result of biological N_2-fixation. The Mechanisms involved have a significant plant-growth promotion potential. In these relationships the bacteria receive non-specific photosynthetic carbon from the plant and, in turn, provide the plant with fixed nitrogen, hormones, signal molecules, vitamins, iron, etc (Mikhailouskaya and Bogdevitch, 2009) [21]. Previous studies showed that the combination of biofertilizers with organic or chemical fertilizers further enhanced the growth and yield of different crops (Kumar *et al*., 2019a; Kumar *et al*., 2019b) [14, 15]. Further, the continuous application of biofertilizers years after year is also beneficial to improve the soil fertility status (Kumari *et al*., 2019b; Kumar *et al*., 2019b) [17, 15]. Hence, the present investigation was formulated to study the impact of INM module including different types of biofertilizers on growth and yield attributes of cape gooseberry.

2. Materials and Methods

For the current investigation, cape gooseberry (*Physalis peruviana* L.) was used as the experimental plants. The plants were planted at the main field at 60 × 45 cm spacing on 17th November 2019. Each and every experimental plants were applied with the nutrients as per the treatment details – 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; T_7: 50% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each.

Azotobacter, PSB and KSB were appliec at the root zone during transplanting. However, the application of N, P and K fertilizer in the form of Urea, DAP and MOP was done one day before transplanting. The lay out of the experiment was on Completely Randomized Block Design (CRBD) with three replications.

Vegetative, physiological and reproductive growth of the plants was observed under field condition. After harvesting, yield was calculated and biochemical analyses of fruit were carried out.

2.1 Vegetative and physiological growth of the plant

Leaf length and breadth was measured manually with the help of measuring scale. Further, chlorophyll content (chlorophyll a, and b) of the leaves was analysed at vegetative stage and again at fruiting stage following the method of Barnes *et al*., (1992) [4] and the ratio of chlorophyll a: b was calculated thereafter.

2.2 Reproductive growth, yield and fruit quality attributes

The duration from bud break to flowering was counted manually for each and every experimental cape gooseberry plants.

On the other hand, all the fruits from an individual plant were picked manually in each harvesting and weighted them on digital weighing balance. At the end of last harvesting, yield/plant was calculated by adding the value of fruit weight in each harvesting. Thereafter, yield per acre area was calculated by using following formula- Yield acre^{-1} = Yield Plant^{-1} × No. of plants accommodates acre^{-1} area Thereafter, sugar:acid ratio of the ripped cape gooseberry fruits was determined by dividing the total sugar content with titratable acidity for ten individual fruits under each replication and average value was calculated thereafter. Sugar content in the ripe fruit was estimated by Lane and Eynone (1923) method.

Data were analyzed using statistical software (OPSTAT, HAU, Hissar).

3. Results

3.1 Vegetative and physiological growth of the plant

The experimental results revealed that the leaf length and breadth of the experimental cape gooseberry plants varied significantly under different nutrient modules (Table 1). Leaf length was measured maximum in the treatment comprising 100% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each (T_2) followed by 90% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each (T_3) which was 4.96 and 1.76% higher than the contol (9.07 cm). However, with the reduction of RDF doses below 80%, the leaf length stared to reduce significantly and it was recorded minimum in 50% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each (T_7) treatment (8.52 cm) followed by 60% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each (T_6) and 70% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each (T_5) treatment. Similarly, leaf breadth was also recorded maximum in the treatment comprising 100% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each (T_2) which was 3.06% higher than the control (7.51 cm). However, it was recorded minimum in 50% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each (T_7) treatment (7.24 cm) followed by 60% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each (T_6) and 70% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each (T_5) treatment.

Chlorophyll a:b ratio of cape gooseberry at vegetative and fruiting stage was also differed significantly under different INM modules (Table 1). At vegetative stage, the ratio of chlorophyll a and b was recorded maximum in 100% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each (T_2) treatment (3.95) with at par with the treatment comprising 90% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each (3.88). However, it was reduced drastically in 50% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each (T_7), 60% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each (T_6) and 70% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1}

each (T_5) treatment (3.41, 3.43 and 3.61, respectively). Similarly, chlorophyll a:b ratio at fruiting stage was also recorded maximum in 100% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each (T_2) treatment followed by in 90% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each (T_2) treatment (4.35 and 4.24, respectively) while minimum in 50% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each (T_7) followed by 60% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each (T_6) treatment (4.03 and 4.16, respectively). Further, an interesting resuls was obtained that the ratio of chlorophyll a:b was significantly higher during fruiting stage as compared to vegetative stage, irrespective of treatment differences.

3.2 Reproductive growth, yield and fruit quality attributes

The duration from bud break to flowering was recorded earliest in 50% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each (T_7) with similar duration in 60% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each (T_6) treatment (15.33 days). However, late flowering after bud break was observed in the treatment comprising 100% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each (T_2) which took 1.33 extra days as compared to control (20.00 days). Further, the earliness in flowering after bud break was also observed in 90% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each, 80% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each, and 70% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each treatment (16.33, 16.67 and 16.00, respectively).

The yield of cape gooseberry was also improved significantly under different INM modules as compared to control (Table 2). It was recorded maximum in 90% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each (T_3) with at par yield in 80% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each (T_4), 70% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each (T_5) and 60% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each (T_6) treatments (12.08, 11.94, 11.75 and 11.75, respectively). However, the yield was recorded minimum control with at par result in 50% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each (T_7) treatment (7.85 and 7.96 tonnes acre^{-1}).

The sugar: acid ratio was recorded maximum in 80% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each (T_4) followed by 90% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each (T_3), 70% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each (T_5) treatments (16.62, 15.69 and 15.60, respectively) with miniumum in control (10.48) which was statistically at par with 50% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each (T_7) treatment (11.15).

4. Discussion

The increases vegetative with respect to leaf length and breadth and physiological growth with respect to the ratio of chlorophyll a:b of the experimental cape gooseberry plants under integrated nutrient module might be due to the effect of bio-fertilizers to enhance the nutrient uptake process especially nitrogen which ultimately plays significant role in integration of several amino acids (Awasthi *et al.,* 1998). These amino acids are subsequently provide the framework for mitochondria, chloroplast and other photosynthetic structure to accelerate different biochemical reactions resulting improved vegetative and physiological activities within the plant system. It confirms the earlier observations of Gajbhiye *et al.* (2003) [8] and Singaravel *et al.* (2008) [26] in tomato and okra. Further, these improved vegetative and physiological growth of Azotobacter along with PSB and KSB inoculated cape gooseberry plants might helped to improve the reproductive growth of cape gooseberry under the present research work. Similar results were also obtained earlier by Kumar *et al.* (2019a) [14] in strawberry.

In addition, the increased physiological growth of biofertilizer treated cape gooseberry plants helps to accumulate maximum amount of carbohydrate within the photosynthetic organs of the plant. Further, the treatments of biofertilizers also accelerate the translocation process of stored carbohydrates from source (leaf) to sink (growing fruits) resulting improvement in the crop yield. It confirms the earlier findings of Kumar *et al.* (2019b) [15] in strawberry and Hazarika and Aheibam (2019) [10] in lemon.

On the other hand, quality attributes of ripped cape gooseberry fruits under the current experiment were improved significantly due to the multi-inoculation of biofertilizers. The improvement of Sugar: Acid ratio in combined application of bio-fertilizers along with reduced NPK doses might be due to the increased production of sugars from protein hydrolysis and ascorbic acid oxidation (Hazarika *et al*., 2015) [11] which confirms the previous report of Kumar *et al*. (2019a) [14] in strawberry and Dey *et al.* (2005) [6] in guava.

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

Treatment	Vegetative growth		Physiological growth	
	Leaf Length (cm)	Leaf breadth (cm)	Chlorophyll a/b ratio at vegetative stage	Chlorophyll a/b ratio at fruiting stage
T_1 - 100% RDF (Control)	9.07	7.51	3.73	4.15
T_2 - 100% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each	9.52	7.74	3.95	4.35
T_3 - 90% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each	9.23	7.58	3.88	4.24
T_4 - 80% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each	9.18	7.55	3.69	4.22
T_5 - 70% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each	8.95	7.45	3.61	4.17
T_6 - 60% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each	8.78	7.44	3.43	4.16
T_7 - 50% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each	8.52	7.24	3.41	4.03
CD ($p \leq .05$)	0.25	0.21	0.11	0.12
SE (m)	0.08	0.07	0.25	0.07
SE (d)	0.12	0.10	0.35	0.10
CV (%)	1.56	1.57	11.73	3.01

Table 2: Effect of integrated nutrient module on reproductive behaviour and yield and fruit quality of cape gooseberry (*Physalis peruviana* L.)

Treatment	Duration from bud break to flowering (Days)	Yield (Tonnes acre^{-1})	Sugar: Acid ratio
T_1 - 100% RDF (Control)	20.00	7.85	10.48
T_2 - 100% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each	21.33	9.83	13.80
T_3 - 90% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each	16.33	12.08	15.69
T_4 - 80% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each	16.67	11.94	16.62
T_5 - 70% RDF + Azotobacter, PSB and KSB @ 10 g plant-1	16.00	11.75	15.60
T_6 - 60% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each	15.33	11.77	14.96
T_7 - 50% RDF + Azotobacter, PSB and KSB @ 10 g plant^{-1} each	15.33	7.96	11.15
CD ($p \leq .05$)	2.32	0.68	2.11
SE (m)	0.74	0.22	0.68
SE (d)	1.05	0.31	0.96
CV (%)	7.45	3.62	8.36

5. Conclusion

Combined application of Azotobacter, PSB and KSB @ 10 g plant^{-1} each along with reduced NPK is very effective tool for improving physiological as well as reproductive growth of cape gooseberry plants with increased yield of better quality fruits. Treatment comprising 90% RDF of NPK + Azotobacter, PSB and KSB @ 10 g plant^{-1} (T_3) is found most suitable for improving the yield and quality of cape gooseberry fruit with at par result in 80% RDF of NPK + Azotobacter, PSB and KSB @ 10 g plant^{-1} (T_4), 70% RDF of NPK + Azotobacter, PSB and KSB @ 10 g plant^{-1} (T_5) and 60% RDF of NPK + Azotobacter, PSB and KSB @ 10 g plant^{-1} (T_6) treatments. Hence, it can be concluded that the integrated nutrient module comprising 60% RDF of NPK + Azotobacter, PSB and KSB @ 10 g plant^{-1} (T_6) is the best treatment to improve the production system of cape gooseberry in sustainable manner for long run with reduced application of mineral fertilizers.

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