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Integrated nutrient management in cape gooseberry

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ABSTRACT

Excessive use of inorganic fertilizers may lead to health hazards, ecological vulnerabilities and deterioration of soil health. Hence, the present experiment was conducted to substitute the mineral fertilizers with biofertilizers in cape gooseberry by maintaining the yield potential and soil fertility status. Cape gooseberry plants were treated with *Azotobacter*, phosphate solubilizing bacteria (PSB) and potassium solubilizing bacteria (KSB) @ 10 g plant^{-1} each with a reduced dose of recommended fertilizer (RDF) from 100 to 60%. The highest yield was recorded with 90% RDF + *Azotobacter*, PSB and KSB treatment, statistically at par with 60% RDF + *Azotobacter*, PSB and KSB treatment. Fruit weight was also increased significantly in 60-90% RDF + *Azotobacte*r, PSB, and KSB-treated plants. The best quality fruits were obtained in 60% or 90% RDF + *Azotobacte*r, PSB and KSB treated plants. From the experimental findings, it can be concluded that the integrated nutrient module comprised of 60% RDF of NPK + *Azotobacter*, PSB and KSB @ 10 g plant^{-1} proved the best treatment to improve the production of quality fruits in cape gooseberry.

Keywords: *Physalis peruviana* L., *Azotobacter*, Fruit quality, Fruit yield, KSB, PSB.

INTRODUCTION

Cape gooseberry (*Physalis peruviana* L.), an important annual fruit crop of the *Solanaceae* family, having high nutrients, is in great demand in the fresh market as well as in processing industries. On the other hand, the annual nature of the crop helps to give a profitable return in the 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) due to non-availability of the scientific package of practices. Hence, to exploit the yield potentiality of this crop in the country, it is very important to integrate various nutrient sources in a sustainable manner.

Due to the shallow root system, the production of large number of berries per unit area with improved fruit quality as well as increasing sensitivity of the crop to nutritional imbalance, cape gooseberry needs extensive use of mineral fertilizers particularly nitrogenous and potassic fertilizers (Hazarika and Aheibam, 8). But inorganic forms of fertilizers are short in supply, and very expensive, which ultimately raises the cost of production of the crop (Hamlet, 7). In addition, even though inorganic forms of fertilizers have a direct impact to increase yield of the crop but simultaneously their excessive or imbalance use may lead to health hazards, ecological vulnerabilities and diminution of physico-chemical characteristics of the soil. Further, importing inorganic fertilizers increase the burden on foreign exchange reserves significantly.

Biofertilizers are known to be environment friendly, and has the potential to reduce the cost of crop production with maximum possible returns. Further, biofertilizer formulations comprised of beneficial microbes in viable condition, play the a significant role in improving the fertility status of the soil and also improve the growth and development of the plant through the biological activity of other desired microorganisms (Kumar *et al.*, 11). Moreover, biofertilizers also increase the efficiency of natural resources. There are many bacterial organisms including *Azotobacter*, *Azospirillum*, phosphate solubilizing bacteria (PSB), potash solubilizing bacteria (KSB) etc., which are colonized in the root rhizosphere of the crop and stimulate plant growth and development with increased yield in a variety of fruit crops (Kumar *et al.*,11; Karlıdag *et al.*, 10; Rana and Chandel,14). Keeping these views in mind, the present investigation was carried out to standardize the integrated nutrient module in cape gooseberry for improving fruit yield and quality without hampering the soil fertility status.

MATERIALS AND METHODS

The seeds of locally grown cape gooseberry strain were sown in the nursery during the first

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week of October, and Healthy seedling of one month old having uniform growth were selected for transplanting (second week of November) in the main experimental plot at Horticultural Garden, Bihar Agricultural College, Sabour, Bihar, India. The experiment was conducted for two consecutive years (2018-19 and 2019-20). During the entire course of investigation (November to May for both the year), all the plants were maintained under uniform schedule of cultural operations.

Nitrogen (N), phosphorous (P) and potassic (K) fertilizers were applied in the form of urea, diammonium phosphate (DAP) and muriate of potash (MOP). Full dose of N and P along with half dose of K were applied one day before transplanting, while remaining half dose of K was applied 60 days after transplanting as per the treatment details. Each cape gooseberry plant was supplied with *Azotobacter*, PSB and KSB @ 10 g plant^{-1} each at the root zone during transplanting. Treatments for the experiments were: 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.

Physiological growth *viz*., specific leaf weight (SLW), leaf relative water content (RWC) and leaf chlorophyll content (chlorophyll a, chlorophyll b and total chlorophyll) were measured during the fruiting stage of the plant. Specific leaf weight was determined by dividing leaf weight by leaf area. Leaf relative water content of the recently mature leaf was determined following the method suggested by Weatherley (18) while leaf chlorophyll content was estimated as per the method described by Barnes *et al.* (3). The days to first flowering, flowering duration, days to first fruit setting, duration of fruit set to maturity and days to first harvesting were noted manually through visual observations. After collecting ten mature fruits from each experimental cape gooseberry plant, they were weighed individually on digital weighing balance and average fruit weight was calculated thereafter. At the end of last harvesting, yield plant^{-1} was calculated by adding the value of fruit weight of each harvesting and yield ha^{-1} was calculated, thereafter.

Hand refractometer (Atago, Tokyo, Japan) was used to measure total soluble solids (TSS) while titration method (Ranganna, 15) was followed to determine the titratable acidity of ripened cape gooseberry fruits. Further, TSS: acid ratio was calculated. The method described by Lane and Eynone (12) was followed to estimate the reducing and non-reducing sugar contents. Total phenolic content was estimated by the method described by Singleton *et al.* (17), while total flavonoid content was determined using aluminum chloride method (Zhishen *et al.*, 19). The antioxidant capacity of the ripened fruit was estimated according to the method of Apak *et al.* (1).

The experiment was laid out on completely randomized block design (CRBD) with three replications. Data of two consecutive years (2018-19 and 2019-20) were pooled to preset the average data. Critical difference (CD) at 5% level of significance was taken to compare the mean difference among the treatments. Statistical analysis of the data was done using software SAS 9.3; SAS Institute, Cary, NC, USA, while Duncan's multiple range test (DMRT) was used to compare the means.

RESULTS AND DISCUSSION

The physiological growth of cape gooseberry plant as influenced by the treatments are given in Table 1. SLW was recorded highest in the nutrient module comprising 100% RDF + *Azotobacter*, PSB and KSB @ 10 g plant^{-1} each (T_2), T_3, T_4, T_5 and T_6 treatments (11.66, 11.42, 9.12, 8.64 and 8.21% higher than the control, respectively). Similarly, the leaf RWC was highest (76.21%) in the treatment comprising of 100% RDF of NPK + *Azotobacter*, PSB and KSB @ 10 g plant^{-1} each (T_2). Besides, the treatments T_3, T_4 and T_5 also had significantly higher leaf RWC than control (12.74, 9.49 and 8.97% higher than the control, respectively). On the other hand, chlorophyll a was registered to be the highest in the module comprising of 100% RDF of NPK along with combined application of *Azotobacter*, PSB and KSB @ 10 g plant^{-1} each (T_2) without having significant difference with T_3 and T_4 treatments (12.30, 8.20 and 3.57% higher than the control, respectively), however, it was lowest in control (T_1) with no significant difference in T_7. Similar pattern was also observed for chlorophyll b as well as total chlorophyll contents. Increased physiological growth of the plant under integrated nutrient module might be due to the effect of bio-fertilizers to enhance the nutrient uptake especially nitrogen, which ultimately plays significant role in integration of several amino acids (Awasthi *et al.*, 2), which provide the framework for mitochondria, chloroplast and other photosynthetic structure to accelerate different biochemical reactions within the plant system as also reported by Gajbhiye *et al.* (6) in tomato and Singaravel *et al.* (16) in okra.

The data relating to flowering and fruit harvesting as influenced by INM module are presented in

Table 1. Effect of integrated nutrient module on physiological growth of cape gooseberry plant.

Treatment	Specific leaf weight (mg cm^{-2})	Leaf RWC (%)	Chlorophyll A (mg g^{-1} FW)	Chlorophyll B (mg g^{-1} FW)	Total chlorophyll (mg g^{-1} FW)
T_1	25.21^{c}	65.87^{c}	3.17^{c}	0.81^{d}	4.28^{d}
T_2	28.15^{a}	76.21^{a}	3.56^{a}	1.05^{a}	5.03^{a}
T_3	28.09^{a}	74.26^{ab}	3.43^{ab}	1.01^{ab}	4.84^{ab}
T_4	27.51^{a}	72.12^{ab}	3.41^{ab}	0.95^{bc}	4.67^{bc}
T_5	27.39^{ab}	71.78^{ab}	3.35^{b}	0.92^{c}	4.65^{bc}
T_6	27.28^{ab}	69.48^{bc}	3.32^{bc}	0.86^{cd}	4.50^{cd}
T_7	26.03^{bc}	66.61^{c}	3.18^{c}	0.86^{cd}	4.43^{cd}

Value indicates mean of three replicates. Different letters in the same column indicate significant differences at $P \leq 0.05$ (Duncan's Multiple Range Test).

Table 2. The earliest flowering (48.00 days after transplanting) was observed in the module comprising 50% RDF of NPK along with the application of *Azotobacter*, PSB and KSB @ 10 g plant^{-1} each (T_7), having statistical similarity with T_6 and T_5 treatments. However, the longest flowering period (129.67 days) was observed in the treatment comprising of 100% RDF + *Azotobacter*, PSB and KSB @ 10 g plant^{-1} each (T_2), which was statistically at par with T_3, T_4, T_5 and T_6 treatments. Similarly, minimum time to set 1st fruit after anthesis of 1st flower was taken by the plants which received 60% or 70% RDF of NPK along with *Azotobacter*, PSB and KSB @ 10 g plant^{-1} each (3.00 days earlier than the control, each). Further, among different modules, the earliest fruit maturity was attained in the treatment comprising of 80% RDF application along with *Azotobacter*, PSB and KSB @ 10 g plant^{-1} each (T_4) having value *at par* with T_6 (13.67 and 12.67 days earlier as compared to control, respectively). However, the longest duration after fruit set to maturity was observed in control (T_1) without significant difference with T_7 treatment. On the other hand, the earliest harvesting of 1st cape gooseberry fruit was obtained in the treatment comprising 80% RDF + *Azotobacter*, PSB and KSB @ 10 g plant^{-1} each (T_4) with *at par* result in T_5 and T_6 (26.67, 25.00 and 24.00 days earlier as compared to control, respectively) treatments. 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 green structures for longer period, resulting the longer duration of flowering and fruiting in those plants. Further, the enhancement in the synthesis of different plant growth hormones like GA and cytokinins by biofertilizers (Martinez *et al.,* 13) 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.* (11) in strawberry.

The fruit yield and quality of cape gooseberry were significantly influenced by the INM module (Table 3). Average fruit weight under the current experiment was increased significantly in all the nutrient modules over the control (7.61 g) except in 50% RDF + *Azotobacter*, PSB and KSB @ 10 g plant^{-1} each (T_7) treatment module, where it was increased marginally over control with non-significant

Table 2. Effect of integrated nutrient module on flowering and fruiting behaviour of cape gooseberry.

Treatment	Days to 1st flowering (Days)	Flowering duration (Days)	Days to 1st fruit setting (Days)	Duration of fruit set to maturity (Days)	Days to 1st harvesting (Days)
T_1	52.00^{ab}	113.00^{b}	11.33^{a}	64.67^{a}	117.00^{a}
T_2	53.33^{a}	129.67^{a}	11.00^{a}	58.67^{ab}	112.00^{ab}
T_3	50.00^{bcd}	128.00^{a}	9.33^{ab}	52.33^{b}	96.00^{c}
T_4	50.67^{bc}	127.33^{a}	10.00^{ab}	51.00^{b}	90.33^{c}
T_5	49.33^{cd}	127.67^{a}	8.33^{b}	52.33^{b}	92.00^{c}
T_6	48.00^{d}	126.67^{a}	8.33^{b}	52.00^{b}	93.00^{c}
T_7	48.00^{d}	109.00^{b}	10.33^{ab}	60.00^{ab}	109.00^{b}

Value indicates mean of three replicates. Different letters in the same column indicate significant differences at $P \leq 0.05$ (Duncan's Multiple Range Test).

Table 3. Effect of integrated nutrient module on yield and quality attributes of cape gooseberry.

Treatment	Fruit weight (g)	Yield (tonnes ha^{-1})	TSS: Acid ratio	Reducing sugars (%)	Non reducing sugar (%)	Flavonoid (μg g^{-1}FW)	Phenol (mg Gallic acid equiv. g^{-1} FW)	Antioxident capacity (μmol. Trolox equiv. 100 g^{-1} FW)
T_1	7.61^{c}	19.42^{c}	14.72^{c}	7.23^{b}	2.23^{b}	38.43^{c}	5.18^{c}	17.45^{c}
T_2	8.75^{b}	24.31^{b}	19.49^{b}	8.07^{a}	2.48^{a}	48.94^{ab}	5.60^{abc}	21.46^{ab}
T_3	9.77^{a}	29.75^{a}	22.12^{ab}	8.47^{a}	2.59^{a}	52.43^{a}	6.08^{a}	23.18^{a}
T_4	9.72^{a}	29.50^{a}	23.41^{a}	8.56^{a}	2.62^{a}	50.77^{ab}	6.11^{a}	23.30^{a}
T_5	9.70^{a}	29.07^{a}	21.98^{ab}	8.48^{a}	2.60^{a}	51.90^{a}	5.91^{ab}	22.89^{ab}
T_6	9.77^{a}	29.08^{a}	21.08^{ab}	8.46^{a}	2.60^{a}	50.16^{ab}	5.83^{abc}	22.54^{ab}
T_7	7.80^{c}	19.62^{c}	15.72^{c}	7.48^{b}	2.29^{b}	44.56^{bc}	5.25^{bc}	19.80^{bc}

Value indicates mean of three replicates. Different letters in the same column indicate significant differences at $P \leq 0.05$ (Duncan's Multiple Range Test).

variation. However, the individual berry weight was highest in the nutrient module comprising of 60% RDF of NPK in combination with *Azotobacter*, PSB and KSB @ 10 g plant^{-1} each (T_6) and T_3 treatment (28.38% higher than control, each) with *at par* fruit weight in T_4 and T_5 treatments (27.73 and 27.46% higher than the control, respectively). Similarly, fruit yield was also increased significantly over control (19.42 t ha^{-1}) in all the nutrient modules except in 50% RDF + *Azotobacter*, PSB and KSB @ 10 g plant^{-1} each (T_7) treatment module. The highest fruit yield was recorded under the nutrient module comprising of 90% RDF + *Azotobacter*, PSB and KSB @ 10 g plant^{-1} each (T_3) treatment (53.19% higher than control) which was statistically *at par* with T_4, T_5 and T_6 treatments (51.87, 49.68 and 49.71% increased yield over control, respectively). The increased activity of 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 the maximum conversion of flowers to fruits. Further, the increased accumulation of carbohydrate within the fruit directly increased the fruit weight, which might have ultimately improved the crop yield. These findings are in agreement with the observations of Hazarika and Aheibam (8) in lemon and Kumar *et al.* (11) in strawberry.

The response of different integrated nutrient modules significantly influenced the TSS: acid ratio of ripened cape gooseberry fruit under the present research work (Table 3). The highest TSS: acid ratio was calculated in the module comprising 80% RDF + *Azotobacter*, PSB and KSB @ 10 g plant^{-1} each (T_4) (23.41) having *at par* results with T_3, T_5 and T_6 treatments (22.12, 21.98 and 21.08, respectively). Similar pattern was also observed for reducing and non-reducing sugar contents in ripened cape gooseberry fruits. On the other hand, maximum flavonoid content was estimated in the treatment comprising of 90% RDF of NPK + *Azotobacter*, PSB and KSB @ 10 g plant^{-1} each (T_3) which was statistically *at par* with T_5, T_4 and T_6 treatments (36.43, 35.05, 32.11 and 30.52% higher than the control). The similar observations were also recorded for total phenol content in cape gooseberry fruits. Further, total antioxidant capacity of ripened cape gooseberry fruits was also increased in all the nutrient modules over control. The highest antioxidant capacity was recorded in 80% RDF + *Azotobacter*, PSB and KSB @ 10 g plant^{-1} each (T_4) treatment (33.52% higher than the control), which was statistically *at par* with T_3, T_5, T_6 and T_2 treatments (32.84, 31.17, 29.17 and 22.98% higher than control, respectively), while it was lowest in control with non-significant variation in T_7 treatment.

The quality attributes of ripened cape gooseberry fruits under the current experiment were improved significantly due to inoculation of bio-fertilizers. The improvement of TSS: acid ratio in combined application of bio-fertilizers along with reduced NPK doses might be due to the increased production of sugars and other soluble compounds from protein hydrolysis (Hazarika *et al.*, 9). Finding of the current investigation confirms the earlier report of Kumar *et al.* (11) in strawberry and Dey *et al.* (4) in guava. Further, the application of nitrogen fixing bacteria, PSB, KSB along with reduced NPK might have significant role in the regulation of absorption as well as translocation processes of different metabolites particularly carbohydrates, which in turn improve the fruit quality significantly, as also observed by Dutta *et al.* (5).

From the results of present study, 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.

AUTHORS' CONTRIBUTION

Conceptualization of research work (MK, HM and MS); Designing of the experiment (MK); Execution of field/lab experiments and data collection (VK); Analysis of data and interpretation (VK and MS); Preparation of the manuscript (MK and HM).

DECLARATION

The authors declare no conflict of interest.

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