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Effect of integrated nutrient management on reproductive, yield, and physical quality traits in cape gooseberry (*Physalis peruviana* L.)

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Abstract
An experiment was carried out during the winter seasons of 2023-24 and 2024-25 at the Banda University of Agriculture and Technology, Banda (U.P.), to examine the effect of Integrated Nutrient Management (INM) on phenology, yield, and fruit quality of Cape gooseberry (*Physalis peruviana* L.). The study had 11 treatment combinations involving different proportions of NPK, organic manures (FYM, vermicompost, poultry manure), and biofertilizers (*Azotobacter* and PSB), in a Randomized Block Design with three replicates. Results had shown that the treatment T_3 consisting 75% NPK + 25% vermicompost + Halo Azo + Halo PSB significantly improved phenological stages such as bud initiation, flower opening, and fruit set, and recorded the highest number of flowers and fruits per plant. This treatment also produced fruits with superior physical traits-higher fruit length, width, weight, volume, and specific gravity-resulting in the maximum yield per plant (889.98 g), per plot (5.34 kg), and per hectare (89.00 q). The improved performance is mainly due to enhanced nutrient availability, microbial activity, and rhizosphere. The findings suggest that slight substitution of inorganic fertilizers with vermicompost and biofertilizers under INM is a sustainable and effective strategy to enhance growth, yield, and fruit quality in Cape gooseberry, especially in nutrient-deprived regions.

Keywords: INM, phenology, cape gooseberry, FYM, vermicompost, poultry manure and biofertilizer, rhizosphere

Introduction
Cape gooseberry (*Physalis peruviana* L.), also known as goldenberry or Rasbhari, is a minor fruit crop gaining increasing attention due to its high nutritional and medicinal value. It is native to South America and belongs to the Solanaceae family and is now grown in tropical and subtropical regions across the world, including India (Puente *et al.*, 2011) [9]. The fruit is rich in bioactive compounds such as ascorbic acid, carotenoids, phenolics, and antioxidants, making it beneficial for scavenging of oxidative stress, inflammation, and chronic diseases (Ramadan, 2011; Rockenbach *et al.*, 2008) [10, 13]. Despite its potential, the productivity and quality of Cape gooseberry in India remain low, mainly due to inappropriate nutrient management practices. INM involves the combined and balanced use of organic manures, biofertilizers, and inorganic fertilizers and emerged as an effective approach to enhance soil fertility, plant health, and sustainable productivity. INM enhances nutrient use efficiency, enhances microbial activity, and sustains long-term soil health while lowering dependency on inorganic fertilizers (Ramesh *et al.*, 2009; Sharma & Mittra, 1991) [11, 14]. Organic sources such as farmyard manure (FYM), vermicompost, and poultry manure not only supply macro and micronutrients but also improve soil structure, moisture retention, and microbial biomass (Subba Rao, 2001) [17]. Biofertilizers like *Azotobacter* and phosphate-solubilizing bacteria (PSB) accelerate nutrient availability and uptake through biological nitrogen fixation and phosphorus solubilization (Bhattacharyya & Tandon, 2012) [2]. Studies on INM have demonstrated significant improvements in phenological behavior, yield parameters, and biochemical quality traits. For instance, in guava and papaya, INM led to enhanced fruit weight, TSS, and vitamin C content compared to chemical fertilization alone (Sharma *et al.*, 2013; Kumar *et al.*, 2015) [15, 6].

However, limited studies are available on the integrated nutrient response in Cape gooseberry, particularly under the agro-climatic conditions of semi-arid region. Keeping the importance of improving fruit yield and nutritional quality sustainably in mind, evaluating INM's effect on Cape gooseberry is both demanding and necessary.

Materials and Methods

The present investigation was conducted during the winter seasons of 2023-24 and 2024-25 at the Banda University of Agriculture and Technology, Banda (U.P.), to assess the effect of Integrated Nutrient Management (INM) on phenology, yield, and quality traits of Cape gooseberry (*Physalis peruviana* L.). The experiment was carried out in a Randomized Block Design (RBD) with 11 treatments and 3 replicates, using a combination of inorganic fertilizers (NPK), organic manures (FYM, vermicompost, poultry manure), and biofertilizers (Halo Azotobacter and Phosphate Solubilizing Bacteria-PSB) i.e., T_1: Control, T_2: 75% NPK + 25% FYM + Halo Azo + Halo PSB, T_3: 75% NPK + 25% Vermicompost + Halo Azo + Halo PSB, T_4: 75% NPK + 25% Poultry manure + Halo Azo + Halo PSB, T_5: 50% NPK + 50% FYM + Halo Azo + Halo PSB, T_6: 50% NPK + 50% Vermicompost + Halo Azo + Halo PSB, T_7: 50% NPK + 50% Poultry manure + Halo Azo + Halo PSB, T_8: 25% NPK + 75% FYM + Halo Azo + Halo PSB, T_9: 25% NPK + 75% Vermicompost + Halo Azo + Halo PSB, T_{10}: 25% NPK + 75% Poultry manure + Halo Azo + Halo PSB, T_{11}: 25% NPK + 25% FYM + 25% Vermicompost + 25% Poultry manure + Halo Azo + Halo PSB. Seedlings raised from seeds were transplanted at a spacing of 1 m × 1 m and treated with biofertilizer inoculants before planting. The experimental plot, characterized by clay loam soil with slightly alkaline pH (8.64), was prepared to fine tilth. The recommended dose of fertilizer (100:100:50 kg/ha of N:P:K) was applied in split doses, while organic manures were incorporated 15 days before transplanting. The biofertilizers were applied as per treatment combinations. Standard agronomic packages including weeding, irrigation, and plant protection were followed throughout the cultivation. Observations were recorded on phenological traits (days to first bud initiation, days to first flower opening, number of flowers per plant, days to first fruit set), physical quality traits (number of fruits per plant, fruit length, fruit width, fruit weight, fruit volume and specific gravity) and yield parameters (yield per plant, yield per plot, yield per hectare). The collected data were analyzed statistically using analysis of variance (ANOVA) as per the method outlined by Panse and Sukhatme (1985), and treatment means were compared using the critical difference at 5% significance level.

Results and Discussions

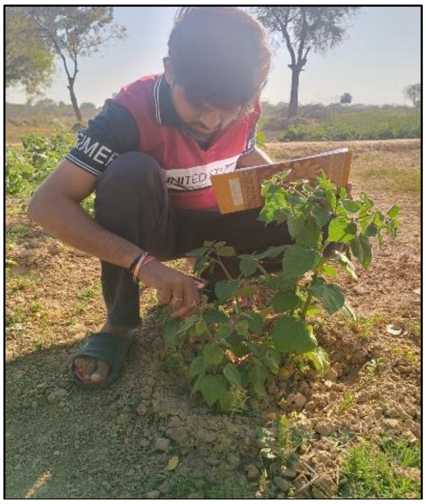
The present study showed that INM had a profound and statistically significant effect on phenological traits, physical quality parameters, and fruit yield of Cape gooseberry (*Physalis peruviana* L.). Among all treatments, the combination of 75% recommended dose of NPK + 25% vermicompost + biofertilizers (*Azotobacter* + PSB) was consistently superior across two consecutive seasons (2023-24 and 2024-25). This treatment significantly improved principal phenological events such as first bud initiation (50.35 days), first flower opening (55.51 days), and fruit set (63.62 days) while compared to the control treatment, which recorded 60.15, 67.05, and 75.35 days, respectively (Table 1, 2,3). These reductions in phenological durations suggest faster crop establishment and early reproductive development. This could be due to improved soil microbial activity, better nutrient availability, and phytohormonal crosstalk—particularly gibberellins and cytokinins—which are known to be promoted by both vermicompost and microbial inoculants (Arancon *et al.*, 2004; Subba Rao, 2001) [1, 17]. Vermicompost improves root development, aeration, and moisture holding capacity in the soil, permitting more efficient nutrient uptake during early vegetative stages (Bhattacharyya & Tandon, 2012) [2]. Similar effects have been reported in papaya and tomato, where INM treatments led to precocity in flowering and fruit set due to enhanced physiological efficiency (Naik *et al.*, 2011; Gopinath *et al.*, 2008) [7, 5]. The number of flowers per plant (105.27) and fruits per plant (96.28) were markedly higher in the same INM treatment, significantly outperforming the control (51.78) and (43.81) respectively (Table 4, 5). This finding can be explained by the dual action of vermicompost and biofertilizers, which not only made available a broad range of nutrients but also stimulate rhizospheric microbial activities, thereby improving plant metabolism and assimilate distribution (Ramesh *et al.*, 2009; Edwards *et al.*, 2010) [11, 3]. The improved fruiting may also be linked to enhanced flower retention and reduced abscission, as organic inputs help in stabilizing hormone levels and cell wall integrity during the reproductive phase (Pathak & Ram, 2002) [8]. These findings was in accordance with those observed in other horticultural crops such as guava and brinjal, where INM was reported to improve floral traits and fruit set percentage (Sharma *et al.*, 2013) [15]. The integrated treatment significantly enhanced fruit morphology, had highest fruit length (25.46 mm) (Table 6), width (29.08 mm) (Table 7), fruit weight with husk (9.00 g), fruit weight without husk (8.36 g) (Table 8 & 9) and fruit volume (9.39 cc) (Table 10) as compared to the control treatment which produced smaller fruits (length: 18.62 mm; width: 21.48 mm; weight with husk: 5.87 g; weight without husk 5.17g; volume: 6.58 cc). The improvement in physical traits could be due to better nitrogen availability, which is necessary for cell enlargement and synthesis of protein during fruit development (Turan & Esringü, 2007) [18]. Additionally, organic inputs like vermicompost increase humic acid content and root proliferation, allowing more water and nutrients availability and translocation toward fruit development (Arancon *et al.*, 2004; Bhattacharyya & Tandon, 2012) [1, 2]. The specific gravity, which reflects internal fruit quality and dry matter content, was also highest (0.89) (Table 11) in the superior treatment, indicating better firmness and nutrient density. The treatment with 75% NPK + 25% vermicompost + biofertilizers produced the highest yield per plant (889.98 g), per plot (5.34 kg), and per hectare (89.00 q/ha), which was about three times higher than the control treatment (246.61 g/plant, 1.48 kg and 24.66 q/ha) (Table 12, 13 & 14). This improvement is likely due to additive effects of improved flowering, fruit retention, fruit size, and nutrient use efficiency. Vermicompost and biofertilizers enhance soil structure, increase cation exchange capacity, and mobilize essential nutrients such as N, P, and K in plant-available forms (Ramesh *et al.*, 2005; Singh *et al.*, 2019) [12, 16]. These mechanisms support higher biomass allocation to economic parts (fruits), leading to increased yields. Ghosh *et al.* (2004) [4] also demonstrated similar results in other cropping systems where INM increased productivity and enhanced soil health under semi-arid conditions.

Flower initiation

Full bloom flower

Fruit (green stage)

Fruit (fully ripe)



Data collection

Fruit wt. with husk

Fruit wt. without husk

Fruit width

Fruit inside husk

Table 1: Effect of integrated nutrient management on days to first bud initiation

Treatments	Treatment Combinations	Years		Pooled
		2023-24	2024-25	
T_1	Control	60.67	59.64	60.15
T_2	75% NPK + 25% FYM + Halo Azo + Halo PSB	56.11	55.19	55.65
T_3	75% NPK + 25% VC + Halo Azo + Halo PSB	50.93	49.78	50.35
T_4	75% NPK + 25% PM + Halo Azo + Halo PSB	54.03	53.60	53.81
T_5	50% NPK + 50% FYM + Halo Azo + Halo PSB	57.74	56.75	57.24
T_6	50% NPK + 50% VC + Halo Azo + Halo PSB	56.35	55.82	56.09
T_7	50% NPK + 50% PM + Halo Azo + Halo PSB	58.13	57.19	57.66
T_8	25% NPK + 75% FYM + Halo Azo + Halo PSB	57.18	55.84	56.51
T_9	25% NPK + 75% VC + Halo Azo + Halo PSB	57.09	56.04	56.56
T_{10}	25% NPK + 75% PM + Halo Azo + Halo PSB	58.65	57.71	58.18
T_{11}	25% NPK + 25% FYM + 25% VC + 25% PM + Halo Azo + Halo PSB	59.72	58.94	59.33
	CD at 5%	5.12	4.97	4.97
	SEm±	1.73	1.69	1.68

Table 2: Effect of integrated nutrient management on days to first flower opening

Treatments	Treatment Combinations	Years		Pooled
		2023-24	2024-25	
T_1	Control	67.67	66.43	67.05
T_2	75% NPK + 25% FYM + Halo Azo + Halo PSB	64.28	63.61	63.95
T_3	75% NPK + 25% VC + Halo Azo + Halo PSB	55.90	55.13	55.51
T_4	75% NPK + 25% PM + Halo Azo + Halo PSB	63.67	62.19	62.93
T_5	50% NPK + 50% FYM + Halo Azo + Halo PSB	65.32	64.60	64.96
T_6	50% NPK + 50% VC + Halo Azo + Halo PSB	64.61	64.14	64.38
T_7	50% NPK + 50% PM + Halo Azo + Halo PSB	66.00	65.01	65.50
T_8	25% NPK + 75% FYM + Halo Azo + Halo PSB	65.56	64.28	64.92
T_9	25% NPK + 75% VC + Halo Azo + Halo PSB	65.27	64.23	64.75
T_{10}	25% NPK + 75% PM + Halo Azo + Halo PSB	65.00	64.51	64.75
T_{11}	25% NPK + 25% FYM + 25% VC + 25% PM + Halo Azo + Halo PSB	66.29	65.33	65.81
	CD at 5%	5.88	5.55	5.77
	SEm±	1.99	1.88	1.96

Table 3: Effect of integrated nutrient management on days to first fruit set

Treatments	Treatment Combinations	Years		Pooled
		2023-24	2024-25	
T_1	Control	77.09	73.62	75.35
T_2	75% NPK + 25% FYM + Halo Azo + Halo PSB	72.98	71.23	72.11
T_3	75% NPK + 25% VC + Halo Azo + Halo PSB	63.91	63.33	63.62
T_4	75% NPK + 25% PM + Halo Azo + Halo PSB	72.47	70.60	71.53
T_5	50% NPK + 50% FYM + Halo Azo + Halo PSB	74.87	72.35	73.61
T_6	50% NPK + 50% VC + Halo Azo + Halo PSB	74.10	71.30	72.70
T_7	50% NPK + 50% PM + Halo Azo + Halo PSB	74.91	71.52	73.21
T_8	25% NPK + 75% FYM + Halo Azo + Halo PSB	74.00	72.20	73.10
T_9	25% NPK + 75% VC + Halo Azo + Halo PSB	74.55	71.68	73.11
T_{10}	25% NPK + 75% PM + Halo Azo + Halo PSB	74.00	73.19	73.59
T_{11}	25% NPK + 25% FYM + 25% VC + 25% PM + Halo Azo + Halo PSB	75.49	74.65	75.07
	CD at 5%	6.43	6.32	6.44
	SEm±	2.18	2.14	2.18

Table 4: Effect of integrated nutrient management on number of flowers per plant

Treatments	Treatment Combinations	Years		Pooled
		2023-24	2024-25	
T_1	Control	51.23	52.33	51.78
T_2	75% NPK + 25% FYM + Halo Azo + Halo PSB	94.99	96.67	95.83
T_3	75% NPK + 25% VC + Halo Azo + Halo PSB	104.10	106.44	105.27
T_4	75% NPK + 25% PM + Halo Azo + Halo PSB	96.88	98.88	97.88
T_5	50% NPK + 50% FYM + Halo Azo + Halo PSB	60.12	63.20	61.66
T_6	50% NPK + 50% VC + Halo Azo + Halo PSB	87.46	89.52	88.49
T_7	50% NPK + 50% PM + Halo Azo + Halo PSB	70.64	71.43	71.04
T_8	25% NPK + 75% FYM + Halo Azo + Halo PSB	67.89	68.03	67.96
T_9	25% NPK + 75% VC + Halo Azo + Halo PSB	60.88	61.09	60.99
T_{10}	25% NPK + 75% PM + Halo Azo + Halo PSB	70.55	75.00	72.78
T_{11}	25% NPK + 25% FYM + 25% VC + 25% PM + Halo Azo + Halo PSB	78.88	80.12	79.50
	CD at 5%	7.00	7.26	7.27
	SEm±	2.37	2.46	2.46

Table 5: Effect of integrated nutrient management on number of fruits per plant

Treatments	Treatment Combinations	Years		Pooled
		2023-24	2024-25	
T_1	Control	43.40	44.22	43.81
T_2	75% NPK + 25% FYM + Halo Azo + Halo PSB	87.45	88.33	87.89
T_3	75% NPK + 25% VC + Halo Azo + Halo PSB	94.43	98.14	96.28
T_4	75% NPK + 25% PM + Halo Azo + Halo PSB	87.76	90.80	89.28
T_5	50% NPK + 50% FYM + Halo Azo + Halo PSB	51.60	53.51	52.55
T_6	50% NPK + 50% VC + Halo Azo + Halo PSB	85.55	87.65	86.60
T_7	50% NPK + 50% PM + Halo Azo + Halo PSB	76.28	77.70	76.99
T_8	25% NPK + 75% FYM + Halo Azo + Halo PSB	47.70	49.06	48.38
T_9	25% NPK + 75% VC + Halo Azo + Halo PSB	60.70	62.11	61.40
T_{10}	25% NPK + 75% PM + Halo Azo + Halo PSB	72.48	73.17	72.82
T_{11}	25% NPK + 25% FYM + 25% VC + 25% PM + Halo Azo + Halo PSB	62.34	63.08	62.71
	CD at 5%	6.25	7.01	6.19
	SEm±	2.12	2.38	2.10

Table 6: Effect of integrated nutrient management on fruit length (mm)

Treatments	Treatment Combinations	Years		Pooled
		2023-24	2024-25	
T_1	Control	18.56	18.68	18.62
T_2	75% NPK + 25% FYM + Halo Azo + Halo PSB	21.82	22.17	21.99
T_3	75% NPK + 25% VC + Halo Azo + Halo PSB	25.13	25.79	25.46
T_4	75% NPK + 25% PM + Halo Azo + Halo PSB	22.59	22.98	22.78
T_5	50% NPK + 50% FYM + Halo Azo + Halo PSB	20.33	21.87	21.10
T_6	50% NPK + 50% VC + Halo Azo + Halo PSB	21.76	21.88	21.82
T_7	50% NPK + 50% PM + Halo Azo + Halo PSB	21.33	21.56	21.45
T_8	25% NPK + 75% FYM + Halo Azo + Halo PSB	20.00	20.56	20.28
T_9	25% NPK + 75% VC + Halo Azo + Halo PSB	21.23	21.48	21.36
T_{10}	25% NPK + 75% PM + Halo Azo + Halo PSB	20.70	20.87	20.79
T_{11}	25% NPK + 25% FYM + 25% VC + 25% PM + Halo Azo + Halo PSB	20.76	21.09	20.92
	CD at 5%	2.23	2.46	2.36
	SEm±	0.76	0.83	0.80

Table 7: Effect of integrated nutrient management on fruit width (mm)

Treatments	Treatment Combinations	Years		Pooled
		2023-24	2024-25	
T_1	Control	21.40	21.56	21.48
T_2	75% NPK + 25% FYM + Halo Azo + Halo PSB	25.12	25.23	25.18
T_3	75% NPK + 25% VC + Halo Azo + Halo PSB	29.06	29.10	29.08
T_4	75% NPK + 25% PM + Halo Azo + Halo PSB	25.16	25.78	25.47
T_5	50% NPK + 50% FYM + Halo Azo + Halo PSB	23.26	23.46	23.36
T_6	50% NPK + 50% VC + Halo Azo + Halo PSB	24.56	24.66	24.61
T_7	50% NPK + 50% PM + Halo Azo + Halo PSB	23.70	23.89	23.80
T_8	25% NPK + 75% FYM + Halo Azo + Halo PSB	22.57	23.18	22.88
T_9	25% NPK + 75% VC + Halo Azo + Halo PSB	23.88	23.97	23.93
T_{10}	25% NPK + 75% PM + Halo Azo + Halo PSB	23.10	24.01	23.56
T_{11}	25% NPK + 25% FYM + 25% VC + 25% PM + Halo Azo + Halo PSB	24.11	24.54	24.33
	CD at 5%	2.38	2.67	2.39
	SEm±	0.81	0.91	0.81

Table 8: Effect of integrated nutrient management on fruit weight with husk (g)

Treatments	Treatment Combinations	Years		Pooled
		2023-24	2024-25	
T_1	Control	5.59	6.15	5.87
T_2	75% NPK + 25% FYM + Halo Azo + Halo PSB	7.78	8.22	8.00
T_3	75% NPK + 25% VC + Halo Azo + Halo PSB	8.66	9.33	9.00
T_4	75% NPK + 25% PM + Halo Azo + Halo PSB	8.00	8.59	8.30
T_5	50% NPK + 50% FYM + Halo Azo + Halo PSB	6.63	7.00	6.81
T_6	50% NPK + 50% VC + Halo Azo + Halo PSB	7.36	7.90	7.63
T_7	50% NPK + 50% PM + Halo Azo + Halo PSB	6.38	6.87	6.63
T_8	25% NPK + 75% FYM + Halo Azo + Halo PSB	7.13	7.72	7.42
T_9	25% NPK + 75% VC + Halo Azo + Halo PSB	6.39	6.92	6.66
T_{10}	25% NPK + 75% PM + Halo Azo + Halo PSB	6.01	6.55	6.28
T_{11}	25% NPK + 25% FYM + 25% VC + 25% PM + Halo Azo + Halo PSB	7.00	7.53	7.27
	CD at 5%	0.58	0.66	0.63
	SEm±	0.20	0.23	0.21

Table 9: Effect of integrated nutrient management on fruit weight without husk (g)

Treatments	Treatment Combinations	Years		Pooled
		2023-24	2024-25	
T_1	Control	4.80	5.53	5.17
T_2	75% NPK + 25% FYM + Halo Azo + Halo PSB	7.01	7.67	7.34
T_3	75% NPK + 25% VC + Halo Azo + Halo PSB	7.96	8.76	8.36
T_4	75% NPK + 25% PM + Halo Azo + Halo PSB	7.16	7.98	7.57
T_5	50% NPK + 50% FYM + Halo Azo + Halo PSB	5.83	6.44	6.14
T_6	50% NPK + 50% VC + Halo Azo + Halo PSB	6.63	7.27	6.95
T_7	50% NPK + 50% PM + Halo Azo + Halo PSB	5.70	6.26	5.98
T_8	25% NPK + 75% FYM + Halo Azo + Halo PSB	6.35	7.09	6.72
T_9	25% NPK + 75% VC + Halo Azo + Halo PSB	5.64	6.26	5.95
T_{10}	25% NPK + 75% PM + Halo Azo + Halo PSB	5.29	5.91	5.60
T_{11}	25% NPK + 25% FYM + 25% VC + 25% PM + Halo Azo + Halo PSB	6.17	6.93	6.55
	CD at 5%	0.61	0.65	0.61
	SEm±	0.21	0.22	0.21

Table 10: Effect of integrated nutrient management on fruit volume (cc)

Treatments	Treatment Combinations	Years		Pooled
		2023-24	2024-25	
T_1	Control	6.47	6.70	6.58
T_2	75% NPK + 25% FYM + Halo Azo + Halo PSB	8.46	8.55	8.51
T_3	75% NPK + 25% VC + Halo Azo + Halo PSB	9.34	9.44	9.39
T_4	75% NPK + 25% PM + Halo Azo + Halo PSB	8.54	8.69	8.62
T_5	50% NPK + 50% FYM + Halo Azo + Halo PSB	7.33	7.45	7.39
T_6	50% NPK + 50% VC + Halo Azo + Halo PSB	8.11	8.13	8.12
T_7	50% NPK + 50% PM + Halo Azo + Halo PSB	7.00	7.08	7.04
T_8	25% NPK + 75% FYM + Halo Azo + Halo PSB	7.78	7.90	7.84
T_9	25% NPK + 75% VC + Halo Azo + Halo PSB	7.13	7.28	7.21
T_{10}	25% NPK + 75% PM + Halo Azo + Halo PSB	7.05	7.20	7.13
T_{11}	25% NPK + 25% FYM + 25% VC + 25% PM + Halo Azo + Halo PSB	8.03	8.22	8.13
	CD at 5%	0.71	0.73	0.69
	SEm±	0.24	0.25	0.23

Table 11: Effect of integrated nutrient management on specific gravity

Treatments	Treatment Combinations	Years		Pooled
		2023-24	2024-25	
T_1	Control	0.74	0.83	0.78
T_2	75% NPK + 25% FYM + Halo Azo + Halo PSB	0.83	0.90	0.86
T_3	75% NPK + 25% VC + Halo Azo + Halo PSB	0.85	0.93	0.89
T_4	75% NPK + 25% PM + Halo Azo + Halo PSB	0.84	0.92	0.88
T_5	50% NPK + 50% FYM + Halo Azo + Halo PSB	0.80	0.86	0.83
T_6	50% NPK + 50% VC + Halo Azo + Halo PSB	0.82	0.89	0.86
T_7	50% NPK + 50% PM + Halo Azo + Halo PSB	0.81	0.88	0.85
T_8	25% NPK + 75% FYM + Halo Azo + Halo PSB	0.82	0.89	0.86
T_9	25% NPK + 75% VC + Halo Azo + Halo PSB	0.79	0.86	0.83
T_{10}	25% NPK + 75% PM + Halo Azo + Halo PSB	0.75	0.82	0.79
T_{11}	25% NPK + 25% FYM + 25% VC + 25% PM + Halo Azo + Halo PSB	0.77	0.84	0.81
	CD at 5%	0.02	0.03	0.02
	SEm±	0.01	0.01	0.01

Table 12: Effect of integrated nutrient management on yield per plant (g)

Treatments	Treatment Combinations	Years		Pooled
		2023-24	2024-25	
T_1	Control	245.22	248.00	246.61
T_2	75% NPK + 25% FYM + Halo Azo + Halo PSB	804.15	815.42	809.78
T_3	75% NPK + 25% VC + Halo Azo + Halo PSB	886.62	893.33	889.98
T_4	75% NPK + 25% PM + Halo Azo + Halo PSB	827.36	832.09	829.72
T_5	50% NPK + 50% FYM + Halo Azo + Halo PSB	455.88	465.76	460.82
T_6	50% NPK + 50% VC + Halo Azo + Halo PSB	776.53	781.33	778.93
T_7	50% NPK + 50% PM + Halo Azo + Halo PSB	709.90	714.50	712.20
T_8	25% NPK + 75% FYM + Halo Azo + Halo PSB	570.14	578.70	574.42
T_9	25% NPK + 75% VC + Halo Azo + Halo PSB	423.90	428.54	426.22
T_{10}	25% NPK + 75% PM + Halo Azo + Halo PSB	356.76	364.87	360.82
T_{11}	25% NPK + 25% FYM + 25% VC + 25% PM + Halo Azo + Halo PSB	532.45	540.00	536.23
	CD at 5%	57.07	59.79	54.09
	SEm±	19.35	20.27	18.34

Table 13: Effect of integrated nutrient management on yield per plot (kg)

Treatments	Treatment Combinations	Years		Pooled
		2023-24	2024-25	
T_1	Control	1.47	1.49	1.48
T_2	75% NPK + 25% FYM + Halo Azo + Halo PSB	4.82	4.89	4.86
T_3	75% NPK + 25% VC + Halo Azo + Halo PSB	5.32	5.36	5.34
T_4	75% NPK + 25% PM + Halo Azo + Halo PSB	4.96	4.99	4.98
T_5	50% NPK + 50% FYM + Halo Azo + Halo PSB	2.74	2.79	2.76
T_6	50% NPK + 50% VC + Halo Azo + Halo PSB	4.66	4.69	4.68
T_7	50% NPK + 50% PM + Halo Azo + Halo PSB	4.26	4.29	4.28
T_8	25% NPK + 75% FYM + Halo Azo + Halo PSB	3.42	3.47	3.45
T_9	25% NPK + 75% VC + Halo Azo + Halo PSB	2.54	3.57	3.06
T_{10}	25% NPK + 75% PM + Halo Azo + Halo PSB	2.14	2.19	2.16
T_{11}	25% NPK + 25% FYM + 25% VC + 25% PM + Halo Azo + Halo PSB	3.19	3.25	3.22
	CD at 5%	0.33	0.34	0.32
	SEm±	0.11	0.12	0.11

Table 14: Effect of integrated nutrient management on yield per hectare (q)

Treatments	Treatment Combinations	Years		Pooled
		2023-24	2024-25	
T_1	Control	24.52	24.80	24.66
T_2	75% NPK + 25% FYM + Halo Azo + Halo PSB	80.42	81.54	80.98
T_3	75% NPK + 25% VC + Halo Azo + Halo PSB	88.67	89.33	89.00
T_4	75% NPK + 25% PM + Halo Azo + Halo PSB	82.74	83.21	82.98
T_5	50% NPK + 50% FYM + Halo Azo + Halo PSB	45.59	46.58	46.09
T_6	50% NPK + 50% VC + Halo Azo + Halo PSB	77.65	78.13	77.89
T_7	50% NPK + 50% PM + Halo Azo + Halo PSB	70.99	71.45	71.22
T_8	25% NPK + 75% FYM + Halo Azo + Halo PSB	57.01	57.88	57.45
T_9	25% NPK + 75% VC + Halo Azo + Halo PSB	42.39	42.85	42.62
T_{10}	25% NPK + 75% PM + Halo Azo + Halo PSB	35.67	36.49	36.08
T_{11}	25% NPK + 25% FYM + 25% VC + 25% PM + Halo Azo + Halo PSB	53.25	54.07	53.66
	CD at 5%	5.23	5.35	5.67
	SEm±	1.77	1.82	1.92

Conclusions

The study clearly revealed that integrated nutrient management, particularly the combination of 75% recommended dose of NPK with 25% vermicompost along with biofertilizers (Halo *Azotobacter* and PSB), significantly enhances the phenological development, fruit yield, and quality attributes of Cape gooseberry (*Physalis peruviana* L.). This treatment consistently outperformed others by promoting early flowering and fruiting, increasing the number of flowers and fruits per plant, and improving fruit size, weight, and specific gravity—ultimately leading to the highest yield per plant and per hectare. The results highlight the synergistic effect of organic and inorganic inputs in optimizing nutrient availability, enhancing soil health, and improving crop productivity. Thus, the strategic inclusion of vermicompost and biofertilizers in nutrient management practices offers a viable and sustainable approach for optimizing Cape gooseberry cultivation, especially in regions with low soil fertility and limited input availability.

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