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Effect of different level of N, P and K on flowering, yield and quality of Guava under meadow orchard system

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Abstract
The present investigation carried out to evaluate effects of doses of N, P and K on the growth, flowering, yield and fruit quality of Guava variety L-49 at Fruit Research Station, Lalbaug, CoH, JAU, Junagadh, during the years 2022-23 and 2023-24 in meadow orchard. The experiment was laid out in RBD with Factorial concept consisting three levels of nitrogen N_1:30, N_2:60 and N_3:90 g/plant, two levels of phosphorus P_1:15 and P_2:30 g/plant and three levels of potash K_1:15, K_2:30 and K_3:45 g/plant. The results revealed that the minimum days to first flowering, days from flowering to fruit set and days to first harvest were recorded with treatment N_2, P_2 and K_2, while highest number of flowers/shoot was recorded with N_3, P_2 and K_2. For yield and yield attributing parameters, the highest fruit set, number of fruits/shoot, fruit weight, yield/plant was recorded in treatment N_3, P_2 and K_2. For quality parameters, maximum TSS, ascorbic acid content and total sugar was recorded in N_2, P_2 and K_2. The interaction effect of nitrogen, phosphorus and potash showed that maximum fruit weight and yield (kg/plant) were observed in N_3K_2. While, maximum TSS and Total Sugar were found in in N_2K_2.

Keywords: Guava, meadow orchard, nitrogen, phosphorus, potash, flowering, yield, quality

Introduction

Guava (*Psidium guajava* L.) is a well-known tropical fruit that is highly prized for its nutritional content, which includes a lot of vitamin C, dietary fiber and a variety of antioxidants. It plays a crucial role in the agricultural economies of many nations and is widely grown in tropical and subtropical regions. Effects of climate change are becoming prominent recently in form of rising temperature, uneven and altered precipitation patterns and an increase in extreme weather events are becoming noticeable. These changes directly influence maturity and development of fruit crops, leading to shifts in phenology, modifications in fruit yield, and alterations in fruit composition. To ensure the continued production and sustainability of fruit crops, building resilience becomes of utmost importance. Innovative cultivation methods that boost productivity and fruit quality are constantly sought after to meet rising global demand and boost guava farming's profitability (Karagatiya *et al*. 2023) [25].

States like Uttar Pradesh, Maharashtra, Bihar and Gujarat are major growing regions, and India is the largest producer of guava, contributing significantly to global production. Guava grows on 306.64 thousand hectares in India, produces 4516.16 thousand tons annually and its productivity is 14.73 MT/ha. The guava crop covers 14.33 thousand hectares in Gujarat, with a productivity of 12.23 MT/ha and a total production of 175.33 thousand tons.

Without considering the range of guava's inherent soil fertility and productivity, the current system of guava nutrition is based on general recommendations for the entire state. One of the most expensive recurring inputs for fruit production is the application of manures and fertilizers. High-density orchards, where nutrient dynamics and plant interactions differ significantly, may not be suitable for conventional fertilization methods, which are frequently developed for conventional low-density planting systems. Therefore, the goal of nutrient management ought to be to provide essential nutrients at the optimal rate for proper growth, development and sustainable fruit production growth. High-density guava orchards' environmental impact must be reduced by employing precise and effective fertilization methods (Tilman *et al*. 2002) [50]. The development of standardized fertilization guidelines will equip guava farmers with actionable insights to optimize their fertilization practices. This necessitates targeted research to develop precise NPK recommendations that cater to the unique requirements of guava in the meadow orchard system. Growers will be able to make informed decisions about nutrient application, reducing wastage and ensuring that their orchards receive the right amount of nutrients at the right time.

Materials and Methods

An investigation on "Effect of different level of N, P and K on growth and yield of Guava under meadow orchard system" was conducted at Fruit Research Station, Lalbaug, College of Horticulture, Junagadh Agricultural University, Junagadh during the year 2022-23 and 2023-24. The experimental material for the present investigation was comprised of eighteen treatments (Table 1).

Table 1: Treatment details

Sr. No.	Treatment Combination
1	$N_1P_1K_1$
2	$N_1P_1K_2$
3	$N_1P_1K_3$
4	$N_1P_2K_1$
5	$N_1P_2K_2$
6	$N_1P_2K_3$
7	$N_2P_1K_1$
8	$N_2P_1K_2$
9	$N_2P_1K_3$
10	$N_2P_2K_1$
11	$N_2P_2K_2$
12	$N_2P_2K_3$
13	$N_3P_1K_1$
14	$N_3P_1K_2$
15	$N_3P_1K_3$
16	$N_3P_2K_1$
17	$N_3P_2K_2$
18	$N_3P_2K_3$

Factor A (Levels of nitrogen)	Factor B (Levels of phosphorus)	Factor C (Levels of potash)
N_1-30 g/plant	P_1-15 g/plant	K_1-15 g/plant
N_2-60 g/plant	P_2-30 g/plant	K_2-30 g/plant
N_3-90 g/plant		K_3-45 g/plant

The experimental material consisted of 1 year old guava plants cultivar Lucknow-49. These plants are spaced at 2 m × 1 m distance. In all 216 uniform plants of guava were selected for the experimentation. All the experimental plants were managed with uniform cultural practices as per the standard recommendations with respect to farm yard manures, irrigation and plant protection measures during investigation. The experiment was laid out in randomized block design with factorial concept.

Results and Discussion

1. Response of N, P and K on Flowering Parameters

1.1 Days Taken to First Flowering

1.1.1 Effect of nitrogen, phosphorus and potash

The data in table 2 indicates effect of different levels of nitrogen, phosphorus and potash on days taken to first flowering had significant variations during the years 2022-23 and 2023-24 as well as in pooled analysis. Minimum days were required for first flower initiation (26.02) during first year, (27.21) during the second year and (26.62) pooled data was recorded in the treatment N_2 which was found at par with treatment N_1 (27.81) and (28.84) in both the years, respectively.

The treatment P_2 recorded the shortest duration to first flowering with an average of (26.64) in the first year, (27.81) in the second year and (27.22) when the data from both years were combined.

Minimum days were required for first flower initiation (26.28) during first year, (27.33) during the second year and (26.80) pooled data was recorded in the treatment K_2 which was found at par with treatment K_1 (27.90) and (28.85) during both the years respectively.

In guava cultivation, the management of nitrogen (N), phosphorus (P) and potassium (K), which play critical roles in regulating transitions between vegetative and reproductive phases, maintaining hormonal balance and managing sink-source dynamics. The shortest time required for the first flower initiation was observed in the treatment with 60 g of nitrogen per plant (N_2). These findings suggest that moderate nitrogen levels promote earlier flowering, likely due to a balance between vegetative and reproductive growth. In contrast, excessive nitrogen (90 g/plant, or N_3) may prolong vegetative growth, slightly delaying the initiation of flowering. The treatment with 30 g of phosphorus pentoxide per plant (P_2) also contributed significantly to improved flowering parameters. The shortest time to first flowering 26.64, 27.81 and 27.22 pooled was noted under P_2, underscoring the role of phosphorus in early reproductive development. Phosphorus facilitates root activity, ATP production, and the synthesis of flowering hormones (such as florigen), aiding early and uniform flower initiation. Among the potassium treatments, 30 g of potassium oxide per plant (K_2) led to the earliest flowering 26.28, 27.33 and 26.80 pooled, comparable to K_1 in both years. Potassium plays a vital role in enzyme activation, water regulation, and the translocation of assimilates, which likely explains this early flower initiation. Bohara *et al*. (2024) [11] in guava, Chanta *et al*. (1995) [13] and Tamanna and Hasan (2018) [47] observed similar findings in papaya and Shinde V. B. (2017) [43] in custard apple.

1.1.2 Interaction effect

The interaction effects of varying levels of N, P and K on days taken to first flowering were found to be non-significant during both years and in the pooled results.

1.2 Number of Flowers per Shoot

1.2.1 Effect of nitrogen, phosphorus and potash

The data compellingly demonstrated in table 2 shows that different levels of nitrogen, phosphorus and potash have a significant impact on the number of flowers per shoot across the years 2022-23 and 2023-24, as well as in the combined analysis. Notably, treatment N_3 yielded the highest average number of flowers per shoot, with impressive figures of (5.89) in the first year and (6.30) in the second year, leading to a robust pooled average of (6.09). This treatment's performance is statistically comparable to treatment N_2, which achieved noteworthy averages of (6.06) during the second year. These results clearly highlight the importance of nitrogen levels in maximizing flower production.

Treatment P_2 produced the highest average number of flowers per shoot, with (5.80) in the first year, (6.21) in the second year and an overall average of (6.00) when the data from both years were combined.

The maximum number of flowers per shoot was observed in treatment K_2 (5.87) in the first year and (6.30) in the second year, which was comparable to treatment K_3, with (5.65) and (6.05) flowers per shoot, respectively. The pooled data suggested that treatment K_2 had the significantly highest number of flowers per shoot (6.08).

In terms of the number of flowers per shoot, N_2 achieved the highest counts of (5.89), (6.30) and (6.09) pooled, which were statistically comparable to N_3 in the first year and to N_1 in the second year.

This indicates that N_2 supports optimal floral development without encouraging excessive vegetative growth, which could limit the initiation of flower buds. The highest number of flowers per shoot (5.80), (6.21) and (6.00) pooled was recorded under P_2, confirming its positive impact on reproductive differentiation. The maximum number of flowers per shoot (5.87), (6.30) and 96.08) pooled was also observed with K_2, and this was similar to K_3 in both years, suggesting that potassium positively influences floral productivity. Similar findings were in found by Singh *et al.* (2008) [44] in guava and Ahmed *et al.* (2001) [2], Malshe (2001) [29], Das *et al.* (2006) [15], Anwar *et al.*, (2011) [7] and Sudha and Balmohan (2012) [45] in mango.

Table 2: Response of different levels of N, P and K on flowering parameters of guava under meadow orchard system

Treatment	Days taken to first flowering			Number of flowers per shoot			Days taken from flowering to fruit set *			Days to first harvest #		
Nitrogen (N)												
	22-23	**23-24**	**Pooled**	**22-23**	**23-24**	**Pooled**	**22-23**	**23-24**	**Pooled**	**22-23**	**23-24**	**Pooled**
N_1	27.81	28.84	28.32	5.47	5.86	5.66	24.10	27.83	25.96	124.07	127.86	125.97
N_2	26.02	27.21	26.62	5.65	6.06	5.86	23.05	26.08	24.56	113.77	115.41	114.59
N_3	29.31	30.25	29.78	5.89	6.30	6.09	25.20	28.87	27.03	119.89	123.58	121.74
S.Em.±	0.649	0.675	0.468	0.097	0.106	0.072	0.477	0.597	0.382	2.706	2.812	1.951
C.D. 5%	1.87	1.94	1.32	0.28	0.30	0.20	1.37	1.72	1.08	7.78	8.09	5.51
Phosphorus (P)												
P_1	28.78	29.72	29.25	5.54	5.94	5.74	24.92	28.57	26.75	122.99	126.40	124.70
P_2	26.64	27.81	27.22	5.80	6.21	6.00	23.30	26.61	24.96	115.50	118.17	116.83
S.Em.±	0.530	0.551	0.382	0.080	0.086	0.059	0.389	0.488	0.312	2.210	2.296	1.593
C.D. 5%	1.52	1.58	1.08	0.23	0.25	0.17	1.12	1.40	0.88	6.36	6.61	4.50
Potassium (K)												
K_1	27.90	28.85	28.38	5.48	5.87	5.68	25.05	28.51	26.78	123.80	127.42	125.61
K_2	26.28	27.33	26.80	5.87	6.30	6.08	23.16	26.32	24.74	114.02	115.31	114.67
K_3	28.96	30.12	29.54	5.65	6.05	5.85	24.13	27.94	26.04	119.91	124.12	122.01
S.Em.±	0.649	0.675	0.468	0.097	0.106	0.072	0.477	0.597	0.382	2.710	2.810	1.951
C.D. 5%	1.87	1.94	1.32	0.28	0.30	0.20	1.37	1.72	1.08	7.78	8.09	5.51
Interaction (N x P)												
S.Em.±	0.918	0.954	0.662	0.138	0.149	0.102	0.674	0.845	0.540	3.827	3.977	2.760
C.D. 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (N x K)												
S.Em.±	1.124	1.168	0.811	0.169	0.183	0.124	0.826	1.034	0.662	4.687	4.871	3.380
C.D. 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (P x K)												
S.Em.±	0.918	0.954	0.662	0.138	0.149	0.102	0.674	0.845	0.540	3.827	3.977	2.760
C.D. 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (N x P x K)												
S.Em.±	1.590	1.652	1.147	0.239	0.259	0.176	1.168	1.463	0.936	6.629	6.889	4.780
C.D. 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV%	9.94	9.95	9.95	7.29	7.38	7.34	8.39	9.18	8.87	9.63	9.76	9.70
		S.Em.±	C.D. 5%		S.Em.±	C.D. 5%		S.Em.±	C.D. 5%		S.Em.±	C.D. 5%
Year (N x P)		0.936	NS		0.144	NS		0.764	NS		3.903	NS
Year (N x K)		1.147	NS		0.176	NS		0.936	NS		4.780	NS
Year (P x K)		0.936	NS		0.144	NS		0.764	NS		3.903	NS
Year (N x P x K)		1.622	NS		0.249	NS		1.324	NS		6.760	NS
Days taken to first flowering has been counted from 28th may *i.e.* date of pruning												
***** Days taken from flowering to set has been counted from days to first flowering to days to fruit set started												
# Days to first harvest has been counted from days to first flowering to first harvesting started												

1.2.2 Interaction effect

The interaction effects of varying levels of N, P, and K on number of flowers per shoot were found to be non-significant during both years and in the pooled results.

1.3 Days Taken from Flowering to Fruit Set

1.3.1 Effect of nitrogen, phosphorus and potash

The varying levels of nitrogen, phosphorus and potash significantly affect the number of days from flowering to fruit set over the years 2022-23 and 2023-24, as well as in the combined analysis as depicted in table 2. Notably, treatment N_2 required the fewest days from flowering to fruit set, with impressive averages of (23.05) in the first year and (26.08) in the second year, leading to a robust pooled average of (24.56). This treatment's performance is statistically comparable to treatment N_1, which achieved noteworthy averages of (24.10) during the first year.

The treatment P_2 recorded the shortest duration from flowering to fruit set, with an average of (23.30) in the first year, (26.61) in the second year and (24.96) when the data from both years were combined.

Minimum days were required for flowering to fruit set (23.16) during first year and (26.32) during the second year in treatment K_2 which was found at par with treatment K_3 (24.13) and (27.94) respectively. The pooled data suggested that treatment K_2 had the significantly least number for flowering to fruit set (24.74).

1.3.2 Interaction effect
The interaction effects of varying levels of N, P and K on Days taken from flowering to fruit set were found to be non-significant during both years and in the pooled results.

1.4 Days to First Harvest
1.4.1 Effect of nitrogen, phosphorus and potash
The data as per table 2 indicated that effect of different levels of nitrogen, phosphorus and potash significantly affect the number of days to first harvest over the years 2022-23 and 2023-24, as well as in the combined analysis. The treatment N_2 required the least days taken to first harvest, with impressive averages of (113.77) in the first year and (115.41) in the second year, leading to a robust pooled average of (114.59). This treatment's performance is statistically comparable to treatment N_3, which achieved noteworthy averages of (119.89) during the first year. The shortest duration from flowering to fruit set pooled was again recorded in N_2, indicating faster fruit setting due to a balanced availability of carbohydrates and hormonal regulation.
The treatment P_2 recorded the shortest duration to first harvest, with an average of (115.50) in the first year, (118.17) in the second year and (116.83) when the data from both years were combined. Additionally, P_2 resulted in the shortest duration from flowering to fruit set and early harvest times highlighting that phosphorus application accelerates reproductive maturity by supporting energy transfer and fruit development processes.
Minimum days were required for first harvest (114.02) during first year and during the second year (115.31) in treatment K_2 which was found at par with treatment K_3 (119.91) in the first year. The pooled data suggested that treatment K_2 had the significantly least number days to first harvest (114.67). Shorter durations from flowering to fruit set and earlier harvest times indicate that potassium enhances reproductive efficiency by ensuring better carbohydrate partitioning and fruit development.
The best flowering performance in guava was achieved with moderate nitrogen (N_2) and phosphorus (P_2) levels, which significantly promoted flowering. These findings suggest that a balanced nutrient management strategy—in particular, a combination of moderate nitrogen and adequate phosphorus and potassium—is crucial for optimizing flowering dynamics in guava within meadow orchard systems. This approach ultimately enhances fruit yield potential. Similarly, the least number of days to the first harvest was associated with N_2, confirming that a moderate nitrogen dose promotes synchronized and efficient transitions from flowering to fruiting. Similar findings were reported by Thirupathi *et al*. (2016) [49] in guava and in other fruit crops by Jain *et al*. (2020) [24] in sapota.

1.4.2 Interaction effect
The interaction effects of varying levels of N, P, and K on days taken to first harvest were found to be non-significant during both years and in the pooled results.

2. Response of N, P and K on yield parameters
2.1 Fruit Set (%)
2.1.1 Effect of nitrogen, phosphorus and potash
The data depicted in table 3 indicated that effect of different levels of nitrogen, phosphorus and potash significantly affect the fruit set (%) over the years 2022-23 and 2023-24, as well as in the combined analysis. Notably, treatment N_3 had the highest fruit set (%) (89.07) in the first year and (77.50) in the second year, leading to a robust pooled average of (83.29). This treatment's performance was statistically comparable to that of treatment N_2, which recorded (85.36) and (74.16) during both years respectively. Whereas, treatment N_1 had the lowest fruit set (%) with averages of (79.19) in the first year, (64.80) in the second year, and a pooled average of (72.00).
Treatment P_2 produced the highest fruit set (%), with (88.84) in the first year, (76.74) in the second year, and an overall average of (82.79) when the data from both years were combined. In contrast, treatment P_1 resulted in the lowest fruit set (%), with (80.24) in the first year, (67.57) in the second year, and a pooled average of (73.90).
The maximum fruit set (%) was observed in treatment K_2 (88.53) in the first year, (75.61) in the second year and the pooled data averaging (82.07). This treatment's performance was statistically comparable to that of treatment K_3. In contrast, treatment K_1 resulted in the minimum fruit set (%), recording (79.77) in the first year, (68.21) in the second year, and an average of (73.99) in the pooled data.

2.1.2 Interaction effect
The data revealed substantial variation in fruit set percentages were found to be non-significant during both years and in the pooled results.
In this study, the highest percentage of fruit set was observed under treatment N_3, with values of 89.07% in 2022-23, 77.50% in 2023-24, and a pooled average of 83.29%. Treatment N_2 followed closely during year 2023-24, showing statistically similar results. This indicates that higher nitrogen levels positively influence flower fertilization and early fruit development. The trend can be attributed to nitrogen's role in enhancing vegetative vigor, leaf area, and metabolic activity, which collectively boost photosynthetic production and flower supply. Moreover, phosphorus treatment P_2 also demonstrated significant improvement in fruit set, 88.84%, 76.74% and 82.79% during both the years as well as pooled data, respectively. This suggests that phosphorus is important for reproductive development and the growth of pollen tubes, aiding in achieving fruit set. Likewise, potassium treatment K_2 showed a significant enhancement in fruit set, with values ranging from 88.53%, 75.61% and 82.07% during both the years as well as pooled data, respectively. This effect is likely due to potassium's role in improving flower quality and promoting carbohydrate translocation. Similar findings were reported by Binepal *et al*. (2013) [10], Sharma and Mursaleen (2014) [41] and Baviskar *et al*. (2018) [9] in guava. Pandey and Rehalia (2012) [34] and Kashyap *et al*. (2012) [26] in pomegranate, Anusha *et al*. (2020) [6] in sapota and Palepad (2020) [33] in custard apple.

2.2 Number of fruits per shoot
2.2.1 Effect of nitrogen, phosphorus and potash
The data from the table 3 indicated that effect of different levels of nitrogen, phosphorus, and potash significantly

affect the number of fruits per shoot over the years 2022-23 and 2023-24, as well as in the combined analysis. Notably, treatment N_3 yielded the highest average number of fruits per shoot, with impressive figures of (4.43) in the first year and (4.08) in the second year, leading to a robust pooled average of (4.26). In contrast, treatment N_1 lagged, producing the lowest number of fruits per shoot, with averages of (3.60) in the first year, (3.13) in the second year, and a pooled average of (3.37). These results clearly highlight the importance of nitrogen levels in maximizing fruit production.

Treatment P_2 produced the highest average number of fruits per shoot, with (4.33) in the first year, (3.99) in the second year, and an overall average of (4.16) when the data from both years were combined. In contrast, treatment P_1 resulted in the lowest average number of fruits, with (3.71) in the first year, (3.31) in the second year, and a pooled average of (3.51).

The maximum number of fruits per shoot was observed in treatment K_2 (4.41) in the first year, (4.01) in the second year and the pooled data averaging (4.21). In contrast, treatment K_1 resulted in the minimum number of fruits per shoot, recording (3.62) in the first year, (3.29) in the second year, and an average of (3.45) in the pooled data.

2.2.2 Interaction effect

The data revealed substantial variation in number of fruits per shoot were found to be non-significant during both years and in the pooled results.

The maximum number of fruits per shoot was observed in the N_3 treatment, with an average of 4.26 fruits, followed closely by P_2 at 4.16 and K_2 at 4.21. This indicates that all three macronutrients—nitrogen (N), phosphorus (P), and potassium (K)—positively influenced this trait. The higher fruit count per shoot under these treatments may be attributed to improved flower retention, reduced flower drop, and a better supply of nutrients during fruit initiation. Adequate nitrogen supports cell division and growth; phosphorus facilitates energy transfer during flower and fruit formation; and potassium enhances fruit load by decreasing abscission through stronger stalk development and hormone balance. These findings are supported by the research of Kumar *et al*. (2008) [28] and Chavan *et al*. (2020) [14] in guava, Gautam *et al*. (2012) [19] in mango and Gochar *et al*. (2017) [20] in phalsa.

2.3 Fruit Weight (g)

2.3.1 Effect of nitrogen, phosphorus and potash

The data from table 3 signifies that effect of different levels of nitrogen, phosphorus, and potash on fruit weight (g) was found significant during the years 2022-23 and 2023-24 as well as in pooled analysis. Maximum fruit weight (g) (125.52) was recorded in the treatment N_3 during first year which was at par with the treatment N_2 (119.26) in second year. Whereas fruit weight (g) (126.86) was found significantly highest in treatment N_3 during the second year and pooled data (126.16). The treatment N_1 resulted in the minimum fruit weight (g) (107.99) in first year and (108.37) in second year and (108.18) pooled data.

Significantly maximum fruit weight (g) (121.47) was recorded in the treatment P_2 during first year and (125.79) during second year as well as in pooled data (123.63). The treatment P_1 resulted in the minimum fruit weight (g) (113.71) in first year and (110.72) in second year and (112.22) pooled data.

The maximum fruit weight (g) was observed in treatment K_2 (123.27) in the first year, (123.81) in the second year and the pooled data averaging (123.54). In contrast, treatment K_1 resulted in the minimum fruit weight (g), recording (114.17) in the first year, (114.42) in the second year, and an average of (114.30) in the pooled data.

2.3.2 Interaction effect

The interaction effects of different levels of nitrogen (N), phosphorus (P), and potassium (K) on fruit weight (g) was found to be non-significant for both years and the pooled results. The only exception was the effect of N and K on fruit weight (g) as shown in table 4. Maximum fruit weight (g) was observed in treatment combination N_3K_2 (133.62) during first year which was at par with N_2K_2 and N_3K_3. While during second year maximum fruit weight (g) (132.61) was noted in in treatment combination N_3K_2 which were statistically at par with N_2K_2, N_3K_3, N_3K_1, and N_2K_1, respectively. The pooled analysis indicated that treatment combination N_3K_2 (133.12) had highest fruit weight (g) followed by N_2K_2. The least fruit weight (g) was observed in treatment combination N_1K_1 in both the years and pooled data.

Fruit size, which directly affects marketability and yield, was highest in the N_3 treatment at an average of 126.19 grams. This value was significantly greater than all other treatments and comparable to the N_2 treatment in the first year. This finding highlights the critical role of nitrogen in promoting cell enlargement and dry matter accumulation in developing fruits. The P_2 treatment, with an average size of 123.63 grams, and the K_2 treatment, at 123.54 grams, performed second best. This suggests that both phosphorus and potassium positively influence the development of fruit size. Phosphorus enhances the energy supply through ATP, which is vital for fruit growth, while potassium supports sugar translocation, turgor pressure, and enzymatic activity. These findings are consistent with the research of Singh *et al*. (2016) and Das *et al*. (2012), which demonstrated the positive impact of nitrogen, phosphorus, and potassium (NPK) on guava fruit weight. The broader range of statistically similar treatments observed in the second year may be attributed to more favorable climatic conditions that enhanced nutrient uptake efficiency across the treatments. Additionally, the soil's improved buffering capacity in the second season, due to residual fertility, and possibly greater plant maturity and canopy size could have led to a more stable source-sink relationship. Similar findings were reported by Sarolia *et al*. (2020) [40] and Challa *et al*. (2021) [12] in guava, Ahmed *et al*. (2011) [1] in mango, Azam *et al*. (2022) [8] in pomegranate and Navgare *et al*. (2021) [32] in banana.

Table 3: Response of different levels of N, P and K on yield parameters of guava under meadow orchard system

Treatment	Fruit set (%)			Number of fruits per shoot			Fruit weight (g)			Yield per plant (kg)		
						Nitrogen (N)						
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
N1	79.19	64.80	72.00	3.60	3.13	3.37	107.99	108.37	108.18	2.75	2.41	2.58
N2	85.36	74.16	79.76	4.04	3.73	3.88	119.26	119.53	119.40	3.48	2.98	3.23
N3	89.07	77.50	83.29	4.43	4.08	4.26	125.52	126.86	126.19	3.92	3.33	3.62
S.Em.±	1.682	1.653	1.179	0.099	0.095	0.069	2.318	2.524	1.713	0.085	0.076	0.057
C.D at 5%	4.84	4.75	3.33	0.28	0.27	0.19	6.67	7.26	4.84	0.25	0.22	0.16
						Phosphorus (P)						
P1	80.24	67.57	73.90	3.71	3.31	3.51	113.71	110.72	112.22	3.11	2.52	2.81
P2	88.84	76.74	82.79	4.33	3.99	4.16	121.47	125.79	123.63	3.66	3.29	3.48
S.Em.±	1.373	1.350	0.963	0.081	0.078	0.056	1.893	2.061	1.399	0.070	0.062	0.047
C.D at 5%	3.95	3.88	2.72	0.23	0.22	0.16	5.44	5.93	3.95	0.20	0.18	0.13
						Potassium (K)						
K1	79.77	68.21	73.99	3.62	3.29	3.45	114.17	114.42	114.30	3.17	2.70	2.94
K2	88.53	75.61	82.07	4.41	4.01	4.21	123.27	123.81	123.54	3.77	3.26	3.52
K3	85.32	72.64	78.98	4.03	3.65	3.84	115.33	116.54	115.93	3.21	2.75	2.98
S.Em.±	1.682	1.653	1.179	0.099	0.095	0.069	2.318	2.524	1.713	0.085	0.076	0.057
C.D at 5%	4.84	4.75	3.33	0.28	0.27	0.19	6.67	7.26	4.84	0.25	0.22	0.16
						Interaction (N x P)						
S.Em.±	2.379	2.338	1.668	0.140	0.135	0.097	3.278	3.569	2.423	0.121	0.107	0.081
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
						Interaction (N x K)						
S.Em.±	2.914	2.863	2.042	0.171	0.165	0.119	4.015	4.371	2.968	0.148	0.131	0.099
C.D. at 5%	NS	NS	NS	NS	NS	NS	11.55	12.57	8.38	0.42	0.38	0.28
						Interaction (P x K)						
S.Em.±	2.379	2.338	1.668	0.140	0.135	0.097	3.278	3.569	2.423	0.121	0.107	0.081
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
						Interaction (N x P x K)						
S.Em.±	4.120	4.049	2.888	0.242	0.234	0.168	5.678	6.182	4.197	0.209	0.186	0.140
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV%	8.44	9.72	9.03	10.44	11.10	10.75	8.36	9.05	8.72	10.69	11.07	10.89
		S.Em.±	C.D. at 5%		S.Em.±	C.D. at 5%		S.Em.±	C.D. at 5%		S.Em.±	C.D. at 5%
Year (N x P)		2.358	NS		0.137	NS		3.427	NS		0.114	NS
Year (N x K)		2.888	NS		0.168	NS		4.197	NS		0.140	NS
Year (P x K)		2.358	NS		0.137	NS		3.427	NS		0.114	NS
Year (N x P x K)		4.085	NS		0.238	NS		5.935	NS		0.198	NS

Table 4: Interaction effect of different levels of N × K on fruit weight (g) and yield (kg/Plant) of guava under meadow orchard system

Treatment	Fruit weight (g)			Yield per plant (kg)		
	Interaction (N x K)					
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
N_1K_1	100.53	99.85	100.19	2.31	2.10	2.20
N_1K_2	108.31	110.61	109.46	3.03	2.61	2.82
N_1K_3	115.12	114.65	114.89	2.93	2.51	2.72
N_2K_1	121.32	121.68	121.50	3.58	2.99	3.29
N_2K_2	127.88	128.21	128.05	3.99	3.43	3.71
N_2K_3	108.59	108.70	108.64	2.87	2.52	2.69
N_3K_1	120.67	121.72	121.19	3.62	3.01	3.32
N_3K_2	133.62	132.61	133.12	4.30	3.73	4.01
N_3K_3	122.28	126.26	124.27	3.83	3.23	3.53
S.Em.±	4.015	4.371	2.968	0.148	0.131	0.099
C.D at 5%	11.55	12.57	8.38	0.42	0.38	0.28
CV%	8.36	9.05	8.72	10.69	11.07	10.89

2.4 Yield Per Plant (Kg)

2.4.1 Effect of nitrogen, phosphorus and potash

The data revealed that significant differences in yield per plant (kg) was observed because of different levels of nitrogen, phosphorus and potash during both the years and in pooled analysis also as in table 3. Significantly maximum yield per plant (kg) (3.92) during first year, (3.33) second year and pooled data (3.62). The treatment N_1 resulted in the minimum yield per plant (kg) (2.75) in first year and (2.41) in second year and (2.58) pooled data.

Significantly maximum yield per plant (kg) (3.66) was recorded in the treatment P_2 during first year and (3.29) during second year as well as in pooled data (3.48). The treatment P_1 resulted in the minimum yield per plant (kg) after harvest (3.11) in first year and (2.52) in second year and (2.81) pooled data.

Maximum yield per plant 3.77 kg, 3.26 kg and 3.52 kg was found in treatment K_2 and in pooled data, respectively While minimum yield per plant (kg) for both the years and pooled data was found in treatment K_1 3.17 kg, 2.70 kg and 2.94 kg, respectively.

2.4.2 Interaction effect

The interaction effects of different levels of nitrogen (N), phosphorus (P), and potassium (K) on yield per plant (kg) was found to be non-significant for both years and the pooled results. The only exception was the effect of N and K on yield per plant (kg) as shown in table 4. Maximum yield per plant (kg) was observed in treatment combination N_3K_2 4.30 kg and 3.73 kg during both the years, respectively which was at par with N_2K_2 3.99 kg and 3.43 kg, respectively. The pooled analysis indicated that treatment combination N_3K_2 (4.01) had highest yield per plant (kg). The lowest yield per plant (kg) was observed in treatment combination N_1K_1 in both the years and pooled data.

The data suggest a synergistic effect between high nitrogen (N_3) and moderate potassium (K_2), as indicated by the consistently superior performance of the N_3K_2 treatment across both years and in pooled data. Nitrogen promotes vigorous vegetative and reproductive growth, while potassium aids in efficient carbohydrate partitioning and fruit development. Notably, the N_2K_2 treatment, which involves a slightly reduced nitrogen dose, produced statistically similar yields, emphasizing that both nutrient sufficiency and balance are more critical than the quantity of individual nutrients. This interaction likely results from enhanced root growth and nutrient absorption, improved source-sink dynamics between leaves and fruits, and stronger enzymatic activity and hormonal regulation involved in fruit set and development. These findings are supported by the research of Kumar *et al*. (2008) [28] in guava, Gondaliya *et al*. (2025) [21], Reddy *et al*. (2000) [37], Nagraj and Sharma (2018) [31] and Parmar *et al*. (2025) [35] in mango, Singh *et al*. (2003) in sapota and Thanki *et al*. (2022) [48] in dragon fruit.

3. Response of N, P and K on quality parameters

3.1 TSS (ºBrix)

3.1.1 Effect of nitrogen, phosphorus and potash

The data from table 5 indicated significant differences in TSS (ºBrix) during both the years and in pooled analysis also. Significantly maximum TSS (ºBrix) (13.27) in first year and (13.88) in second year and (13.58) pooled data was recorded in the treatment N_2 during. This treatment's performance was statistically comparable to that of treatment N_1, which achieved noteworthy averages of (12.71) during the first year. The treatment N_3 resulted in the minimum TSS (ºBrix) (11.25) in first year and (11.77) in second year and (11.51) pooled data.

Significantly maximum TSS (ºBrix) (12.85) in first year and (13.50) in second year and (13.17) pooled data was recorded in the treatment P_2 during. The treatment P_1 resulted in the minimum TSS (ºBrix) (11.98) in first year and (12.27) in second year and (12.12) pooled data.

Significantly maximum TSS (ºBrix) (12.87) in first year and (13.49) in second year and (13.18) pooled data was recorded in the treatment K_2 during. The treatment K_1 resulted in the minimum TSS (ºBrix) (12.15) in first year and (12.42) in second year and (12.28) pooled data.

3.1.2 Interaction effect

The interaction effects of different levels of nitrogen (N), phosphorus (P), and potassium (K) on TSS (ºBrix) were found to be non-significant for both years and the pooled results. The only exception was the effect of N and K on TSS (ºBrix) as seen in table 6. Significantly, maximum TSS (ºBrix) was observed in treatment combination N_2K_2 (13.72) during first year, (14.40) during second year and (14.06) in pooled analysis, respectively. This treatment's performance was statistically comparable to that of treatment N_1K_2 followed by N_2K_3, N_1K_1 and N_2K_1 during the first year and treatment N_1K_2 followed by N_2K_3 and N_2K_1 during the second year as well as treatment N_1K_2 followed by N_2K_3 in pooled data. The minimum TSS (ºBrix) was observed in treatment combination N_3K_1**.**

Total Soluble Solids (TSS) in guava, measured in °Brix, is an important quality parameter that indicates the sweetness and overall flavor of the fruit. Higher TSS values typically suggest better eating quality and greater consumer acceptability. The current study showed that TSS content was significantly affected by different levels of nitrogen (N), phosphorus (P), potassium (K), and their interactions (N × K). Moderate applications of nitrogen may improve photosynthesis and sugar accumulation without promoting excessive vegetative growth, which can dilute the concentration of assimilates. However, excess nitrogen (N_3) tends to encourage vegetative growth at the expense of soluble sugar concentration in the fruits, thereby reducing TSS. Conversely, insufficient nitrogen (N1) may limit the production of photosynthates, also leading to a decrease in sugar buildup.

The combination of moderate nitrogen (N_2) and moderate potassium (K_2) appears to be ideal for sugar synthesis, translocation, and retention in guava fruits. TSS was lowest when there was excess nitrogen (N_3) combined with low potassium (K_1), indicating a negative interaction between excessive vegetative growth and insufficient sugar accumulation. The best-performing combinations, such as N_2K_2 and N_2K_3, demonstrate a balanced nutrient environment that enhances carbohydrate metabolism and translocation, ultimately enriching fruit sweetness. Similar beneficial effects have been reported by Raghavendra *et al*. (2018) [18], Chavan *et al*. (2020) [14] and Sarolia *et al*. (2020) [40] in guava. Ahmed *et al*. (2011) [1], Sarkar *et al*. (2012) [39] and Vala *et al*. (2020) [51] in mango. Suresh kumar *et al*. (2011) [46] and Ganvit *et al*. (2024) [17] in custard apple. Garhwal *et al*. (2014) [18] in citrus. Kumar *et al*. (2020) [27] in banana.

3.2 Ascorbic acid (mg 100 ml^{-1})

3.2.1 Effect of nitrogen, phosphorus and potash

The data from table 5 indicated significant differences in ascorbic acid (mg 100 ml^{-1}) during both the years and in pooled analysis also. Significantly maximum ascorbic acid (mg 100 ml^{-1}) (183.36) in first year and (193.43) in second year and (188.40) pooled data was recorded in the treatment N_2 during. This treatment's performance was statistically comparable to that of treatment N_1, which achieved noteworthy averages of (186.01) during the second year. The treatment N_3 resulted in the minimum ascorbic acid (mg 100 ml^{-1}) (163.73) in first year and (165.97) in second year and (164.85) pooled data.

Significantly maximum ascorbic acid (mg 100 ml^{-1}) (177.14) in first year and (186.77) in second year and (181.96) pooled data was recorded in the treatment P_2 during. The treatment P_1 resulted in the minimum ascorbic acid (mg 100 ml^{-1}) (168.45) in first year and (176.84) in second year and (172.65) pooled data.

Significantly maximum ascorbic acid (mg 100 ml^{-1}) (180.78) in first year and (193.42) in second year and (187.10) pooled data was recorded in the treatment K_2 during. This treatment's performance was statistically comparable to that of treatment K_3, which achieved noteworthy averages of (173.21) during the first year. The treatment K_1 resulted in the minimum ascorbic acid (mg 100 ml^{-1}) (164.40) in first year and (171.50) in second year and (167.95) pooled data.

Table 5: Interaction effect of different levels of N × K on quality parameters of guava under meadow orchard system

Treatment	TSS (ºBrix)			Ascorbic acid (mg 100 ml^{-1})			Total sugar (%)		
Nitrogen (N)									
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
N_1	12.71	13.00	12.86	171.30	186.01	178.66	7.90	8.59	8.24
N_2	13.27	13.88	13.58	183.36	193.43	188.40	9.07	9.86	9.46
N_3	11.25	11.77	11.51	163.73	165.97	164.85	8.92	9.74	9.33
S.Em.±	0.214	0.249	0.164	2.800	3.232	2.138	0.165	0.189	0.125
C.D at 5%	0.62	0.72	0.46	8.05	9.30	6.04	0.48	0.54	0.35
Phosphorus (P)									
P_1	11.98	12.27	12.12	168.45	176.84	172.65	8.38	9.14	8.76
P_2	12.85	13.50	13.17	177.14	186.77	181.96	8.88	9.65	9.26
S.Em.±	0.175	0.203	0.134	2.286	2.639	1.746	0.135	0.154	0.102
C.D at 5%	0.50	0.59	0.38	6.58	7.59	4.93	0.39	0.44	0.29
Potassium (K)									
K_1	12.15	12.42	12.28	164.40	171.50	167.95	8.09	8.83	8.46
K_2	12.87	13.49	13.18	180.78	193.42	187.10	9.07	9.86	9.46
K_3	12.22	12.74	12.48	173.21	180.50	176.85	8.73	9.49	9.11
S.Em.±	0.214	0.249	0.164	2.800	3.232	2.138	0.165	0.189	0.125
C.D at 5%	0.62	0.72	0.46	8.05	9.30	6.04	0.48	0.54	0.35
Interaction (N x P)									
S.Em.±	0.303	0.352	0.232	3.960	4.570	3.024	0.234	0.267	0.177
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (N x K)									
S.Em.±	0.371	0.431	0.285	4.850	5.597	3.703	0.286	0.327	0.217
C.D. at 5%	1.07	1.24	0.8	NS	NS	NS	0.82	0.94	0.61
Interaction (P x K)									
S.Em.±	0.303	0.352	0.232	3.960	4.570	3.024	0.234	0.267	0.177
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (N x P x K)									
S.Em.±	0.525	0.61	0.402	6.859	7.916	5.237	0.405	0.462	0.307
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV%	7.32	8.20	7.79	6.87	7.54	7.24	8.13	8.52	8.35
		S.Em.±	C.D. 5%		S.Em.±	C.D. 5%		S.Em.±	C.D. 5%
Year (N x P)		0.329	NS		4.276	NS		0.251	NS
Year (N x K)		0.402	NS		5.237	NS		0.307	NS
Year (P x K)		0.329	NS		4.276	NS		0.251	NS
Year (N x P x K)		0.569	NS		7.406	NS		0.434	NS

3.2.2 Interaction effect

The interaction effects of varying levels of N, P, and K on ascorbic acid (mg 100 ml^{-1}) were found to be non-significant during both years and in the pooled results

Ascorbic acid, commonly known as vitamin C, is an essential nutrient and a key quality indicator in guava fruit. It significantly contributes to the fruit's antioxidant capacity and health benefits. This study showed that the levels of nitrogen, phosphorus, and potassium have a substantial impact on the ascorbic acid content in guava fruits. The findings suggest that a moderate dose of nitrogen is optimal for synthesizing ascorbic acid. However, excessive nitrogen (N_3) likely promoted vegetative growth at the expense of biochemical quality, while a lower dose (N_1) may have limited overall metabolic activity. Phosphorus also plays a crucial role in energy transfer and nucleic acid synthesis, supporting the biosynthesis of vitamin C. Adequate phosphorus levels may have stimulated the metabolic pathways associated with the formation of ascorbic acid. Furthermore, potassium levels significantly influenced the vitamin C content. Potassium regulates water relations, photosynthesis, and enzyme activation, all of which affect the synthesis and retention of ascorbic acid in fruits. A moderate potassium dose (K_2) appeared to strike the ideal balance, while both lower (K_1) and higher (K_3) doses may have disrupted physiological homeostasis, leading to reduced vitamin C content. Similar beneficial effects have been reported by Binepal *et al.* (2013) [10], Raghavendra *et al.* (2018) [18] and Sahu and Sahu (2020) [38] in guava. Sarkar *et al.* (2012) [39] and Hasan *et al.* (2013) [23] in mango. Ferreira *et al.* (2022) [16] in custard apple.

Table 6: Interaction effect of different levels of N × K on TSS and Total Sugar of guava under meadow orchard system

Treatment	TSS (ºBrix)			Total sugar (%)		
	Interaction (N x K)					
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
N_1K_1	13.11	13.08	13.09	7.76	8.44	8.10
N_1K_2	13.59	14.05	13.82	8.19	8.90	8.54
N_1K_3	11.44	11.87	11.66	7.75	8.42	8.08
N_2K_1	12.91	13.40	13.16	8.83	9.60	9.21
N_2K_2	13.72	14.40	14.06	9.18	9.98	9.58
N_2K_3	13.18	13.85	13.51	9.20	10.01	9.60
N_3K_1	10.42	10.79	10.60	7.68	8.46	8.07
N_3K_2	11.28	12.03	11.66	9.83	10.69	10.26
N_3K_3	12.05	12.50	12.27	9.25	10.06	9.65
S.Em.±	0.371	0.431	0.285	0.286	0.327	0.217
C.D at 5%	1.07	1.24	0.80	0.82	0.94	0.61
CV%	7.32	8.20	7.79	8.13	8.52	8.35

3.3 Total sugar (%)

3.3.1 Effect of nitrogen, phosphorus and potash

The data from table 5 indicated significant differences in total sugar (%) during both the years and in pooled analysis also. Significantly maximum total sugar (%) (9.07) in first year and (9.86) in second year and (9.46) pooled data was recorded in the treatment N_2 during. This treatment's performance was statistically comparable to that of treatment N_1, which achieved noteworthy averages of (8.92) in first year and (9.74) in second year and (9.33) pooled data. The treatment N_3 resulted in the minimum total sugar (%) (7.90) in first year and (8.59) in second year and (8.24) pooled data.

Significantly maximum total sugar (%) (8.88) in first year and (9.65) in second year and (9.26) pooled data was recorded in the treatment P_2 during. The treatment P_1 resulted in the minimum total sugar (%) (8.38) in first year and (9.14) in second year and (8.76) pooled data.

Significantly maximum total sugar (%) (9.07) in first year and (9.86) in second year and (9.46) pooled data was recorded in the treatment K_2 during. This treatment's performance was statistically comparable to that of treatment K_3, which achieved noteworthy averages of (8.73) in first year and (9.49) in second year and (9.11) pooled data. The treatment K_1 resulted in the minimum total sugar (%) (8.09) in first year and (8.83) in second year and (8.46) pooled data.

3.3.2 Interaction effect

The interaction effects of different levels of nitrogen (N), phosphorus (P), and potassium (K) on total sugar (%) were found to be non-significant for both years and the pooled results. The only exception was the effect of N and K on total sugar (%) as per table 6. Significantly, maximum total sugar (%) was observed in treatment combination N_3K_2 (9.83) during first year, (10.69) during second year and (10.26) in pooled analysis, respectively. This treatment's performance was statistically comparable to that of treatment N_3K_3 followed by N_2K_3, and N_2K_2 during the first year and treatment N_3K_3 followed by N_2K_3, and N_2K_2 during the second year as well as treatment N_3K_3 in pooled data.

The total sugar content in guava is a crucial quality trait, as it directly influences the fruit's taste, consumer acceptance, and market value. The present investigation has shown that moderate levels of nitrogen, phosphorus, and potassium significantly enhance the total sugar concentration in guava fruits. Among the individual nutrient treatments, the highest total sugar content was observed with nitrogen (N_2) at 9.07% in 2022-23, 9.86% in 2023-24, and a pooled value of 9.46%. This was followed closely by phosphorus (P_2) at a pooled value of 9.26% and potassium (K_2) at 9.46% pooled. These results indicate that an optimal—not excessive—supply of nutrients is essential for the biosynthesis and accumulation of sugars.

The interaction effects revealed that the combination of high potassium (K) with adequate to high nitrogen (N) resulted in the maximum total sugar content of 10.26% (pooled) when using N_3K_2. This value was statistically comparable to those obtained with N_3K_3, N_2K_3, and N_2K_2, suggesting that increased potassium along with sufficient nitrogen significantly boosts sugar metabolism. This synergistic effect may be due to enhanced photosynthetic activity and improved carbohydrate translocation. These findings highlight the importance of balanced fertilization, particularly the interplay between nitrogen and potassium, in achieving superior fruit sweetness and overall quality in guava grown in meadow orchard systems. Similar beneficial effects have been reported by Binepal *et al*. (2013) [10], Sharma *et al*. (2014), Raghavendra *et al*. (2018) [18], Chavan *et al*. (2020) [14] and Sahu and Sahu (2020) [38] in guava. Ahmed *et al*. (2011) [1], Sarkar *et al*. (2012) [39], Hasan *et al*. (2013) [23], Mirjha *et al*. (2018) [30] and Vala *et al*. (2020) [51] in mango. Garhwal *et al*. (2014) [18] in citrus. Gondaliya *et al*. (2023) [22] in custard apple.

Conclusion

Based on results obtained from present investigation it can be concluded that various doses of N, P and K for meadow orchard system in Guava (withholding irrigation in March and pruning upto 90 cm during May) reported better on flowering, yield and quality. Among doses of nitrogen, treatment N_2 (60 g) recorded better for flowering parameters *viz*. days for first flower initiation, flowering to fruit set and first harvest and TSS. Treatment N_3 (90 g) recorded higher yield parameters *viz*. fruit set (%), number of fruits per shoot, fruit weight (g) and yield per plant (kg) and Total sugars (%). For effect of phosphorus P_2 (30 g) and potash K_2 (30 g), all the flowering, yield and quality parameters were found the best. For interaction effects, the treatment combination of N_3K_2 (N:90 g and K:30 g) resulted in higher fruit weight, yield and TSS.

Hence, for getting better growth and flowering in meadow orchard of guava should be fertilized with N 90 g, P 30 g and K 30 g per plant for its individual effect.

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