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Research Article

Response of Pomegranate (*Punica granatum* L.) to UTPANN Fermented Organic Manure: Growth, Yield, and Quality Perspectives

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Abstract

A field experiment was conducted during two consecutive seasons 2024–2025 in Banaskantha to evaluate the effect of fermented organic manure UTPANN FOM on growth, yield, and fruit quality of pomegranate (*Punica granatum* L.) under field conditions. The treatment significantly improved fruiting parameters, with fruit set increasing to 67.2–67.8% and fruit drop decreasing to 32.2–32.8%, thereby enhancing overall fruit retention. Yield was markedly enhanced, reaching 60.4–61.2 t/ha compared to control. A marked reduction in physiological disorders such as fruit cracking and sunburn was also observed, leading to a higher proportion of marketable fruits (86.3–87.1%). In addition, improvements in vegetative growth, flowering behaviour, and yield attributes were observed. Fruit quality was enhanced, particularly in terms of fruit weight (about 400 g), juice content (>60%), and total soluble solids (~17°Brix), along with reduced acidity. The results highlight the effectiveness of UTPANN FOM as a nutrient-rich organic input that enhances soil biological activity and nutrient availability. It also promotes beneficial microbial activity and improves soil health, leading to better plant growth and productivity. Thus, UTPANN FOM can serve as a sustainable and eco-friendly alternative to conventional nutrient management practices in pomegranate cultivation.

Keywords: Bio-Organic Inputs; Field Experiment; Fermented Manure; Microbial Inoculants; Nutrient Uptake; Organic Farming; *Punica granatum* L.; Sustainable Agriculture

Introduction

Pomegranate (*Punica granatum* L.) is an economically and nutritionally important fruit crop cultivated extensively in tropical and subtropical regions of the world, particularly in countries such as India, Iran, and Spain [1]. The fruit is highly valued for its rich nutritional composition, including vitamins (C and K), essential minerals, dietary fiber, and a wide range of bioactive compounds such as polyphenols, flavonoids, and anthocyanins [2]. These compounds possess strong antioxidant properties and are associated with multiple health benefits, including the reduction of cardiovascular diseases, inflammation, and certain types of cancer [3]. Pomegranate has become a commercially significant fruit crop with substantial export potential owing to its high nutritional value and increasing consumer demand [4]. In India, pomegranate cultivation has expanded considerably in recent years, especially in Maharashtra, Gujarat, and Karnataka, due to favorable agro-climatic conditions that enhance crop growth and productivity [5].

Pomegranate is a nutrient-responsive perennial crop that requires an adequate and balanced supply of essential macronutrients, including nitrogen (N), phosphorus (P), and potassium (K), along with micronutrients, for optimal vegetative growth, flowering, fruit development, and yield [6]. Crop nutrient requirements have traditionally been fulfilled through the application of inorganic fertilizers, which provide rapid nutrient availability and can substantially enhance crop productivity in the short term. However, their prolonged and indiscriminate use is increasingly associated with adverse agronomic and environmental consequences. These include soil structure degradation and loss of soil organic carbon, along with alterations in microbial diversity, nutrient imbalances, and increased environmental pollution through leaching and greenhouse gas emissions [7]. Moreover, farmers, particularly in developing agricultural systems, are increasingly facing financial pressure due to the rising cost of chemical fertilizers [8].

In view of these limitations, the adoption of sustainable and environmentally sound nutrient management practices has become imperative. Among various alternatives, fermented organic manure has gained considerable attention as an effective approach to improve soil fertility and crop productivity [9]. Fermented organic manure is produced through the controlled microbial decomposition of organic substrates such as farmyard manure, cow dung, cow urine, crop residues, jaggery, and pulse flour [10]. The fermentation process involves the proliferation and metabolic activity of beneficial microorganisms, including bacteria, fungi, and actinomycetes, which convert complex organic compounds into simpler, plant-available forms [11]. This process enhances nutrient availability while simultaneously enriching the manure with microbial metabolites, enzymes, vitamins, and plant growth-promoting substances [12].

Fermented organic formulations, particularly liquid organic manures, are rich in diverse populations of plant growth-promoting rhizobacteria (PGPR), including *Azotobacter*, *Azospirillum*, *Bacillus*, and *Pseudomonas* species [13]. These microorganisms play a crucial role in enhancing nutrient availability through biological nitrogen fixation, solubilization of phosphorus and potassium, and production of phytohormones such as indole-3-acetic acid (IAA), gibberellins, and cytokinins [14]. In addition, the production of organic acids during fermentation facilitates the dissolution of insoluble nutrient forms, thereby increasing their availability to plants [15]. The synergistic action of these microbial processes effectively improves nutrient uptake efficiency and promotes plant growth [16].

In addition to its role in nutrient supply, Fermented organic manure enhances the physical, chemical, and biological properties of the soil, while also providing essential nutrients. It improves soil structure, increases water retention capacity, and promotes microbial activity in the rhizosphere [17]. The enhanced microbial population supports efficient nutrient cycling, organic matter decomposition, and suppression of soil-borne pathogens [18]. Moreover, the presence of bioactive compounds and enzymes in fermented manure promotes root development, enhances physiological processes, and improves plant tolerance to abiotic stresses such as drought and salinity [19].

In perennial fruit crops such as pomegranate, the application of fermented organic manure plays a significant role in sustaining long-term soil fertility and productivity [20]. It has been reported to improve vegetative growth parameters, including plant height, canopy development, and leaf area, as well as reproductive attributes such as flowering, fruit set, and yield [21]. Additionally, it positively influences fruit quality characteristics, including size, color, total soluble solids, and shelf life [22]. The integration of fermented organic manure into nutrient management practices reduces dependency on chemical fertilizers, lowers production costs, and minimizes environmental risks, thereby contributing to sustainable agricultural systems [23].

Despite its established benefits, the use of fermented organic manure in pomegranate agriculture remains largely unexplored in the field condition. Most existing studies have primarily focused on annual crops, with limited emphasis on perennial fruit crops such as pomegranate. Furthermore, variations in preparation methods, composition, and application rates of fermented organic manures necessitate systematic evaluation to establish standardized and efficient utilization practices.

Therefore, the present investigation aimed to evaluate the effect of UTPANN FOM, a fermented organic manure, on the growth, flowering, yield, and fruit quality of pomegranate (*Punica granatum L.*) under field conditions. UTPANN FOM is formulated to enhance nutrient availability and stimulate soil biological activity, thereby supporting improved plant growth and productivity. The study assessed its influence on key parameters including fruit set, fruit retention, yield attributes, and quality characteristics. The objective was to determine its potential in improving crop performance and promoting sustainable nutrient management with reduced dependence on chemical fertilizers.

Materials and Methods

Experimental site

The field experiment was conducted during two consecutive growing seasons (2024 and 2025) under open field conditions in Banaskantha. The experimental site is characterized by semi-arid climatic conditions with low rainfall and high temperature, which are favorable for pomegranate cultivation. The soil of the experimental field was well-drained and suitable for fruit crop production. Standard agronomic practices were followed throughout the experimental period.

Crop and plant material

Pomegranate (*Punica granatum* L.) was used as the experimental crop. Uniform, healthy, and bearing plants were selected for the study to ensure reliability and uniformity in observations.

Experimental design and treatments

The experiment was conducted in a Randomized Block Design (RBD) with two treatments, each replicated appropriately. The treatments consisted of a control (no application of fermented organic manure) and the application of UTPANN FOM at 4 kg per plant. Uniform plants were used for each treatment, and all experimental units were maintained under similar cultural practices to minimize variability.

Treatment details

A fermented organic manure, UTPANN FOM, formulated to enhance nutrient availability and soil biological activity, was used in the present study. It was applied as a soil amendment at a rate of 4 kg per plant. The control treatment did not receive any application of fermented organic manure. All other agronomic practices, including irrigation, pruning and plant protection measures, were maintained uniformly across treatments.

Observations and data collection

Vegetative growth and flowering characteristics

Vegetative growth parameters were recorded at regular intervals throughout the experimental period to assess plant development, including percentage increase in plant height and plant spread. Flowering characteristics were evaluated by recording the number of male and hermaphrodite flowers per plant at the peak flowering stage.

Fruit Set, drop and retention attributes

Fruit set (%), fruit drop (%), and fruit retention (%) were determined to evaluate reproductive efficiency. These parameters were calculated based on the total number of flowers produced, the number of fruitlets formed, and the number of fruits retained until harvest, following standard procedures.

Yield and associated attributes

At harvest, yield-related observations were recorded from each experimental unit. The number of fruits per plant and total fruit weight per plant (kg) were measured, and yield was extrapolated and expressed in tonnes per hectare (t/ha). The incidence of physiological disorders, including fruit cracking (%) and fruit sunburn (%), was also recorded. Marketable fruit percentage (%) was calculated based on the proportion of healthy and undamaged fruits.

Fruit quality attributes

Fruit quality characteristics were assessed using standard analytical procedures. Parameters such as average fruit weight (g), aril weight (g per fruit), and juice content (%) were recorded. Biochemical attributes, including total soluble solids (°Brix) and titratable acidity (%), were determined to evaluate fruit quality.

Statistical analysis

The experimental data were subjected to statistical analysis using analysis of variance (ANOVA) appropriate for Randomized Block Design. The significance of differences among treatment means was tested using the critical difference (CD) at 5% level of significance.

Results and Discussion

Effect of UTPANN FOM on fruit set, drop and retention

The application of UTPANN FOM substantially influenced fruiting behaviour of pomegranate during both years of study (Table 1). Fruit set percentage increased markedly in treated plants, reaching 67.2% in 2024 and 67.8% in 2025, whereas control plants recorded around 52%. In contrast, fruit drop was considerably reduced under treatment, declining to nearly 32% compared to about 48% in control. This reduction in fruit drop ultimately led to a notable improvement in fruit retention, which increased to more than 67% in treated plants as compared to approximately 52% in untreated plants.

In a separate study on pomegranate, the application of organic manures, particularly when combined with mineral fertilizers, resulted in reduced fruit drop (15–23%) and increased fruit retention (77–84%) [24].

Another research study indicated that organic nutrient sources improved fruit set in pomegranate, with the highest value (67.16%) recorded when 100% RDN was applied through poultry manure. This may be due to enhanced phosphorus availability, which supports better flowering and fruit development, emphasizing the role of organic nutrient management [25].

Year	Treatment	Fruit set (%)	Fruit drop (%)	Fruit retention (%)
2024	Control	52.3	47.7	52.3
	Treated	67.2	32.8	67.2
	CD (P ≤ 0.05)	2.10	2.10	2.10
2025	Control	51.6	48.4	51.6
	Treated	67.8	32.2	67.8
	CD (P ≤ 0.05)	2.08	2.08	2.08

Table 1: Fruit set, fruit drop, and fruit retention (%) of pomegranate under UTPANN FOM application.

Effect on physiological disorders (Fruit Cracking and Sunburn)

The treatment showed an effective result in reducing physiological problems. Fruit cracking was drastically decreased from 16-17% in control plants to less than 7% in treated plants. Table 2 indicate that the occurrence of fruit sunburn was markedly reduced in treated plants, registering less than 5%, while control plants exhibited a higher incidence of approximately 15%. This demonstrates that the application of UTPANN FOM effectively mitigates environmental stress-related fruit damage.

Previous research reported that fertilizer treatments had a pronounced effect on fruit cracking in pomegranate. The lowest incidence of fruit cracking was recorded with the application of granule humic substances and biofertilizers (7.5% in 2014 and 2.25% in 2015), whereas control plants exhibited the highest levels (22.67% in 2014 and 16.47% in 2015). Furthermore, Fruit cracking decreased in the second year, which was attributed to improved soil fertility resulting from continuous organic applications [26].

Year	Treatment	Fruit cracking (%)	Fruit sunburn (%)
2024	Control	16.4	14.8
	Treated	6.9	5.4
	CD (P ≤ 0.05)	0.36	0.41
2025	Control	16.9	15.2
	Treated	6.5	5.1
	CD (P ≤ 0.05)	0.39	0.43

Table 2: Incidence of fruit cracking and sunburn (%) in pomegranate under treatment conditions.

Effect on marketable fruit and yield

A substantial improvement in fruit percentage was observed with the application of UTPANN FOM as indicated in table 3. Treated plants recorded more than 86% marketable fruits, whereas control plants showed only about 68%. The reduction in the incidence of fruit cracking and sunburn was mainly responsible for the increased output. The treatment resulted in greater yields of 60.4 and 61.2 t/ha in 2024 and 2025, respectively, compared to around 36 t/ha in the control. The observed differences were statistically notable at the 5% probability level.

Another study reported that fruit yield in pomegranate was markedly higher under farmyard manure application (20 kg per tree), recording a 22.3% increase. This was more than double (105.3% higher) than the yield obtained with inorganic fertilizers alone, emphasizing the effectiveness of organic nutrient management in enhancing crop performance [27].

Comparatively in, other study on pomegranate, the organic treatment comprising Jeevamrut (16.08 L/plant) + vermicompost (24.79 kg/ plant) recorded a fruit yield of 17.38 kg/plant. This suggests that organic nutrient combinations are effective in enhancing fruit yield, which may ultimately contribute to improved marketable yield [28].

Effect on vegetative growth parameters

The results demonstrated that UTPANN FOM enhanced the vegetative growth of pomegranate plants. Treated plants showed

Year	Treatment	Marketable fruit (%)	Yield (t /ha)
2024	Control	68.5	36.8
	Treated	86.3	60.4
	CD (P ≤ 0.05)	0.55	2.35
2025	Control	67.9	36.1
	Treated	87.1	61.2
	CD (P ≤ 0.05)	0.57	2.40

Table 3: Marketable fruit percentage and yield (t/ha) of pomegranate as influenced by treatment.

greater increases in plant height plant height increasing by 20–21% and canopy spread by 23–24% over the two years, whereas control plants exhibited comparatively lower growth increments. These result indicate that the treatment improved nutrient availability and promoted overall plant vigor, as summarized in Table 4.

In pomegranate, the treatment comprising recommended dose of NPK fertilizers combined with biofertilizers, namely Nitrobene (*Azotobacter* spp.), Phosphorene (phosphate-solubilizing bacteria), and Potasene (potassium-solubilizing bacteria), recorded the highest increment in plant height (86.33% and 81.00%) and maximum canopy development (2.83 and 2.67 lateral shoots; 8.0 and 8.0 main branches per transplant) during both seasons. However, these improvements were achieved through combined chemical and microbial inputs, whereas organic manures provide a more sustainable alternative by enhancing nutrient availability and soil microbial activity [29].

Year	Treatment	Percent increase in plant height (%)	Percent increase in plant spread (%)
2024	Control		
	Treated	20.2	22.7
	CD (P ≤ 0.05)	1.50	1.30
2025	Control	9.7	9.5
	Treated	21.0	23.4
	CD (P ≤ 0.05)	1.52	1.34

Table 4: Vegetative growth response of pomegranate plants under UTPANN FOM application.

Effect on flowering behaviour

Based on the observations presented in Table 5, flowering patterns were altered by the treatment. Control plants produced a greater number of male flowers, while plants receiving UTPANN FOM showed a decrease in male flowers accompanied by an increase in hermaphrodite flowers, reaching approximately 75–77 flowers per plant. This increase in hermaphrodite flowers corresponded with enhanced fruit set and overall yield, showing a positive influence of the treatment on reproductive efficiency.

Another study shows that the application of organic manures, particularly Jeevamrut + Vermicompost, notably increased the number of hermaphrodite flowers in pomegranate, recording 149–150 flowers per plant, comparable to inorganic fertilizer. This increase is attributed to improved nutrient availability and enhanced microbial activity, which stimulate plant growth regulators [30].

Year	Treatment	Male flowers per plant	Hermaphrodite flowers per plant
2024	Control	165.4	64.8
	Treated	149.8	75.6
	CD (P ≤ 0.05)	7.80	4.80
2025	Control	167.1	65.2
	Treated	148.3	76.8
	CD (P ≤ 0.05)	7.90	4.85

Table 5: Flowering behaviour of pomegranate in terms of male and hermaphrodite flowers per plant

Effect on yield attributes

The results presented in Table 6 show that the use of UTPANN FOM markedly enhanced yield performance, as evidenced by increased fruit load and greater biomass accumulation per plant. Treated plants consistently produced more than 50 fruits per plant, with total fruit biomass exceeding 20 kg per plant. In contrast, untreated control plants exhibited reduced fruit retention and lower cumulative fruit weight, demonstrating the positive effect of UTPANN FOM on productivity and yield attributes.

Previous research on pomegranate have demonstrated that the use of biofertilizers enhances key yield components. The combination of *Azotobacter chroococcum* and *Glomus mosseae* as a dual inoculation resulted in the highest number of fruits per plant and increased individual fruit weight. Fruits from this treatment averaged 401–405 g, surpassing those of the control group, which recorded 378–382 g per fruit [31].

Similar observations have shown that applying cow dung manure as a slurry is more effective at boosting pomegranate fruit yield than using traditional manure methods. Although raw farmyard manure (FYM) led to higher flowering intensity (230.5 to 265.2 flowers per plant), fruit production remained relatively low at 20.6 to 28.0 fruits per plant under raw FYM treatments [32].

Year	Treatment	No. of fruits per plant	Weight of fruits per plant (kg)
2024	Control		
	Treated	50.8	20.32
	CD (P ≤ 0.05)	3.10	1.15
2025	Control	31.8	12.72
	Treated	52.1	20.84
	CD (P ≤ 0.05)	3.20	1.18

Table 6: Effect of treatment on fruit set, fruit drop and yield of pomegranate over two years.

Effect on fruit physical quality attributes

The data presented in Table 7 revealed that application of UTPANN FOM brought noticeable improvements in physical characteristics of pomegranate fruits during both years. The average fruit weight was higher in treated plants, reaching 401 g in 2024 and 405 g in 2025, compared to 382 g and 378 g in control, respectively. Aril weight increased to 226 g per fruit under the treated plants, leading to a higher amount of edible tissue. This enhancement reflects improved fruit development and more efficient nutrient transfer in response to the treatment.

Consistent findings were observed with the application of 50% of the recommended dose of nitrogen (RDN) combined with organic inputs and bio-inoculants (T6), which substantially enhanced fruit weight and aril weight in pomegranate. Under this treatment, fruits attained an average weight of 294.2 g and an aril weight of 139.0 g, whereas the control treatment (100% recommended dose of fertilisers, T1) recorded lower fruit and aril weights of 230.5 g and 86.0 g, respectively indicating enhanced nutrient assimilation and more efficient fruit development [33].

In other study treatment with *A. brasilense* + *G. mosseae* (dual inoculation) increased the average fruit weight of pomegranate to 401–405 g and aril weight to 226–229 g per fruit, compared to control plants, which had fruit weight of 378–382 g and aril weight of 201–205 g [34].

Year	Treatment	Average fruit weight (g)	Aril weight (g/fruit)
2024	Control	382	205
	Treated	401	226
	CD (P ≤ 0.05)	12.5	8.4
2025	Control	378	201
	Treated	405	229
	CD (P ≤ 0.05)	13.1	8.8

Table 7: Physical quality characteristics of pomegranate fruits (fruit weight and aril weight).

Effect on fruit chemical quality attributes

Application of UTPANN FOM influenced the chemical attributes of pomegranate fruits (Table 8). Juice content increased to 61.2% and 62.1% in 2024 and 2025, respectively, compared to 54.6% and 53.9% in control plants, while total soluble solids (TSS) were elevated to 16.7 and 17.1°Brix relative to 14.8 and 14.6°Brix in the control. Concurrently, titratable acidity decreased to 0.42% and 0.41% under treatment from 0.48% and 0.49% in control, indicating an improved sugar–acid balance.

A comparable observation was reported in another study on pomegranate, the combined application of vermicompost and plant growth-promoting rhizobacteria (PGPRs) produced the highest juice content (58.69%). The increase in juice content may be associated with improved nutrient availability, which enhanced metabolic activity and supported greater juice formation in fruits [35].

Other observations were reported in a study on the pomegranate cultivar Bhagwa, where the treatment comprising 50% recommended dose of fertilizers (RDF) combined with FYM and *Azotobacter* resulted in the highest juice content (58.69%), total soluble solids (15.91 °Brix), and sugar–acid ratio (30.53), whereas the control recorded lower values of 52.82%, 14.80 °Brix, and 20.61, respectively. The observations imply that enhanced nutrient availability under the treatment likely stimulated metabolic activity, leading to greater accumulation of sugars and juice in the fruits [36].

Year	Treatment	Juice content (%)	Total soluble solids (°Brix)	Titratable acidity (%)
2024	Control	54.6	14.8	0.48
	Treated	61.2	16.7	0.42
	CD (P ≤ 0.05)	2.3	0.9	0.04
2025	Control	53.9	14.6	0.49
	Treated	62.1	17.1	0.41
	CD (P ≤ 0.05)	2.5	1.0	0.05

Table 8: Chemical quality attributes of pomegranate fruits (juice content, TSS, and acidity).

Conclusion

The present study demonstrated that the application of UTPANN FOM improved growth, yield, and fruit quality of pomegranate under field conditions. The treatment enhanced fruit set and retention, reduced physiological disorders, and increased the proportion of marketable yield. Improvements in vegetative growth and flowering behaviour further contributed to higher productivity. Fruit quality parameters were also positively influenced, indicating better overall crop performance. The consistent response observed over two consecutive seasons suggests that UTPANN FOM can serve as an effective organic input for improving productivity and fruit quality while reducing reliance on chemical fertilizers, thereby supporting sustainable pomegranate cultivation. The study shows the potential of integrating fermented organic manure into nutrient management practices as a practical approach for enhancing crop performance. The consistency of these responses over two consecutive seasons indicates that UTPANN FOM can serve as a reliable organic input for sustaining productivity and enhancing fruit quality, while reducing reliance on chemical fertilizers and promoting environmentally sustainable pomegranate cultivation.

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