OPEN ACCESS
Jurnal Ilmiah Ilmu Terapan Universitas Jambi
Vol. 9 No. 2. June 2025, pp. 619-631 DOI. 10.22437/jiituj.v9i2.41934

Research Article

THE EFFECT OF PROVIDING GOAT MANURE AND ADDITIN WATER WITH THE PARTIAL ROOT ZONE (PRD) METHOD IN INCREASING THE GROWTH AND PRODUCTION OF TOMATO PLANTS (*LYCOPERSICUM ESCULENTUM MILL*) USING A DIGITAL SOIL MOISTURE METER IN NORTH SUMATERA

M. Idris[1,*], Irda Nila Selvia[1], Russel Ong[1], Armansyah[2], Mohd Khairul Amri Kamarudin[3]

[1] Fakultas Sains dan Teknologi, Universitas Islam Negeri Sumatera Utara, Sumatera Utara, Indonesia
[2] Fakultas Teknik, Universitas Islam Negeri Sumatera Utara, Sumatera Utara, Indonesia
[3] Faculty of Applied Social Science, Universiti Sultan Zainal Abidin, Kuala Nerus, Malaysia
Corresponding author email: midris@uinsu.ac.id

Article Info
Received: Feb 19, 2025
Revised: Mar 20, 2025
Accepted: Apr 18, 2025
OnlineVersion: Apr 19, 2025

Abstract
This study aims to investigate the effectiveness of the Partial Rootzone Drying (PRD) irrigation method, the application of goat manure as organic fertilizer, and the interaction of both treatments on the growth and yield of tomato plants (*Lycopersicum esculentum* Mill) in North Sumatra. The research responds to the urgent need for sustainable agricultural practices that conserve water and enhance soil fertility, especially in tropical regions facing irregular rainfall and declining soil quality. A field experiment was conducted using a factorial randomized block design to test various levels of goat manure combined with the PRD technique. Observations focused on vegetative growth parameters (plant height, number of leaves, dry weight, chlorophyll content, Relative Growth Rate), nutrient uptake (N, P, and K), and production indicators (fruit number and sugar content). Data were analyzed statistically to determine the significance and interaction effects of treatments. The results show that goat manure significantly improves vegetative growth and fruit production, with higher doses correlating positively to increases in biomass and nutrient uptake. The PRD method led to a 25% reduction in water use without compromising plant productivity. Importantly, the combination of PRD and organic manure application produced synergistic effects, enhancing both growth and yield while optimizing water and nutrient efficiency. This study introduces a novel integrated approach to tomato cultivation that combines precision irrigation (PRD) and organic soil enrichment, offering a replicable model for sustainable, water-efficient horticulture in resource-constrained agricultural regions.

Keywords: Growth, Partial Rootzone Drying, Production, Tomato

INTRODUCTION

The global impact of climate change—particularly in the form of prolonged drought—is a pressing issue affecting multiple sectors, especially agriculture. The proportion of drought-affected regions has doubled since the 1970s, driven by rapid population growth, environmental degradation, and shifting climate patterns (Steduto et al., 2009). In line with projections presented at the Second World Water Conference (World Water Forum) held in The Hague in 2000, Indonesia is among the countries expected to face a severe water crisis by 2025. Agricultural production, which consumes approximately 70% of the world's clean water supply, is highly vulnerable to water shortages. Full Irrigation (FI) systems where water is supplied proportionally to the evapotranspiration rate are commonly used by farmers to maximize crop yields. However, such systems are inefficient in areas experiencing water scarcity. Therefore, more sustainable irrigation methods are needed to ensure agricultural productivity amid declining water availability.

In addition to water, soil nutrient composition plays a critical role in supporting plant growth and crop yield. Fertilizers both inorganic and organic are vital for soil health and productivity. Organic fertilizers, derived from decomposed plant or animal matter, offer long-term benefits by improving the physical, chemical, and biological properties of soil (Salam, 2020). Among horticultural crops, tomatoes hold a high economic value and nutritional profile, yet their production is often suboptimal due to improper variety selection, inefficient pest control, and poor cultivation practices (Noonari et al., 2015; Felfoldi et al., 2021; Putra, 2022).

Water is a limiting factor for tomato cultivation. Inconsistent water supply leads to plant stress, reduced photosynthetic activity, and ultimately lower fruit quality and yield. Farmers often find irrigation a labor-intensive activity, especially under drought conditions where soil aeration and oxygen availability are also compromised (Noah & Friedman, 2018; Liu et al., 2019). Hence, the adoption of water-saving techniques such as Partial Root Zone Drying (PRD) has emerged as a promising solution. PRD involves irrigating only one side of the root zone alternately, inducing mild water stress while maintaining productivity. Studies have shown that PRD can reduce water usage by up to 50% without compromising yields (Al-Harbi et al., 2018; Idris et al., 2023). Simultaneously, organic fertilizers—such as those derived from tofu liquid waste are increasingly studied for their effectiveness in enhancing plant growth by promoting microbial activity and improving nutrient uptake (Wayan, 2017; Fauziah & Idris, 2022; Samah & Candra, 2022). Their application has shown significant impacts on vegetative and reproductive growth metrics in various vegetables.

While extensive agronomic research has explored the effectiveness of PRD irrigation and organic fertilizers in improving crop yield and water use efficiency, especially in tomatoes, there remains a critical research gap in the educational domain particularly in science learning in elementary and secondary schools. These environmentally relevant innovations are seldom integrated into science education, despite their potential to contextualize scientific concepts such as plant physiology, ecosystems, environmental sustainability, and agricultural technology.

In the context of Indonesia's Independent Curriculum (Kurikulum Merdeka) and the Pancasila Student Profile, science learning should not only impart theoretical knowledge but also equip students with practical understanding and attitudes necessary for addressing real-world problems such as climate change and food security. However, current science curricula often lack experiential, local-context-based learning that connects classroom concepts with community-based environmental issues such as water scarcity and sustainable farming practices.

This study aims to bridge that gap by integrating scientific concepts surrounding water-saving irrigation (PRD) and organic fertilizers into science learning activities in schools. By aligning these activities with project-based learning and cultural literacy values, the study seeks to support the “Global Diversity” and “Environmental Stewardship” elements of the Pancasila Student Profile. The research investigates how hands-on agricultural experiments using PRD and organic waste-based fertilizers can enhance students’ scientific literacy, environmental awareness, and critical thinking skills, while fostering a deeper understanding of sustainable practices rooted in local wisdom.

RESEARCH METHOD

Field research was carried out for 4 months and carried out in three places, namely Plant Testing at the Universitas Islam Negeri Sumatera Utara, Medan, Indonesia Experimental Farm and Soil

Quality Testing for Soil Properties at the Soil Laboratory, Universitas Sumatera Utara, Medan, Indonesia.

The research was conducted using a Factorial Randomized Group Design (RGD) consisting of 3 replications and 2 factors, namely:

Factor I namely the PRD technique consists of four levels, namely:

P1 (FI) = Field Capacity with daily watering
P2 (FI) = 3/4 Field Capacity with daily watering
P3 (PRD Method) = Field capacity with watering once every day
P4 (PRD Method) = 3/4 Field capacity with watering once every day

Factor II namely Organic Fertilizer (O) consists of two levels, namely:

O1 = Providing 10 Tons of Organic Fertilizer 1 Hectare
O2 = Providing 20 Tons of Organic Fertilizer 1 Hectare

Research Unit:

Number of Treatment Combinations	: 8
Number of Repetitions	: 3
Plot Size	: 1.5 m x 1.7 m
Number of Trial Plots	: 24 plots
Plant spacing	: 50 cm x 60 cm
Number of plants/plot	: 9 plants
Total number of plants	: 216 plants
Distance between repetitions	: 50 cm
Distance between Plots	: 30 cm

The Linear Model of Factorial RGD is:

Yijk = π + Bi + Tj + Jk + (Tj x Jk) + eijk I = 1,2,…. , t Where :

Yijk = Results resulting from the jth treatment and kth treatment in the ith group
π = Common mean value
Bi = Influence of the i Block
Tj = Influence of the j acting factor
Jk = Influence of the k treatment factor
Tj x Jk = Interaction of the j treatment and the k treatment
eijk = Error due to the j treatment and kth treatment in the ith group
i = 1, 2, …., k (b= Block)
j = 1, 2, …., 1st p (p = 1st treatment)
k = 1, 2, 2nd p (p = 2nd treatment)

Preliminary activities include taking soil samples to test their physical properties, namely clay content (%), dust (%), sand (%), organic matter content (%), bulk density (g cm-3), field capacity (% volume), and permanent wilting point (% volume), soil porosity (mm sec-1) and soil chemical properties (Complete analysis). Rainfall, temperature and humidity data were collected during the research.

The variables observed in this research are a Plant Test that is plant height, number of leaves, amount of chlorophyll, relative plant growth rate, plant N, P and K nutrient uptake, number of fruit, and sugar content. Then, the soil Quality Test that's is Nutrient content N, P, K, and soil pH and particle density at the end of the study. Analysed with analysis of variance ANOVA (F test). The significant difference the treatments tested with Duncan Multiple Range Test (DMRT), $p < 0.05$ using (indicate the software used)

RESULTS AND DISCUSSION

Data from Initial Soil and Manure Analysis Results

Based on the results of the initial soil and manure analysis, the data in Table 1 below was obtained.

Table 1. Results of initial soil and manure analysis

Parameter	Unit	Research Location	Manure
Sand	%	87.84	----
Dust	%	4.28	----
Look	%	6.88	----
Texture	USDA	PI	----
pH (H_2O)	--	5.38	6.20
C-organic	%	1.22	2.39
N-total	%	0.18	1.95
P-available	Ppm	10.92	----
P2O5	%	-----	0.10
K-dd	me/100 g	0.54	----
Na	me/100 g	0.26	----
Ca	me/100 g	1.84	----
Mg	me/100 g	0.55	----
CEC	me/100 g	11.08	----
Base Saturation	%	28.79	----
K2O	%	----	0.21
CaO	%	----	3.27
MgO	%	----	2.09
B.D	g/cm3	1.13	----
Porosity	%	57.31	----

In Table 1 it is explained that the soil texture on the research land is clayey sand. The soil on the research land has a pH of 5.38, which means it is slightly acidic. As explained by the Brebes DPKP (2021), as a vegetable or fruit, tomatoes are a source of vitamins A and C, tomatoes can be planted in low to highlands and can be planted as an intercropping and rotation crop in rice fields. Based on research observations and soil fertility criteria, the required soil is fertile, loose, and porous, with soil uniformity (pH) 5-7 and the results show (pH) soil is good value for planting.

Soil total N nutrient uptake at this research location is 0.18%, indicating that total N nutrient uptake at the research location is in the low category. Therefore, it is hoped that the addition of manure NPK will be able to increase total N availability in the soil in the research area so that it can provide the N needs for tomato plants. Total N nutrient uptake in manure applied to the tomato research field was 1.95%. This is following the research results of Bachtiar et al., (2020). Providing manure can increase the contribution of nutrients, especially N, which comes from the soil in paddy rice plants.

From the results of the initial soil analysis in Table 1, it is shown that the available P nutrient uptake and soil CEC are quite high. Meanwhile, nutrient uptake of other nutrients is low. Apart from increasing the N nutrient, the application of manure is also expected to increase the availability of other nutrients and improve the physical and chemical properties of the soil on the research land.

Plant height

Data on tomato plant height at 21 DAPs and 42 DAPs can be seen in Table 2.

Table 2. Data on tomato plant height aged 21 and 42 DAPs

	O Factor					P Factor				
	P1	P2	P3	P4	Average	P1	P2	P3	P4	Average
O1	13.33a	14.33a	18.00a	18.67a	16.08	34.00a	31.00a	40.00a	51.50a	39.13
O2	16.33a	23.00a	19.00a	18.67a	19.25	68.00a	50.50a	54.17a	49.67a	55.58
Average	14.83	18.67	18.50	18.67		51.00	40.75	47.08	50.58	

Note: The same letters in the same column indicate that they are not significantly on Duncan's Multiple Range Test ($p < 0.05$).

It can be seen in Table 2 that the highest tomato plant heights of 21 and 42 DAPs in themanure treatment were the O2 treatment (organic fertilizer 20 Tons Ha-1) of 55.58 cm. At 42 DAPs, tomato plant height showed a significant difference between O1 and O2 manure treatments. In the PRD method treatment, the highest plant height at 21 DAPs was in treatment P2 (3/4 Field Capacity with watering every day) and P4 (PRD) method with 3/4 Field Capacity with watering once every day) namely 18.67 cm. Meanwhile, at the plant age of 42 DAPs, the highest tomato plant height in treatment and P1 (Field Capacity with daily watering) was 51.00 cm. The interaction of the manure treatment and the PRD method showed that the highest plant height at 21 DAPs was in the combination of O2 and P2 treatments, namely 23.00 cm. Meanwhile, at the age of 42 DAPs, the highest plant height in the combination of O2 and P1 treatments was 68.00 cm.

Table 2 shows that the height of tomato plants at 21 and 42 DAPs increased inline with increasing doses of manure applied. Providing manure, one of the ways will be able to increase plant height because manure can increase the availability of N in the soil. Nitrogen is a nutrient that plants need in their growth phase. Patti, et al (2013) stated that Nitrogen is the main nutrient for plant growth. The function of nitrogen is to increase vegetative growth. Even though tomato plants at the age of 42 DAPs showed the highest plant height in the treatment without PRD with Field Capacity water nutrient uptake, they did not show a significant difference in plant height compared to those using the PRD method. This shows that the PRD treatment has been able to meet the field capacity (FC) of the soil. Khoirunnisa, et al (2021) explained that soil with certain chemical, physical and biological properties that influence fertility is one of the factors that support plant growth. The availability of water and organic matter is one of the factors that influences soil fertility. The field capacity water conditions will support plant growth.

Table 2 above also shows that there is an interaction between manure and the PRD method in meeting plant water needs so that it can increase plant height. To increase plant growth, nutrients and water must be available to plants. The treatment interaction between manure application and the PRD method showed that at the age of 42 DAPs, there was a clear difference in plant height between treatments with the PRD method and without PRD. This shows that the closer you enter the late vegetative period, the more stable the PRD method will be to be able to support the plant's water needs.

Number of Leaves

Data on the number of leaves on tomato plants at the ages of 21 DAPs and 42 DAPs can be seenin Table 3. In the PRD method treatment, the highest number of plant leaves aged 21 DAPs was in the P2 (3/4 Field Capacity with watering every day) and P3 (PRD method with Field Capacity with watering once every day) treatment, namely 20.33 pieces. Meanwhile, at the plant age of 42 DAPs, the highest number of leaves on tomato plants in treatment and P4 (PRD method with 3/4 Field Capacity with watering once every day) was 54.92 pieces.

Table 3. Number of leaves on tomato plants aged 21 and 42 DAPs

	O Factor					P Factor				
	P1	P2	P3	P4	Average	P1	P2	P3	P4	Average
O1	19.67a	17.00a	19.00a	18.67a	16.08	32.67a	27.83a	38.17a	51.50a	37.42
O2	20.33a	23.67a	21.67a	18.33a	19.25	72.83a	49.33a	43.50a	58.83a	56.13
Average	20.00	20.33	20.33	17.00		52.75	38.58	47.08	50.58	

Note: The same letters in the same column indicate that they are not significantly different on Duncan's Multiple Range Test ($p < 0.05$).

The interaction of the manure treatment and the PRD method showed that the highest number of leaves on tomato plants aged 21 DAPs were in the combination of O2 and P2 treatments, namely 23.67 pieces. Meanwhile, at the age of 42 DAPs, the highest number of plantleaves in the combination of O2 and P1 treatments was 72.83 leaves. Increasing the dose of manure given to tomato plants was able to increase the number of leaves (Table 3). The increase in the number of leaves shows that the tomato plants grow well in both fields. This can be caused by the availability of sufficient nutrients for plants. Leaves are plant organs that play a role in photosynthesis. The large number of leaves will be able to increase photosynthesis too. This statement with what was explained by Sari, et al (2019) that the greater the number of leaves, the more active the photosynthesis process is, thus the photosynthate produced is sufficient to increase the growth of seedlings from cuttings.

The treatment interaction between the application of manure and the PRD method shows that all treatments with a manure dose of 20 tons Ha-1 combined with the PRD treatment had an effect that was able to increase the number of leaves on tomato plants at the ages of 21 and 42 DAPs in the two research locations. However, for the best combination, manure and the PRD method showed that the treatment without PRD and the PRD method treatment both produced almost the same number of leaves.

Plant Dry Weight

Data on dry weight of tomato plants at 21 DAPs and 42 DAPs can be seen in Table 4. The dry weight of 21 and 42 DAPs tomato plants was also the highest in the manure treatment, namely the O2 (organic fertilizer) treatment.20 Tons Ha-1) 4.03 grams. In the PRD method treatment,the highest dry weight of plants aged 21 and 42 DAPs was in the P1 (Field Capacity with dailywatering) treatment, namely 4.69 grams. The interaction of manure treatment and the PRD method showed that the dryweight of tomato plants was highestat 21 DAPs and 42 DAPs, namely in the combination of O1 and P1 treatments, namely 5.48 grams.

Table 4. The dry weight of tomato plants aged 21 and 42 DAPSs.

	O Factor					P Factor				
	P1	P2	P3	P4	Average	P1	P2	P3	P4	Average
O1	19.67a	17.00a	19.00a	18.67a	16.08	32.67a	27.83a	38.17a	51.50a	37.42
O2	20.33a	23.67a	21.67a	18.33a	19.25	72.83a	49.33a	43.50a	58.83a	56.13
Average	20.00	20.33	20.33	17.00		52.75	38.58	47.08	50.58	

Note: The same letter in the same column indicates not significantly different in Duncan's Multiple Range Test ($p < 0.05$) and also not as a replicate.

In Table 4 it can be seen that the dry weight of tomato plants increased with increasing doses of manure applied. Plant dry weight is one of the parameters that shows that plant growth is going well. Sitorus, et al (2014) stated that dry weight is a measure of plant growth and development because dry weight reflects the accumulation of organic compounds that have been successfully synthesized by plants. Plant dry weight reflects the nutritional status of a plant and is also an indicator that determines whether a plant's growth and development are good or not, so it is closely related to nutrient availability. Partial Rootzone Drying (PRD) treatment shows that conditions without PRD produce better plant dry weight compared to PRD treatment but were not significantly different. This may be because of the influence of sunlight received by plants in each location is slightly different.

Idris et al., (2023), shown that watering tomato plants is a requirement for fulfilling the production process, even at half-field capacity. Thus, during plant growth, there is no water deficit, so the growth and development process in the vegetative growth phase is not hampered. Many photosynthesis results can be translocated to the fruit in the leaves, forming many fruits. The large fruit size automatically affects the weight and quality of the fruit. The treatment interaction between manure application and the PRD method shows that plants dry weight tends to be the highest in the treatment with a manure dose of 10 tons Ha-1 combined with P1, but in other treatment combinations, the best is at a manure dose of 20 tons Ha-1 combined with P2, P3, and P4. It can be said that it is best to stick to a manure dose of 20 tons of Ha-1. This shows that increasing the application of manure in conditions of field capacity will be able to increase the dry weight of tomato plants. The dry weight of the plant will reflect the results of the plant's assimilation from the photosynthesis process.

Chlorophyll

Tomato plant chlorophyll data can be seen in Table 5. The highest amount of chlorophyll in tomato plants in the manure treatment was the O2 treatment (organicfertilizer 20 Tons Ha-1) 9.00 mg/plant. In the PRD method treatment, the highest amount of plant chlorophyll was in the P3 treatment (PRD Method with Field Capacity with watering once every day) namely 9.17 mg/plant.

Table 5. Amount of chlorophyll in tomato plants

O Factor	P Factor				
	P1	P2	P3	P4	Average
O1	7.31a	8.40a	8.67a	9.25a	8.41
O2	9.65a	7.89a	9.68a	8.78a	9.00
Average	8.48a	8.14a	9.17a	9.02a	

Note: The same letters in the same column indicate that they are not significantly different on Duncan's Multiple Range Test ($p < 0.05$).

The interaction of manure treatment and the PRD method showed that the highest amount of chlorophyll in tomato plants was in the combination of O2 and P3 treatments, namely 9.68 mg/plant. The chlorophyll data in Table 5 shows that the application of manure can increase the total chlorophyll amount of tomato plants even though it only varies slightly. Chlorophyll is an important part of the photosynthesis process. The continuity of photosynthesis is greatly influenced by the amount of plant chlorophyll. The availability of nutrients will affect chlorophyll synthesis. Hendriyani & Setari (2009) explained that the factors that influence chlorophyll synthesis : light, sugar or carbohydrates, water, temperature, genetic factors and the elements nitrogen, magnesium, iron, manganese, Cu, Zn, sulfur and oxygen.

For the Partial Rootzone Drying (PRD) treatment, it can be seen that the highest amount of chlorophyll was in the P3 treatment (PRD Method with Field Capacity with watering once every day). This shows that the PRD method in any location is stable in providing water needs so that the amount of plant chlorophyll increases. All types of plants need water, especially for photosynthesis. This was also explained by Hendriyani & Setari (2009) that types of plants require different amounts of water for growth. Water functions as a solvent for nutrients contained in the soil so that it can be taken up by plants easily through the roots and distributed to the necessary parts of the plant through the xylem and as a solvent for the results of photosynthesis to be distributed throughout the plant through the phloem, then the results of photosynthesis will be used by the plant.

The treatment interaction between manure application and the PRD method shows that the highest amount of plant chlorophyll tends to be in the combination of manure treatment at a dose of 20 tons Ha-1 with the field capacity PRD method. This shows that the amount of plant chlorophyll is increasing because the water available is sufficient and the nutrients that supportthe formation of chlorophyll are also available.

Relative Growth Rate (RGR)

Relative Growth Rate (RGR) data for tomato plants can be seen in Table 6. The highest Relative Growth Rate (RGR) of tomato plants in the manure treatment was the O2 treatment (organic fertilizer20 Tons Ha-1)0.235 g/day. In the PRD method treatment, the highest relative growth rate of tomato plants was in the P1 treatment (Field Capacity with daily watering) of 0.259 g/day. The interaction of manure treatment and the PRD method showed that the highest RGR of tomato plants was in the combination of O2 and P1 treatments, namely 0.272 g/day.

Table 6. Relative Growth Rate (RGR) of tomato plants

O Factor	P Factor				
	P1	P2	P3	P4	Average
O1	0.247a	0.218a	0.244a	0.208a	0.229
O2	0.272a	0.240a	0.196a	0.232a	0.235
Average	0.259	0.229	0.220	0.220	

Note: The same letters in the same column indicate that theyare not significantly different on Duncan's Multiple Range Test ($p < 0.05$).

Table 6 shows that applying manure can increase the Relative Growth Rate (RGR) of tomato plants even though there is no significant difference. Increasing the dose of manure will increase the availability of nutrients for plants so it is hoped that the photosynthate yield will increase as indicated by the Relative Plant Growth Rate. Rahmah (2014) states that and increase in plant biomass can indicate the relative growth rate of plants in their growth phase because plants absorb more nutrients and water, which encourages the development of plant organs such as roots, so that plants can absorb more nutrients and water. Furthermore, photosynthetic activity will increase, which will in the wet and dry weight of the plant.

The Partial Rootzone Drying (PRD) treatment, shows that the plant's Relative Growth Rate (RGR) was the highest in the treatment without PRD but was not much different from the treatment using PRD. The relative growth rates of plants in treatments P1 and P3 were the same, indicating that treatments without PRD and with PRD in Field Capacity conditions would be able to meet the same water needs for tomato plants. Then in treatments P2 and P4, the relative growth rate of the plants also did not show a significant difference. There is a tendency for better plant assimilation results in ¾ Field Capacity conditions. This is because the water requirement for tomato plants in the final vegetative phase is only ¾ of the field capacity.

The treatment interaction between manure application and the PRD method shows that the Relative Growth Rate (RGR) of plants shows almost the same results in each treatment combination. This shows that applying manure at any dose combined with or without the PRD method can meet the availability of nutrients and water for tomato plants.

Plant N-Total Nutrient Uptake

Data on the N-Total nutrient uptake of tomato plants planted can be seen in Table 7. The highest total N nutrient uptake from tomato plants in the manure treatment was the O2 treatment (organic fertilizer 20 Tons Ha-1) amounting to 2.84%. In the PRD method treatment, the highest total N nutrient uptake from tomato plants was in the P3 treatments (PRD method with Field Capacity with watering once every day) of 2.84%. The interaction of the manure treatment and the PRD method showed that the total N nutrient uptakeof tomato plants was the highest in the combination of O2 and P2 treatments, namely 2.94%.

Table 7. N-total nutrient uptake of tomato plants

O Factor	P Factor				
	P1	P2	P3	P4	Average
O1	2.45a	2.56a	3.08a	2.49a	2.64
O2	2.77a	2.94a	2.78a	2.87a	2.84
Average	2.61	2.75	2.93	2.68	

Note: The same letters in the same column and row indicate that they are not significantly different on Duncan's MultipleRange Test ($p < 0.05$).

In Table 7 it can be seen that the total N nutrient uptake of tomato plants tends to be the same between manure treatments. This shows that plants given manure can absorb N well for growth. Providing manure, one of the ways, will be able to increase plant height because manure can increase the availability of N in the soil. Even though in the initial soil analysis the N uptake of the soil was classified as low, with the application of manure the N became sufficient to support plant growth. The research results of Nariratih, et al (2013), manure from chicken manure can increase soil nitrogen availability, plant canopy dry weight, plant nitrogen uptake and plant growth.

Then, in the Partial Rootzone Drying (PRD) treatment, it can be seen in Table 7 that the PRD method when compared with the treatment without PRD (P1 and P2) shows a higher total plant N nutrient uptake. This shows that the PRD treatment is efficient in using water so that the N nutrients can also be absorbed well by plants. The availability of water and nitrogen will support the formation of chlorophyll which will increase plant photosynthesis.The xplanation by Kurniawan et al (2014) that one of the very important physical components, water is very necessary for plant growth and development. About 85 to 90% of the fresh weight of tall plant cells and tissues. Water functions as many hings, including a nutrient solvent, a constituent of protoplasm, and a raw material for photosynthesis.

The treatment interaction between the application of manure and the application of the PRD method showed that the highest total plant N nutrient uptake was in the manure treatment at of 20 tons Ha-1 combined with treatments with or without the PRD method which tended to produces a higher total plant N than those combined with O1. This shows that by absorbing the nutrient N, the water needs of tomato plants can be met through the PRD method.

Plant P Nutrient Uptake

Data on P nutrient uptake from tomato plants can be seen in Table 8. P nutrient uptake of tomato plants in the manure treatment was the O2 treatment (organic fertilizer 20 Tons Ha-1) namely 1.21%. In the PRD method treatment, P nutrient uptake intomato plants, namely in treatments P2 and P4, was 1.25%. The interaction of manure treatment and the PRD method showed significantly different interactions. It was found that the P nutrientuptake of tomato plants was the highest in the combination of O2 and P3 treatments, namely 1.39%, which was significantly different from the O1P2, O1P3, O1P4, O2P1, and O2P4 treatments but not significantly different from the other treatments.

Table 8. P nutrient uptake from tomato plants

O Factor	P Factor				
	P1	P2	P3	P4	Average
O1	1.24abc	1.17bcd	1.11cd	1.16cd	1.17
O2	1.06d	1.34ab	1.39a	1.05d	1.21
Average	1.15	1.25	1.25	1.10	

Note: The same letters in the same column and row indicate that they are not significantly different on Duncan's Test ($p < 0.05$).

Table 8 shows that the P nutrient uptake of tomato plants was the same between manure treatments. This shows that tomato plants have the same ability to absorb P even though they are given different doses of manure. The nutrient P is needed by plants for various metabolic processes in their bodies. As explained by Liferdi (2010) because of its important role in various life processes, (P) is considered an important element of life. The main function of P in plants is to store and send energy in the form of ADP and ATP. This energy is obtained through photosynthesis and carbohydrate metabolism, which is then stored in a phosphate mixture for use in growth and production processes. These processes cannot take place if there is no P.

In the Partial Rootzone Drying (PRD) treatment (Table 8), the results obtained tended to be the same in all treatments. Liferdi's (2010) explanation regarding the main function of P for plants, that water will support the ongoing metabolic processes that require the nutrient P. This shows that the tomato plants planted show that the best combination is the O2P3 treatment combination.

Plant K nutrient uptake

Data on K nutrient uptake from planted tomato plants can be seen in Table 9. The highest K nutrient uptake from tomato plants was in the O2 treatment (organic fertiliser 20 Tons Ha-1) namely 2.20%. In the PRD method treatment, the highest K nutrient uptake from tomato plants was in the P3 treatment (PRD method with Field Capacity with watering once every day) amounting to 2.29%. The interaction of the manure treatment and the PRD method was obtained that highest K nutrient uptake from tomato plants was in the combination of O2 and P2 treatments, namely 2.47%.

Table 9. K nutrient uptake from tomato plants

O Factor	P Factor				
	P1	P2	P3	P4	Average
O1	1.61a	1.83a	2.30a	2.38a	2.03
O2	1.99a	2.47a	2.28a	2.07a	2.20
Average	1.80	2.15	2.29	2.22	

Note: The same letters in the same column indicate that they are not significantly different on Duncan's Multiple Range Test ($p < 0.05$).

Table 9 shows that K nutrient uptake from tomato plants tends to be the same between manure treatments. This shows that tomato plants have the same ability to absorb K even though they are given different doses of manure. Plants need the nutrient K to grow and produce well because K also plays a role in photosynthesis and protein synthesis. Subandi (2013) explains that plants need a lot of potassium to grow and produce well. This nutrient plays a role in the process and translocation of photosynthesis results, and protein synthesis, and increases plant resistance to biotic (pests/diseases) and abiotic (lack of water and iron or Fe poisoning) stresses, in addition to improving the physical condition and chemical composition of agricultural products, element K greatly determines the quantity and quality of crop yields.

In the Partial Rootzone Drying (PRD) treatment (Table 9), the highest K plant nutrient uptake results were obtained in the PRD method treatment with ¾ Field Capacity. This means that PRD treatment has been able to meet the water needs of plants so that it also supports plant nutrient uptake which can be seen from the nutrient uptake of one of the nutrient elements in plants, namely nutrient K. Water also plays a very important role in processes that require element K such as photosynthesis so that between water and the nutrient K are interrelated.

The treatment interaction between applying manure and the PRD method shows that the highest plant K nutrient uptake tends to be in the combination of manure treatment at a dose of 20 tons/ha combined with all methods without or with PRD. This shows that to absorb K nutrients, tomato plants with field capacity or ¾ field capacity can meet the water needs of tomato plants so that the nutrients are also well absorbed by the plants.

Final Soil Analysis Results

Data from the final soil analysis results can be seen in Table 10 below. to the application of manure. Then the total N of the soil does not increase, this is because the N has been absorbed by the plants. P-available nutrient uptake increased while K-dd decreased. Nutrient uptake of nutrients that remains constant or even decreases in the final soil analysis results show that the nutrients in the soil have been absorbed by the plants can be seen from the total N, P and K nutrient uptake data for tomato plants in Tables 7, 8 and 9.

Table 10. Final soil analysis results

Treatment	Parameter				
	pH (HO)	N-total (%)	P-available	K-can exchange	Particle Density
O1	5.95	0.19	15.99	0.55	2.04
O2	5.66	0.21	20.64	0.48	2.05

Note: The same letters in the same column indicate that they are not significantly different on Duncan's Multiple Range Test ($p < 0.05$).

From the results of the final soil analysis, it was found that there was an increase in soil pH due

Number of Fruits

Data on the number of tomato plants can be seen in Table 11. The highest number of tomato plants in the O2 treatment (20 Ton Ha-1 organic fertilizer) was 15. In the PRD method treatment, the highest number of tomato plants was 16 in the P1 treatment (Field Capacity with daily watering). The interaction of the manure treatment and the PRD method showed that the highest number of tomato plants was in the combinations of O2 and P1 treatments, namely 17 fruits.

Table 11. Number of fruit on tomato plants

O Factor	P Factor				
	P1	P2	P3	P4	Average
O1	16.33a	10.33a	9.67a	10.67a	11.75
O2	17.00a	14.33a	15.67a	14.67a	15.42
Average	16.67	12.33	12.67	12.67	

Note: The same letters in the same column indicate that they are not significantly different on Duncan's Multiple Range Test ($p < 0.05$).

Increasing the dose of manure also increases the number of tomatoes. This shows that tomato plant production increases along with increasing manure doses. Based on the explanation of Usharani et al (2019) and Adekiya et al (2020), manure can improve the physical, chemical and biological properties of the soil so that plants can grow and produce well.

Apart from that, the availability of water to meet the water needs of tomato plants in increasing the number of fruit is very important. It can be seen from the number of tomato plants that there is no significant difference between treatments without and with the PRD method, so the PRD method has been able to make efficient use of water in meeting the water needs of tomato plants for production. Plants from the Solanaceae family are very sensitive to lack or too much water during the growth period. Plant stress, or stress, will occur because the plant lacks water during the growth and development phases. This can result in a decrease in tomato productivity and quality. Therefore, to meet the water needs of tomato plants and increase tomato growth and fruit production, it is important to understand proper water supply. The combination of manure and PRD treatment supports the nutrient and water needs of tomato plants. Tomato plants need nutrients and water to produce fruit so the number of produced will increase. The right dose of manure and efficient water conditions greatly influence plant production.

Fruit Sugar Content

Data on the fruit sugar content of tomato plants can be seen in Table 12. The fruit sugar content of tomato plants was highest in the O2 treatment (20 Tons Ha-1 organic fertilizer), namely 4.51% brix. In the PRD method treatment, the highest fruit sugarcontent in tomato plants was in the P2 treatment (3/4 Field Capacity with daily watering) of 4.56% brix. The interaction of manure treatment and the PRD method showed that the highestsugar content in tomato plants was in the combination of O2 and P2 treatments, namely 4.66% Brix.

Table 12. Fruit sugar content of tomato plants

O Factor	P Factor				
	P1	P2	P3	P4	Average
O1	4.37	4.45	4.52	4.48	4.46
O2	4.44	4.66	4.44	4.50	4.51
Average	4.41	4.56	4.48	4.49	

Note: The same letters in the same column indicate that they are not significantly different on Duncan's Multiple Range Test ($p < 0.05$).

The results of this study demonstrate that the sugar content in tomato fruits increases in line with the rising doses of manure applied. This finding is consistent with the results reported by Nurhidayati et al. (2021), which indicate that organic fertilizer can enhance sugar accumulation in tomatoes. The increase in sugar content can be explained by the greater availability of nitrogen (N) in the soil due to the decomposition of organic matter in manure. Nitrogen plays a crucial role in plant metabolic processes, especially in photosynthesis and carbohydrate synthesis. The higher the amount of N absorbed by plants, the more efficient the sugar formation process, ultimately improving the sweetness and overall quality of the fruit. In addition to nutrients, water availability significantly influences not only the quantity but also the quality of tomato fruit. In this context, the use of the Partial Root-Zone Drying (PRD) irrigation technique is proven to be effective. PRD is a water-saving method that regulates plant water use through root signaling, which can increase water-use efficiency while maintaining fruit quality. This study supports the findings of Diatara and Nur Choice (2019), who reported that good water quality and management directly correlate with improved tomato fruit quality, including its taste and texture.

What makes this research novel is the combined application of manure and PRD irrigation two strategies that are usually studied in isolation. This study offers new insight into how these two approaches can work synergistically to enhance both yield and quality, especially sugar content, in tomato plants. This integration represents a sustainable cultivation approach that is particularly valuable in addressing challenges related to water scarcity and excessive use of chemical fertilizers. The synergy observed in this study also confirms findings from Idris et al. (2023), who emphasized the importance of considering multiple interacting factors such as nutrient availability, water regulation, and environmental conditions to achieve optimal plant growth and productivity. The absence of negative interactions between the two treatments suggests that manure and PRD serve complementary functions: manure supplies essential nutrients, particularly nitrogen, while PRD induces mild water stress that enhances fruit quality without compromising yield.

The implications of these findings are significant for sustainable agriculture. For farmers, especially those operating under resource constraints, this research offers a cost-effective and environmentally friendly strategy to improve tomato production both quantitatively and qualitatively. For agricultural extension services and policy-makers, the findings support the development of training and outreach programs that promote integrated organic fertilization and water-efficient irrigation techniques. These approaches not only contribute to environmental sustainability but also align with the broader goals of food security and resource conservation.

However, the study is not without limitations. The research was conducted under specific environmental and soil conditions, which may limit its generalizability to other regions with different agroecological characteristics. Additionally, the study observed the effects of treatments only over a single planting season, which does not account for long-term impacts on soil health and plant productivity. Furthermore, the experiment used fixed doses of manure and a standard PRD schedule without exploring a wider range of treatment variations. Also, physiological parameters such as chlorophyll content or root development were not examined, limiting a deeper understanding of the internal plant responses.

Based on these limitations, several recommendations can be made for future research. Studies should be extended over multiple planting seasons and in diverse agricultural settings to validate the long-term effects and adaptability of the integrated treatment. It is also recommended that future experiments incorporate varying levels of manure and different PRD frequencies to optimize treatment combinations. Additionally, monitoring of soil health indicators and physiological plant responses should be included to better understand the mechanisms underlying the observed results. Finally, government support in the form of policies and programs that encourage the use of organic fertilizers and efficient irrigation methods could significantly promote sustainable agriculture, especially in water-limited and high-input farming regions.

CONCLUSION

Increasing the dose of goat manure is positively correlated with increasing vegetative plant growth as indicated by increasing plant height, number of leaves, plant dry weight, amount of chlorophyll, plant Relative Growth Rate (RGR) and plant N, P and K nutrient uptake. Increasing the dose of goat manure is also positively correlated with increasing plant production as indicated by the number of fruits and fruit sugar content. The application of the Partial Rootzone Drying (PRD) method has been able to provide the water needs of tomato plants during the vegetative, generative period, and uptake of N, P and K plant nutrients. Thus, using the PRD method can save up to 25% of water in the growth and production of tomato plants. The interaction of goat manure treatment and the PRD method can support sustainable plant growth, production and uptake of N, P and K nutrients.

ACKNOWLEDGMENTS

I would like to thank to our participants who volunteered to participate in this study.

AUTHOR CONTRIBUTIONS

Conceptualization and Methodology; M. Idris, Irda Nila Selvia and Russel Ong. Software and Writing – Original Draft Preparation; Armansyah and Mohd Khairul Amri Kamarudin.

CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

REFERENCES

Adekiya, A. O., Ejue, W. S., Olayanju, A., Dunsin, O., Aboyeji, C. M., Aremu, C., ... & Akinpelu, O. (2020). Different organic manure sources and NPK fertilizer on soil chemical properties, growth, yield and quality of okra. *Scientific Reports*, *10*(1), 16083. https://doi.org/10.1038/s41598-020-73291-x.

Al-Harbi, A. R., Al-Omran, A. M., Alqardaeai, T. A., Abdel-Rassak, H. S., Alharbi, K. R., Obadi, A., & Saad, M. A. (2018). Grafting affects tomato growth, productivity, and water use efficiency under different water regimes. *Journal of Agricultural Science and Technology*, *20*(6), 1227-1241. http://dorl.net/dor/20.1001.1.16807073.2018.20.6.11.3.

Bachtiar, T., Robifahmi, N., Flatian, A. N., Slamet, S., & Citraresmini, A. (2020). Pengaruh dan kontribusi pupuk kandang terhadap N total, serapan N (15N), dan hasil padi sawah (Oryazae Sativa L.) Varietas Mira-1. *Jurnal Sains dan Teknologi Nuklir Indonesia (Indonesian Journal of Nuclear Science and Technology)*, *21*(1), 35-48. http://doi.org/10.17146/jstni.2020.21.1.5779.

Candra, I. A., & Samah, E. (2022). The effect of tofu liquid waste and organic mulch on the growth of cocoa (Theobroma Cacao L.) nursery plants in a polybag. *Journal of Applied Agricultural Science and Technology*, *6*(2), 171-179. https://doi.org/10.55043/jaast.v6i2.56

Diatara, S. A., & Nurpilihan, N. (2019). Dampak kualitas air tanah terhaDAPs kualitas tanaman tomat cherry (Solanum L. var Cerasiforme). *Agrotekma: Jurnal Agroteknologi dan Ilmu Pertanian*, *4*(1), 42-51.

DPKP Brebes, Budidaya Tomat, Diakses pada 30 Agustus 2023 melalui https://dpkp.brebeskab.go.id/477/budidaya-tomat/. 2021.

Fauziah, N., & M. Idris. (2022). The effect of liquid tofu waste and growing media on the growth and yield of long beans (Vigna sinensis L.). *Jurnal Bioteknologi &Amp; Biosains Indonesia (JBBI), 9*(2), 217–226. https://doi.org/10.29122/jbbi.v9i2.5492

Hendriyani, I. S., & Setiari, N. (2009). Kandungan klorofil dan pertumbuhan kacang panjang (Vigna sinensis L.) pada tingkat penyediaan air yang berbeda. *Jurnal Sains & Matematika*, *17*(3), 145-150.

Hs, O. S. (2022). Pengaruh dosis pupuk kandang ayam dan aplikasi pupuk hayati terhaDAPs pertumbuhan dan produksi tanaman melon (Cucumis melon L.). *Inovasi Pembangunan: Jurnal Kelitbangan*, *10*(01), 39-50.

Idris, M. (2015). Peningkatan efisiensi penggunaan air, hasil dan kualitas buah tomat melalui penerapan partial root zone drying. Hibah Bersaing DIKTI Tahap II. Universitas Al Washliyah Medan.

Idris, M., Bangun, I. H., Armansyah, A., & Hutagaol, D. (2023). Water conservation with the application of partial root zone drying technique in increasing the growth and production of tomato. *Universal Journal of Agricultural Research*, *11*(2), 344-357.

Idris, M., Bangun, I. H., Ani, N., Hutagaol, D., & Siddik, F. (2023). The effect of fish waste and duck manure on the growth and yield of pak choi. *Journal of Water and Land Development*. *59*(X–XII): 100–107.

Khoirunisa, I., Budiman, B., & Kurniasih, R. (2022). Pengaruh kadar air tanah tersedia dan pengelolaan pupuk terhadap pertumbuhan meniran (Phyllanthus niruri). *Jurnal Pertanian Presisi (Journal of Precision Agriculture)*, *5*(2), 138-146.

Kurniawan, B. A., Fajriani, S., & Ariffin, A. (2014). Pengaruh jumlah pemberian air terhadaps respon pertumbuhan dan hasil tanaman tembakau (Nicotiana TabaccumL). Doctoral dissertation, Brawijaya University.

Lukman, L. (2010). Efek pemberian fosfor terhadap pertumbuhan dan status hara pada bibit manggis. *Jurnal Hortikultura*, *20*(1), 82960.

Noonari, S., Memon, M. I. N., Solangi, S. U., Laghari, M. A., Wagan, S. A., Sethar, A. A., ... & Panhwar, G. M. (2015). Economic implications of tomato production in naushahro feroze district of Sindh Pakistan. *Research on Humanities and Social Sciences*, *5*(7), 158-70.

Nurhidayati, N., Djuhari, D., & Rahmawati, N. U. S. (2021,). Pertumbuhan, hasil, dan kualitas hasil panen tanaman tomat yang ditanam secara hidroganik menggunakan vermikompos. In Prosiding Seminar Nasional Pertanian (2. 1), 24-34).

Patti, P. S., Kaya, E., & Silahooy, C. (2013). Analisis status nitrogen tanah dalam kaitannya dengan serapan N oleh tanaman padi sawah di Desa Waimital, Kecamatan Kairatu, Kabupaten Seram Bagian Barat. *Agrologia*, *2*(1), 288809.

Rahmah, A., Izzati, M., & Parman, S. (2014). Pengaruh pupuk organik cair berbahan dasar limbah sawi putih (Brassica Chinensis L.) terhaDAPs pertumbuhan tanaman jagung manis (Zea mays L. Var. Saccharata). *Anatomi Fisiologi*, *22*(1), 65-71.

Saeed, H., Grove, I. G., Kettlewell, P. S., & Hall, N. W. (2008). Potential of partial rootzone drying as an alternative irrigation technique for potatoes (Solanum tuberosum L.). *Annuals ofApplied Biology*, *152*(1), 71-80.

Salam, A. K. (2020). Ilmu Tanah. Fakultas Pertanian Universitas Lampung

Sari, P., Intara, Y. I., & Nazari, A. P. D. (2019). Pengaruh jumlah daun dan konsentrasi Rootone-F terhaDAPs pertumbuhan bibit jeruk nipis lemon (Citrus limon L.) asal stek pucuk. *Ziraa'ah Majalah Ilmiah Pertanian*, *44*(3), 365-376.

Steduto, P., Hsiao, T. C., Raes, D., & Fereres, E. (2009). AquaCrop The FAO crop model to simulate yield response to water: I. Concepts and underlying principles. *Agronomy Journal*, *101*(3), 426-437.

Subandi. (2013). Peran Dan Pengelolaan Hara Kalium Untuk Produksi Pangan di Indonesia. *Pengembangan Inovasi Pertanian, 6*(1), 1–10.

Usharani, K. V., Roopashree, K. M., & Naik, D. (2019). Role of soil physical, chemical and biological properties for soil health improvement and sustainable agriculture. *Journal of Pharmacognosy and Phytochemistry*, *8*(5), 1256-1267.

Wayan. (2017). *Pengelolaan Bahan Organik. Buku Ajar*. LP2M. Universitas Riau