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Research article

Improve pineapples growth by nano-membranes accessory and under stress condition in far north of Taiwan

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Abstract: The dual layers of Nano-membranes barrier, could succeeded in regulation nutrient element and control water-borne disease by improving aerations through added dual layers of nano-membranes, this plantation model provide concept of providing hydrophilic properties and 500 nm pore size believed to be much precision tools for agricultural utilization. This rebuilding of pineapple cultivation was optimized in green-house with natural ventilation, Optimized humidity and free watering were properly practiced by implement of diffusion cage for a novel revealed boundary effect by 500 nm mold inject product. Effect indicated as indicated: Cellulose, PBT, CTA in sequence have better boundary effects over limiting the diffusion of nitrate, phosphate, and a small part of potassium in the root boundary regime through proper moisture with 0.5–0.8 L/pot button irrigation, The intensity of boundary effect were revealed in kinetic analysis follow in sequence: EC (1500 mg L^{-1}) >> nitrate (300 mg L^{-1}) > TPO (2.5 mg L^{-1}), while highly fluctuate for TPO. Then indication of hydrophilic PBT was better than PP was verified in barrier model. In the growth stage, separate initial I–III for direct releasing from the fertilizer and III–VI for hydrolysis & secretion of nutrient, especially for TPO anion form, indicate highly ion charged or polar attraction exerted. While phosphate was delivered slowly, the organic practice was found promising in deliver and uptake to the final two or three stage for flowering and fruiting. The verification of deliver of nutrient by double caged box in the rhigime zone, indicated effective in lowered the damping off/nematode syndrome, which opened the extension cropping in suboptimal area for pineapples. The success of growth character improved by control disease and pest, reach complete maturation.

Under 80 % of final fruiting, the balance analysis show consistence in expectation for Pya (wild) > Pyc (hybrid) > Pyb (interbreed).

Keywords: cellulose; polybutylene terephthalate (PBT); cellulose triacetate (CTA); hydrophilic; microbial community; nano-membranes; dual layer diffusion barrier; nutrient regulation; disease control

1. Introduction

Pineapples were tropical crop majorly breeding in Philippines and Hawaii as well as one of the economical agro-product in southern part of Taiwan. It was one of the most portentous products derivable for health, medical wide use [1]. However, the suitable temperature range for pineapple was 21–28 ℃, and the night temperature of foggy water was 18–25 ℃ for optimal growth. Cultivation area nowadays could gradually change from shifting stably from original 2 years planting area and adapted into more precipitated and humid area from climate warming. Many practices had proved that the rule normally grows only below the North regression line in Taiwan was broken up now [2–4]. Even success planting happened in Daxi, TaoYuan county, have long period of precipitation and humidified winter break through the plantation line at south ZhangHua [5–7]. In this experiment, the trial to build facility with technology for growing pineapple even more consistently in the northern part of Taoyuan, New Taipei city, Taisan. In which, a 4.2 meters tall PE film agriculture house was installed, high ventilation facility for maintaining the surface temperature to 20–25 ℃ from June to November 6 months were perceived. The operation trials for maintain growth was also evaluated and perceived by balance growth theory [8–10].

One of the biggest problems related to the amount of water irrigation and result failure growth. Generally speaking, it must meet the proper precipitation and humidity requirement under the change, and the index was to be soft rot, especially combined nematode syndrome [2,11,12]. Since nano-membranes were the key tools for clean wastewater, even the drinking water which acted in screening and remove bio-agent. In this case, soft rot pathogens, liquid nutrients, organic matters, free water, aeration [13–19] et al., all could be regulated by the membrane bound chamber [20–22]. In these trials, a dual cage box was installed for regulate, mostly on nutrient and aeration. Indirectly limiting the spread of bio-agent observed [23–26].

Pineapple responded quickly upon unsuitable growth conditions, the leaves turn slant, reddish, and even whitish when the temperature lowered. The factors influenced the nutrient translocation to leaves or roots were equally important for successful maturation [2]. The growth appearance was theoretical accessed by balanced growth profile, based on allometric allocation to leaves and root with balanced state. The model experimentally reported by using washed silica sand had only 19% plant responded balanced in idealized growth chamber. allometric slope usually < 1, lowered transport responded, high variation as 35% drafted as low distributed at strong light and high strength of nutrient, even worse, only 18% fit balanced, 55% lowered [26], by significantly shifting to the root which means ideal growth is hard to control. Table 1 shows the model accessed by culturing over 27 herbaceous species and bout 1150 plants grown in 4 scenarios [27] assessed. As climate change alters the traditional area for stable agricultural production, to meet its challenge for trying to build new ways in controlling cultural condition for escaping epidemic infections as pineapples, a unique crop in Southern part of Taiwan. To find reasons for its unsuitable of planting in northern than ZhangHua.

Table 1. Biomass translocation in the maturation growth stage[1].

Allocation or Growth stage	Allometry slopes[2]	Biomass of leaf to root, g $g^{-1,3}$
Average/low (Leaf to root growth)	0.527–0.91/10^{-4}	0.5/0.42–0.59
Average/high (Leaf to root growth)	0.866–1.099/12	0.33/0.27–0.41
Initial of growth	>1	More leaf than root biomass
Maturation of growth	<1	An increase in root mass, less proportional as leaf

[1]Strong light as 1100 µmol^{-2} S^{-1}, with full strength Nutrient Hoaglands solution for growth.

[2]The slope of allometric relationship by in (leaf mass) ≒ α + βIn (root mass) for different in (root mass).

[3]Medium value of dried weight of selected allocation parameters based on 1150 plants of 22 different species grown in combination of high and full-strength Hoagland's solution.

[4]Variety over 22 experimental varieties.

This means the development plant might be vulnerable be influenced by the mineral element irrigation. It was beneficial to build the application model for fertilizer and fertigation method for investigation their balancing effect over experimental plant. We found the balanced model in this experiment had potential to identify Pineapple by responding fertigation quickly pertaining to perennial, herbaceous property. Also, it's shallow and with juicy root, vulnerable to be invaded by water-borne pathogens, so the growth weight was also responsive too to the parameter varied during the growth.

Since these pathogens were pertaining to saprophyte property. The assessed surrounding full with indirect indicator such as *Coliform Bacteria* and *Enterococci* could be persisted in ecological niche [28], which make the surveying route flexible for starting a new evaluation system from organic and with high fertigation rate in the Balanced growth model [29,30]. These criteria worth pineapples growth evaluation possible in the northern part of Taiwan revealed.

2. Materials and methods

2.1. Materials

2.1.1. Porous membrane preparation

Four treatment nano membranes were prepared, include: polypropylene (PP, 500 nm ∅), polybutylene terephthalate (PBT, 500 nm ∅), cellulose triacetate (CTA, 450 nm ∅), and cellulose (No. 1, 1000 nm ∅) were prepared by injection and molten process (Table 2). After double rolled into 2.5 cm (in ∅) X 10 cm (L) column. Tested soil media were installed and ready for test nitrate, phosphate, potassium ion delivering properties.

2.1.2. Soil absorption/diffusion column installation, preparation

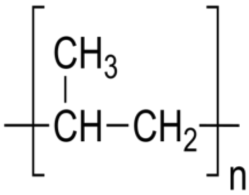
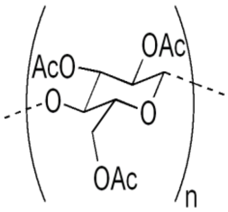
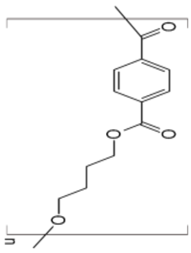
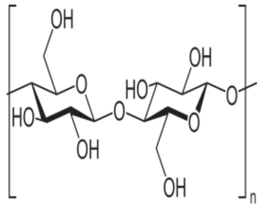
Soil matrix diffusion model for regulation NPK from nanomembrane [31,32]

Four types of membranes were tested on two types of soil that are Yang Ming soil and artificial peat. The soil was dried and sieved through steel sieve with 3 different sizes of 2.5 mm (7.5 mesh), 1 mm (16 mesh) and 0.25 mm (60 mesh) respectively. Afterwards, 10g soil sample was poured into each tube that contained different types of membranes. Then they were immersed in 100 mL solution with a concentration of 500 mg L^{-1} NO_3^-, 40 mg L^{-1} TPO, and 20 mg L^{-1} K^+; and were shaken at 100 rpm for set periods of 15, 30, 45, 60, 75, 90, 105, 120 minutes, respectively.

Diffusion design of nutrient release from organic fertilizer [33] and transport through nanomembrane

The soil samples were collected in 5 several stages with 3 weeks apart from each stage. The total of samples included 5 samples of CK (without membrane), 5 samples of PP, 5 samples of PBT for each stage. The collected samples were stored and naturally dried, and then these samples were passed through a sieve with 20 mesh size.

Table 2. Characteristic of experimental membranes.

Descripted Item	Polypropylene (PP)	Cellulose triacetate (CTA)	Polybutylene terephthalate (PBT)	Cellulose
Chemical structure				
	$(C_3H_6)_n$	$(C_6H_7O_2(OOCCH_3)_3$	$(C_{12}H_{12}O_4)_n$	$(C_6H_{10}O_5)_n$
Property	-High mechanical strength, but brittle. -High printing ability, tasteless and non-toxic, resistant to 100 ℃. -Water proofing for gas and grease [34].	-Films with glossy surfaces, high optical clarity, high dielectric constant, easily laminated, coated, folded, and die-cut. -Solvent, alkali, Soluble, good melt fluidity and easy to form process[35]..	Sensitive above 60 ℃, UV, flammable through low Tg. Increase stability through additives before use [36].	-Odorless, hydro-philic, [20] Insoluble in water, most organic solvents, is chiral, biodegradable. -Melt at 467 ℃ in pulse tests [20]. Broken down chemically into glucose units by concentrated mineral acids at high temperature.
Hydro-philicity	+	++	+++	+++
Hydro-phobicity	++	++	+	+
Present Survey & Discussion	– Interwoven cloth – 500 nm – Nutrient delivery – Soil conditioning	– Smear & reaction – Thin cutting, 450 nm – Nutrient delivery	– Interwoven cloth 500 nm – Nutrient delivery – Soil conditioning	– Co-precipitation – Composite membrane >1200 nm – Antimicrobial, anti-molding

2.2. Analytical methods

2.2.1. Analysis of total fertility, nitrate, K^+

Electro conductivity (EC) was analyzed by sensor probe (Horiba, LAQUA twin EC-33, Japan), with high conductivity calibrated at 1413 us/cm, and low concentration standard; Nitrate-N was measured by (Horiba, LAQUA twin NO_3^-, Japan), with calibration range at 34–3000 mg L^{-1} as standard; K^+ was measured by (Horiba, LAQUA twin K^+, model S030, Japan), with calibration range at 150–2000 mg L^{-1} as standard.

2.2.2. Determination of total phosphate by molybdenum blue colorization

TP was measured by API Aquarium agent. After homogenate by add 6 drops of A&B agent, TP was measured in a range of 0–10 mg L^{-1}, with calibrated in λ = 650 nm OD.

2.2.3. Determination of organic matter

Organic matter (%) determined by volatile solid (550 ℃ weight loss) / total solid (105 ℃ weight).

2.2.4. Measurement of soil pH

Diluted 1g soil sample with 4 mL distilled deionized (DD) water by using Vortex mixer VM-1000 to mix well, then microprocessor pH meter was used to measure the pH of the sample.

2.2.5. Experimental set up

Soil NPK delivering apparatus design [37–39]

In an attempting to estimate the limitation and dissuasive regulation about the disease agent and NPK nutrient, a diffusion barrier was parallel set for determining membrane type, as well as ionic species, could select by the experimental membrane provided. As in the experimental procedure, four kinds of the membrane, as CTA, PP, PBT as well as cellulose were adapted for the diffusion process. The gradient of ionic concentration could further analyze by polynomial curve fitting as determining the diffusion coefficient. By enroll mechanism, rounded woven as comb into rectangular shape by single membrane sheet (500 Φ). When operated, the outer reservoir filled 100 mL of experimental nutrient fluid, with set nutrient concentration provided; when the diffusion process, pour into 20 mesh screened (Figure 1). The influence of different types of membrane on the diffusion and maintenance of NPK fertilizer on Yang-Ming soil using model 1 is presented below. In the beginning, 100 mL of NPK solution was poured into the outer reservoir. The initial concentration of a nutrient solution was 500 mg NO_3^-, 40 mg TPO, and 20 mg K^+. Since starting diffusion, 3 mL of solution in the outer reservoir was collected every 15 minutes for further analysis. Specifically, 1 mL in 3 mL of samples was used to analyze NO_3^-, K^+, and EC. The rest of 3 mL samples was diluted with 1 mL of DD water for analyzing TPO.

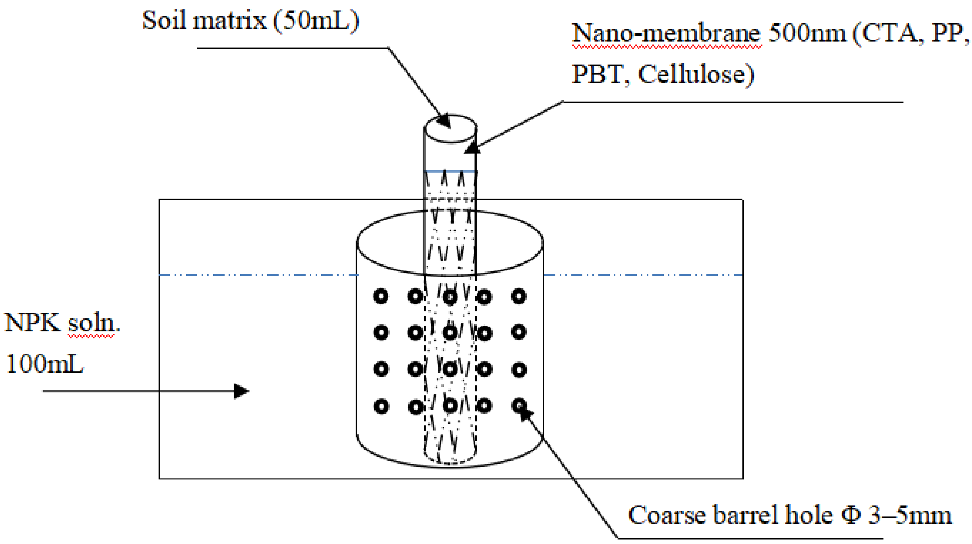


Figure 1. NPK Delivering and regulation through nano membrane barrel.

For NO_3^- and K^+ analysis, 1 g of treated soil sample was sampled, added with 9 mL of DD water, shaking through for 1.5 minutes. After shaking, the mixture was centrifuged for 10 minutes, then 1 mL of clear solution was taken to analyze NO_3^- and K^+ by LAQUA twin NO_3^- and LAQUA twin K^+. Next, take 2.5 mL solution diluted with 2.5 mL DD water for TPO analysis by Spectrophotometer at A = 650 nm.

Soil NPK delivering accessory design in plantation [40]

The soil diffusion model demonstrated as a cascade model that compares the hydrolyzed NPK could be penetrated and effective through different pure, which determine by sampling underground sample and analyze the water-extractable portion of the soil content was analyzed. The very effect of microbial retention or indirectly NPK releasing could be revealed by sampling underneath the cascade for different kind of membrane adopted (Figure 2).

1 g of treated soil was taken and mixed with 4 mL of DD water. Using Vortex mixer model VM-1000 to shake then measure pH by Microprocessor pH Meter. The soil samples were collected in 5 stages, with three weeks apart from each stage. The total samples included 5 samples of CK (without membrane), 5 samples of PP, and 5 samples of PBT for each stage. Samples collected were stored and naturally dried, and then passed through a 20-mesh size sieve.

For the organic matter (OM), using a total of 15 ceramic cups to store soil sample, 5 g of soil samples from each type of membrane was dried in an oven at 55 ℃ and stored overnight. Then continued to be baked in furnaces at 550 ℃ and stored for 6 hours. Soil samples after each burning process are carefully weighed and recorded to use for equation 3.

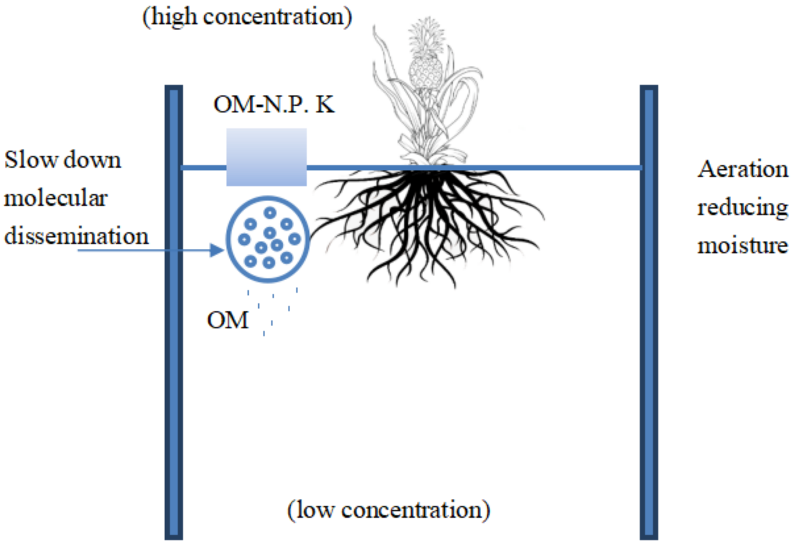


Figure 2. Nutrient delivery design from organic fertilizer by nano-membrane.

2.3. Balanced growth algorism for evaluation nutrient transfer efficiency

Balanced growth of pineapple was evaluated using many hypothesized rule of balanced growth [41,42]; which indicate allometric allocation theorem [43] as unique property assumed.

$$M_L \cdot Am \fallingdotseq M_R \cdot Um \tag{1}$$

The hypothesis of balanced growth relied on,

$$dC/dt \fallingdotseq dN/dt \tag{2}$$

So,

$$M_L\ .\ dC/M_L\ dt \fallingdotseq M_R\ .\ dN/M_R\ dt \tag{3}$$

The hypothesis supports the indication that plant will preferentially allocate biomass to the plant organ continuing in harvesting the resource. Because carbon assimilated during the growth, while water and mineral nutrient are captured by roots, biomass allocation to the leaves according to the plant species, if light becomes more limiting, and favor root if the mineral nutrient becomes limiting to growth. Thus, the balanced Algorism assumed and taking logarithms,

$$\ln(M_L) \fallingdotseq \ln(M_R) + \ln(Um) - \ln(Am) \tag{4}$$

$$\ln(M_L) \fallingdotseq \alpha + \beta\ln(M_R) + \delta_1 \ln(Um) - \delta_2 \ln(Am) \tag{5}$$

Where:
-M_L & M_R are the dry mass of photosynthetic organs (leaves) & roots;
-A_m & U_m are the net whole plant rates of carbon & nutrient uptake per unit leaf or root mass;
-N & C are the mass of the limiting nutrient & carbon.

The partial intercept (α) and partial slope (β) used to quantify the allometric relationship between leaf and root mass translocated, partial slope δ1 and δ2 quantify how far changes in the whole-plant with rates of carbon assimilation and nutrient uptake per unit leaf or root mass change to the overall intercept. The present experiment will focus on exponential weighting of upper and under-ground parts for initial evaluation growth status.

3. Results and discussion

According to the guidebook for the cultivation of pineapples, the required condition notes as in the table indicated hard to manipulate. Problems either with over fertigation, exceeding amend with organic matter, complicated microbial sources, higher humidity and over water clogging, all cause serious risk of growth failure, even whole plant would die within 3 days if contaminated by water borne fungus (Table 3).

Table 3. Guide notes for cultivation of pineapples.

Optimal growth condition			
Temperature range	21–28	pH (acidic)	5.5–6.5
	18–25		
Humidity	75–87	EC	<0.3
(limit, %)	55		
Illuminance	18000~25000	Pathogens	Black rot
Ventilation	Shout, Spikes, cozy	Watering (node)	4–5 day
(if below)	leaves, slant	Hot summer	15 days
		Cold winter	2 weeks

In this report, we found extended clogging water during irrigation practice when the environment is not heat enough to evaporate the excess amount of water. Pathogens like Pythium, *Phytophthora* rot emerging quickly destroyed some 20 plantlet was possible if irrigation water was not lowered. Beside highly increase ventilation by Nano-membrane, also the nutrient assumed to be some degree secured in the boundary layer of the media incorporated as next paragraph analyzed.

3.1. Effect of membranes on delivery of fertility by apparatus design

The nano-membrane examined could easily filtrated liquid fertilizer which benefit to ventilation also. These results showed they had good properties for management include pH, water, even nutrient delivery assumed. Since water clogging and humidors problem were resolved by using nano-membrane, Further, the membrane effect on the nutrient transfer and deliver in the plantation root region was analyzed to be dynamic by implement different plantation media. In practice, we found Yang Ming soil could be formulated more suitable for provide stable elements nutrient than with artificial peat media as compared to previous reference with hydrophilic property, also facilitate in building effective microbial community[44–46]. The status of NPK nutrient, limit as in a boundary by membrane applied, in either case, show great benefit over-regulate moisture condition by quick drainage for remove assess of irrigation water, also important for enhance phosphate, potassium, nutrient available growth elements for the latter fruiting and maturation. Based on the results indicated, that more hydrophilic one-PBT showed effective performance than hydrophobic CTA. Since phthalate ester has polar or hydrogen bonding for linkage anionic ion-$PO_4^{\equiv}$, NO^{-3} were more affected than K^+ for limiting movement as shown in Figure 3.

3.1.1. Boundary effect of nano-membranes on nitrate deliver in Yaming soil

As described in Figure 3A, each membrane exerts its effect on NO^{-3} delivery; results showed that hydrophilic membrane as PBT or cellulose hold more NO^{-3} ion in soil comparing with other membranes, while PP holds less ion as expected. More precisely compared, control result as Figure 3B shown that the NO^{-3} were quickly diffused out within 60 minutes if there were bi nano membrane barreled. The type of membrane resist diffusion and bound NO^{-3} in the soil follows the trend PBT > cellulose > CTA > PP. In which, more hydrophilic and polar texture had more effect on the nitrate bounded inside the membrane.

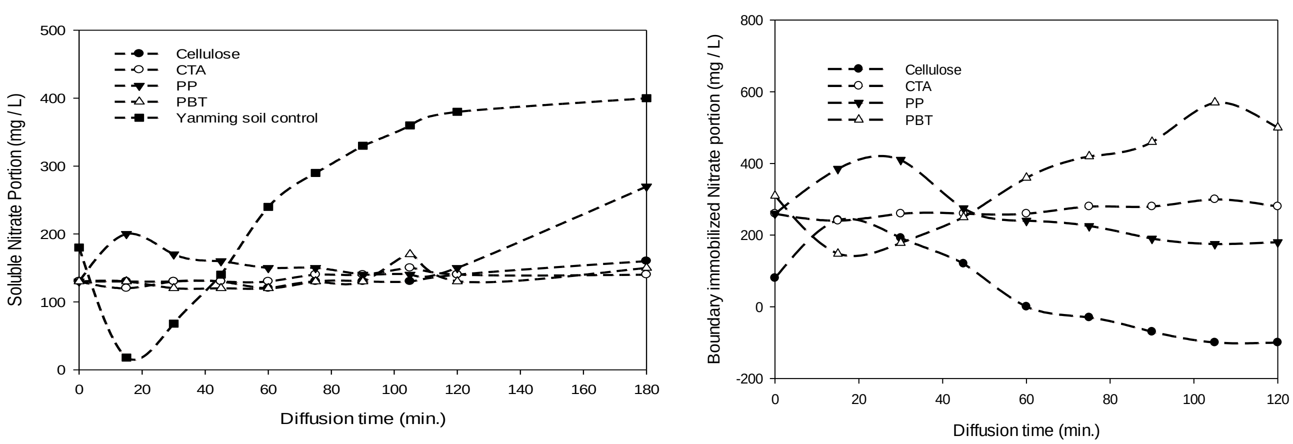


Figure 3. Effect of membrane on the diffusion of Nitrate—Yang Ming soil A, Soluble diffusion portion; B, Boundary immobilized portion.

3.1.2. Boundary effect of nano-membranes on Potassium deliver in Yaming soil

The simple diffusion through the nano-membrane had indicate positive in trend for NP nutrient. The micropore exert their significant effect to the root was expected. It revealed in this report for better nutrient holding, adjust moisture beside aeration, as as conventional usage cellulose brick, baked clay, hole for general practice. Since seedling nurssary was important for promote fundamental part of circular economy. We hope these knowledge could provide tools for raising up productivity [47].

Results of the diffusion boundary effect had shown that nano-membrane had no influence on the movement of potassium. Figure 4A indicated that K^+, up to 200 mg L^{-1} could penetrate soil particle in no time and there was a concentration peak in 30 min., indicated soluble portion reached the peripheral region. While diffusion tendency shown hydrophilic property slowed down the diffusion process as: Cellulose > CTA > PBT, possibly more depended on polar, surface charge. Inversely, PP exerted fastest diffusion rate and less attracted by the media (Figure 4B). The attraction effect for each membrane versus time could be plotted as Figure 4, exerted the same inclination as the same time of moving and steadily release of K^+ by surface attraction forces.

A B

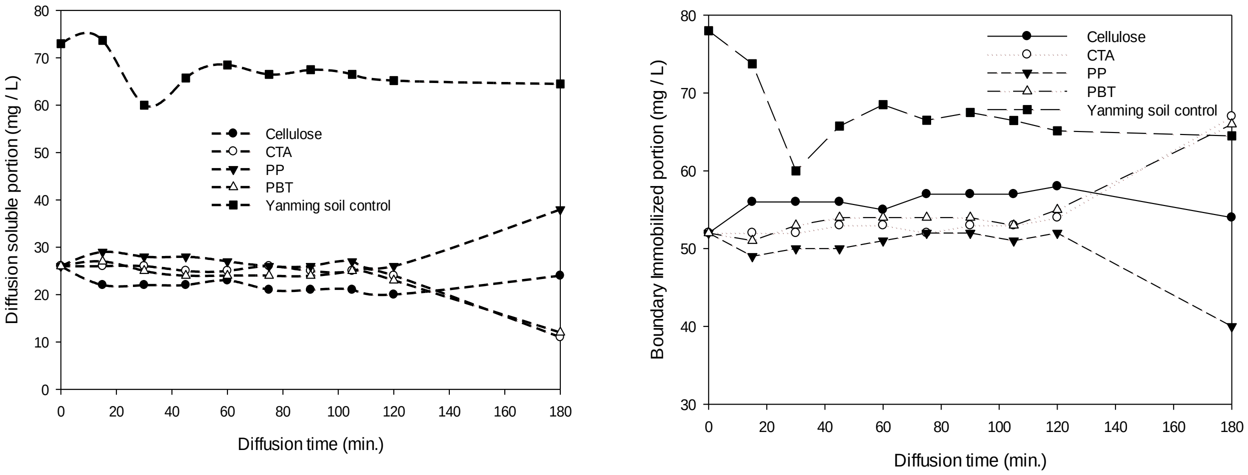


Figure 4. Effect of membrane on the diffusion of Potassium—Yang Ming soil A, Soluble diffusion portion; B, Boundary immobilized portion.

3.1.3. Boundary effect of nano-membranes on Phosphate deliver in Yaming soil

The slow-release mechanism observed in the boundary barrel model with different membrane analyzed. The difference exerted a synchronized cyclization process in 30, 70 min. appeared in the diffusion process. The lowering tendency in sequence ordered: Cellulose > PP > CTA > PBT. Later with inversion sequence: PBT > PP > CTA > cellulose. The possibility of repeated interacted mechanism reacted (Figure 4,5, A). The variant sequence of cellulose, PBT was obvious in low stability and switching which triggered the slow movement phosphate ion—2 mg L^{-1}, by its low solubility (Figure 5, B).

A B

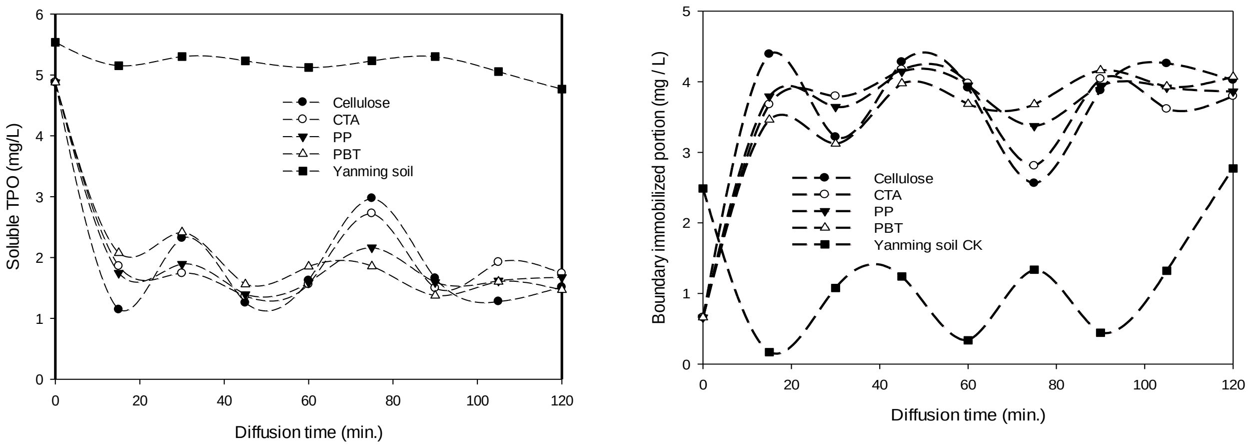


Figure 5. Effect of membrane on the diffusion of Phosphate—Yang Ming soil A, Soluble diffusion portion; B, Boundary immobilized portion.

3.1.4. Boundary effect of nano-membranes on EC deliver in Yaming soil

On diffusion of ion EC, the barrel effect of PP was higher, might as Ca++, Mg++ ion might precipitate and cause limiting in diffusion. PBT was second been affected. Sequence compared as follows PP > PBT > cellulose > CTA. The total ion diffused out from soil followed unknown exchangeable mechanism that caused chaos in trend (Figure 6A).

After a period of testing, the results showed that pineapples using nano-membranes, especially PBT membrane, produced better results than without the control as shown in Figure 6A. Yellowish pineapples and death due to root rot by soft rot fungus mostly appear on pineapple plants without using membranes as shown in Figure 6B.

A B

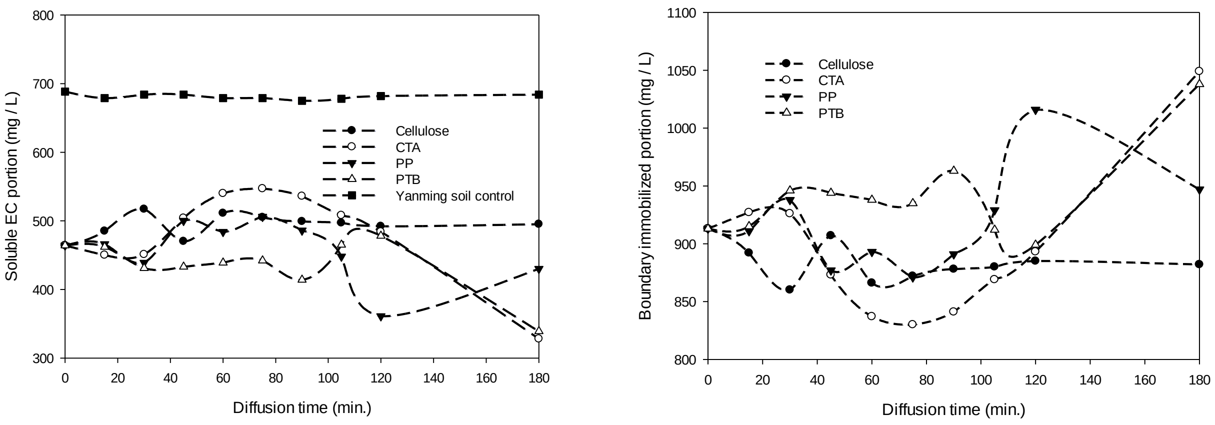


Figure 6. Effect of membrane on the diffusion of EC—Yang Ming soil A, Soluble diffusion portion; B, Boundary immobilized portion.

Because organic cultivation is under extremely dynamic inhomogeneous environment, under high level of addition and deployment, the interaction between biological growth and soil properties such as particle, pores size, and pH will cause differences in the microenvironment of aeration properties and water retention, making it difficult to obtain uniform planting. The results showed that the pineapple in this experiment planted in northern Taiwan belong to a relatively low temperature and impossible succeed breeding environment. Due to the occasionally clogging formed by stagnant water in the medium, the result of the epidemic of aquatic vector fungi was proliferated. Figure 7A is the planting site of this experimental framework. From the height and ventilation architecture, it can conceive that it is beneficial to the evapotranspiration of water, which can greatly reduce the chance of vector breeding and infection. Contrast, the control with use of plastic potted plants resulted poor evapotranspiration and has rapid onset with more than 30% of diseased plants occurred. The plants fell and died within two days, which belonged to heart corruption symptom (Figure 7 F, G).

After using the nano film and limiting the irrigation water to 0.8 to 1 liter provided to the bottom layer every three days. Most of the opportunities to inhibit the breeding of disease vectors can be obtained; the three commercial strains show that they can quickly adjust during the needed of time and correct the conditions, maintaining vigorous growth (Figure 7 B–E). Especially after the middle stage of growth, it needs to be kept under low-solubility nutrients and kept under long-term developmental conditions. This experiment shows that under the condition of an 80 cm vertical soil column, with a relatively hydrophilic PBT membrane quality, it can adjust to be the best soil moisture, with providing Pyc-hybrid, and convince of excellent growth results. For varieties with lower resistance to Pyb, it is also possible to readjust the applicable conditions in the future to provide favorable planting techniques for the construction of microenvironments that may be required by different environments. This comprehensively shows that commercial pineapples can use thin film technology to obtain full benefits during the movement of climate change. The basic data of the growth period could provide for evaluation comparison.

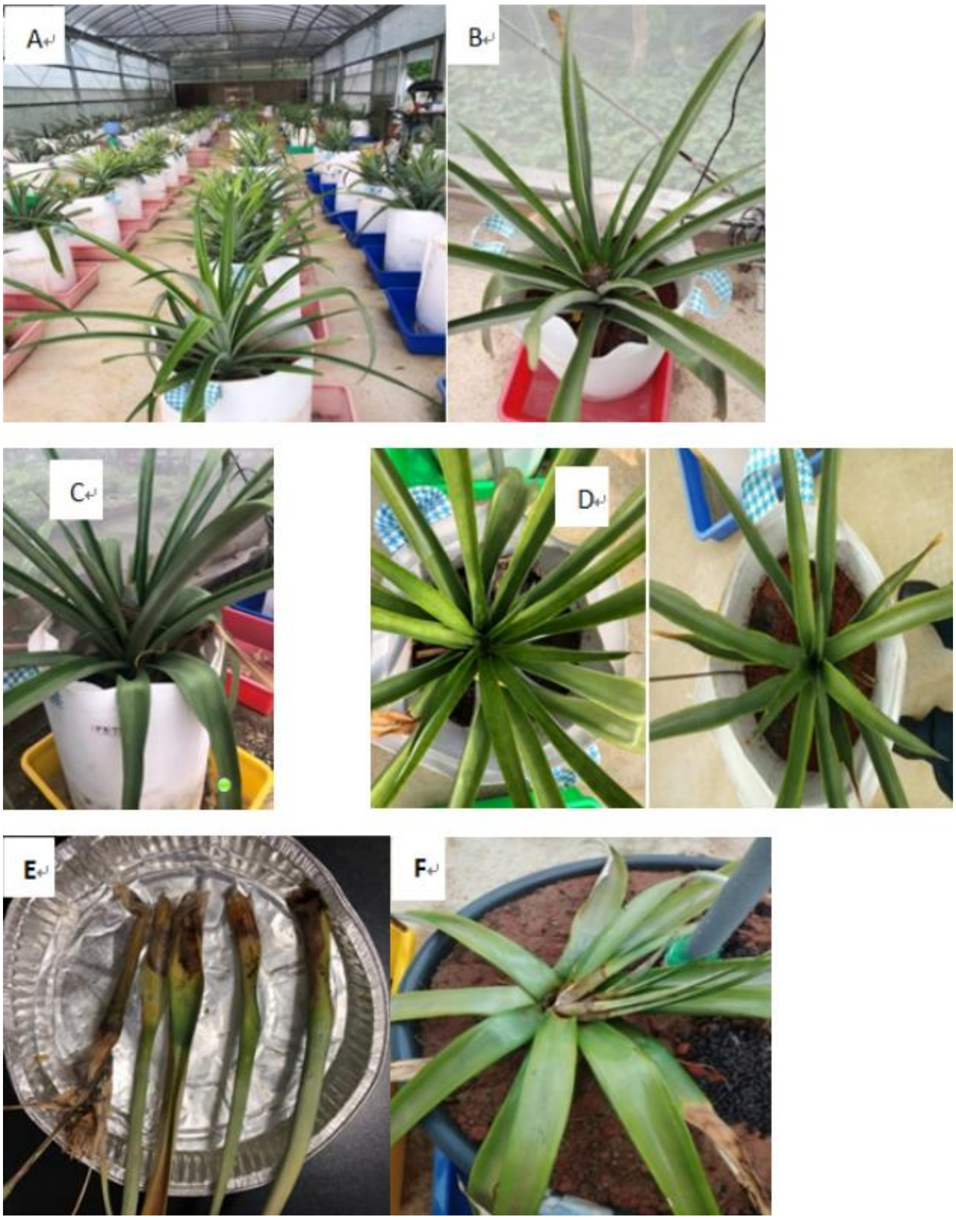


Figure 7. Balance growth of pineapple in a height lifted agriculture house A—whole experiment scape; B—variety Pyc in fruiting stage; C—variety Pya in fruiting; D—Pyb early fruiting; E—pyb early fruiting; F—stock infection with soft rot symptom; G—control without membrane for quick invasion of soft rot.

3.2. Determination of success fertigation and balanced growth of pineapple in Yaming soil with delivering accessory

3.2.1. Effect of membrane implementation

Since the nutrient reserving were benefited by using nano-membrane, an implementation to pineapple were practiced for revealing slow release through the dual channel design. The multiple effect on moisture extent, aeration, pathogen occurrence and harvesting properties was observed. It was found applicable in pineapple because after a long term, with 1 year of planting, the precision concept was not failed. The balanced growth analysis indicate the variation in sequence for the breeding were correct. It means fouling is not severe for some reasons in this organic culture condition as many research indicated [48]. It protruded that the solublizing effective organism as Phosphate solubilizer, saprophyte nitrifying group were active and help avoid fouling easily happened in slurry, wastewater operations.

From the install of model, PP and PBT nano-membranes were more effective than the other two membranes. With the deliver accessary regulate and whole peripheral boundary circled the root. After 1 and half year of planting, PBT provided the highest fertility in the growth period-stage I–III. As results indicated, higher concentrations than three folds nitrate nitrogen of the PP series shown in stage I indicated. Overall, compared with the non-woven membrane fertility, control fertility was delayed, and only 50% PBT nitrate fertility could be detected (Figure 8A).

For TPO fertility, the effect of nano-membranes as indicated in Figure 8B, the PBT membrane was more stable; however, the utilizable concentration reached 4 mg/L, lowering till flowering. Although constantly provided phosphorus, potassium seemed insufficient after the third period stage.

The nano-membrane regulate K_2O potassium nutrient, all membranes were stably deliver with a little difference. However, results in Figure 8C, indicated PBT deliver higher than others, reached over 1 to 2 times higher in the second stage.

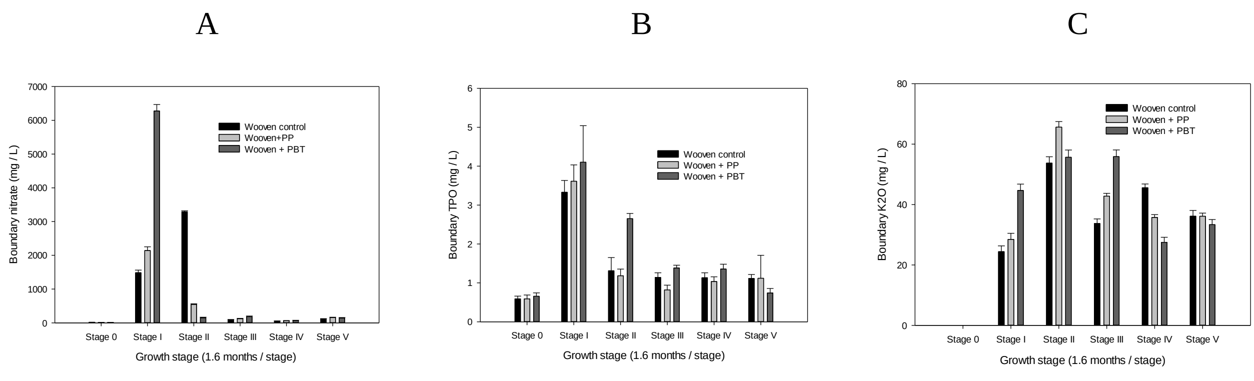


Figure 8. Effect of membranes on NPK nutrient of soil for each growth stage A—Membranes on nitrate effect; B—Membranes on Phosphate effect; C—Membranes on potassium effect.

3.2.2. Effect of nano-membrane on soil property

For the membrane effect on the soil pH, as indicated in Figure 4 planted in plastic pots with restrict aeration, soil pH became more acidified when transferred to the planting bag with various membrane instead, at the beginning stage, soil pH became acidified to pH 4.5–4.8. Fortunately, after two weeks, pH rises to 5.5–6, which meant either the OM became stabilized quickly and the nutrient were adsorbed by the pineapple. The main improvement in planting conditions was the maintenance of proper soil moisture and aeration, and it inferred the main cause for suppression the pathological agent, meantime stabilize the fermentative population toward aerobic community. Then, soil pH rises to 5.5–6 at second stage—pertaining to improve aerobiosis. The third phase kept increase pH rise to 6.2–6.4, in which chaotic trend among the treated, the control soil pH appears more alkaline after stage III, which meant the acidification microbial population had drastically changing, while either though the pH of the non-woven control group was higher than hydrophobic PP, PBT, with a declining pH 0.2–0.3 compared to control average and through the entire planting period. These were believed to be the most important factor influence to soil fertility as well as disease occurrence.

Results as Figure 9A indicated that PP series could maintained higher OM in stages II, III, average was 13.5%; it meant amount of cellulose decomposing was slower due to its lower degrader reacted. Compared with PBT treatment series, after third stage, the lignocellulose degrader activated and decompose faster, and the results were surveyed which released small molecules of humid acid, which became the important component for success planting (Figure 9B). They controlled the plant diseases and insect pests by effective responding the fertigation strategy.

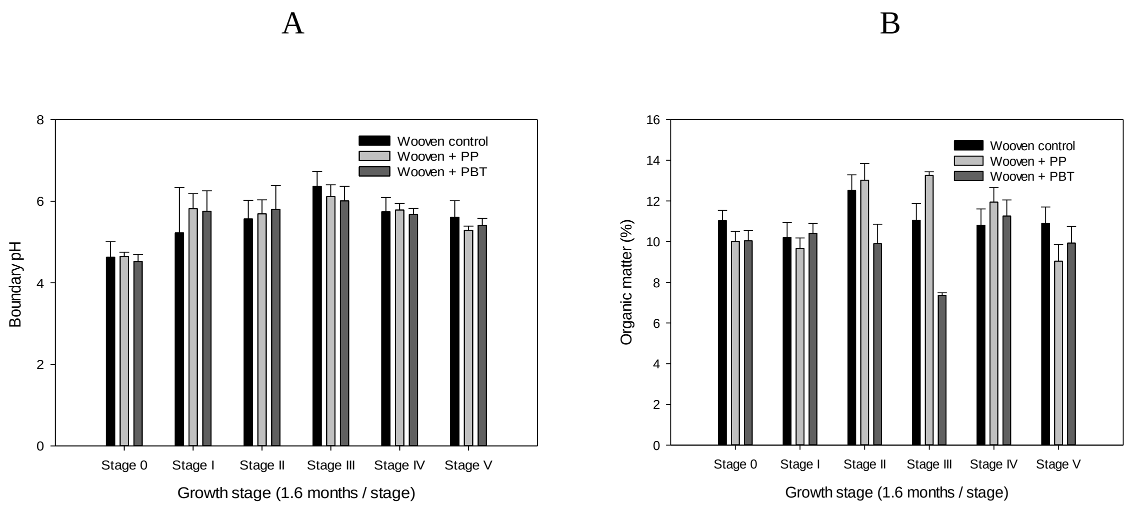


Figure 9. Effect of membranes on pH of soil for each stage; Effect of membranes on OM of soil for each stage

3.2.3. Growth status comparison

Finally, we concluded that after complete stage-V, breeding over 1 and half years, maturation results showed the distribution of biomass in root or translocate into the shoot maintained all stage for the breeding variety from wild to the hybridized species tested. Wild species with allomeric slope correlated to 0.9362, indicated their efficiently shifted to the growing shoot even to the maturation stage (Figure 10A). It also meant the process controlled in good growth condition. Since native wild type has vigor growth and disease resistance for Pya. While Pyb pertaining to be selected with possess fruit flavor, but low disease resistance, while under the same leveling of NPK strategy for evaluation expression, indicated the balanced growth condition, the Allomeric slope was lowered, = 0.912, it meant the nutrient is transported for growth could be little bit lowered than Pya expected (Figure 10B).

The hybrid Pyc as shown with even slower in biomass translocation in same growth status, allometric slope = 0.8771, indicated biomass extension during growth was lowered pertaining to the root environment need more adjust for its physiological status. Overall, the growth conditions were good control to the final fruit harvesting stage, as appearance that high proportion of the plantlets were near balanced condition (Figure 10C).

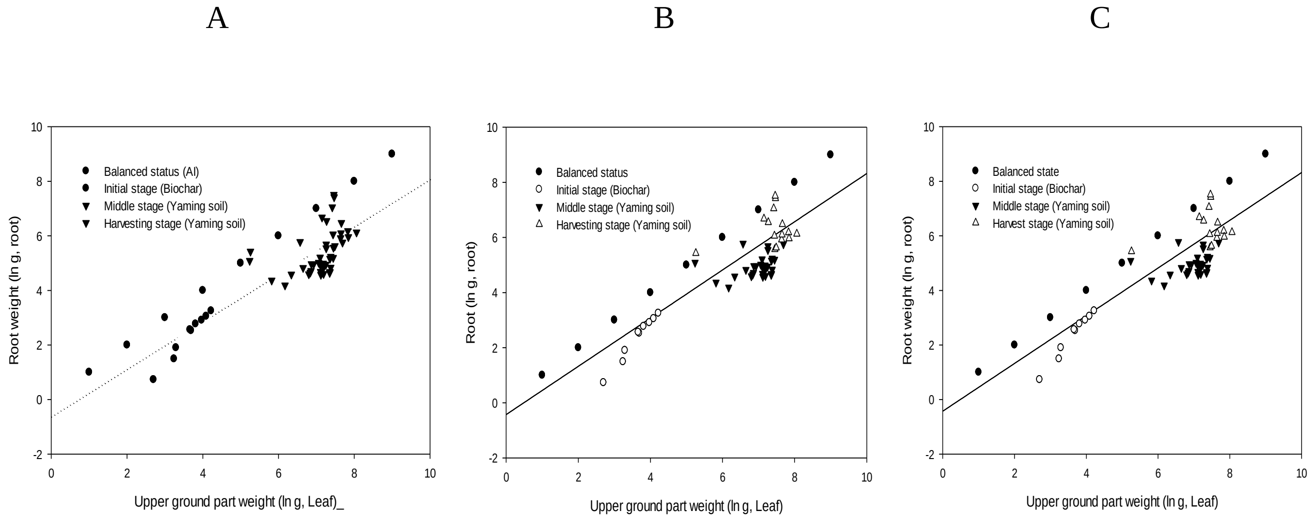


Figure 10. Balanced growth status of Pineapple Pya. A, Biomass extension = 1.1127; Allomeric slope = 0.9362; B, Balanced growth status of Pineapple Pyb. Biomass extension = 0.9884; Allomeric slope = 0.9115; C, Balanced growth status of Pineapple Pyc. Biomass extension = 0.8333; Allomeric slope = 0.8771.

We found the root of the planting were healthy and dispersed into root hair, thus gained significant weight. Second, the fruiting was normal, high sugar content to 15 %, usually detected, but the harvest weights were lowered, which means the reserved phosphate was not transformed into the soluble nutrient as needed. It still need more design in the bottom for EM proliferation [49]. In suggested, PBT might have the best potential for their property and results. However, the stability should adjusted to more resistive, glass fiber in increase stability is one way for their final safe destiny.

4. Conclusion

The boundary effect strengthened by the implement with nano membranes were found and varied for the regulation to the element species, trend followed as nitrate > phosphate > K^+ indicated the anion form more effectively build up as slow release via exchange mechanisms. The elemental chemical form would affect its solubility, which eventually provides different bio-available level build-up in the root regime.

Good delivery capability pertaining to hydrophilic properties as within possibility of help in slow diffuse soluble, bio-available portion of element in the boundary regime through proper water retention and ion load during the implement of fertigation. The promising effect for implement nano-membrane revealed followed: PBT > cellulose > CTA > PP for the same trend in fertility and vigorous growth, perhaps related to the supplement of huge humidity lost during the treatment and escaped from heavy disease die off. With the promising precision irrigated system, plantation of pineapple could go wider in the climate-warming region.

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Conflicts of interest

The authors declare no conflict of interest.

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