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ISAR Journal of Multidisciplinary Research and Studies
Abbriviate Tittle- ISAR J Mul Res Stud
ISSN *(Online)*- 2583-9705
https://isarpublisher.com/journal/isarjmrs

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On-farm Effects of Subsurface Drainage Systems on the Yield, Soil Properties, and Economics of Chinese Cabbage (*Brassica Pekinensis* L. Rupr.) Production in the Rainy Season at Svay Rieng Province, Cambodia

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Article History
Received: 14.10.2023
Accepted: 01.11.2023
Published: 20.11.2023

Abstract: Subsurface drainage is important to drain out excess waters and salts from low-lying waterlogged areas. In such a system, a web of porous tile pipes is buried in the soil to collect excess water from the soil and drain it out into drainage canals. Draining water from the production area under plastic houses and net houses would help farmers to solve the problem of highly saturated soil and can continue their production during the wet season. A study was conducted to ensure the on-farm impact of subsurface drainage system on the yield, soil properties, and economics of Chinese cabbage (*Brassica Pekinensis L. Rupr.*) production in the rainy season at Svay Rieng Province, Cambodia. The on-farm experiment was conducted with farmers in Svay Chrum District, Svay Rieng Province, Cambodia. The treatments consisted of three subsurface drainage (SD) systems under three growing conditions (GC) including open field (OF), net house (NH), and plastic house (PH) with five replications of 45 total plots. The results of the experiment revealed positive improvement in terms of the yield of the Chinese cabbage at a rate of 15% and 22% for SD2 and SD3 systems respectively; and 58% and 66% for NH and PH conditions respectively. Although, the results also showed that the change of soil chemical properties of soil samples analysis from pre and post subsurface drainage installation have indicated a slightly significant increase at a value of soil WHC: 6.04% and 6.23% for SD2 and SD3 systems; with WHC: 4.88% and 4.97% for NH and PH conditions respectively. On the contrary, the results from the soil samples have revealed the slightly decrease of chemical properties at a value of soil pH: 0.32 and 0.56, EC: 27.73 us/cm and 31.18 us/cm, CEC: 0.13 meq/100g and 0.17 meq/100g, available N: 0.32 mg/kg and 0.56 mg/kg, available P: 0.13 mg/kg and 0.14 mg/kg, and exchange K: 0.0055 mg/kg and 0.0060 mg/kg for SD2 and SD3 systems; with pH: 0.32 and 0.50, EC: 22.71 us/cm and 20.38 us/cm, CEC: 0.14 meq/100g and 0.11 meq/100g, available N: 0.32 mg/kg and 0.50 mg/kg, available P: 0.12 mg/kg and 0.118 mg/kg, and exchange K: 0.0042 mg/kg and 0.0039 mg/kg for NH and PH conditions respectively. The soil chemical properties could be interpreted at least the loss of N: 0.77 kg/ha and 1.34 kg/ha, P: 0.31 kg/ha and 0.34 kg/ha, and K: 0.013 kg/ha and 0.014 kg/ha for SD2 and SD3 systems; with N: 0.77 kg/ha and 1.20 kg/ha, P: 0.29 kg/ha and 0.28 kg/ha, and K: 0.010 kg/ha and 0.009 kg/ha for NH and PH conditions from the soil content respectively. Anyways, the economics analysis results still presented the positive improvement on net profits of the Chinese cabbage production at a rate of OF: 13.35% and 29.19%, NH: 28.48% and 48.09%, and PH: 27.51% and 40.82% for SD2 and SD3 systems in comparing with SD1 respectively. In the meanwhile, the increase of return on investment (ROI) of the Chinese cabbage production at a rate of OF: 6.38% and 20.31%, NH: 40.81% and 69.16%, and PH: 51.47% and 75.59%; with the increase of economic efficiency (EF) of the Chinese cabbage production at a rate of OF: 2.79% and 8.87%, NH: 15.36% and 26.04%, and PH: 16.30% and 23.94% for SD2 and SD3 systems were also improved in comparing with SD1 respectively. Consequently, the results suggest that the subsurface drainage systems provided a great benefit contribution to vegetable producers at the saturated fields in terms of a production period that can be extended from intermittent to year-round. The increasing and decreasing values of soil chemical properties in the soil content were slightly back and forth which would be uncountable to take into the account. However, the economics benefits of the subsurface drainage system indicated the high enormous profits, return on investment, and economics efficiency for vegetable producers. Thus, the vegetable producers should be recommended to grow their vegetables under the net house (NH) or plastic house (PH) to increase the productivity with more potential output price at rainy season to generate their daily incomes and livelihood.

Keywords: Chinese cabbage, subsurface drainage, growing condition, chemical soil properties, economic efficiency.

INTRODUCTION

Subsurface drainage is important to drain out excess waters and salts from low-lying waterlogged areas. In such a system, a web of porous tile pipes is buried in the soil to collect excess water from the soil and drain it out into drainage canals. The subsurface drainage system certainly lowers the water table and corrects any salinity problem if good quality water is available for effective irrigations. It is more effective than tube wells for lowering the

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water table and reclaiming salt-affected soils (Woltere et al. 1996). Proper management of irrigation practices could provide various benefits to crop production such as extended crop season, increased yield, and improved aeration of root zone. However, the development of drainage systems has been lagging far behind the development of irrigation, leaving agriculture at a high risk of losing productive lands due to waterlogging and salinization (Abdel, 2000). Chinese cabbage (*Brassica Pekinensis L. Rupr.*) is a popular leafy vegetable of Cambodian farmers and consumers among many kinds of vegetables for their daily food security and income generation (Um Raingsey, 2015). The drainage system could increase the yield of Chinese cabbage from 26% to 34% (Hong et al., 2021). The drainage system provides substantial benefits to agricultural production which could contribute to (i) increasing farm income; (ii) intensification and diversification of cropping; and (iii) generation of employment (Datta et al., 2004). Anyways, the maximum yield is still limited in comparing to the production in the dry season which would to be taken measure. Therefore, the introduction of the subsurface drainage system under the plastic house and net house conditions in rainy season are essential to study in determining its potential contribution to vegetable production during the rainy season which could also be essential for other vegetable producers across the country. Draining water from the production area under plastic houses and net houses would help farmers to solve the problem of highly saturated soil and can continue their production during the wet season. The system will be of great benefit to vegetable producers in terms of a production period that can be extended from intermittent to year-round. Although, many dissolved ions including essential plant nutrients are likely to be removed from soil in drained water. The losses of nutrients in such a system needs proper monitoring (Ochs, 1987) to get sustainable output without deteriorating the soil fertility and other soil characteristics. Because of the increased availability of irrigation water and rapid drainage, there would be substantial amount of leaching of valuable nutrients beyond the root zone that would eventually retard soil fertility and productivity if not properly replenished. It is important to note that the nutrient and salt leaching is usually high in recently installed drainage system, which decreases with time as the salt and nutrient concentrations in soil decreases (Althoff and Kleveston, 1996). Assessment of soil for nutrient losses is frequently required to take timely measure to protect soil resources. Furthermore, the installation of drainage and plastic or net house should be included in the production cost that would not be economically back and forth. Thus far, the specific objective of the research is to ensure the on-farm impact of subsurface drainage system on the yield, soil properties, and economics of Chinese cabbage (*Brassica Pekinensis L. Rupr.*) production in the rainy season at Svay Rieng Province, Cambodia.

MATERIALS AND METHODS

Experimental Site

The experiment was conducted in Svay Chrum District, Svay Rieng Province, Cambodia (Fig. 1) with fifteen farmers' fields of vegetable producers who are members of Svay Rieng Agricultural Cooperatives (SAC). The experiment was carried out from August to November 2022. The soil characteristics of the experimental fields are located on the saturated soil of abandoned paddy fields with soil pH around 5.5 of the loamy soil (averagely, clay: 17.5%, silt: 39.4%, sand: 41.4%). The rainy seasonal precipitation ranges from 142.4mm to 248.9mm, while the temperature ranges from 27.9 ^{o}C to 29.8 ^{o}C, and humidity range from 80% to 92.5% (Table 1).

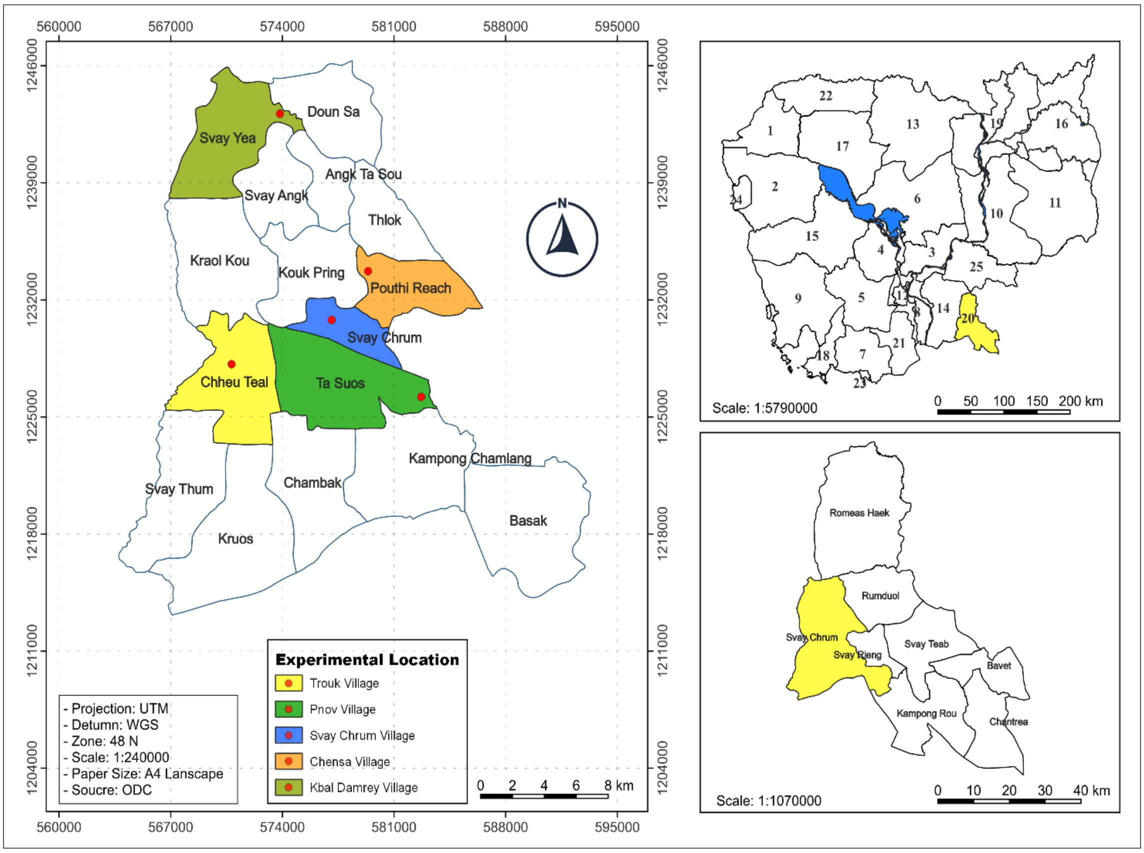

Figure 1: The experimental location in Svay Chrum District, Svay Rieng Province, Cambodia

Table 1: Monthly rainfall, temperature, and humidity during growing season in 2021-2022

Month	Rainfall (mm)		Temperature (^oC)		Humidity (%)	
	2021	2022	2021	2022	2021	2022
Aug	218.8	174.3	30.0	29.4	91.0	87.5
Sept	255.5	238.5	29.3	29.8	96.0	85.0
Oct	254.2	248.9	28.8	27.9	92.5	92.5
Nov	248.4	142.4	29.0	29.0	86.0	85.0
Total	976.9	804.1	117.0	116.0	365.5	350.0

Experimental Design

The factorial design is used, containing fifteen farmers' fields with five replications and nine combined treatments including three SD systems and three GCs (Figure 2). The same design of the Subsurface drainage (SD) systems (SD1 = No Subsurface drainage pipe, SD2 = 2 rows Subsurface drainage pipe per bed, SD3 = 3 rows Subsurface drainage pipe per bed) were applied under the different Growing Conditions (GC) of open field (OF), net house (NH), and plastic house (PH). One farmer's field was used as one GC, and three SD systems were allocated. The pipes were sawed in a row at every 2 cm with 1/3 dept of pipe size to make holes for water inlets to drain through outlets to the nearby canal. The total land area for each farmer's field was 5m x 15m=75m^2. The net house was fully covered by a 150 meshes net, and the plastic house was surrounded covered by a 150 meshes net with 300UV plastic covered on top of the roof.

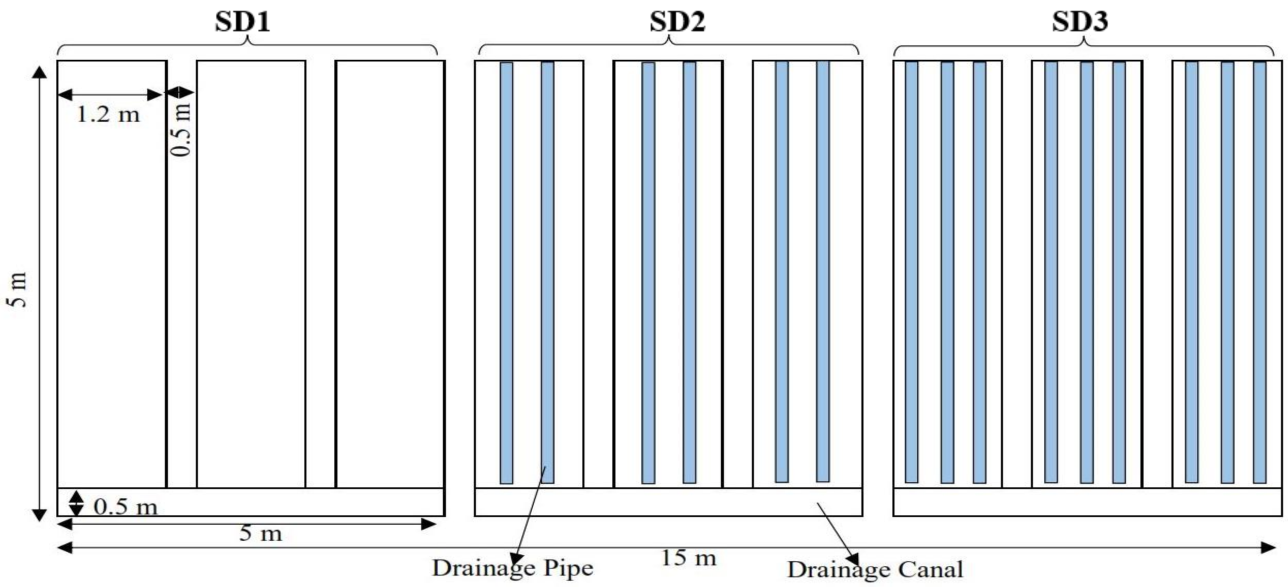

Figure 2: Illustration of the experimental design for each farmer's field

Agronomic Practices

The Chinese cabbage seedlings were grown on the raised bed with the PVC pipe being buried (sawed side goes to the ground) at a depth of 20 cm underneath the root zone. Mechanical methods were used for pest management. The weeding was controlled every week till the harvesting by hands. During the experiment, the diseases were not observed. The insects were normally bothering during the experiment, even in the net house or plastic house condition. The chemical methods of crop protection were used by spraying natural pesticides and by hand picking. For the irrigation, the plants were irrigated from pumped water sources by hand spraying with 20 liter-bucket. In case it was not enough or no rain, the water was applied at field capacity.

Data Collection

The stem density and weight of the Chinese cabbage were collected to calculate the yields (estimated max yield: is the average weight of complete useful stems with 100% density at the harvesting date, useful yield: is the weight of good or consumable or marketable stems, damage yield: is the estimated weight of useless and died stems). Furthermore, the soil samples were collected at the depth of 20 cm before the installation of subsurface drainage and the post subsurface drainage soil samples were collected immediately after the harvest of Chinese cabbage. The soil samples were preserved for chemical properties analysis as below comparison of soil parameters.

Table 2: Comparison parameter for chemical soil properties

No.	Parameter	Unit	Method
1	Potential Hydrogen (pH)	Unit	KCl
2	Electrode Conductivity (EC)	uS/cm	Soil 1:5 Water
3	Cation Exchange Capacity (CEC)	meq/100g	Ammonium Acetate
4	Available Nitrogen (N)	mg/kg	Kjeldahl
5	Available Phosphorus (P)	mg/kg	Olsen
6	Exchange Potassium (K)	mg/kg	Flame Photometer
7	Water Holding Capacity (WHC)	%	Filter Paper Press

Moreover, the actual cost and income of the Chinese cabbage production had also been recorded.

Statistical Analyses

The collected data was analyzed as a factorial design using Statistix 8 program for the analysis of variance (ANOVA) and LSD mean comparison at p-value ($p<0.01$, $p<0.05$), while the Ms. Excel program was used to analyze the economic efficiency and the return on investment of the Chinese cabbage production. Before the analysis, the data were normalized to exclude the covariance being observed from the differentiation among farmer's plot.

RESULTS AND DISCUSSION

Table 3: Yield of Chinese cabbage

Growing Conditions (GC)	Subsurface Drainage (SD)	Total Yield (ton/ha)		
		Estimated Max Yield	Damage Yield	Useful Yield
Open Field (OF)	SD1	32.03i	22.50a	9.53g
	SD2	32.42h	21.84a	10.58fg
	SD3	32.90g	21.32a	11.58f
Net House (NH)	SD1	33.36f	11.79b	21.57e
	SD2	35.90e	10.25c	25.65d
	SD3	36.92d	8.52d	28.40c
Plastic House (PH)	SD1	36.49c	9.79cd	26.70d
	SD2	37.90b	5.92e	31.97b
	SD3	38.58a	4.07f	34.51a
CV (%)		1	3	3
Sig. (GC)		**	**	**
Sig. (SD)		**	**	**
Sig. (GC X SD)		**	**	**

Note: a,b,c,... are significantly different means within column (a>b>c); at $p<0.05$ (* $p<0.05$, ** $p<0.01$)

The result (Table 3) showed that the estimated maximum yield, damaged yield, and useful yield of the Chinese cabbage are statistically significant different in comparing with SD1 for SD2 and SD3 under OF, NH, and PH conditions respectively; which could make a significant impact on the productivity of the cabbage with a p-value less than 0.01. All parameters interaction of GCxSD gradually developed and became significant. In overall, the PH condition with SD3 was observed to be the best performance for estimated maximum yield and useful yield, while under PH condition with SD2 and under NH condition with SD3 were observed to be better performance in comparing to SD1 in all growing conditions. In addition, OF condition with SD1 was observed to be the worst performance for the damaged yield. This experimental result indicated high productive benefits for the Chinese cabbage in terms of yield at a rate of 15% and 22% for SD2 and SD3 systems respectively; and 58% and 66% for net house and plastic house conditions respectively. In comparison to the previous assignment “On-farm effects of drainage systems on productivity of Chinese cabbage (*Brassica Pekinensis* L. Rupr.) at Svay Rieng Province” conducted at the same location during the dry season, the increase is 26% to 34%, respectively (Chhun, et al., 2021). The yield from the experiment was slightly better than the one being conducted during the dry season at the Royal University of Agriculture with a yield of 28 tons/ha (Teb Kimheng, 2015). In addition, the results of the experiment were quite better in comparison to the installation of a subsurface drainage system resulting in an improvement of paddy yield by 13.27 %. However, it was the first year after the installation of the subsurface drainage; the yield could be expected to improve considerably during the succeeding seasons with appropriate and better cropping and irrigation management practices (Sahana et al., 2023). Similarly, Abdel-Dayem, and Ritzema (1990) reported an increased yield of many crops to a tune of 10 percent for rice, 48 percent for berseem, 75 percent for maize, and more than 130 percent for wheat under a subsurface drainage system. The increase was due to improvement in soil physical and chemical properties viz., infiltration rate, porosity, pH, EC, ESP, improved nutrient availability, improved air and water condition at the crop root zones in the drained field. In addition, the enormous increase would be resulted in reducing of water stress and strong drops of rain under the net house and plastic house protection during the rainy season. This would be more precise with the full-control condition of experimentation which would be possible in generalizing the actual condition of the country. This would bring enormous economic benefits for farmers. A report from the Ministry of Agriculture, Forestry, and Fishery showed that Cambodia produces about 2,500 tons of vegetables per day; leaving a daily shortfall of roughly 900 tons, all of which must be imported (Phnom Penh Post, 2022). This would be translated into approximately contribution of 375-550 tons per day with the application of subsurface drainage and approximately contribution of 1,450-1,650 tons per day with the application of growing condition (net house and plastic house) at least during the wet season production (June to December) for Cambodia at the maximum scenario.

Table 4: Change of chemical soil properties before and after structure installation

Growing Conditions (GC)	Subsurface Drainage (SD)	pH	EC (uS/cm)	CEC (meq/100g)	Available N (mg/kg)	Available P (mg/kg)	Exchange K (mg/kg)	WHC (%)
Open Field (OF)	SD1	(0.3140)d	(10.454)d	(0.0640)e	(0.0800)f	(0.0980)d	(0.00089)e	1.3740e
	SD2	(0.5080)b	(29.496)b	(0.1240)c	(0.1580)e	(0.1380)ab	(0.00584)bc	5.9060c
	SD3	(0.6860)a	(36.214)a	(0.1900)a	(0.4520)c	(0.1440)a	(0.00672)a	6.1520b
Net House (NH)	SD1	(0.1200)ef	(9.832)d	(0.0860)d	(0.1200)ef	(0.1060)d	(0.00094)e	2.3820d
	SD2	(0.3020)d	(28.530)bc	(0.1460)b	(0.3020)d	(0.1320)bc	(0.00555)cd	6.0780bc
	SD3	(0.5300)b	(29.776)b	(0.1840)a	(0.5300)b	(0.1360)abc	(0.00632)b	6.1820ab
Plastic House (PH)	SD1	(0.0800)f	(8.420)d	(0.0540)e	(0.3140)d	(0.0980)d	(0.00092)e	2.4080d
	SD2	(0.1580)e	(25.172)c	(0.1300)c	(0.5080)b	(0.1283)c	(0.00555)d	6.1500b
	SD3	(0.4520)c	(27.554)bc	(0.1340)bc	(0.6860)a	(0.1289)c	(0.00637)bcd	6.3500a
CV (%)		8.12	12.65	8.43	10.76	5.6	10.04	3.08
Sig. (GC)		**	**	**	**	**	**	**
Sig. (SD)		**	**	**	**	**	**	**
Sig. (GC x SD)		**	ns	**	**	ns	*	**

Note: a,b,c,... are significantly different means within column (a>b>c); at p<0.05 (* p<0.05, ** p<0.01)

The result (Table 4) presented that the chemical properties change of soil samples analysis from pre and post subsurface drainage installation have indicated a slightly increase of soil pH and WHC for SD2 and SD3 under OF, NH, and PH conditions respectively, which could make a significant improvement on the aeration of the soil and less soil compaction after a strong drop of rain with p-value less than 0.01. On the contrary, the results of the chemical properties change had revealed the slightly decrease of the soil EC, CEC, available N, available P, and exchangeable K for SD2 and SD3 under OF, NH, and PH conditions respectively; which could make at least a significant loss of soil fertilities with p-value less than 0.01. All parameters interaction of GCxSD gradually significant change, except the interaction of GCxSD on EC and available P were not significant change. In overall, the PH condition with SD3 was observed to be the best performance for the change of pH and WHC, while under OF condition with SD3 was observed to be the worst performance for the change of EC, CEC, available P, and available K in comparing to SD1 and SD2 in all growing conditions. In addition, the PH condition with SD3 was also observed to be the worst performance for the change of available N in comparing to SD1 and SD2 in all growing conditions. According the yield increase (Table 3) was due to improvement in soil physical and chemical properties viz., infiltration rate, porosity, pH, EC, ESP, improved nutrient availability, improved air, and water condition at the crop root zones in the drained field (Ritzema, 1990). The poor yield of maize in the undrained field due to poor soil physicochemical properties viz., shallow water table depth, high pH, EC, and ESP (Stieger and Feller, 1994; Samad et al., 2001; and Zhang et al., 2015), which limits the growth and development of crops in waterlogged saline-alkali soil (Arumugam et al., 2019). The intensive leaching of water from the drained soils had caused downward movement of soil chemical properties including the decrease of pH, EC, CEC, available N, available P, and exchange K from the soil content.

Similar results were also reported by Hamir et al. (2013). The loss of soil nutrients from the soil content (Table 4) could be translated by Sunita Gaind (2019) at least the loss of N: 0.768 kg/ha and 1.244 kg/ha, P: 0.312 kg/ha and 0.336 kg/ha, K: 0.013 kg/ha and 0.014 kg/ha for SD2 and SD3; with N: 0.768 kg/ha and 1.2 kg/ha, P: 0.288 kg/ha and 0.283 kg/ha, K: 0.010 kg/ha and 0.009 kg/ha for OF, NH, and PH conditions respectively. These results were very slightly loss in comparing with the loss of N: 35.53 kg/ha, P: 5.56 kg/ha, and K:15.16 kg/ha reported by Arumugam et al. (2019). Anyways, the increase of WHC: 6.04% and 6.23% for SD2 and SD3 systems; with WHC: 4.88% and 4.97% for NH and PH conditions respectively. The result revealed the positive improvement of the soil supported by Kumar et al., (2011), who observed that the presence of poor aeration and nutrients availability coupled with poor water quality in undrained field decreased the soil bulk density and water holding capacity (WHC) due to soil deflocculation by the high concentration of sodium and it adversely affect the germination and plant growth.

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	Growing Conditions (GC)	Subsurface Drainage (SD)	Fix Cost ($/ha)	Variable Cost ($/ha)	Total Cost ($/ha)
Production Cost	Open Field (OF)	SD1	104.86	3,016.67	3,121.53
		SD2	354.86	3,016.67	3,371.53
		SD3	467.36	3,016.67	3,484.03
	Net House (NH)	SD1	5,104.86	3,016.67	8,121.53
		SD2	5,354.86	3,016.67	8,371.53
		SD3	5,467.36	3,016.67	8,484.03
	Plastic House (PH)	SD1	5,104.86	3,350.00	8,454.86
		SD2	5,354.86	3,350.00	8,704.86
		SD3	5,467.36	3,350.00	8,817.36
	Growing Conditions (GC)	Subsurface Drainage (SD)	Useful Yield (ton/ha)	Contracted Unit Price ($/ton)	Total Income ($/ha)
Production Income	Open Field (OF)	SD1	9.53	750.00	7,147.50
		SD2	10.58	750.00	7,935.00
		SD3	11.58	750.00	8,685.00
	Net House (NH)	SD1	21.57	1,000.00	21,570.00
		SD2	25.65	1,000.00	25,650.00
		SD3	28.4	1,000.00	28,400.00
	Plastic House (PH)	SD1	26.7	1,000.00	26,700.00
		SD2	31.97	1,000.00	31,970.00
		SD3	34.51	1,000.00	34,510.00
	Growing Conditions (GC)	Subsurface Drainage (SD)	Net Profit ($/ha)	ROI (%)	Economic Efficiency (%)
Production Benefits	Open Field (OF)	SD1	4,025.97	128.97	228.97
		SD2	4,563.47	135.35	235.35
		SD3	5,200.97	149.28	249.28
	Net House (NH)	SD1	13,448.47	165.59	265.59
		SD2	17,278.47	206.40	306.40
		SD3	19,915.97	234.75	334.75
	Plastic House (PH)	SD1	18,245.14	215.79	315.79
		SD2	23,265.14	267.27	367.27
		SD3	25,692.64	291.39	391.39

As presented in the table 5 above, the production cost including depreciation of fix cost and variable cost such as the expense on inputs, drainage installation, net or plastic house structure, labor, and so on. the production cost per cycle of Chinese cabbage was the biggest expense with 8,704.86 $/ha and 8,817.36 $/ha, followed by 8,371.53 $/ha and 8,484.03 $/ha, and 3,371.53 $/ha and 3,484.03 $/ha for SD2 and SD3 in comparing with SD1 system under the PH, NH, and OF conditions respectively. Although, the results also showed that the production income per cycle of Chinese cabbage provided also the most outputs with 31,970.00 $/ha and 34,510.00 $/ha, followed by 25,650.00 $/ha and 28,400.00 $/ha, and 7,935.00 $/ha and 8,685.00 $/ha for SD2 and SD3 in comparing with SD1 system under the PH, NH, and OF conditions respectively. Furthermore, the results also showed that the production net profit per cycle of Chinese cabbage provided the most benefit with 23,265.14 $/ha and 25,692.64 $/ha, followed by 17,278.47 $/ha and 19,915.97 $/ha, and 4,563.47 $/ha and 5,200.97 $/ha for SD2 and SD3 in comparing with SD1 system under the PH, NH, and OF conditions respectively. In the meanwhile, the return on investment (ROI) of the Chinese cabbage production at a rate of OF: 135.35% and 149.28%, NH: 206.40% and 234.75%, and PH: 267.27% and 291.39%; with the economic efficiency (EF) of the Chinese cabbage production at a rate of OF: 235.35% and 249.28%, NH: 306.40% and 334.75%, and PH: 367.27% and 391.39% for SD2 and SD3 systems were also well improved in comparing with SD1 respectively. The economics analysis results could be translated with the positive improvement on net profits of the Chinese cabbage production at a rate of OF: 13.35% and 29.19%, NH: 28.48% and 48.09%, and PH: 27.51% and 40.82% for SD2 and SD3 systems in comparing with SD1 respectively. In addition, the increase of return on investment (ROI) of the Chinese cabbage production at a rate of OF: 6.38% and 20.31%, NH: 40.81% and 69.16%, and PH: 51.47% and 75.59%; with the increase of economic efficiency (EF) of the Chinese cabbage production at a rate of OF: 2.79% and 8.87%, NH: 15.36% and 26.04%, and PH: 16.30% and 23.94% for SD2 and SD3 systems were also improved in comparing with SD1 respectively. The Agricultural and Rural Development Bank (ADB) reported in the research project on “Chinese Cabbage Production Under Net House Condition in Takeo Province” that the net profit of Chinese cabbage production was 623.43$/240m^2 (approximately 25,976.04 $/ha), which was almost the same profitable as the one was finding under the plastic house condition at the rainy season on this experiment. The profit was considered the most important factor in analyzing the financial efficiency of the Chinese cabbage farming model of two farmer’s groups as the study showed that the average profit of households in the net house was 2.7 times higher than that of the household outside the net house (Duong Ngoc Thanh, et al., (2023). This data was still very lower multiply than the one had been resulted for net house and plastic house in comparing with open field in this paper.

CONCLUSIONS

The subsurface drainage (SD2 and SD3) systems with net house (NH) and plastic house (PH) conditions provided a great benefit contribution to the vegetable producers at the saturated fields in terms of Chines cabbage yield and production period that can be extended from intermittent to year-round. The increasing and decreasing values of soil chemical properties in the soil content under the subsurface drainage (SD2 and SD3) systems with all growing conditions were slightly back and forth which would be uncountable to take into the account. However, the economics benefits of the subsurface drainage (SD2 and SD3) systems with net house (NH) and plastic house (PH) conditions indicated high enormous profits, return on investment, and economics efficiency for long term vegetable producers.

ACKNOWLEDGEMENTS

The author would like to acknowledge the sub-research project “Effects of Drainage System and Green House on the Productivity of Vegetable Production” funded by “Higher Education Improvement Project (HEIP)” through “Svay Rieng University, Cambodia”

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