Effect of subsurface drainage for multiple land use in sloping paddy fields

K. Y. Jung[A], E. S. Yun[A], K. D. Park[A], Y. H. Lee [A], J. B Hwang[A], C. Y Park[A] and Edwin P. Ramos[B]

[A]Department of Functional Crops, NICS, RDA, Neidong, Milyang 627-803, South Korea, Email jungky@korea.kr
[B]Nueva Vizcaya State University, Bayombong 3700, Nueva Vizcaya, Philippines, Email epramos_16@hahoo.com

Abstract
Subsurface drainage improves the productivity of poorly drained soils by lowering the water table, providing greater soil aeration, and enabling faster soil drying and improving root zone soil layer condition. The lower portion of sloping paddy fields normally contains excessive moisture and the water table is higher caused by the inflow of groundwater from the upper part of the field resulting in non-uniform water content distribution. The purpose of this study is to monitor on-farm water table fluctuations and to evaluate the effect of drainage in the soil and its relation to soybean yield. Four drainage methods namely open ditch, vinyl barrier, tile drainage and tube bundle were installed within 1-m position from the lower edge of the upper embankment of sloping alluvial paddy fields. The tile drainage method drained the field faster as compared to the other drainage methods. Results also revealed that the subsurface drainage system can increase crop yield and the overall economic productivity of the soil.

Key Words
Subsurface drainage, moisture stress index, soybean, water table level, paddy field.

Introduction

Subsurface drainage has been widely used in developed countries and by mid-1980s, it was started to be recognized as a solution to water logging and salinity problems in irrigated areas of the developing world. The main reason of using subsurface drainage in paddy field is to improve the soil and create more conducive working conditions for the use of farm machinery especially for large scale paddy plot farming as well as upland crop farming in paddy field (Ogino and Murashima 1993). There are considerable areas of wet paddy fields in Korea that requires improvement of its drainage system. It is well established that one of the most widely accepted methods of improving drainage system in wet fields is subsurface drainage (Lee and Kim 1997). In the late 1980s, the Korean government has encouraged the use of surface drainage for sustainable farming of paddy field. The total area of drained wetland is 170,000 ha or equivalent to 13.1 % of the total area of paddy fields in Korea (Korea Rural Community and Agriculture Corporation 2008). Paddy fields in Korea are particularity different from those in the European countries and America in that they drain excess soil water from shallow surface soil layer. Especially, in alluvial sloping paddy fields, upland crops can be damaged by either rainfall or capillary rise of the water table caused by percolating water beneath the upper fields during summertime rainy season causing variations in soil moisture even in identical fields with curved parallel terracing and contour-lined layout in sloping area where the length of short side is relatively short.

Drainage systems are designed to alter field hydrology by removing excess water from water logged soil. The American Society of Agricultural and Biological Engineers (ASABE 2008) provided scientific criteria from which guidelines are now available to determine the necessity for drain spacing which varies a 7-15 m, with 10 m being a popular distance and trencher depth is about 50 cm and width range from 20 cm to 35 cm depending on the trencher used and diameter of the drain pipe. Drainage improves farm productivity and net returns by adding productive areas without extending farm boundaries. Yield increases of between 10-25 % can be expected depending upon the initial drainage status of the land.

Methods

Site description

Experiment were carried at four poly drained paddy fields located at Oesan-ri, Buk-myeon, Changwon-si out in alluvial slopping paddy fields (35˚22 N, 128˚35 E). The size of standard field plot is 20 m ×80 m; one shot side faces a farm drain. The soil was Jisan series which is a member of the fine loamy, mixed, mesic family of Fluvaquentic Endoaquepts (low humic-gley soils) developed from weakly stratified local alluvial materials in gently sloping narrow valley alluvium and on alluvial fans derived from granite, andesit porphyry and similar soil materials. These soils have moderately thick dark grayish brown loamy Ap horizons and very thick grayish brown light loam cambic Bg horizons with white colored ferrous carbonate ($FeCO_3$) mottles. The Cg horizons are gray or dark bluish gray sandy loam with few white ferrous carbonate ($FeCO_3$) mottles.

Table 1. Selected soil physical properties of the research site. The site is composed primarily of Jisan series(fine loamy, mixed, mesic family of Fluvaquentic Endoaquepts).

Horizon	Depth (cm)	Bulk density (Mg/m^3)	Three phases (%)			Porosity (%)	Textural Class	Water holding capacity (%)	
			Solid	Water	Air			-33KPa	-1500KPa
Ap1	0~10	1.18	44.5	40.2	15.3	55.5	loam	41.4	21.7
Ap2	10~20	1.55	58.6	25.9	15.5	41.4	loam	26.9	11.0
Ag	20~24	1.62	61.2	24.1	14.6	38.8	loam	21.6	9.9
Bg	24~35	1.60	60.3	22.3	17.4	39.7	Sandy loam	18.5	8.1
BCg	35+	1.60	60.4	25.0	14.5	39.6	Sandy loam	19.3	9.0

Drainage system

The drainage system is designed to remove excess water from the soil quickly enougth to minimize crop stress thru at 1-m position of beneath upper field bank using four kinds drainage methods, namely open ditch, vinyl barrier, tile drainage, and tube bundle (Figure 1). The field experiment had been installed at pooly drained paddy field in 2007. The polythene (HDPE) corrugated pipes wrapped with poly wave nets tile drainage were placed in trenches measuring 50 cm wide and 60 cm deep. The pipes were then encased in a mixture of gravel to a circumference thickness of 10-15 cm. then the trenches were filled with dug earth to the orignal level. These pipes eventually drain through the wall into the open perimeter ditch (Figure 1). The drainage system investigation was laid out in a randomised complete block design with two replications.

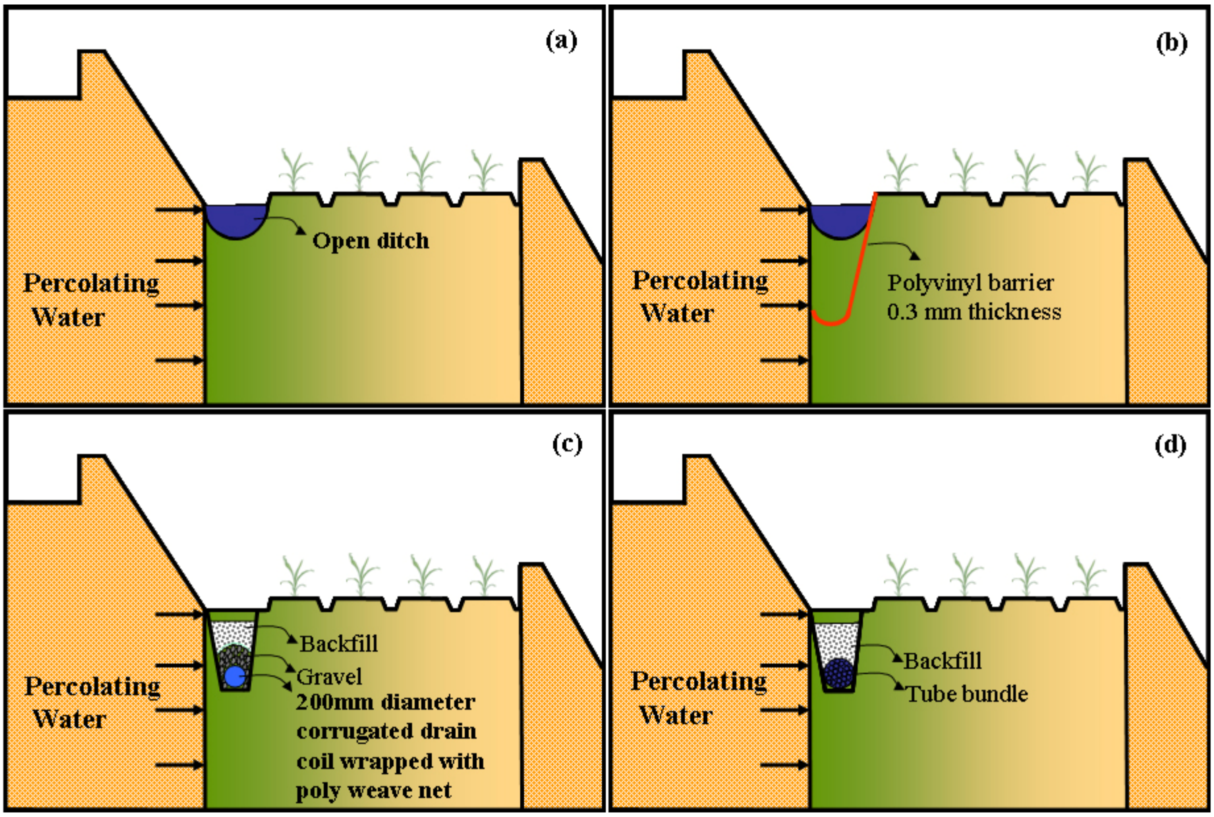

Figure 1. Schematic showing various drainage system. (a) Open ditch (b) Vinyl barrier (c) tile drainage (d) Tube bundle.

Water table monitoring and soil moisture measurements

The measurement of soil moisture levels after drainage, which are used to determine the soil bearing capacity were made at 3, 10 and 15-m positions from the edge of the upstream bank of the field where the each drainage type was constructed. During the same period of soil moisture measurement, the water table levels were monitored from 150-cm long small tube wells made from 50-mm poly vinylchloride (PVC) pipes.

Waterlogging was assessed over the season using the water table levels from the tube wells placed every 60-m in a grid pattern and by calculating the daily sum of excess water in the profile above 30 cm soil depth (SEW_{30}) for each deep well (McFarlane *et al.* 1989). SEW_{30} values are dependent on both surface and subsurface drainage. In most cases several alternative combinations of surface and subsurface drainage can be used to satisfy a given SED_{30} limit. Drainage requirements for trafficability during the seedbed perparation periods were about the same for three locations (Skaggs 1980). The SEW_{30} was calculated using the expression

$$SEW_{30} = \sum_{i=1}^{n} (30 - x_i)$$

where x_i is the water table depth on the i^{th} day, with $i = 1$ being the first day and n the number of days in the growing season(Setter and Waters 2003, McFarlane *et al.* 1989).

Results

The infiltration rate of 20.87 cm/hr recorded in the subsurface drained fields was substantially higher than the 0.15 cm/hr obtained in the field with open ditch. The decrease in moisture within the soil profile and the attainment of the maximum water-holding capacity after the occurrence of rainfall is faster in the tile drainage than in the open ditch drainage method (Figure 2). The sum of excess water days (SWD_{30}), used to represent the moisture stress index, was lowest in the tile drainage method at 31 days compared with the open ditch drainage method at 135 days(Table 2). The soil water content spatial variability was highest in the vinyl barrier method 270.8 m, followed by subsurface method 223.2m, tube bundle 140.1m and open ditch drainage method 64.6m. The effectiveness drainage on tile drainage method more cleared up than the other drainage methods. It was showed that the tile drainage system had helped in increasing crop yields as well as improving soil productivity and consequently total economic value of such a production (Figure 2).

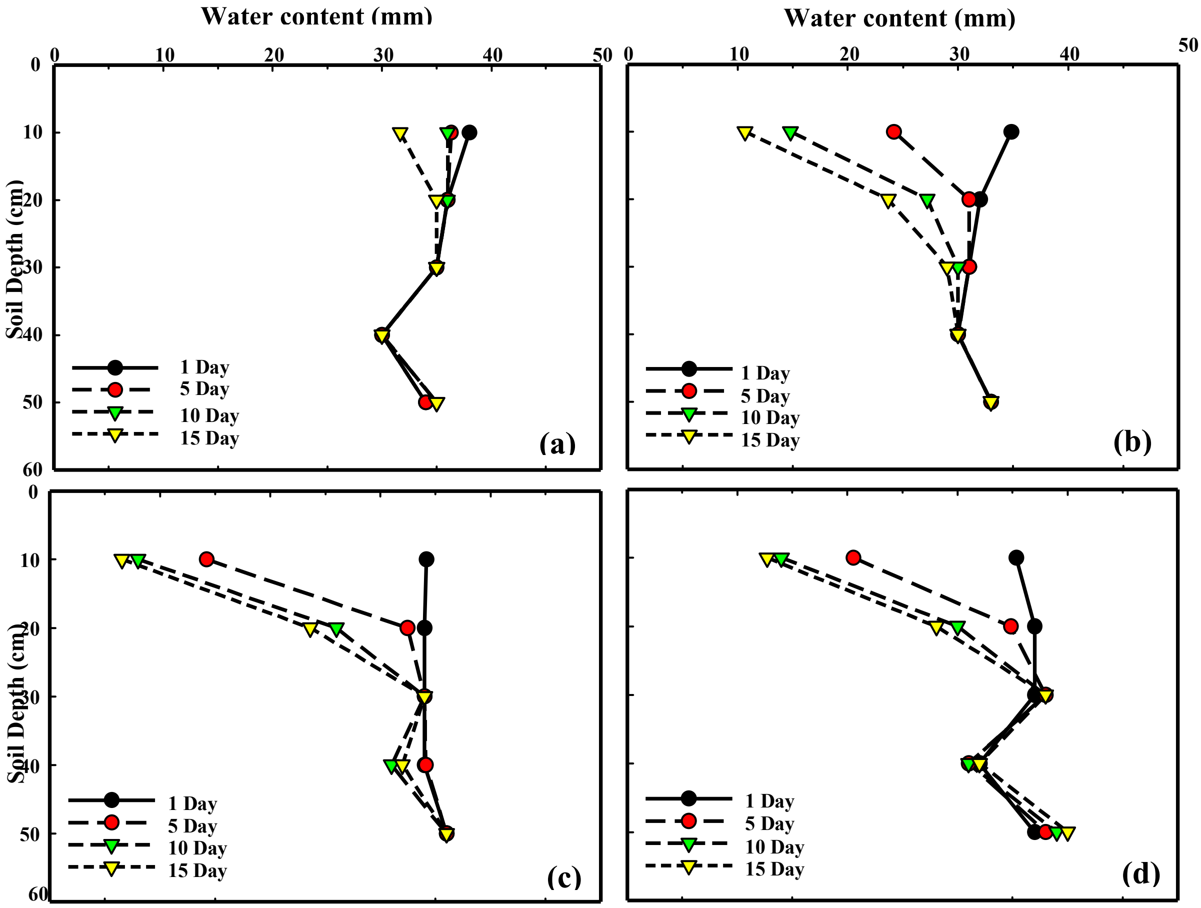

Figure 2. Soil water content of soil horizon after rainfall. (a) Open ditch (b) Vinyl barrier (c) Tile drainage (d) Tube bundle.

Table 2. **Comparison of various stress index factors in different drainage type.**

Type of Drainage	SEW_{30}^{A} (> 30mm/hr)	Average Water content (mm)	Duration time Excess Water (> 30mm/hr)	Decrease of ground water table (cm/hr)	SED_{30}^{B}
Open ditch	1,270	30.10	340	0.28	135
Vinyl barrier	165	20.03	52	1.37	125
Tile drainage	100	12.15	48	9.50	31
Tube bundle	114	12.60	51	7.37	100

$^{A}SEW_{30}$: Sum of Excess Water Depth, $^{b}SED_{30}$: Sum of Excess Water Day.

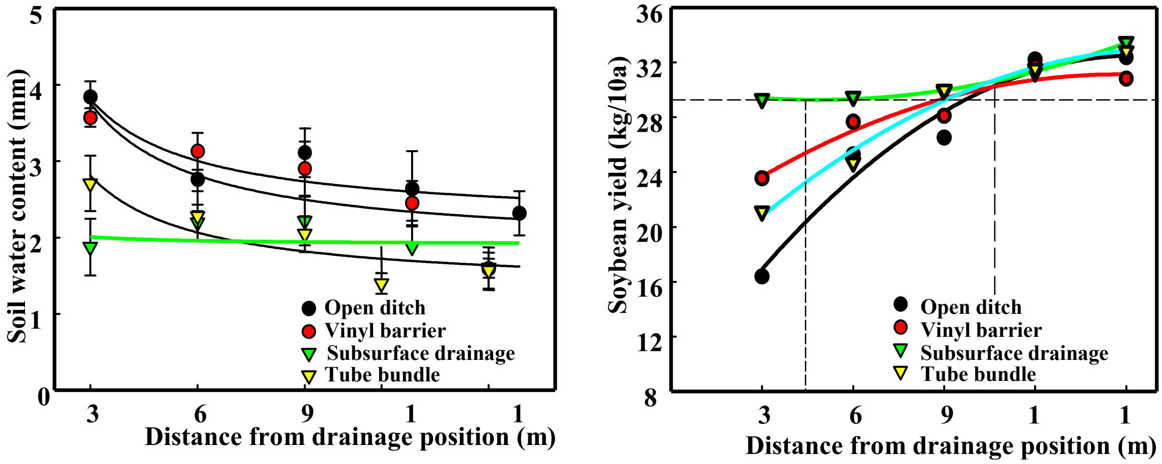

Figure 3. Comparison of soil moisture content and soybean yield at drainage installed position by drainage method.

Conclusion

The Infiltration rate showed high tendency to tile drainage method about 20.87 cm/hr than in open ditch method 0.15 cm/hr. The decrement of the moisture of the depth of the remaining water appeared the change of the soil moisture on tile drainage than a open ditch method greatly based on reach the maximum water holding capacity after rain fall according to the overdue days. Sum of excess water day (SWD_{30}) used to represent the moisture stress index was most low on the tile drainage 31 days compared with the open ditch 135 days. The tile drainage method drained the field faster as compared to the other drainage methods. Results also revealed that the subsurface drainage system can increase crop yield and the overall economic productivity of the soil. Yield of soybean at subsurface drainage treatment were higher than yield from the open ditch drainage. Soybean yield and soil water content is uniform distance from drainage position.

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