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The Effect of Evaporation Suppressant on Standing Water in the Ricefield and on the Growth and Yield Performance of Lowland Rice

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ABSTRACT

Effect of evaporation suppressant (ES) on lowland rice production was investigated in the field during wet season (WS) 2015 and dry season (DS) 2018. Treatments were control (no evaporation suppressant), 50% of recommended rate (RR) of evaporation suppressant and 100% RR for three replications. During WS, ES can suppress as much as 61% of evaporation with an average of 18.67% suppression for 100% RR. It is highly significant to apply during DS wherein it suppressed water evaporation by as much as 100% with an average suppression of 57.34%. Evaporation suppressant had no significant adverse effect on different rice plant growth parameters like plant height, phenological stages and yields. Treatment means for yields were not significantly different compared to the control. Application of evaporation suppressant can be economically feasible during DS and is not advisable during the WS where water is not limiting unless prolonged dry spell is forecasted or onset of rain is delayed. Although it can further save money and suppress evaporation (46.15% on the average) if applied at 50% of RR, a full use of 100% RR is still advisable due to its full spread on top of the water layer so long as wind disruption will not be a problem.

Keywords: evaporation suppressant, water saving technology, lowland rice production

INTRODUCTION

Bouman, *et al.* (2005) found that the average value of water productivity with respect to total water input was 2,500 li for every kg of paddy rice produced in Asia. According to IRRI (2007), the traditional way of growing irrigated rice used, on the average, about 3,000 li of water from land preparation up to harvest for every kg of paddy rice produced. After further studies, Bouman (2009) stated that on the average, rice production used about 1,400 li of water by evaporation and transpiration to produce 1 kg of paddy rice and more than half of water applied in rice fields was lost due to seepage and percolation. Hence better water management is needed (Bouman, *et al.,* 2007; Chapagain, 2009; Chen, 2005; Dawe, 2005). Researchers did not stop in improving technologies that would address this problem. A suite of water conservation technologies (Bouman, et al., 2007; Cabangon, et al., 2011) was developed to increase water productivity by reducing seepage and percolation flows as well as evaporation. An evaporation suppressant was used to reduce evaporation. The evaporation suppressant can be in the form of chemical surface films (Assouline, Narkis & Or, 2011) just like the evaporation suppressant developed by Peralta *et al.*(2016). These formulations may vary in form, either paste, slurry or solution and in the component/element present (PhilRice, 2001).

Baradas and Peralta (2003) estimated that by applying evaporation suppressant to rice fields, up to two (2) million liters of water ha^{-1} or 200 mm could be saved in 1 cropping season compared with the traditional practice of continuous flooding. It was estimated from the field trials of evaporation suppressant, that rice yields can be increased by as much as 22 cavan ha^{-1} whereas the use of evaporation suppressant is worth about 6-7 cavan ha^{-1} only. Aside from rice fields, evaporation suppressants can also be applied to small farm reservoirs (Kumawat, 2013), municipal water reservoirs, small water impounding projects (SWIP), and on aquaculture ponds. According to PhilRice (2001), the use of evaporation suppressants reduced evaporation by at least 50% without yield reduction.

The problem was the adoption of the evaporation suppressant technology by farmers. There was no published study on assessment of technology adoption for evaporation suppressant in the Philippines. Valdez (2018), a researcher and at the same time a farmer, stated that farmers might not be aware of the beneficial use of evaporation suppressant in rice field. Farmers might not be fully convinced of the safety and benefits of applying evaporation suppressant to their rice fields. Evaporation suppressant must be non-toxic to avoid adverse effect on living organisms – rice plants, fish, aquatic plants and other micro-organisms.

The evaporation suppressant consists of ampiphilic compounds derived from oils or fats (e.g. coconut oil or palm kernel oil or palm oil) that are only partially soluble in water (Peralta, 2016). The traditional chemical suppressants consisted of fatty alcohols that only stayed in the field for 3–4 days. The need to employ an evaporation suppressant that stays longer in the field, non-toxic and biodegradable was recognized. In addition, the evaporation suppressant should form a mechanically strong film on the water surface that is capable of self-healing if disrupted (PhilRice, 2001).

This paper presented an investigation into the reduction of evaporation rate upon application of the evaporation suppressant on the water surface in the rice field and the evaporation suppressant's effect on the growth and yield performance of lowland rice. Reduction in the amount of evaporation suppressant applied was further evaluated if it is possible to further save money.

METHODOLOGY

Duration and Location of the Study

The study was conducted during the wet season 2015 and the dry season 2018. It was established at Bulacan Agricultural State College, Pinaod, San Ildefonso, Bulacan. This is approximately located at 15° 44' N, 120° 31' E. The rice variety used was PSB Rc 18. The land was prepared using a hand tractor for primary and secondary tillage (Figure 1).

Experimental Design

There were three (3) treatments with three (3) replications: (a) T1 (control with no evaporation suppressant applied), T2 (50% of the recommended rate of evaporation suppressant) and T3 (full recommended rate of evaporation suppressant). Each plot size was about 30 m^2 (5m x 6 m) area with 20 cm by 20 cm hill distance of transplanted 15-day old seedlings. Plots were separated with bunds and spaced with a buffer zone 1 m in width with standing water to eliminate seepage between plots. This set-up was in completely randomized design (Figure 1) and designation for each plot was randomly done. Border plants served as replacement for plants that did not survive after transplanting. Missing hills were replanted 7 days after transplanting.

Complete fertilizer was basally applied at a rate of 40 kg ha^{-1} and urea at 40 kg ha^{-1} at mid-tillering (30-35 days after sowing-DAS) and panicle initiation (45-50 DAS) stages. Occasional manual weeding was done to keep the field clean. Occasional sprayings of insecticide were done if insect pests were observed.

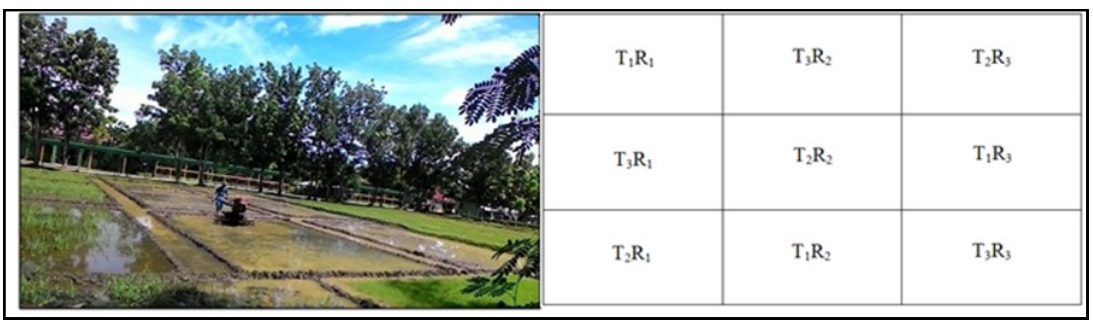

Figure 1. Land preparation and random assignments of plots.

Irrigation water was delivered to the plots with the use of a water pump at a depth of 5 cm. Field water tubes made of perforated polyvinyl chloride (PVC) pipes, 15 cm in length were installed at a depth of 5 cm in strategic locations in every plot. The water level in the tube was measured from the top to the level of the water inside the tube. Irrigation of every plot was done when the level of water reached ground level. Applications of evaporation suppressant were done with standing water at critical stages of rice production, i.e., 1 week before panicle initiation, 1 week before and after flowering, and at grain filling stages (Bouman, Lampayan and Toung, 2007). The evaporation suppressant, developed and concocted by Peralta, *et al.* from the Institute of Chemistry of University of the Philippines Los Baños in 2016, was applied by pouring the emulsion to the plot with a dosage of 2 mL per plot.

Data Collection

Daily evaporation

Daily evaporation (mm day^{-1}) in every plot was measured using the installed field water tubes for all the treatments. Perforated PVC pipes, open at both ends, were attached with measuring tapes and used as the stilling well (Figure 2). A styrofoam material with pointer served as measuring device to determine the evaporation rate.

Weather Data

Daily evaporation and rainfall data were collected from nearby weather station of Bureau of Soil and Water Resources during the time of set-up.

Crop Phenology

Plant heights at mid-tillering (30 DAT) and at panicle initiation stages were measured from the ground level up to the tip of the plant when upright. The date of panicle initiation was also recorded.

Yield components

Ten (10) hill samples were collected and processed at the laboratory. According to IRRI-Dobermann (2018) components of yield can provide information that make up the final yield which is expressed as:

Yield = no. of panicles per m^2 x no. of filled grains per panicle x average weight of a grain

Equation 1

Grain yield was taken from a 2x3 m^2 crop cut from the center of the plot. The weight was converted to ton ha^{-1} at 14%MC.

Statistical Analysis

The growth performance, yield and yield components were then compared to the potential performance of the rice variety according to the recorded data from PhilRice. This was done to evaluate properly if the growth performance and yield of rice with treatment of evaporation-suppressant were affected by such treatments. Analyses of variance (ANOVA) for completely randomized design were computed and the least significant difference (LSD) at 1% and 5% level of significance were used to compare treatment means.

Economic analysis

The economic analysis was conducted after the experiment using benefit-cost ratio to compare the cost of the water saved and the price of the evaporation-suppressant being used.

RESULTS AND DISCUSSION

Weather Data

Average rainfall during WS was 12.32 mm while evaporation was 5.55 mm (Figure 3). During DS,

Figure 2. Measurement of evaporation using the stilling well and a floater with pointer.

the average rainfall was 7.07 mm and evaporation was 5.45 mm. It can be noted that rainfall was experienced after panicle initiation and this was the case because of early onset of rainfall for DS (BSWM, 2018).

Effects on Evaporation

Treatments have significantly reduced evaporation. T3 (100%RR) had the lowest total evaporation of 59.70 mm from WS and 164.00 mm from DS (Figure 4). The data indicate that the application of evaporation suppressant was not highly effective during WS; thus, as expected, variance of data was not significant due to frequent rainfall. Application of evaporation suppressant at full recommendation during DS significantly reduced water evaporation from the plots. During WS, T2 (50%RR) had a higher percentage of water evaporated compared with no evaporation suppressant (T1; control). This indicates that during rainy season, application of less than the recommended rate renders the evaporation suppressant ineffective and it is as if no evaporation suppressant is applied at all.

The recommended rate is meant to ensure that the continuous film covering the water surface can be regenerated in case of disruption by wind, overflowing water or by losses due to seepage, percolation or microbial action. During the wet season, the additional water that the field receives as rain may significantly disrupt the barrier film because of significant surface -water run-off.

During WS, reduction of water evaporated compared with the control resulted to an average of 18.67% with recorded suppression as high as 61% for full recommendation of rate (RR) of application of evaporation suppressant. For 50% of RR, it averaged 7.33% with suppression as high as 24% (Table 1). During DS, 100%RR on the average suppressed evaporation by 57.34% with highest evaporation suppression of 100%. On the other hand, 50% of RR reduced evaporation by 46.15% on the average. These data mean that evaporation suppressant is effective in suppressing water evaporation at both treatment levels.

The actual evaporation rate for both wet and dry seasons is shown in Figure 5. T1 = control is shown as a dashed blue line. The red solid line is for T2 = 50% of RR while the green solid line is for T3 = Full RR. It can be noticed that most of the observed evaporation rates of T3 are below the actual evaporation rate based on the control which means that the evaporation process was suppressed. This also shows that Full RR is better than 50% RR.

Roberts (1958) stated that 33% of the evaporation will be reduced if evaporation suppressant is applied while Dressler (1958) believed that 40% of water can be

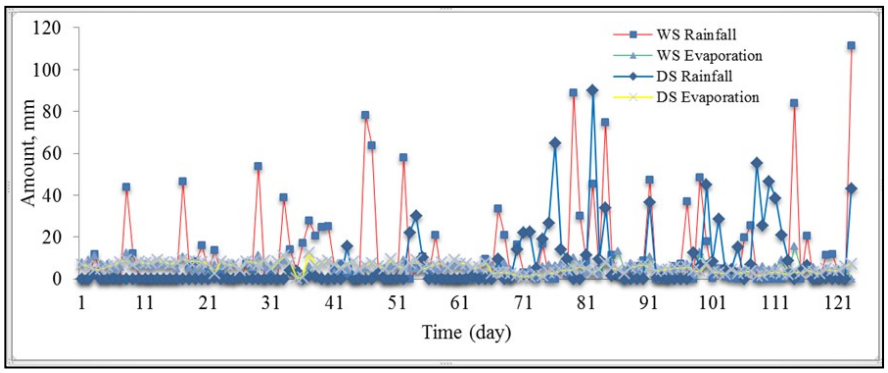

Figure 3. Observed daily evaporation (mm) and rainfall (mm) during rice production.

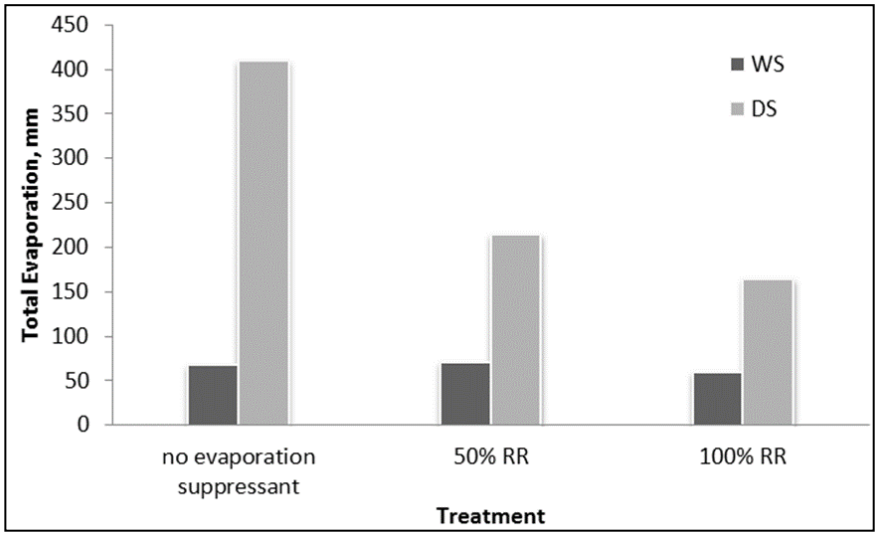

Figure 4. Total average water evaporated per treatment during WS and DS.

saved using evaporation suppressant. However, 20-60% water savings was reported by Prime, et al. (2012) for the study done in the field although for WS it was way below the expected range. The reason could be that evaporation during that time was very low It would reinforce what is expected that during WS, there's no need for evaporation suppressant since there is abundant water supply and rice production would not be water-stressed unless prolonged dry spell is forecast or onset of rain is delayed.

Yield and Growth Performance

The yield of lowland rice from DS 2018 is shown in Table 2. It can be noted that the yield taken from the 2x3 m^2 crop cut was way too low. According to IRRI (2018), the yield components can be used in computing yield to better represent the plot. Yield components (average 1000-grain weight, number of filled grains in a panicle and number of panicles in a square meter) were considered for DS yield. T_3 (100%RR) exhibited the highest yield of 4.72 ton ha^{-1} although variance from other treatments was not significant.

Comparing the yields for the two cropping seasons, T_2 (50%RR) had a higher yield during WS but again variance was not significant (Figure 6). On the average, T_3 (100%RR) had the highest average yield of 4.39 ton ha^{-1} although this was lower than the potential yield of PSB Rc18 of 5.1 ton ha^{-1} (PhilRice, 2011; Escasinas and Zamora, 2011). During DS, application of evaporation suppressant might enhance the environmental conditions around the rice plant since according to PhilRice (2001), evaporation lowers the surrounding temperature up to 2-3° C. It was observed that some plots had bacterial leaf blight (BLB) hence this resulted to lower yield compared with the potential yield. According to PhilRice (2011), PSB Rc18 is susceptible to BLB which can cause wilting of seedlings and yellowing and drying of leaves (Sparks, Castilla and Cruz, 2014). This can severely damage the rice plant that it will sometimes end in massive destruction since photosynthesis and other metabolic processes will not continue if left untreated. But

Table 1. Percentage (%) reduction of evaporation observed during the study.

OBSERVA-TION	WET SEASON		DRY SEASON	
	50% RR	100% RR	50% RR	100% RR
1	0	13	61.54	84.62
2	0	24	16.67	25.00
3	0	14	100.00	100.00
4	24	35	22.73	27.27
5	7	15	0.00	0.00
6	13	6	61.11	66.67
7	22	61	53.57	75.00
8	0	0	50.00	78.57
9	0	0	63.33	83.33
10			48.15	92.59
11			50.00	50.00
12			23.08	38.46
13			40.00	60.00
14			68.00	80.00
15			36.84	57.89
16			62.50	50.00
17			36.00	40.00
18			33.33	0.00
19			50.00	80.00
Average, %	**7.33**	**18.67**	**46.15**	**57.34**

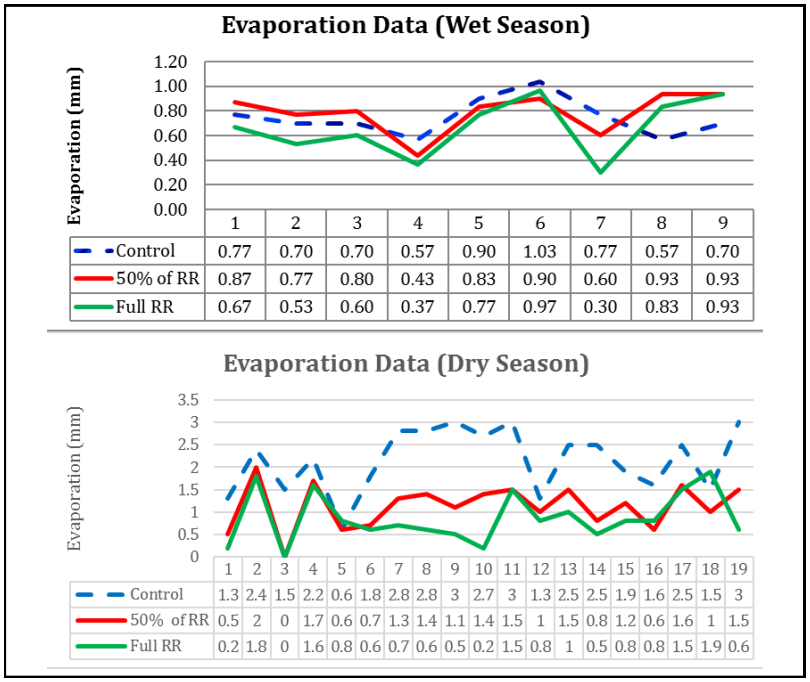

Figure 5. Actual evaporation against number of readings for WS and DS taken during the entire cropping period on days without rainfall intervention.

for this study, the plants were able to recover. A similar result was observed in the study of Baradas and Peralta (1999) where rainfed varieties such as IR55 and PSB Rc-10 were able to recover despite black bug and tungro infestations but with a reduced yield also.

On the average, T_3 (100% RR) underwent panicle initiation earlier than the others (Table 3) although it was not significantly different from other treatments. The treatment means for other parameters like plant height at mid-tillering, panicle initiation and at maturity, did not show significant differences. This means that the application of evaporation suppressant did not seem to have an adverse effect on the growth of PSB Rc18 at any stage. Baradas and Peralta (1999) reported an observed increase in rice yield in almost all of the technological demonstration sites of the different rainfed rice varieties without disease infestation, bringing the observed yields close to the yield levels of irrigated rice. The evaporation suppressant tested suppressed only the water evaporation without any adverse effect on the performance of the rice plant, not only because the evaporation suppressant is environmentally friendly and biodegradable, but also because water stress was alleviated with its use.

Economic Analysis

If the price of water saved (cost of pumping) and the cost of evaporation suppressant are taken into account , it would be ineffective to apply 50% of RR during WS since it will just behave like the control. Assuming an engine that have a discharge capacity of 32.9 li s^{-1}, with fuel consumption of 2.57 li h^{-1} and price of fuel of PhP 53.00 li^{-1}, Table 4 shows the water saved by pumping. Evaporation suppressant is assumed to be applied at the critical periods only of rice production. The estimated price of the evaporation suppressant is PhP 300 li^{-1} (Peralta, 2018).

During WS, even if it will suppress evaporation, application of evaporation suppressant at full recommend-ation would still incur PhP 0.06 loss for every peso invested in evaporation suppressant. However, during DS, application of evaporation suppressant at 50% of RR would have higher benefit-cost ratio of 3.11 while at full recommendation rate it would yield PhP1.96 for every peso invested on evaporation suppressant. But 100% of RR is still recommendable as it covers the entire layer resulting to more reliable suppression. Data showed that water saved was not that high enough in

Table 2. Yield and yield components during DS.

TREAT-MENT	AVERAGE 1000-GRAIN WEIGHT, g	NO. OF FILLED GRAINS PANICLE^{-1}	NO. OF PANI-CLE m^{-2}	YIELD (ton ha^{-1}) from YC	YIELD (ton ha^{-1}) from Crop Cut
CON-TROL	26.66	52	218	3.59	1.02
50% RR	26.35	55	301	4.36	1.39
100% RR	27.57	59	282	4.72	1.19

All treatment means are not significantly different at 1% and 5%.

Table 3. Growth performance of PSB Rc18 during DS.

TREAT-MENT	NO. OF DAYS FOR PANICLE INITIATION	PLANT HEIGHT AT 30 DAT (cm)	PLANT HEIGHT AT 60 DAT (cm)	PLANT HEIGHT AT MATURITY (cm)
CONTROL	70.00	55.37	100.30	118.27
50% RR	70.00	55.90	98.80	125.07
100% RR	69.33	55.13	99.40	128.93

All treatment means are not significantly different at 1% and 5% levels.

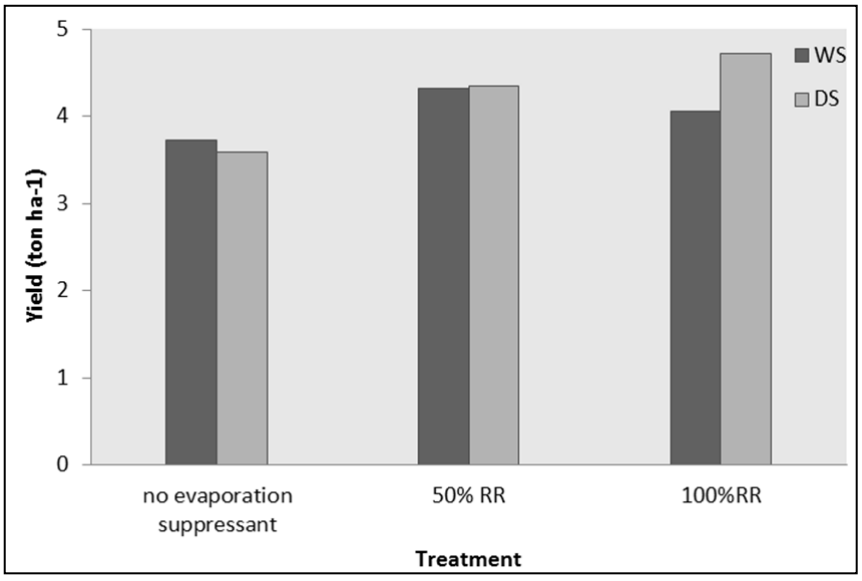

Figure 6. Yield of PSB Rc18 for WS and DS.

the field set-up that it could compensate the amount to pay for the cost of evaporation-suppressant, however, if we are dealing with hundreds of hectares of land with scenarios of expected drought or prolonged dry spells, it will be worth taking the risk of spending for evaporation suppressants than gamble on losing a huge part of the harvest if water shortage occurs.

Table 4. Economic feasibility of evaporation application in rice fields ha^{-1}.

TREAT-MENT	WET SEASON			DRY SEASON		
	Water Saved (m³)	Price of Saved Water (PhP)	Cost of Pumping (PhP)	Water Saved (m³)	Price of Saved Wa-ter (PhP)	Cost of Pump-ing (PhP)
CONTROL	0	0	0	0	0	0
50% RR	0	0	720	1,950	2,242.57	720
100% RR	74	85.10	1,440	2,450	2,817.58	1,440

CONCLUSIONS

Evaporation suppressant was effective in suppressing evaporation in rice production. It is highly significant to apply this during DS wherein it can suppress water evaporation by as much as 100% with an average suppression of 57.34%. Although the use of evaporation suppressant is a chemical intervention, it is made from biodegradable and environment friendly components and no significant adverse effects were observed on different rice plant growth parameters (height at different stages, yield and yield components). Treatment means for yields were also not affected significantly with the application of evaporation suppressant. Evaporation suppressant is not detrimental to rice plants, hence it can be applied during DS to alleviate water stress. Application is economically feasible only during DS and is not advisable during the WS where water is not limiting unless a prolonged dry spell is forecasted or the onset of rain is delayed. Although it can further save money and suppress evaporation (46.15% on the average) if applied at 50% of RR, full use of 100% RR is still advisable due to its full spread on the topmost layer of water as long as wind factor will not take effect.

RECOMMENDATION

Evaporation suppressant is advised to be applied during dry season especially if there is an expectation of weather anomaly like the El Niño phenomenon. This is to reduce water evaporation and save water to sustain rice production during that time. Also, further studies are recommended to further investigate the effect of evaporation suppressant on rice production yields. Its effect on tissues of the rice plant and the residues on soil can be studied. Simultaneous field and laboratory set-ups with the same rice variety during wet and dry seasons for 2 continuous years should be conducted to further evaluate its effect on rice production.

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