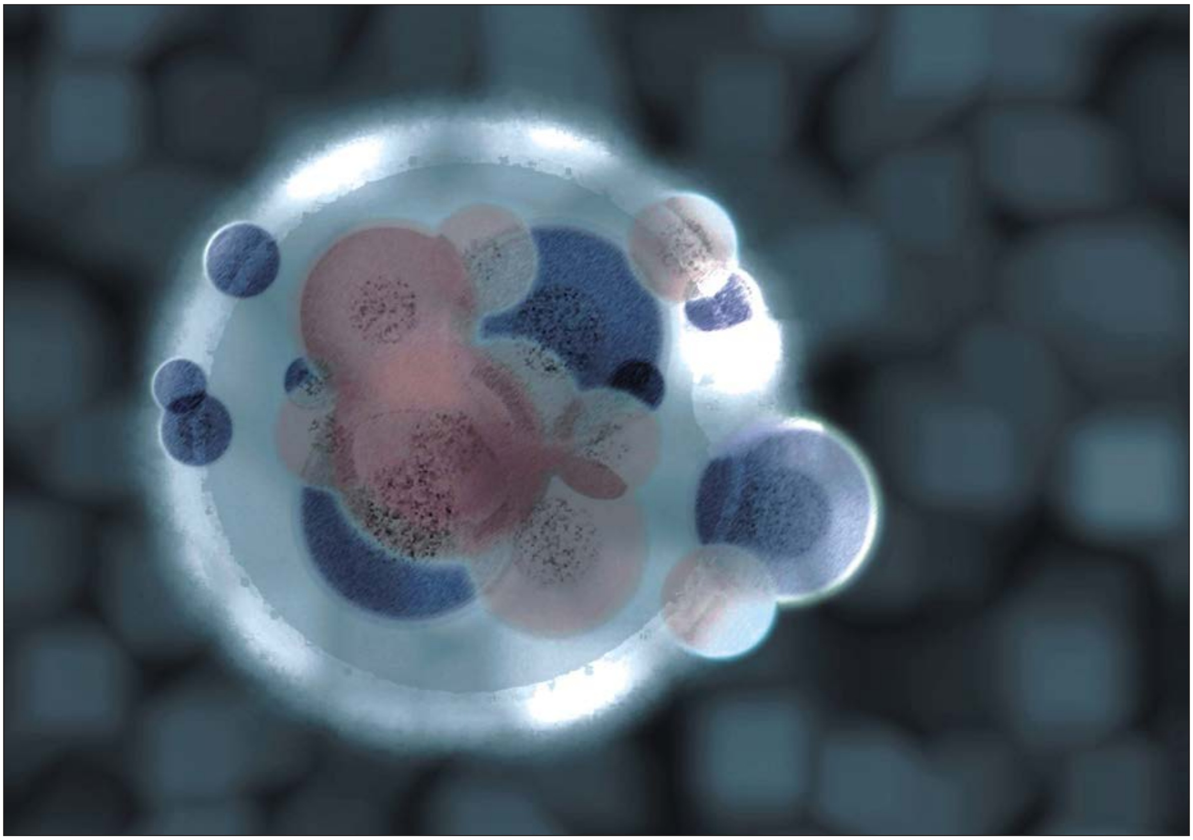

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Management of Cracking Puddled Soils and its Impact on Infiltration

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Abstract: A study of cracking soils management was conducted in the wet soil bin with nine soil management practice treatments to investigate their impact on infiltration rate. The treatments were arranged in a randomized complete block design (RCB) with three replications. It is observed that the management of cracking soils, even at an early stage of crack initiation, has a great influence on infiltration rate. Among the management practices, the hand hoe operation was found to be better than trampling to reduce the cracks when the crack width was 10 mm. It is also observed that there is no influence of crack number on infiltration if a soil management practice is included with irrigation. The study reveals that with a soil management practice, the cracks reduced or were removed in a short period of time even though the cracks were 10 mm wide. In contrast, without soil management, cracks remained open for a long period even after ponding. By practicing soil management during irrigation, a large volume of water can be saved which my help to bring more area under irrigation particularly where there are limited water resources.

Key words: Puddled soil, crack, soil management, infiltration, water saving

INTRODUCTION

Puddling is considered to be a pre-requisite for successful rice production as its strong influence on percolation losses and enhancing characteristics of water use efficiency (Sanchez, 1973). After puddling, intermittent irrigation is recommended for rice production due to its higher water use efficiency rather than continuous submergence (Hukkeri and Sharma, 1980; Islam and Ghani, 1990). Puddled soils often crack when they dry and these cracks are a major problem for intermittent irrigation practices if the cracks which form at the surface soil due to partial drying of a field are connected with those of the subsoil and the water in the paddy field is drained through these continuous cracks (Luthin, 1982). As a result, a large portion of the water added on the soil surface flows through the cracks (Pandy and Pandy, 1992). Therefore, water management on puddled soils is a great problem to the rice farmers. Consequently, Asian farmers prefer continuous ponding to avoid a cracking hazard as well as weed control in the rice field. But limitation of water resources is a serious problem to this approach. On account of that, a vast area remains fallow whereas in some areas a large volume of water is used as ponding due to lack of knowledge and proper management practices.

Shrinkage cracks that develop as a result of drying have a strong influence on infiltration rate. After swelling, infiltration/percolation decreases drastically but dose not stop as some pores remain open and conduct water slowly (Waller and Wallender, 1991). Wet cultivation causes rearrangement of soil particles or domains (Waller and Wallender, 1993). Therefore, intercultural operation during irrigation, such as re-working of the soil may be an important and successful mechanism to reduce cracks in a puddled soil. At present, there are few studies on this aspect. Therefore, this study was conducted to find a suitable soil management or cultivation practices during irrigation for minimizing bypass flow and percolation loss by reducing cracks and increasing the swelling up of the existing cracks. The aim of this experiment is to determine a suitable (easy and low cost) soil management technique to prevent water losses in a cracking soil.

MATERIALS AND METHODS

The study was conducted in the wet soil bin with the following soil management practices treatments:

T_1 = Continuous ponding (about 50 mm height).
T_2 = Irrigation at the crack initiation stage without soil management.
T_3 = Irrigation at the crack initiation stage and re-working of the surface by hand.
T_4 = Irrigation when crack width reach at 5 mm, without any soil management.
T_5 = Irrigation at 5 mm crack width and trampling to reduce the cracks.
T_6 = Irrigation at 5 mm crack width and re-working of the soil by a hand hoe.

T_7 = Irrigation at 10 mm crack width without any soil management.
T_8 = Irrigation at 10 mm crack and trampling to reduce the cracks.
T_9 = Irrigation at 10 mm crack width and re-working of the soil with a hand hoe.
(Maximum crack width was considered for the respective treatment)

The treatments were arranged in a Randomized Complete Block Design (RCBD) with three replications. Due to a shortage of enough space inside the soil bin, only one replication at a time with nine treatments was carried out for a period of 20 days. After the completion of one replication, the soil of each plot was puddled again and another replication started with a new randomization. The clay loam soil was selected for this study because of its quick response of cracking behavior to moisture tension. Accordingly, the clay loam soil was collected from the field and set on the plots. After wetting and puddling, a uniform 150 mm puddled layer was provided on each plot. After that, the plots except T_1 were allowed to dry until the predetermined crack width appeared on the plots as per treatments.

In treatment T_1 (control), the required amount of water was applied after puddling to a height of 50 mm. The reduction in the rate of water level was measured every day. A scale attached on the benchmark trolley was used for this purpose and water was added if necessary to maintain a continuous ponding of 50 mm height. Tensiometer readings on the other plots were taken every day around nine am. Soil management treatments were carried out immediately after the crack width reached the pre-determined level for each plot. In treatments T_6 and T_9, a simple hand hoe was used to re-work the soil. To determine the percolation rates, the plots were ponded to about 50 mm heights immediately after soil management. After 1 h and 3 h of ponding the water level was measured from the benchmark trolley. Subsequently the readings of water height were taken with an interval of 24 h and it was continued for five days. Evaporation and temperature in the bin area was recorded from a pan and a maximum/minimum thermometer.

RESULTS AND DISCUSSION

Infiltration rate after soil management: The infiltration rates of different treatments at the 1, 3, 24, 48, 72 and 96 h of ponding are presented in Fig. 1. It is observed from the figure that the infiltration rate of the treatment T_1 changed rapidly and became close to constant after 24 h of ponding. But in T_2, infiltration rate changed very slowly after ponding the plot. In treatment T_3, the rate of infiltration rapidly reduced in 24 h and it was lower than T_2 due to the influence of soil management.

In general, the rates of infiltration were higher in T_4 than T_5 and T_6 when their cracks width was at 5 mm. The initial infiltration rate of T_4 was very high and it slowly reduced, even though the rates of 24 h and onward was higher than T_5 and T_6 due to the lack of soil management. On the other hand, the initial infiltration rate was almost the same in T_5 and T_6 and it slowly reduced. But in T_6 the rate of infiltration was almost constant at 24 h of ponding, which indicates that the hand hoe operation is more effective in reducing the cracks compared to trampling. At the stage of 10 mm crack width, the initial infiltration rate

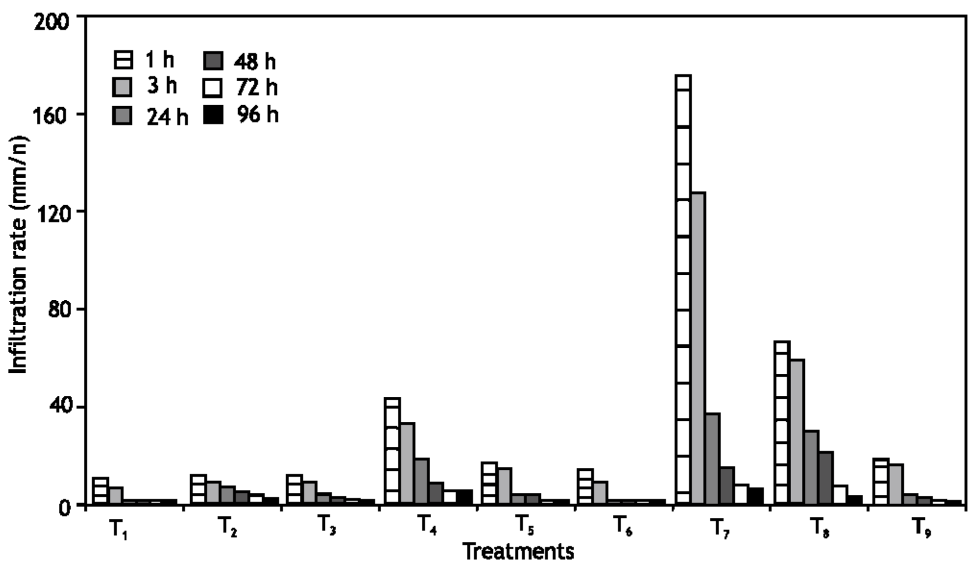

Fig. 1: Pattern of infiltration after watering

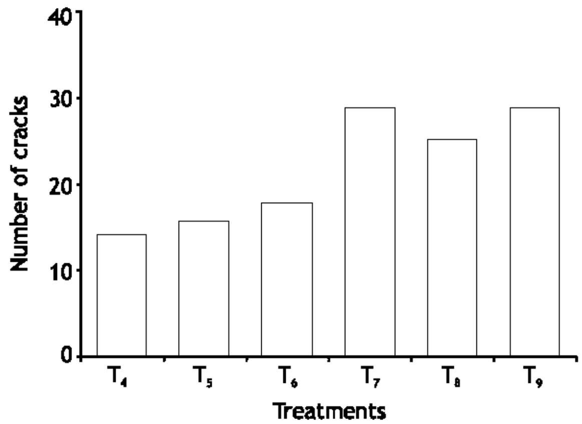

Fig. 2: Number of cracks at watering

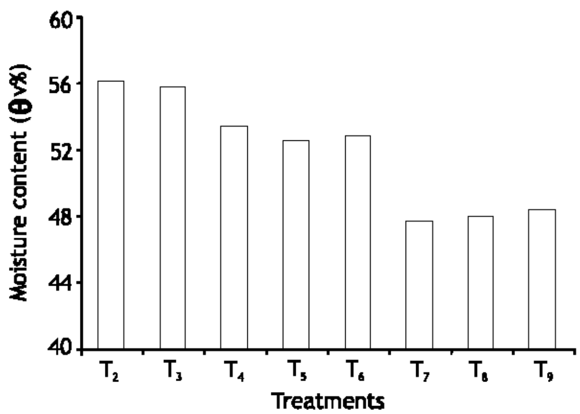

Fig. 3: Moisture content at management level

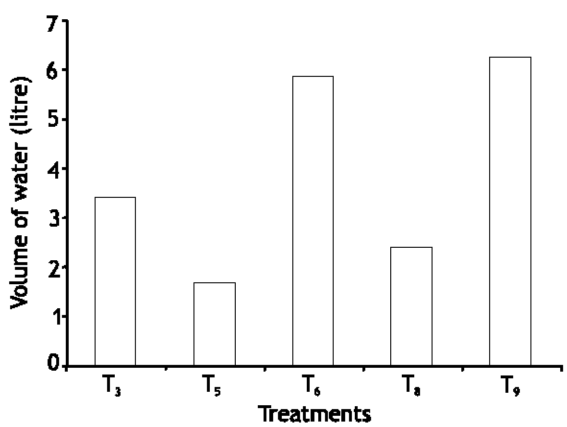

Fig. 4: Pattern of infiltration after soil management

of T_7 was extremely high because of bypass flow due to lack of soil management practices. From the statistical analysis it is found that the infiltration rates after different ponding period are highly significant at the 1% level of probability. Least significant different (LSD) test results indicate that the treatments T_4, T_7 and T_8 differ significantly from the control. This means except T_4, T_7 and T_8 other treatments can be used without significant water losses to infiltration.

The study indicates that, any soil management practices either trampling or hand hoe can be effective in reducing irrigation losses when the crack width is 5 mm. The crack width before irrigation may be allowed to develop to 10 mm if the hand hoe is used to re-work the soil. This finding also reveals that the 5 mm crack width may be the critical stage for irrigation if appropriate soil management techniques are not included with irrigation. For instance, trampling is not suitable at 10 mm crack width because, the trampling may only close the surface or upper portion of the cracks. Consequently, after watering, it needs a longer time to close the whole depth of cracks. On the other hand, soil management with the hand hoe may easily close the crack by remoulding the soil. As a result, there is no significant difference in infiltration losses between treatments T_9 and T_1. Therefore, the study indicates that soil management during irrigation has a great influence on infiltration rate.

Number of cracks on the plots during soil management: An average higher number of cracks were found in T_7, T_8 and T_9 as longer drying period than other treatments. It is observed that the average number of cracks was higher in T_6 than T_4 while crack width was 5 mm, but the irrigation including soil management with hand hoe could help to reduce the cracks, which is reflected through the non significant difference of both (T_5 and T_6) treatments with the control. Similar results were also found in treatments T_7 and T_9. Therefore, the study indicates that, there is no influence of crack number on infiltration if a soil management technique is included with irrigation (Fig. 2).

Moisture content: It can be seen from the graph that the average maximum soil moisture content (Ev) was 48% in the crack initiation period of the treatments T_2 and T_3 followed by about 43% at 5 mm crack width of the treatments T_4, T_5 and T_6. The lowest average moisture content was about 39% at 10 mm crack width of the treatments T_7, T_8 and T_9. The difference of soil moisture content between T_2 and T_9 was about 9% during the soil management period. With this variation of moisture content of these treatments, there was no significant difference of infiltration rate due to the impact of an appropriate soil management practice in T_9 (Fig. 3).

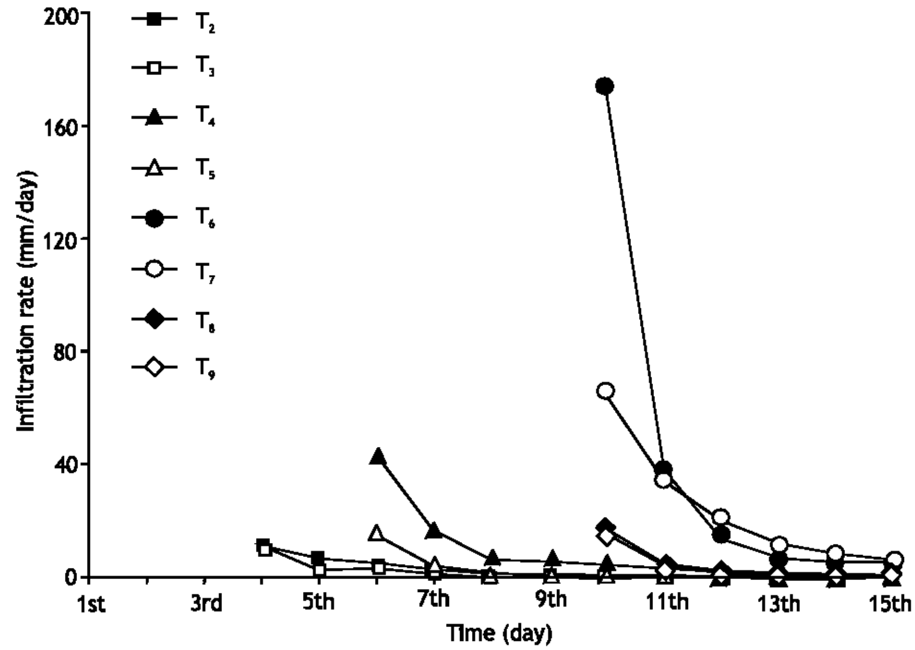

Fig. 5: Time required for different management practices

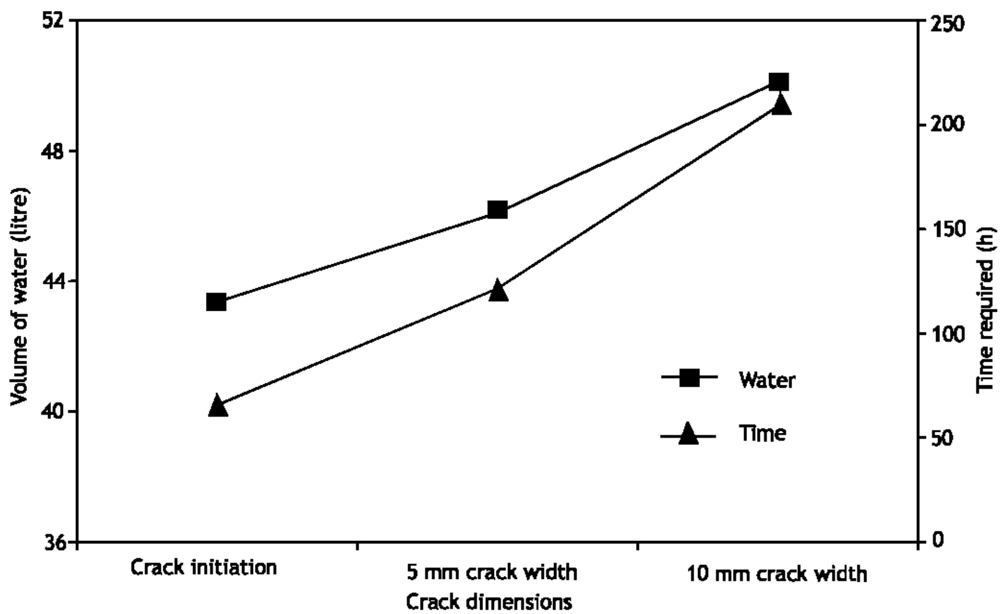

Fig. 6: Extra volume of water and time needed to reach different crack width

Swelling/closing up time of macro pores: It is observed from the graph that the infiltration rate of soil management treatments (T_3, T_5, T_6 and T_9) becomes almost constant after two-three days of ponding. On the other hand, infiltration rate without soil management (T_2, T_4 and T_7) were always higher than soil management treatments. Without soil management the infiltration rate sharply reduced up to 24 h of ponding then it slowly reduced. Treatments T_7 and T_8 required a longer time to reduce their infiltration rate in comparison to the other treatments. The study reveals that with soil management, the cracks in paddy reduced or disappeared within a short period of time even they are 10 mm wide. In contrast, without soil management, cracks were not closed (T_4 and T_7) after a longer period of ponding. This means without soil management, most irrigation water will be lost through cracks. A higher infiltration rate was also found with the management treatment T_8 (trampling) than T_9 (re-working with hand hoe) (Fig. 4). Therefore, this study also indicates that, appropriate soil management practice is necessary for a particular crack width of puddled soil.

Time requirement for different soils management: From the Fig. 5 that the time required for the trampling (T_5 and T_8) was less than the hand hoe operation (T_6 and T_9). In comparison, the time required for the management of 10 mm cracks was higher than for 5 mm cracks due to the hardness of soil. In fact, trampling is not suitable if the crack size is greater than 5 mm on this soil. Soil re-working by hand in treatment T_3 required about 50% less time than the hand hoe operation (in T_6 and T_9), because of its high soil moisture content (48%). As a result, the soil was soft and easily worked. This finding indicates that, if the hand hoe type implements are used to re-work the soil during irrigation, then 5 mm of crack width may be considered for the irrigation interval. This study reveals that by considering crack width and its related soil moisture content, the most economic rice irrigation scheduling with limited water can be determined.

Amount of extra water required for maintaining continuous ponding: The amount of water applied at different times after initial submergence to treatment T_1 to maintain its continuous ponding height of 50 mm are presented in Fig. 6. At the beginning of the experiment, a large amount of water (55-60 liters) was applied in treatment T_1 to reach 50 mm height and this height was maintained throughout the study period. It is observed from the figure that an extra amount of 43 liters of water was applied to T_1 while the crack initiated at the plots of T_2 and T_3 as drying. Similarly, 46 liters of water was applied to T_1 when the crack reached 5 mm widths in the plots of T_4, T_5 and T_6. Finally, it needed an extra amount of 50 liters of water when the crack width reached 10 mm in the plots of T_7, T_8 and T_9. This means T_1 required 43 liter of extra water over the other treatments while the crack initiated on those plots. Similarly, 46 and 50 liters of extra water were needed for T_1 when the crack width reached 5 mm and 10 mm on other treatments plots, respectively. The moisture content at the crack initiation and 5 mm width stages were above the field capacity and 10 mm stage it was below but close to field capacity. Moreover 48% moisture content (crack initiation) was close to saturation moisture level of that soil.

From the different findings of rice irrigation (Hukkeri and Sharma, 1980) it is observed that the rice can be produced without significant yield losses by maintaining the intermittent irrigation rather than ponding. Therefore, on the basis of soil moisture content of different cracking stages of this study, it can be concluded that continuous ponding is not necessary for rice production if water is applied at a pre-determined crack width by considering moisture content.

Time required reaching different crack widths of puddled soils: From the Fig. 6 it is seen that cracks initiated after the 66 h of drying in T_2 and T_3 plots, while the cumulative evaporation of this period was 3 mm and soil moisture remained close to the saturation level. Consequently, there is no need for irrigation at this stage. It is also found that the crack width reached 5 mm after 120 h (five days) of drying, when the soil moisture of this experiment was above the field capacity. An average cumulative evaporation of this period was about 5 mm. Therefore, with the above conditions an irrigation scheduling of 5 days interval may be economic with low cost trampling type of soil management as it take less time than hand hoe operation. The study also reveals that the 10 mm crack width reached at 210 h (nine days) of drying while the average cumulative evaporation was at 8 mm. Therefore, under these situations more than 5 days irrigation intervals by considering evaporation demand and soil moisture for rice production may be applicable if a suitable soil management technique is included with irrigation.

The cracks on puddled soils become irreversible even after a short period of drying. Therefore, the soil management practice is very important to prevent water losses of cracking puddled soils. Soil management even at an early stage of cracking (at crack initiation) has a great influence on infiltration rate. It is observed that any soil management practices like trampling or hand hoeing is equally applicable to reduce the infiltration by removing cracks while the soil is at the 5 mm crack width stage. Among the management practices, the hand hoe operation is better than trampling to reduce the cracks even at 10 mm crack width.

Therefore, an irrigation schedule by considering 5 mm crack width while it occurs at the 5th day of drying with a cumulative evaporation of 5 mm may be economic with low cost trampling type of soil management. Moreover, the soil moisture remained above the field capacity at this stage. Similarly, 10 mm crack width was reached at the 9th day of drying with a cumulative evaporation of 8 mm and the soil still remained close to field capacity. Therefore, under such a condition an irrigation interval more than 5 days for rice production with limited water resource may be considered if a suitable soil management practices are included with irrigation. By practicing the soil management techniques on cracking puddled soils, a large volume of water can be saved, which may help to bring more area under irrigation especially in the area of limited water resource.

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