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# Effectiveness of Irrigation Methods and Time of Providing Water in Maintaining Soil Classification for Increasing Soybean Production

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**ABSTRACT**

This study aimed to get the best irrigation method and determine the best time-effective provision of water to maintain optimum soil moisture for increase soybean crop production. This research was conducted in the field in Maros District, South Sulawesi. The experiment used a split-plot design and was repeated three times. The main plot was an irrigation method, namely the Scatter irrigation, Furrow, and Flood irrigations method, and its plot was the time of irrigation, namely every 15 days of age, at the period of 15 days, and full flowering and irrigation every 10 days. The results showed that the watering technique using the waterlogging method at the time at the age of 15 days and full flowering had the potential to increase the yield production of soybean, that was the number of pods 164.95 pieces, the weight of seeds 37.11 g, and production 4.64 t/ha. The inundation method was more effective in maintaining soil moisture and twice the application time. But in an optimal amount (229 l/time) was very effective in maintaining soil moisture.

## INTRODUCTION

One way to increase soybean production is an increase in a harvested area which can be achieved by extensification to dry land areas which are very extensive in Indonesia. This can be achieved if water management in the land can be implemented optimally. Optimal plant growth and yields can be reached by providing sufficient water. A water management system is needed to support the cultivation system on crops such as soybean plants.

The characteristics of plants, the supplied water, the irrigation methods, and the soil characteristics related to water are significant factors to provide sufficient water for crops. In addition, the local agro-ecological conditions such as soil types, availability of water, and climate can also influence the adequate water to the crops. The missing information on water needs in the tropic causes water use and irrigation (da Silva et al., 2019).

Another thing that needs to be considered in water management is the climate change issue which will cause many economic challenges and social impacts in agriculture (TerAvest, Carpenter-Boggs, Thierfelder, & Reganold, 2015; Vanneuville et al., 2012). However the increased rainfall as a part of climate change can provide some local benefits, there will also be several adverse effects, including reduced water availability and other extreme weather conditions (Arnell, van Vuuren, & Isaac, 2011; Gosling & Arnell, 2016; Mancosu, Snyder, Kyriakakis, & Spano, 2015; Ummenhofer, Meehl, & Ummenhofer, 2017). This is supported by

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Muhumed, Jusop, Sung, Wahab, & Panhwar (2014) that regulating the water supply and managing water availability can increase soybean productivity.

Changes in water resources for agriculture have three consequences. First, the increased water demand is caused by increased crop evapotranspiration due to rising temperatures. The second is increasing water shortages in summer, growing demand for water for irrigation. The third is decreasing water quality due to increasing water temperatures and lower runoff rates in some areas (Iglesias & Garrote, 2015).

Water efficiency, economic benefits, and reduced environmental burdens can be obtained through innovative irrigation practices. Agricultural extension workers and farmers need to provide adequate knowledge of irrigation practices to adapt and implement appropriate solutions (Levidow et al., 2014). Autonomous and planned adaptation strategies by farmers, such as adjusting planting dates to manage crop growth calendars and soil moisture, improved the use of water conservation measures in farmland and land leveling to increase water efficiency in rice depending on surface irrigation (Daccache, Sataya, & Knox, 2015).

Climate change contributes some negative impacts on agriculture. The increase in rainfall is evidence of climate change, reduced water availability, and other unsuitable weather. Regional managers can consider the significant risks related to water management at the land level (Osman, 2018).

Soybean, as the second crop in the dry season, does not require much water. Water readiness is needed in the early stage of growth, flower period, and filling of pods. When experiencing drought, soybean productivity can decrease by 40-65% (Engels, Rodrigues, de Oliveira Ferreira, Inagaki, & Nepomuceno, 2017).

The results study of Aminah et al. (2013) state that soybeans that are given water stress of 150 mm/season (below their average needs) show genuine differences with soybeans that get 300 mm of water/season. There is a very significant decrease in both the plant growth components and the production components. According to the results of research, Jumrani & Bhatia (2018) states that lack of water at the vegetative state (7-12 days after planting) does not cause damage which means but lack of water during the pollination and seed filling phase (30-45 and 55 days after planting) will reduce yields.

The potential of existing dry land provides ample opportunity to study the best time to give the best water for soybean plants on dry land (rainfed). One main obstacle faced in dryland management is little water due to deficient rainfall. The solution offered in this research is the proper management of water delivery time, especially on dry or rain-fed land.

## MATERIALS AND METHODS

### Location and Experimental Design

The experiment was conducted from June to September 2020 in the farmland located at Maros Regency, South Sulawesi, Indonesia. This research setup a split-plot design involving an irrigation method (A) at three ways (scatter, furrow, and flood irrigation method) as the main plots and the time of giving water (W) with three rates (every 15 days of age, 15 days of age and at full flowering and every 10 days of age) as the subplots. Each treatment combination has three replicates.

Materials used include Demas-1 variety soybean seeds, inorganic fertilizers (Urea, SP-36, and KCl), organic fertilizers using cow dung manure, Decis, and Marshal insecticides, paper bags, rope, and others. The tools used include water pumps, hoses, prolong pipes, scales to measure the dry weight of plants, rulers, ovens for the analysis of plant dry matter, fence nets, bamboo stakes, and others.

In the field, treatment plots were made of isolation with a minimum distance of 3 m to avoid water seepage from the other treatment plots. In each main plot, a water gauge is installed to calculate the amount of water entering. The plot size was 3 m x 2 m. The water channel was made 30 cm deep and 25 cm wide. The provision of water in the channel was limited to the height of the canal. While inundation was given to the ground's surface, the plot is closed, so it does not flow out. The Demas-1 variety was planted at a 40 x 20 cm distance, 2-3 seeds/hole. The amount of water given is the same for each treatment, and only the giving time is different. The water requirement for soybean plants is obtained from the author's research data from the previous year at the greenhouse. It was found that the water requirement for soybean crops was 6.1 liters during its life cycle, the number of plants in one bed 75 so that the total water needed in one bed to production is 458 liters. W1 = every 15 days

(5 times of administration) = 458/5 = 92 liters, W2 = at 15 days of age and at full flowering (2 times of giving) = 458/2 = 229 liters and W3 = every 10 days (8 times giving) 458/8 = 57 liters.

### Variable Observation

Plant growth observations were carried out every two weeks, which included: plant height, harvest age, greenness leaves, time of flowering (50%), and plant dry weight. Observation of groundwater content is conducted every ten days to see how much the water application method is used and the best time to provide water to maintain optimal soil moisture levels for soybean plants. Observations of crop production included the number of filling pods, the number of empty pods, the weight of seeds per plant, the weight of 100 seeds, and production per hectare and observed at harvest time.

### Data Analysis

An analysis of variance (ANOVA) followed by a mean comparison based on Honestly Significant Different (HSD) was adopted to check the effect of the treatment on all measured variables by using the statistical program, Statistics 10.

## RESULTS AND DISCUSSION

In our result, the inundation irrigation method treatment with irrigation water is given every 10 and 15 days (both scatter methods, channel, and inundation methods) and have moisture content/ moisture content around the field capacity/close to field capacity. Although the amount of water given is the same, the application timing distinguishes the results. When given every 10 and 15 days, almost every phase of plant growth and development gets adequate water (Table 1). This is probably because most of the soil's pore space is filled with water. The essential factors underlying water management are the properties of plants to their water needs, the amount of water provided, the method of irrigation, and the characteristics of the soil in storing water (da Silva et al., 2019).

In the inundation method with the time of giving water, namely at the age of 15 days and at the time of full flowering, it is able to produce a state of soil water content in sufficient conditions for plant needs. This shows that the efficient application of water, which is only twice during a soybean growing season, is able to maintain soil moisture which will provide high yields, both in terms of growth and production components.

**Table 1.** Effect of irrigation method and timing of irrigation on soil moisture content

| Treatment | Ground Water Content | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII | VIII | IX |
| Field Capacity | 41.15 | 42.98 | 40.93 | 39.87 | 42.67 | 39.99 | 40.95 | 41.54 | 40.29 |
| Scatter methods every 15 days | 33.79 | 34.54 | 32.81 | 30.98 | 31.12 | 29.98 | 32.76 | 34.23 | 32.99 |
| Scatter method at 15 days and on blooming | 32.24 | 39.65 | 32.65 | 29.24 | 40.21 | 36.88 | 27.63 | 26.21 | 23.11 |
| Scatter method every 10 days | 38.99 | 39.23 | 38.56 | 36.45 | 37.97 | 36.90 | 37.78 | 35.11 | 38.59 |
| Channel method every 15 days | 36.35 | 35.99 | 35.69 | 34.77 | 34.90 | 33.78 | 31.99 | 39.45 | 36.45 |
| Channel method at 15 days and on blooming | 33.46 | 37.87 | 33.48 | 30.12 | 39.11 | 27.63 | 28.92 | 28.66 | 22.97 |
| Channel method every 10 days | 39.12 | 38.23 | 38.78 | 37.99 | 40.11 | 39.13 | 37.88 | 37.33 | 38.96 |
| Inundation method every 15 days | 34.76 | 32.99 | 36.96 | 38.32 | 33.67 | 34.68 | 32.99 | 35.80 | 32.73 |
| Inundation at 15 days and on blooming | 32.33 | 38.76 | 36.99 | 35.19 | 39.55 | 33.74 | 32.74 | 28.21 | 21.94 |
| Inundation method every 10 days | 39.87 | 40.98 | 41.22 | 38.78 | 41.10 | 37.99 | 39.79 | 37.24 | 40.11 |

Remarks: Soil moisture content is maintained field capacity form

Plant growth characterized by height shows an interaction between the irrigation method and the time of giving water, where the combination of the inundation method and the time of providing water at the age of 15 days and when in full flowering has the highest effect on plant growth, that is 69.29 cm. It is suspected that 15 days is the vegetative phase and when full flowering is the generative phase. The water needs for plants are fulfilled in the sense that there is a sufficient amount of water available when the plants need it in optimal quantities (229 liters for two times the time of giving) matching according to time. Meanwhile, the water supply every 10 days and every 15 days is assumed that the volume of water was not sufficient, namely only 92 liters for W1 (five times a given) and 57 liters for W3 (eight times a given) (Table 2). This is due to insufficient water availability, which causes nutrients and nutrient solubility in the soil to decrease. Thus, nutrient transport to plant tissue will also be lower. This is in line with research conducted by Li et al. (2020) that soybean plants grown in plastic houses with reduced water supply intervals caused a decrease in plant height by 9.2%. In addition, research conducted by Kumar, Rao, Mohanty, Selvi, & Bhoi (2015) shows that soybeans that are given drought stress by reducing the intensity of water supply in the generative phase also cause a reduction in plant height.

The method of irrigation and the time of application of irrigation water and its interactions affect leaf greenness which is an indicator of leaf chlorophyll content (Table 2). The inundation method with the time of giving irrigation water every 15 days had the highest leaf greenness. They were not significantly different from the water treatment at the age of 15 days and full flowering.

Leaf greenness correlates with leaf chlorophyll content. The greener a leaf is the more chlorophyll content and the higher the ability to photosynthesize. It can also be a sensitive tool to identify genotypic variation in estimating the rate of photosynthesis and can serve as a selection criterion in the Iglesias & Garrote (2015) plant breeding program. Chlorophyll is a determining element of plant photosynthetic ability, which is primarily found in plant leaves. Leaf chlorophyll levels are closely related to leaf greenness. Chlorophyll is a pigment that has a function in the photosynthetic process of plants. The higher the leaf chlorophyll content, the higher the ability to photosynthesize. In photosynthesis, plant chlorophyll is a complex molecule that plays a role in capturing sunlight energy, which is energy and electron transfer (van der Tol et al., 2016).

The interaction between the irrigation method and the time of giving water did not affect the flowering age. The treatment of the time of giving water as a single factor had a significant effect on flowering age. The time of giving water every 10 days gave the fastest effect in flowering age, namely 39, 74 days and significantly different from the time of administration every 15 days (W1) and treatment at 15 days and at full flowering (W2). This is because if the plant gets enough water, the flowering time will also be faster.

The dry weight of the plant also occurred an interaction between the method and the time of giving water, where the combination of the inundation method and the time of giving water at 15 days and when in full flowering showed the best effect on the dry weight of the plant, namely 101.66 g (Table 2). This is because, in the inundation method, the land conditions are wet enough for several hours. The age of 15 days is considered the plants vegetative growth phase, and the age at flowering is the reproductive phase of the plant to get a sufficient amount of water so that it can meet the needs of water in both phases.

Technique irrigation using waterlogging methods and watering time at 15 days and full flowering appears to increase soybean yield potential. These results suggest that the puddle irrigation method/method with the time of giving water at the age of 15 days and full flowering is sufficient to meet the water needs for the growth and production of soybean plants. As evidence, the results of the two analyses show an interaction between the method and the time of giving water (Table 3).

Observations on the weight variables of 100 seeds and the number of empty pods did not show a significant effect between the irrigation method and the time of giving water, but this was different from the variable in the number of filled pods, where the treatment of the inundation irrigation method was given water at the age of 15 days and at the time of flowering full showed a significant interaction with a very high number of filling-pods, namely 164.95 pods, but the resulting seed size was small compared to other treatments, although not significantly different (weight of 100 seeds was not significant). This finding might be caused by due to compensation, from the small size of the seeds but photosynthesis is directed to the formation of a large number of seeds in the pods, so that the effect of fundamental interactions occurs, considering that the time of giving water at the age of 15 days and during full flowering is a time that really requires a sufficient amount of water and this method was effective for maintaining soil moisture for several days. Days until before pod formation because the amount of water given is sufficient for this phase, 229 liters when it enters full flowering.

Likewise, the observation of the production with the irrigation method and the time of giving water showed an interaction, the inundation irrigation method with the time of giving water at the age of 15 days. Full flowering resulted in the highest production of dry soybean seeds, namely 4.16 t/ha and different, very real with other treatment combinations. As explained above, the inundation method is considered capable of maintaining soil moisture, especially when it enters the vegetative phase (age 15 days) and the generative phase (age at full flowering). The amount of water given is sufficient, namely 229 liters if compared with other treatments. However, given every 10 days and every 15 days, the amount of water volume is not sufficient for the optimal water needs for both phases. If experience drought in the vegetative and generative stages, soybean productivity can decrease by 40-65%. This is in line with the results of the research by Suriadi, Zulhaedar, Nazam, & Hip (2021) who suggested that the provision of scheduled water for soybean cultivation on irrigated land to increase production.

Vanneuville et al. (2012) reported that the stress in the vegetative phase has no significant effect on the growth and production of soybean plants. On the other hand, giving stress in the generative phase significantly inhibits growth and reduces production by up to 70%. Giving stress causes the plant to adopt an adaptation mechanism by reducing the number of leaves, narrowing the leaves, reducing the stomatal openings, degradation of leaf chlorophyll, and responding to a motion by folding the leaves. Plant adaptation mechanism affects the value of water use efficiency and radiation use efficiency. Of the two photosynthetic pigments classes carotenoids show multifarious roles in tolerance to water deficit including light harvesting and protection from oxidative damage caused by soil water deficit (Kapoor et al., 2020).

**Table 2.** Effect of the method and time of giving water on plant height, harvest age, leaf greenness, flowering age, and plant dry weight at harvest

| Treatment | Plant Height (cm) | Harvest time (days) | Greenish leaves | Flower Age (days) | Plant Dry Weight (g) |
|---|---|---|---|---|---|
| Field Capacity | 56.37 | 84.77 | 30.51 | 30.67 | 68.11 |
| Scatter methods every 15 days | 65.39 d | 84.56 b | 37.25 cde | 40.56 a | 92.15 cd |
| Scatter method at 15 days and on blooming | 64.14 cd | 84.72 b | 29.95 ab | 47.00 a | 85.89 c |
| Scatter method every 10 days | 66.23 d | 85.84 b | 34.97 bc | 35.78 a | 85.80 c |
| Channel method every 15 days | 54.16 ab | 86.07 b | 36.88 cde | 38.00 a | 68.11 ab |
| Channel method at 15 days and on blooming | 62.99b cd | 89.18 b | 31.98 abc | 43.00 a | 89.59 cd |
| Channel method every 10 days | 55.28 abc | 89.07 b | 28.10 a | 37.00 a | 84.93 c |
| Inundation method every 15 days | 53.10 a | 86.56 b | 42.57 e | 40.67 a | 61.85 a |
| Inundation at 15 days and on blooming | 69.29 d | 76.44 a | 41.83 de | 47.67 a | 101.66 d |
| Inundation method every 10 days | 62.42 b | 87.10 b | 36.69 cd | 32.50 a | 80.44b c |
| HSD 5% | 9.27 | 4.72 | 5.72 | ns | 15.11 |
| Sd | 8.3946 | 4.3982 | 5.4980 | 5.1890 | 13.5733 |

Remarks: HSD = Honestly Significant Difference; ns = not significant; Sd = standard deviation

**Table 3.** Effect of irrigation methods and time of giving water on the weight of 100 seeds, the number of empty pods, number of filling pods, weight planting seeds, and production

| Treatment | Weight 100 seeds (g) | Number of empty pods | Number of contained pods | Weight seed/plant (g) | Produc-tion/ha (ton) |
|---|---|---|---|---|---|
| Field Capacity | 10.56 | 3.78 | 102.89 | 26.14 | 3.27 |
| Scatter methods every 15 days | 11.22 a | 1.56 a | 139.56 de | 33.78 bc | 4.22 bc |
| Scatter method at 15 days and on blooming | 12.78 a | 1.44 a | 123.14 bcd | 31.33 bc | 3.91 bc |
| Scatter method every 10 days | 11.33 a | 1.44 a | 134.11 cd | 33.47 bc | 4.17 bc |
| Channel method every 15 days | 11.00 a | 1.78 a | 105.86 bc | 28.11 ab | 3.51 ab |
| Channel method at 15 days and on blooming | 10.89 a | 0.67 a | 119.33 bcd | 33.33 bc | 4.16 bc |
| Channel method every 10 days | 12.56 a | 3.89 a | 112.89 bcd | 29.00 ab | 3.62 ab |
| Inundation method every 15 days | 14.22 a | 1.67 a | 91.00 a | 21.81 a | 2.72 a |
| Inundation at 15 days and on blooming | 10.67 a | 0.89 a | 164.95 e | 37.11 c | 4.64 c |
| Inundation method every 10 days | 11.89 a | 3.44 a | 120.22 b | 26.79 ab | 3.34 ab |
| HSD 5% | ns | ns | 28.79 | 7.51 | 0.94 |
| Sd | 1.7983 | 1.8802 | 31.3260 | 5.6563 | 0.7069 |

Remarks: HSD = Honestly Significant Difference; ns = not significant; sd = standard deviation

Aminah et al. (2020) reported that keep a water surface at five centimeters increases the weight of soybean seed by 19.23%. The increase of harvest components in the number of pods and the number of seeds/crop by 31.1 % and 37.59% compared to field capacity.

The availability of water during plant growth greatly determines the yield of soybeans. The amount required is different for each growth phase. Water consumption for soybean plants is highly dependent on climate, soil type, soil management, and duration of plant growth. Thus water requirements for each agro-ecosystem area are different. Although soybeans as secondary crops do not require much water, water availability is needed during the vegetative stage, flowering and filling of pods (Bodner, Nakhforoosh, & Kaul, 2015; Dawson, Perryman, & Osborne, 2016; Siczek, Horn, Lipiec, Usowicz, & Mateusz, 2015).

Scheduled irrigation and appropriate dosing are essential in a precision agriculture approach. Provision of water based on the right amount and time will provide the proper water needs to avoid reduced yields. However, if the water supply to the plant exceeds the plant's water requirement, the excess water causes pollutants to the surrounding locations through percolation or runoff (Annandale, Stirzaker, Singels, Van der Laan, & Laker, 2011). In addition, the soybean that experienced water stress during fowering produced lower seed yield and total aboveground dry matter, due to a reduced PAR transmission, a lower assimilatory surface area, and adecline in Radiation use efficiency, compared to soybean under no water stress (Anda, Simon, Soós, Teixeira, & Menyhárt, 2021).

Agricultural development on dry land for food crops needs to be encouraged by various technological innovations, given its enormous potential so that it is pretty potential to support efforts to strengthen food security. Developing lowland dryland agriculture for food now and in the future is a strategic choice facing the challenge of increasing food production to support the national food security programs.

## CONCLUSION

The watering technique using the waterlogging method at the time at the age of 15 days and full flowering had the potential to increase the yield production of soybean, that was the number of pods 164.95 pieces, the weight of seeds 37.11 g, and production 4.64 t/ha. The inundation method was more effective in maintaining soil moisture and twice the application time. But in an optimal amount (229 l/time) was very effective in maintaining soil moisture.

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