Productivity of soybean varieties (*Glycine max* (L.) Merill) in vegetative phases V⁴ and generative phases R¹ classified waterlogged conditions by application of GA₃ and salicylic acid (SA)

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**Abstract.** Water-saturated soil conditions or waterlogging conditions can cause a decrease in soybean productivity. Efforts to destroy crop loss due to inundation through cultivation techniques are considered acceptable so that need for good management in soybean cultivation. This study aims to express at the productivity results of the three varieties namely Deja-1, Dering, and Anjasmoro with the inundation stress in the vegetative phases V₄ and generative R₁ phases with the use of Gibberellic acid (GA₃) and Salicylic acid (SA). The submergence time is given for 72 h in the stated phase. The use of GA₃ and Salicylic acid was given with 3 levels of concentration treatment namely GA₃ (150 ppm) + salicylic acid (100 ppm), GA₃ (200 ppm) + salicylic acid (150 ppm), and GA₃ (250 ppm) + salicylic acid (200 ppm). The outcomes showed the application of GA₃ and salicylic acid showed good production in the number of pods, number of seeds, and weight of seeds. However, the pressure of waterlogging affects the duration of flowering time so that it can cause loss of production.

1. **Introduction**

In Indonesia, the need for soybean (*Glycine max* (L.) Merrill) is increasing every year in line with population growth and to improve income per capita. So to meet the needs of domestic production additional supplies are needed in order to meet those needs. To meet these needs, several efforts have been made, such as expanding cultivated land and increasing production yields [1]. Fulfilment of the need for Indonesian soybeans is 67.28% or as much as 1.96 million tons must be imported from abroad [2].

Water-saturated (stagnant) soil conditions due to water extra from rice or rainwater planting, cause a decrease in soybean productivity ranging from 20-75%. Excess water in the field that causes inundation is generally difficult to manage so it needs to be sought for varieties of water-tolerant soybeans [3]. The magnitude of the negative effect of flooded land on growth and yield reduction for each soybean cultivar varies depending on the phase of plant growth at the time of inundation and the tolerance level of soybean cultivars to inundation stress. [4].
Until now, efforts to reduce yield losses due to inundation through cultivation techniques are considered adequate, but information on soybean cultivars that are tolerant of inundation is relatively limited [5]. Plant resistance to inundation can be in the form of avoidance of oxygen-deficient conditions from leaves to roots and the ability of plants to metabolize, or it can be said that respiration takes place anaerobically [6].

Gibberellins are hormones that accelerate seed germination, flourish buds, stem lengthening, leaf growth, stimulate flowering, fruit development, influence root growth and differentiation [7]. Charitable of GA3 in soybean plants aims to make plants more productive, by eliminating the biological barriers that exist in these soybeans [8]. Salicylic acid (SA) is a molecule or compound in plants whose role is to maintain plant conditions during abiotic and biotic stresses such as low temperatures, drought and disease attacks [9]. SA is a phenolic compound that shows a role in regulating plant growth, especially physiological activities for example photosynthesis, nitrate metabolism, production of ethylene flowering, and protecting biotic stresses and abiotic stresses [10].

This research aims to define the productivity of some varieties of soybean plants (*Glycine max* (L.) Merill.) in the vegetative phase V4 and generative phase R1 in waterlogged conditions with the application of GA3 and SA.

2. Materials and methods

2.1. Experimental design

This research was directed in the experimental field of the Faculty of Agriculture, Universitas Sumatera Utara, Indonesia. Plant materials used in this research comprise soybean seeds, namely Deja-1, Dering, and Anjasmoro varieties obtained from Bean and Tuber Crops Research Institute, Malang, Indonesia, planted in a 10 kg polybag filled with a mixture of soil and compost. The basic fertilizers used are Urea (0.44 g/polybag), Triple Super Phosphate (TSP) (0.68 g/polybag) and KCl (0.44 g/polybag). This research was used gibberellic acid (GA3) and salicylic acid (SA). The numeral of pods and seeds were counted by all pods formed and containing seeds in each plant. The seed weight is calculated by weighing the seeds produced per plant that has been dried. The weight of 100 seeds can be designed using the formula: Weight of 100 seeds = weight of seeds / number of seeds x 100.

Factor I, Varieties of Soybean:
- V1: Deja-1
- V2: Dering
- V3: Anjasmoro

Factor II, Growth Regulatory Substances:
- K1: GA3 (150 ppm) + SA (100 ppm)
- K2: GA3 (200 ppm) + SA (150 ppm)
- K3: GA3 (250 ppm) + SA (200 ppm)

Factor III, Time of Inundation:
- G1: Inundation in phase V4
- G2: Inundation in phase R1

2.2. Application of gibberellic acid (GA3) and salicylic acid (SA)

GA3 and SA were practical with a spray system affording to the usage application, started in the second weeks after planting with 7-day intervals until the vegetative phase V4 and the generative phase R1.
2.3. Waterlogging method
Waterlogging is carried out by submerging the lodging medium into a plastic pool measuring 10m x 2m filled with water, starting when the plant enters the vegetative phase V4 (leaves fully open at the fourth node) and the generative phase R1 (the presence of the first flower) for 72 hours.

3. Results and discussion

3.1. Number of filled pods
The number of pods observed after harvest, can be perceived in Table 1.

| Treatment | Number of Filled Pods |
|-----------|-----------------------|
| V1K1G1    | 21.67                 |
| V1K1G2    | 40.00                 |
| V1K2G1    | 46.33                 |
| V1K2G2    | 40.67                 |
| V1K3G1    | 45.33                 |
| V1K3G2    | 50.67                 |
| V2K1G1    | 32.00                 |
| V2K1G2    | 45.67                 |
| V2K2G1    | 59.67                 |
| V2K2G2    | 37.67                 |
| V2K3G1    | 26.67                 |
| V2K3G2    | 14.00                 |
| V3K1G1    | 42.33                 |
| V3K1G2    | 46.33                 |
| V3K2G1    | 14.00                 |
| V3K2G2    | 55.00                 |
| V3K3G1    | 30.00                 |
| V3K3G2    | 44.67                 |

For variety V1 (Deja-1), the highest number of pods was found in V1K3G2 as many as 50.67 filled pods, which waterlogging stress was applied in the R1 phase. For variety V2 (Dering), the utmost number of pods was found in V2K2G1 as many as 59.67 pods, which waterlogging stress was applied in phase V4 and applied GA3 (200 ppm) and SA (150 ppm). For variety V3 (Anjasmoro), the utmost number of pods was found in V3K2G2 with 55.00 pods in the R1 phase for application of GA3 (200 ppm) and SA (150 ppm). For all treatments, the utmost number of filled pods was in V2K2G1.

The data showed that application of GA3 (200 ppm) and SA (150 ppm) produce the best number of pods on the Dering and Anjasmoro varieties. Plants applied with GA and SA show their effects on abiotic stress by increasing plant growth during stress conditions and the addition of ABA and proline, increasing cell division in the root apical meristems, average photosynthesis and maintaining membrane stability [11].
The result coherent with the statement of Pertiwi, et al [12] which that the spraying of gibberellins has a single effect on the variable percentage of flowers presence pods and the number of empty pods. The percentage of flowers turned to pods decreases with the upturn in gibberellin concentration.

3.2. Number of seeds

The number of seeds observed after harvest, can be perceived in Table 2.

| Treatment  | Number of Seeds |
|------------|-----------------|
| V1K1G1     | 43.33           |
| V1K1G2     | 80.67           |
| V1K2G1     | 95.00           |
| V1K2G2     | 80.33           |
| V1K3G1     | 88.33           |
| V1K3G2     | 108.00          |
| V2K1G1     | 65.33           |
| V2K1G2     | 90.00           |
| V2K2G1     | 117.67          |
| V2K2G2     | 78.33           |
| V2K3G1     | 59.67           |
| V2K3G2     | 27.67           |
| V3K1G1     | 71.33           |
| V3K1G2     | 83.00           |
| V3K2G1     | 27.67           |
| V3K2G2     | 104.33          |
| V3K3G1     | 53.67           |
| V3K3G2     | 91.67           |

In Table 2 shows the number of seeds of all the treatment. The application of GA3 (200 ppm) and SA (150 ppm) or K2 showed the utmost results in variety V2 (Dering) as much as 117.67 seeds by applying waterlogging stress in phase V4 and the variety V3 (Anjasmoro) as much as 104.33 seeds by applying waterlogging stress at phase R1.

From the data obtained shows that the application of GA3 (200 ppm) and SA (150 ppm) produced the highest number of seeds. This is in line with the statements of Silitonga [8] and Efendi [10] that the administration of gibberellins to soybean plants can make plants more productive and salicylic acid shows a role in regulating plant growth, especially physiological activities such as photosynthesis, nitrate metabolism, production of ethylene flowering and protecting biotic stress and abiotic.

3.3. Seeds weight per plant (g)

Seed weight per plant is measured using a scale, can be perceived in Table 3. In the seed weight parameter, the best treatment is found in variety V3 (Anjasmoro) and given GA3 (200 ppm) and SA (150 ppm) as much as 15.24 grams, which is given waterlogging pressure in the R1 phase. In Variety V1 (Deja-1), the highest seed weight was found in V1K3G2 of 12.84 g, which was given waterlogging pressure in the
R₁ phase and applied GA₃ (250 ppm) and SA (200 ppm). In variety V₂ (Dering), the highest seed weight was found in V₂K₂G₁ of 12.44 g, which was given waterlogging pressure in the V₄ phase and applied GA₃ (200 ppm) and SA (150 ppm).

| Table 3. Seeds weight per plant (g) |
|------------------------------------|
| Treatment  | Seeds Weight (g) |
| V₁K₁G₁     | 4.50             |
| V₁K₁G₂     | 9.00             |
| V₁K₂G₁     | 10.06            |
| V₁K₂G₂     | 10.10            |
| V₁K₃G₁     | 10.86            |
| V₁K₃G₂     | 12.84            |
| V₂K₁G₁     | 6.72             |
| V₂K₁G₂     | 9.25             |
| V₂K₂G₁     | 12.44            |
| V₂K₂G₂     | 7.22             |
| V₂K₃G₁     | 6.24             |
| V₂K₃G₂     | 3.06             |
| V₃K₁G₁     | 10.50            |
| V₃K₁G₂     | 12.04            |
| V₃K₂G₁     | 4.08             |
| V₃K₂G₂     | 15.24            |
| V₃K₃G₁     | 6.64             |
| V₃K₃G₂     | 13.29            |

The use of different varieties shows different effects on the application of GA₃ and SA, including the weight of seeds. The seed weight of Anjasmoro variety is higher than the two other varieties which are indicated by differences in seed size according to the character of each varieties. This is matched with the statement of Pertiwi, et al [12] which stated that each variety gives a different effect. The difference is related to the genetic characteristics possessed by each variety so that the ability to respond from each variety is different.

3.4. Weight of 100 seeds (g)

Weight of 100 seeds can be perceived in Table 4. For the weight of 100 seeds showed the highest yield was in Variety V₃ (Anjasmoro) of 14.76 grams in V₃K₂G₂ by applying waterlogging pressure in phase V₄ and applied GA₃ (200 ppm) and SA (150 ppm). In variety V₁ (Deja-1) the highest yield was 12.56 grams in V₁K₂G₂, which was given waterlogging pressure in the R₁ phase and applied GA₃ (200 ppm) and SA (150 ppm). In variety V₂ (Dering) the highest yield was 11.32 grams in V₂K₃G₂, which was given waterlogging pressure in the R₁ phase and applied GA₃ (250 ppm) and SA (200 ppm).
Table 4. Weight of 100 seeds (g)

| Treatment | Weight of 100 Seeds (g) |
|-----------|-------------------------|
| V1K1G1    | 10.31                   |
| V1K1G2    | 11.30                   |
| V1K2G1    | 11.30                   |
| V1K2G2    | 12.56                   |
| V1K3G1    | 12.38                   |
| V1K3G2    | 12.42                   |
| V2K1G1    | 10.45                   |
| V2K1G2    | 10.30                   |
| V2K2G1    | 10.57                   |
| V2K2G2    | 9.55                    |
| V2K3G1    | 10.70                   |
| V2K3G2    | 11.32                   |
| V3K1G1    | 14.67                   |
| V3K1G2    | 14.55                   |
| V3K2G1    | 14.76                   |
| V3K2G2    | 14.58                   |
| V3K3G1    | 11.56                   |
| V3K3G2    | 14.46                   |

The use of different varieties shows different weight of seeds. In the weighting parameter of 100 seeds, each variety has an equivalent average in each treatment, but has differences between varieties. Anjasmoro variety has the utmost weight of 100 seeds and the Dering variety has the lowermost weight of 100 seeds. This is coordinated with the statement of the Bean and Tuber Crops Research Institute [13], that the Anjasmoro variety has a regular weight of 100 seeds of 14.8-15.3 g. The Dering variety has an typical weight of 100 seeds of 10.7 g.

4. Conclusion
The presence of waterlogging greatly affects the duration of flowering for the first time due to a disturbance in the plant which results in the loss of production both in the vegetative and generative phases. For the use of GA3 and SA shows that the use of the right concentration produces good production both in the number of pods, number of seeds and weight of seeds. In this case the best application is 200 ppm GA3 and 150 ppm SA. The use of GA3 and SA on different varieties shows different effects between varieties because the characteristics of each variety are different so the responses given are different.

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