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Effectiveness of concentration of rice husk silica extract on growth and yield of sweet corn (*Zea mays saccharata* Strut)

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Abstract

Qurrohman, B. F. T., Taofik, A., Ramadhani, R. & Suriadikusumah, A. (2022). Effectiveness of concentration of rice husk silica extract on growth and yield of sweet corn (*Zea mays saccharata* Strut). *Bulg. J. Agric. Sci., 28(1)*, 61–68

Most of the soils in Indonesia are acid soils, which result in low availability of silica (Si) in the soil. Corn is a plant that responds to Si's availability in the soil so that the application of exogenous Si in corn cultivation is an alternative solution in increasing productivity. This study aims to test the effectiveness of the exogenous Si concentration derived from rice husk silica extract (RHSE). This study used an experimental research method using a randomized block design, consisting of six (6) treatments = without RHSE, B = 10 ml l^{-1}, C = 20 ml l^{-1}, D = 30 ml l^{-1}, E = 40 ml l^{-1} and F = 50 ml l^{-1} RHSE. Each treatment was repeated four (4) times to obtain 24 experimental units. Growth parameters and yields observed and measured during the study were: Plant height 6 week after plant (WAP), shoot fresh weight, shoot dry weight, fresh yield with husk, fresh yield without husk, and harvest index. This study's data analysis methods were analysis of variance and Duncan's distance test (Duncan's test) at the 5% significant level. The RHSE concentration of 30 ml l^{-1} could be used as a solution to increase the growth and yield of sweet corn. The RHSE application effectively increased the yield by 33% higher.

Keywords: harvest index; nutrient uptake; soil acidity

Introduction

Silica (Si) content in the soil is between 1-45%, but the availability of Si elements that can be used by plants in the soil is lower than the Si content of the soil (Total-Si). Si's low availability in soils in the tropics is due to the desilication process (Husnain & Adamy, 2012). Si-Availability's availability in the soil (Si-Availability) is essential for the Gramineae family plant's growth. Plants of the Gramineae family are included in Si's accumulator plants, and elements of Si for Gramineae are micro-functional elements (Ma et al., 2001). The research results on the role of Si in Gramineae plants showed that the Si element was able to maintain the growth of plants exposed to biotic and abiotic stress. Elemental Si can increase plant macronutrient uptake so that fertilizer use is more efficient and plant productivity increases. The corn plant is a plant of the Gramineae family cultivated in Indonesia, second only to rice. The increase in national maize production is faced with constraints on productive land availability, and most of the corn plants are grown as intercropping in rice cultivation. The rice-corn cropping pattern commonly practiced by farmers has an impact on decreasing Si availability in the soil. The practice of burning straw, according to Darmawan et al. (2006) for 33 years, rice fields in Java have decreased in Si content by 11-12%.

The decrease in available Si can affect the Gramineae family's productivity, for example, rice and corn plants. Use inorganic fertilizers will be more widely used to overcome the low productivity. Efforts to increase productivity with inorganic fertilization without being balanced with organic fertilizers can cause soil degradation (Frasetya et al., 2019). According to (Ma & Yamaji, 2015)a Si permeable channel, belongs to the Nod26-like major intrinsic protein (NIP, the increase in rice production will be achieved if Si's needs are fulfilled. Sufficient Si availability can increase nutrient uptake so that plants quickly absorb the nutrients given. Increasing plant metabolism can reduce nutrient loss in the root zone so that fertilizer application was more efficient. The results of Ma & Yamaji (2015)a Si permeable channel, belongs to the Nod26-like major intrinsic protein (NIP research can be used as a reference that increasing the productivity of maize can be increased by meeting the Si needs available during the cultivation process. The research results strengthened si's role in maize and rice by Mitani et al. (2009), who showed that the results of the isolation of ZmLsi1 and ZmLsi6 homologous maize genes with the OsLsi1 gene in rice plants played a role in Si transport.

The practice of cultivating maize in paddy soil causes the available Si for maize to be lower because rice plants have been used in the previous period. The addition of Si in maize cultivation through fertilization is needed to meet Si needs. Rice husks are a source of Si, which is abundant in rice milling centers. According the potential of Si in rice husks is around 10%. The utilization of rice husk as a source of Si must go through a decomposition process first, but this method requires a relatively longer time than the extraction method (Frasetya et al., 2019). The silica extraction method from rice husks uses strong bases such as KOH, Na_2CO_3, and NaOH. This extraction method has the advantage of producing amorphous silica (Suka et al., 2008). Plants can absorb Si in amorphous form. Based on these considerations, the extraction method with a strong base was used in this study. The extracting material used is a potent base compound KOH. The K^+ ion in KOH is a macro element needed by plants in carbohydrate synthesis and translocation (Agbede, 2018).

The element of Si is a micro-functional element that needs a little, but the lack or the excess of Si nutrients impacts the inhibition of plant growth. In this study, rice husk silica extract was given to corn plants through the leaves by spraying. Fertilization through leaves is not a new method. Farmers generally use this method to overcome nutrient deficiencies and as additional or complementary fertilization. The Si fertilization method by spraying through the leaves has the advantage that plants can directly utilize the Si element given. Another benefit of foliar fertilization is that it is more environmentally friendly because fertilizers' dosage is low. However, fertilization through leaves must consider plant physiology, plant species morphology (such as leaf structure and shape), method of spraying, physico-chemical properties of foliar fertilizers (Puppe & Sommer, 2018). Fertilization of Si through leaves needs to be regulated in the application dose. If the dose is too high, it will cause the plant leaves to wilt, burn the plant's edges (tip burn), and if it exceeds the plant's tolerance limit, it can cause the plant to die. This study aims to obtain the appropriate concentration of rice husk silica extract so that the corn plant's growth increases and its productivity is high.

Materials and Methods

This research was conducted in Sukaharja-Lumbung, Ciamis Regency, West Java, from November 2017 to February 2018. The research location is at an altitude of 600 m above sea level, with an average daily temperature of 26.86ºC and average humidity of 74.77%. The equipment and materials used in this study were divided into two parts, namely equipment, and materials for making rice husk silica extract (RHSE) and equipment and materials used during the cultivation process. The equipment to produce rice husk silica extract is a one-liter measuring cup, stove, pan, 50 mesh filter, wooden spatula, and bucket. The materials needed to make RHSE are rice husks, clean water, and KOH. During the research and observation process, the tools used were hoes, scales, thermo-hygrometer, scissors, shovels, meters, ovens, cameras, and stationery. The materials used in this study were Talenta sweet corn seeds, urea fertilizer, super phosphate (SP-36) fertilizer, and KCl fertilizer.

The research method used was experimental research using a completely randomized block design. Consisting of six treatments, namely A = without RHSE, B = 10 ml 1^{-1}, C = 20 ml l^{-1}, D = 30 ml l^{-1}, E = 40 ml l^{-1} and F = 50 ml l^{-1} RHSE . Each treatment was repeated four times in order to obtain 24 experimental units. Each experimental unit consisted of six corn plants so that 144 maize plant populations were obtained. A random sample of three plants determined each unit of the experiment.

During the research process, the research procedure consisted of several stages, namely the making of RHSE, soil processing, planting, maintenance, application of the treatment, and harvesting.

- The making of RHSE is based on the modification of the extraction method carried out by (Frasetya et al. 2019; Suka et al. 2008). The construction of RSHE begins by refining the husks into flour and then soaking the husks in clean water for two hours to ensure the husks used are clean from impurities such as dust. The soaked husk is then dried and then dried. Two hundred grams of rice husk and 400 ml of 1.5% KOH add 2000 ml of clean water. The ingredients that have been mixed are then heated to boiling at 100ºC. Then let stand for 24 hours so that the solution cools and settles. After 24 hours, the extraction is filtered with a 50 mesh sieve. RSHE solution is ready to be applied according to the treatment concentration.

- Soil tillage is done by hoeing to clear weeds, and the soil structure becomes more crumbly. After being tillage, then made soil beds size 210 cm x 75 cm with a bed height of 30 cm. The spacing used is 25 cm x 75 cm.
- Corn planting is done directly by inserting two corn kernels per plant hole. After two weeks after planting, thinning it out, leaving the corn plants with better growth and the others removed using scissors.
- RHSE treatment concentration was given at the age of 4 weeks after the plant (WAP) by spraying all over the leaf surface at a 1 ml per plant dose.
- Application of urea fertilizer at a 300 kg ha^{-1} (5 g per plant), superphosphate(SP-36) fertilizer 100 kg ha^{-1} (1.7 g per plant), and KCl fertilizer 50 kg ha^{-1} (0.9 g per plant). The application of urea fertilizer is carried out in stages based on the plant's age at the beginning of planting as much as 100 kg ha^{-1} urea, SP-36 fertilizer 100 kg ha^{-1}, and 50 kg ha^{-1} KCl given simultaneously at planting. At the age of 3 weeks after the plant (WAP) and 5 WAP 100 kg ha^{-1} fertilizer was given to the plant.
- In addition to fertilizing, the corn maintenance stage is weed the land from disturbance of weeds, pest attacks, disease attacks, and offering irrigation water.
- In this study, corn plants were harvested at the age of 10 WAP.

Growth parameters and yields observed to measure the control of RHSE concentrations in maize were: Plant height 6 WAP, Shoot fresh weight, Shoot dry weight, fresh husk yield, fresh yield without husk, and harvest index.

The observed data were then analyzed with a 5% real analysis. The result data analysis was then developed by using the Duncan distance difference test at the 5% significant level. A regression analysis was carried out to analyze the data to know the effect of treatment variation on each parameter. Supporting parameters whose data were not analyzed were soil chemical analysis and Si concentration in RHSE in the Faculty of Agriculture land laboratory, Universitas Padjadjaran.

Result and Discussion

Results of soil chemical analysis and Rice Husk Silica Extract

The analysis of soil chemical characteristics (Table 1) shows some typical soil characteristics in tropical areas, namely high soil acidity and low organic matter content (Raboin et al., 2016). Soil acidity affects the availability of macro and microelements. At high pH (pH 6.5 – 8), macro elements are available for plants. On the other hand, at low pH (pH <5.5), the content of aluminum (Al) and manganese (Mn) will reach its maximum point. To some extent, it will reach a toxic limit in some plants (Mccauley et al., 2017). The nitrogen (N) content in the study area was categorized as low. Low N content can be caused by acid soil pH, the washing process, and being absorbed by plants. The low organic carbon content <2% can be used as an indicator that shows the low activity of microorganisms in the research location. Microorganisms obtain energy from carbon compounds so that the low carbon content impacts the limited population and microbial activity in these locations (Bhuyan et al., 2014). The total Si content at the study site was 33.15%, according to Husnain et al. (2012); although the Si content in the soil was high, the availability was low. Several factors that influence Si availability include soil acidity, redox potential, and air temperature.

The result of laboratory analysis of the Si content in RHSE is 0.68% of the potential Si in rice husks, according to Dobermann & Fairhurst (2000)persuading rice farmers to use modern varieties and their accompanying fertilizer inputs was easy because the results, in terms of yield increases, were often spectacular. Simultaneously, governments invested heavily in fertilizer subsidies, improved irrigation facilities, infrastructure, and rice price support mechanisms

Table 1. Soil Sample Analysis

Number	Soil Parameter	Value	Criteria
1.	pH:H_2O	5.26	Acid
2.	pH:KCl 1 N	4.17	–
3.	Organic-C (%)	1.62	Low
4.	Total-N (%)	0.23	Moderate
5.	C/N	7	Low
6.	P_2O_5 HCl 25% (mg/100g)	244.96	Very High
7.	P_2O_5 Bray (ppm P)	15.03	High
8.	K_2O HCl 25% (mg/100g)	26.34	Moderate
9.	Total-Si (%)	33.15	–
10.	Soil Texture		Clay

that made rice intensification (increased input use, increased number of crops per year around 10% (w / w). Si in RHSE 0.68% is dissolved Si while the sediment formed from the extraction process is not used.

Plant Pest and Diseases

From the beginning of planting until harvesting, no disease attacks were found on the plants during the research. However, attacks caused by pests began to occur 3 WAP, namely attacks by armyworms (*Spodoptera litura* or *S. litura*) and stem borer (*Ostrinia furcanalis* or *O. furcanalis*) at 5 WAP (Figure 1). The application of Si on corn plants cannot prevent plants from being attacked by plant pests. The results of the research by Trisnawati et al. (2017) showed the same thing that the application of Si on soybean plants could not prevent the plants from being attacked by *S. litura*. However, the application of Si could reduce *S. litura* leaves' consumption compared to plants that were not given Si.

During the study, pest attack control was carried out by mechanical means for *S. litura* and chemical attacks using insecticides to treat attacks by O. *furcanalis*. The pest *O. furcanalis* attacks maize plants from the vegetative to generative phases.

Plant Height

The results of the analysis of variance showed that the RHSE concentration (p> 0.05) did not affect the height of the 6 WAP maize plants. The results of the regression analysis (Figure 2a) show that the effect of RHSE concentration on plant height has a determination coefficient of R2 = 0.2487 or 24.87%, meaning that the variation in plant height is only 24.87% influenced by variations in RHSE concentrations (Taylor, 1990). According to Puppe and Sommer (2018) , the element Si can reduce the uptake of nitrogen (N) and potassium (K) but increase the uptake of phosphorus (P).

Nitrogen is a component of various metabolic processes and building blocks. Plants in the vegetative growth phase require more N elements than the generative phase. This study's results are in line with the research of Chairunnisa et al. (2013) which emphasized that the addition of Agrosil silica fertilizer and rice straw did not affect corn plant height

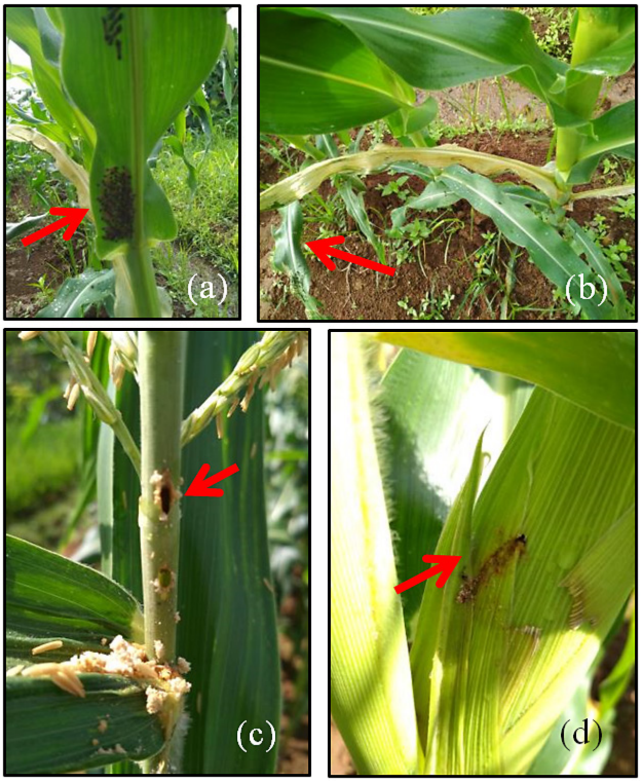
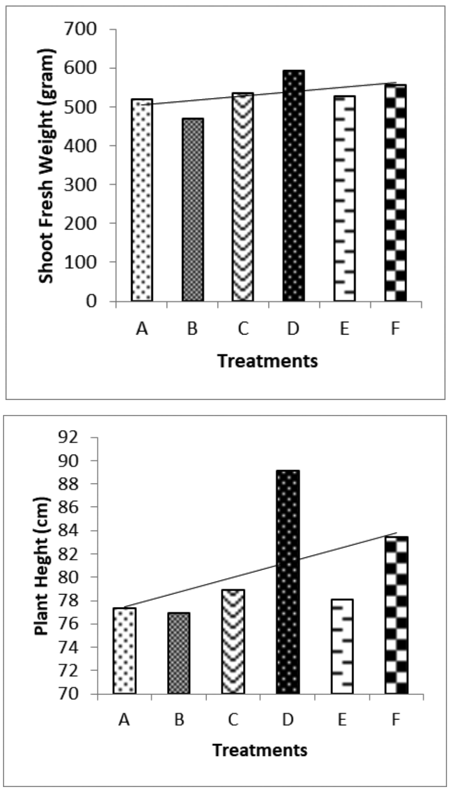


Fig. 1. Pest affected plants (a) *S. litura*, (b) leaf damage due to *S. litura* attack, (c) *O. furcanalis* attack on stems, (d) Serangan *O. furcanalis* attack on corn cobs



(a)

(b)

Fig. 2. Graph of the effect of RHSE on plant height and fresh weight of canopy, (*a*) graph of plant height, and (*b*) graph of fresh weight of plant canopy

compared to controls. Other studies on the Gramineae plant Frasetya et al. (2019) stated that the addition of RHSE to rice plants did not affect rice plant height.

Shoot fresh weight

The results of the analysis of variance showed that the effect of RHSE concentration did not affect the fresh shoot weight (p-value > 0.05). The results of the regression analysis of fresh shoot weight (Figure 2b) based on the coefficient of determination R2 = 0.2546 or 25%, meaning that the RHSE concentration treatment only affects 25% of the formation of fresh shoot weight, other factors influence the remaining 75%. Another factor that affects fresh shoot weight is the plant transpiration rate (Oda & Tsuji, 1992).

Dry shoot weight

The concentration of RHSE did not significantly affect the increase in plant dry weight. The coefficient of determination R2 = 0.5251 or 52.51% (Figure 3a) shows that 52.51% of treatment affects the formation of plant shoot biomass (dry shoot). The availability of sufficient nutrients will increase biomass formation and the distribution of photosynthate products to all parts of the plant. The research results by Santosa et al. (2017) show that plants that get sufficient nitrogen (N) will produce greater biomass compared to plants that are deficient in N elements. The addition of Si can increase the uptake of plant N, P, and K nutrients, but with a note that N, P, and K is available to plants. The Si element's role in plant nutrient uptake is to increase fertilization efficiency (Pati et al., 2016). Application of RHSE concentrations more than 30 ml l^{-1} (Figure 3a) suppressed plant canopy biomass formation. The formation of plant canopy biomass in this study was in contrast to several previous studies Greger et al. (2018) and Pati et al. (2016), who stated that increasing the dose of Si can increase plant growth.

Corn Yield with Husk

The application of RHSE to the yield parameters of corn with husk (husk) showed no effect on the increase in weight of corn with husk. Based on Figure 3b, the increase in corn's wet weight with corn husks began to increase at concentrations of RHSE 20 ml l^{-1} and 30 ml l^{-1}. RHSE application of more than 40 ml l^{-1} showed fluctuating corn yields with corn husks. RHSE concentrations of 20 ml l^{-1} and 30 ml l^{-1} increased yields by 16% and 28% compared without RHSE application. The coefficient of determination R2 = 0.2546 or 25.46%, the effect of RHSE on the corn harvest component with corn husks is only 25% Figure 3b. Elemental Si is not one of the primary nutrients forming plant biomass, but its nature only plays a role in improving plants' physiological and biochemical processes. If other factors such as soil pH and macro and micronutrient availability are limited, their availability will affect maize's growth and yield (Nuryadin et al., 2016; Sirisuntornlak et al., 2020). Corn husks have no economic value, but corn husks protect the seeds and cobs during seed formation until harvest. Another function of corn husks in the cultivation of sweet corn plants is to protect corn kernels from being damaged and maintain their freshness during the distribution process.

Corn Yield Without Husk

The variance analysis results (p<0.05) showed a significant effect of the RHSE application to corn plants on the yield parameters of corn without husked corn. The results of the Duncan distance test at the 5% significance level showed significant differences. The RHSE concentration began to affect a concentration of 20 ml l^{-1} to 30 ml l^{-1} (Figure 4a). The effect of the RHSE concentration decreased at a concentration of 40 ml l^{-1} to 50 ml l^{-1}. The results of this study confirm previous research, which shows that the RHSE concentration of 20 ml l^{-1} affects increasing crop yields (Frasetya et al.,

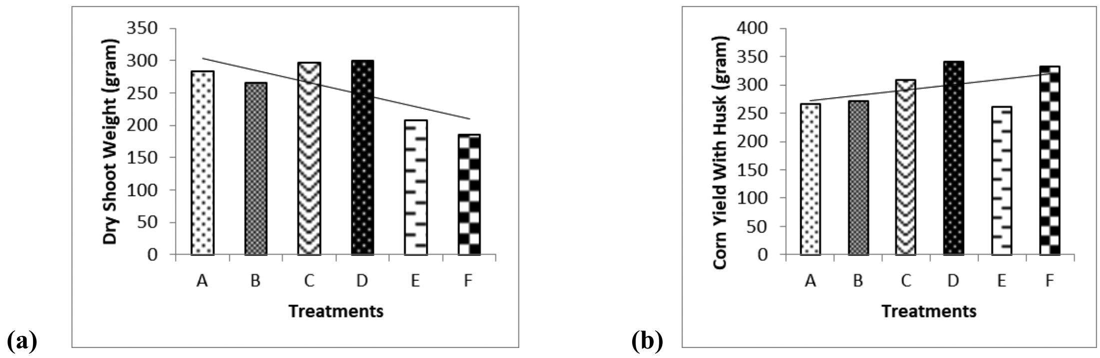


Fig. 3. Graph of effect RHSE to dry shoot weight and corn yield with husk (*a*) Dry shoot weight (*b*) Corn yield with husk

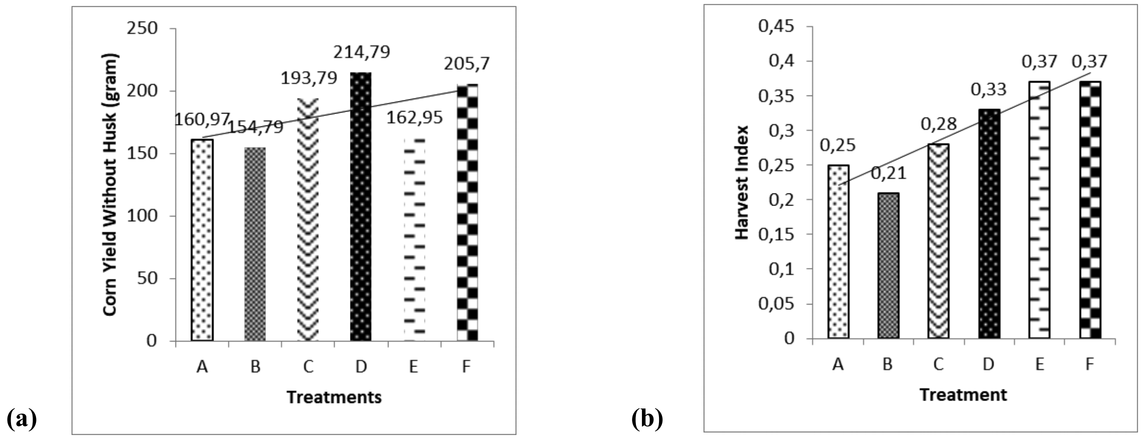


Fig. 4. Graph of effect RHSE to corn yield without husk and harvest index (*a*) Corn yield without husk (*b*) Harvest index

2019). The results of previous studies showed that giving exogenous Si to 1 mM (28 ppm) maize increased yields by 11% higher than without Si application (Sirisuntornlak et al., 2020).

In this study, RHSE 30 ml l^{-1} could increase the yield of maize 33% higher than without the application of RHSE. The application of Si elements to maize by spraying through leaves can increase the concentration of Ca elements so that the increase in Ca and Si elements in plants affects the success rate of pollination and increases plant tolerance to biotic and abiotic stress (Puppe & Sommer, 2018). Figure 5 shows a visual of the yield of corn for each treatment with

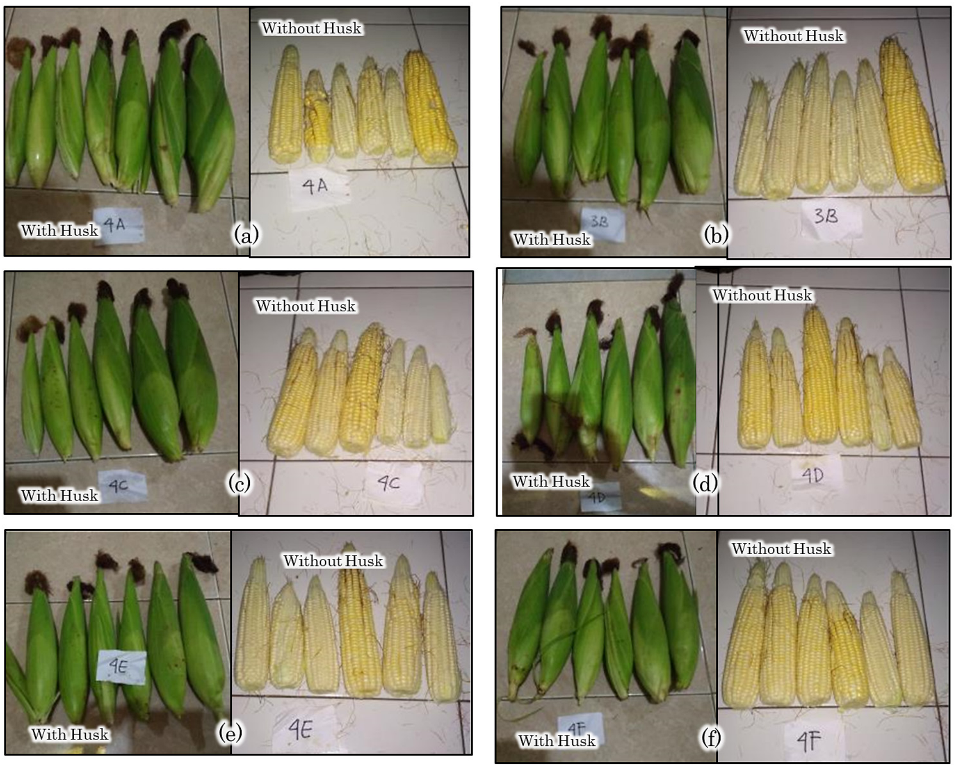


Fig. 5 Harvest yield of corn plant (ear of corn) with husk and without husk of RHSE treatment (*a*) A = without RHSE, (*b*) B = 10 ml L^{-1}, (*c*) C = 20 ml L^{-1}, (*d*) D = 30 ml L^{-1}, (*e*) E = 40 ml L^{-1} and (*f*) F = 50 ml L^{-1}

and without husks. In the treatment without RHSE application (Figure 5a), the yielded maize's quality was lower than the other treatments. Corn kernels formed in the treatment without RHSE were not evenly distributed in each row. The availability of Si elements helps plants to improve their physiological processes. The Si element in plants plays a role in the uprightness of leaves to get more sunlight, and the photosynthesis process runs well (Meena et al., 2014)Si in the soil is continuously lost as the result of leaching process. Subtropical and tropical soils are generally low in available Si and would benefit from Si fertilization. The silicon content in some regions might be limited to sustainable crop production. Hence, improved Si management to increase yield and sustain crop productivity appears to be necessary in temperate as well in tropical countries. In order to address this problem of yield decline or stagnation, it seems necessary to survey the Si status of agriculturally important soils of different parts of the country and develop region-specific integrated nutrient management systems that include the Si element. © 2013 The Author(s.

Filling of seeds and filled seed rows on corn cobs was seen in the 10 ml L^{-1} treatment (Figure 5b), while the uniformity of yield quality was achieved in the application of RHSE 30 ml L^{1} (Figure 5d). In the application of RHSE 50 ml L^{-1}, the corn produced quality was visually almost the same as the application of RHSE 30 ml L^{-1} (Figure 4a). Nevertheless, at a concentration of 50 ml L^{-1}, it was slower to fill the seeds (Figure 5f).

Harvest Index

Harvest index is the ability of plants to convert plant biomass into economically valuable yields. The harvest index can be used as a parameter to measure plants' physiological efficiency (Sharifi et al., 2009). Based on the analysis of Duncan's Multiple Range Test (DMRT) (Figure 4b), it shows that the application of RHSE 40-50 ml l-1 is significantly different compared to without the application of RHSE. The RHSE concentration of 30 ml L-1 based on the DMRT test was not significantly different from the harvest index value with the RHSE concentration of 40-50 ml l-1. RHSE application on maize can increase the harvest index 32-48% higher than without RHSE application. The regression analysis (Figure 4b) shows that the harvest index variation in this study was 84% influenced by the RHSE application. This study's highest harvest index was 0.33-0.37, while the lowest harvest index was 0.21-0.28. The harvest index results in this study were lower than the research done by previous researchers, namely, 0.38-0.50 (Pusparini et al., 2018; Sharifi et al., 2009; Sirisuntornlak et al., 2020). The variation in the harvest index value is generally between 0.2 - 0.5. The harvest index variation in his previous research was influenced by several factors, including plant varieties, climate, soil conditions, spacing, and types of plants in the previous period, and soil processing methods (Ion et al., 2015).

Conclusions and Suggestion

The effective RHSE concentration to increase the growth and yield of sweet corn is 30 ml l^{-1}. Application of RHSE 30 ml l^{-1} can increase corn plants' productivity 33% higher than corn plants without RHSE application.

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