2000) low cation exchange capacity (Brady and Weil, 2004) and relatively low availability of N, P, K, Ca, Mg, and Mo (Bell and Edwards, 1991) (Soil Survey Staff, 2010). Growth and yield of corn on such soils are highly dependent on the level land cultivation and input provided (Hairiah, 1996; Hairiah et al., 2000) (Rees et al, 2001).

Inceptisols soil with high acidity (pH <5.2) reduces crop production as related to nutrient availability in the soil (Djaenudin et al., 2003; Kaya, 2003) (Hairiah, et al, 1998; Buckman and Brady, 1982). At low soil pH, high ionic solubility of Al, Fe, and Mn influences on the growth and development of plants (Baligar et al., 2001; Glendinning, 1986; Hairiah, 1996; Mengel et al., 2001; Tisdale et al., 1993) (Tan, 1998). High concentrations of metals can be toxic to plants and can fixate P-available in the soil (Brady and Weil, 2004; Buol et al., 2003; Date et al., 1995) so plant growth is not good (Firmansyah, 2003).

One effort to overcome such disadvantage in Inceptisols is the application of organic manures that could reduce phosphate fixation by Al oxides through the formation of organo-complex compounds (Sanchez, 1992). Decreasing of phosphate fixation will decrease the solubility of Al, raise soil pH, release phosphate and increase available phosphate in the soil. Addition of organic matter to soil will improve soil structure through clay grains-organic compounds bonding (Hairiah, 1996; Iyamuremye and Dick, 1996; Pena-Mendez et al., 2005; Stevenson, 1986) (Sanchez, 1976; Setijono, 1996). Rusnetty's study (Rusnetty, 2000) showed that the administration of organic matter can increase soil pH, P-available, total N, CEC, K_e and lower Al_e, P sorption, the fraction of Al and Fe in soil, thus increasing the P content of plants, in the end also increase crop yields.

Sago is a plant in the family of palmae with a fairly large planting areas in Indonesia, that is more than 7,000,000 ha (Singhal et al., 2008), or it is equal to approximately 51.3 % of the total area of sago in the world (Alfons & Rivaie, 2011). Sago starch or flavor is the main result produced by the sago plant, while sago by products or wastes are generally used for animal feed, mushroom compost in the planting medium, or as raw material for plywood industry (Singhal et al., 2008; Awg - Adeni et al., 2010). Sago pith waste, in Maluku locally called "*sago ela*" can also play a role in improving the soil fertility. (La Habi et al., 2007; Kaya., 2003). Sago pith waste may be preferred as a source for organic material that has not been widely used, but this material is pretty much available in eastern Indonesia, particularly in Maluku (La Habi *et al*., 2007; La Habi *et al.,* 2014).

Sago pith waste can be recommended as a source of organic material. Sago pith waste is available in abundance in eastern Indonesia, particularly in Maluku, yet it has not been widely used (Kaya, 2003; La Habi, 2007). Sago pith waste of shreded inner material of sago after starch is taken. It contains macro and micro nutrients, including N, P, and K, so if processed into sago pith waste granular compost, it may increase the productivity of the soil in by fixing soil physical and chemical properties. It was reported by Pangloli and Haryanto (Haryanto and Pangloli, 2004) in mushroom production that 1 m^3 of sago pith waste medium could produce about 5.1 kg of mushrooms; while of rice straw medium could produce only 2.7 kg. Used decomposed sago pith waste previously used in mushroom medium can be used as fertilizer. Matulessy (Matulessy, 2006) revealed that independent provision of 1500 g of sea mud to 5 kg of soil and 100 g ela sago to 5 kg of soil significantly influenced the plant vegetative growth. The provision of 300 g sago pith waste to 5 kg of soil could significantly increase plant P uptake. P-available in soil, in the other hand, did not significantly affect the availability of P in soil although there was an increase compared with untreated soil.

One method to improve P content and reduce P deficiency in soil is by provision of P fertilizer (Hairiah, 1996; Sufardi, 1999). However, P fertilizer applied in acid soils such as Inceptisols will dissolve with ground water to form fertilizer solution that will react with clay minerals and oxides and hydroxides of aluminum and iron phosphate which changes the phosphate back from solution phase to unsoluble forms such as varisit and strengit (Brady and Weil, 2004; Tisdale et al., 1993) (Sample, 1980; Follett et al., 1981; Hartono et al, 2004; Tan, 1998). This phenomenon is known as a P fixation or P retention. Therefore, P fertilizing on acidic soils must be accompanied by the provision of ameliorant materials, including organic matter (Brady and Weil, 2004; Hairiah, 1996; Hairiah et al., 2000). Provision of compost and phosphate fertilizers in Iceptisol soil could raise soil pH, P available in soil and P uptake of maize (Sufardi, 1999).

Corn (*Zea mays L.*) is one of the major agricultural commodities in addition to rice and wheat (Kumar et al., 2007; Farhad et al., 2011; Akongwubel et al., 2012; Ayeni et al., 2012) which is consumed as a source of food for humans as well as animal feeds (Ibrahim & Kandil, 2007; Farhad et al., 2011; Ayeni et al., 2012). Recently, corn demand was increase significantly to meet numerous foods industrial materials. In Indonesia, the productivity of corn in 2004 was about 11,162,813 tons, increasing by 2.93% or 276,371 tons compared to the productivity of 2003 (10,886,442 tons). In 2009, the national corn production was 17.63 milion tons (BPS, 2008). On the other data obtained by Maluku Provincial Agriculture Office for the harvested area, the average corn production from 2001 until 2005 overall have increased respectively 4,754 ha to 6,089 ha and 15.54 kw ha^{-1} to 23,42 kw ha-1, but for the city of Ambon was only 54 ha with an average production of 23.33 kw ha-1 ion 2009, the total corn production in north Maluku was reached up to 13.990 tons (BPS north Maluku, 2010).

Maize is a strategic food commodities and ranks second only to rice (Subandi et al., 2004). Based on the data obtained from the Central Statistics Agency (BPS, 2009), the productivity of maize in 2004 amounted to 11,162,813 tons, increasing by 2.93%, or 276, 371 tons compared to the productivity of 2003 (10,886,442 tons). The data obtained by the Maluku Provincial Agriculture Office (BPS, 2006) maize field increased from 4754 hectares to 6089 hectares and production increased from 1,554 $kg.ha^{-1}$ to 2342 $kg.ha^{-1}$ from 2001 to 2005, while for the city of Ambon it was only 54 hectares with an average production of 2,333 $kg.ha^{-1}$. Therefore, maize production in Ambon needs to be increased.

Our study was aimed to determine the available phosphate, phosphate uptake, and maize yield as a result of sago pith waste granular compost treatment and phosphate fertilizer in the inceptisol soil.

2. Methods

The research was conducted in the Brawijaya University greenhouse of Malang from December 2020 to March 2021, while the soil and plant analysis were conducted in the Department of Soil Laboratory Brawijaya University in Malang. Some initial soil chemical indicators analyzed were soil pH (pH of H_2O and pH of KCl) with a glass electrode method (pH-meter), organic C (Walkley & Black method), P-inorganic extraction with H_2SO_4 0.5 M (the total P was analyzed as inorganic P but the soil was first heated at a temperature of 550 ºC, available P by Bray II method, Cation Exchange Capacity (NH_4-OAC 1M, pH 7), and P uptake of plants with wet ashing method (Puslittanak, 1998). We used the Yellow Srikandi corn seeds, urea (46% N), KCl (60% K_2O), and SP-36 (45% P_2O_5), Furadan 3G pesticide, and deionized water.

The experiment was designed using a completely randomized design (CRD) patterned 3 × 3 factorial with three replications. The first factor was the granular sago pith waste (ES) compost with three variations, e.g. KGES0 (control), KGES1 100 $g.pot^{-1}$ (equivalent to 40 $tonnes.ha^{-1}$) and KGES2 200 $g.pot^{-1}$ (equivalent to 80 $tonnes.ha^{-1}$). The second factor was the SP-36 (P) fertilizer also with three variations, e.g. P0 without fertilizer P (control); P1 SP-36 1.908 g $.pot^{-1}$ (equivalent to 120 kg P ha^{-1}), and 3.816 g P2 SP-36 pot^{-1} (equivalent to 240 kg P ha^{-1}). There were two groups of experiment, each of which used a total number of 27 experiment pots in combination of treatments. Soil analysis was carried out on the soil of 27 pots planted with corn just upto the end of the vegetative phase, which is the time of flowering. Corn production was calculated from the other 27 pots planted with corn up to 110 days after planting (DAP).

The experiments were carried out on Inceptisols soil. Soil samples were taken from the topsoil layer (0-20 cm). The soil was air dried and shifted with a 2-mm sieve. Prior to experiments, an initial soil analysis was carried out. For the experiments, 5 kg of soil was put in each pot and mixed with sago pith waste granular compost as prescribed, then incubated for 2 weeks. During the incubation period, the soils were watered to the field capacity. Three days before planting, soil in each treatment pot was mixed with P fertilizer with an appropriate treatment dose, and then urea and KCl as the base fertilizers were administered at seed plantation. 2 corn seeds were planted in each pot. After the seeds growed and aged 2 weeks, the thinning was carried out by taking stunted growth plants with yellow or wilted leaves so that there only one plant per pot left. To keep the soil moist, watering was conducted every morning and evening using clean water and pesticide was used when the plants were attacked by pests and diseases (Dursban 200 EC). The soil pH was measured by using a pH-meter. The Bray II method was used to measure the P-available with 2.5 g soil samples (Puslittanak, 1998). P-absorption was analyzed using the alkaline ashing method (Puslittanak, 1998). Observations were made after the plant reaches the end of the vegetative phase (49 days after planting). The weight of dry corn produced was weighed performed at the harvest time (110 days after planting).

An Anova method was employed to analyse the effect of granule ela sago compost treatment with phosphate fertilizer. If the effect was significantly different then a further least significant difference (LSD) test was taken. The relationship between each parameter was analysed using a path analysis.

3. Results and Discussion

Soil reaction (Soil pH)

The Anova analysis showed that the interaction between sago pith waste granular compost with phosphate fertilizer had no significant effect on the increase in soil pH (Figure 1).

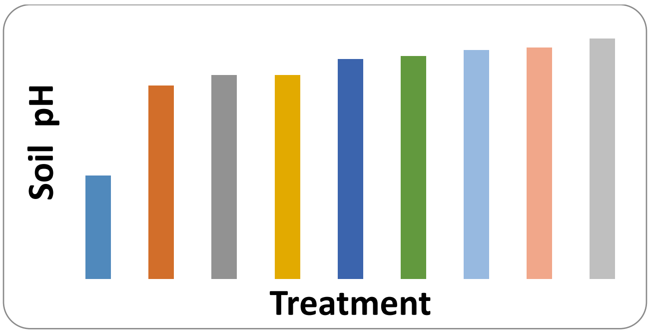


Figure 1. The pH of inceptisols soil after the provision of sago pith waste granular compost and phosphate fertilizers.

Provision of sago pith waste granular compost and phosphate fertilizer did not increase the soil pH. Soil pH was higher in KGES2 with 6.075. This was because the organic compounds that reacts with Al and Fe could produce a chelate, which retards the metal 's ability to bind P (Hanudin, 2004; Iyamuremye and Dick, 1996; Mengel et al., 2001; Pena-Mendez et al., 2005; Stevenson, 1986; Tisdale et al., 1993) (Suriadikarta et al, 2005). As a result, Al, Fe, and Mn in the soil solution reduced and the soil pH rises (Hairiah et al., 2000; Mokolobate and Haynes, 2002; Stevenson, 1986; Tisdale et al., 1993). Increasing of the soil pH after P fertilization is a result of releasng OH^- ions in solution due to partial adsorption of phosphate anions ($H_2PO_4^-$) by Al and Fe oxide hydrate (Afif et al., 1993). In addition, Ca^{2+} ions in the fertilizer will replace H^+ and Al^{3+} ions on the adsorption complex, making the concentration of H^+ ions in solution to decrease and the concentration of OH^- ions to increase (Radjagukguk, 1983)

Available Phosphate (P-Available)

Experiment results showed that the interaction between sago pith waste granular compost with phosphate fertilizer significantly affected the availability of phosphate in the soil (Figure 2).

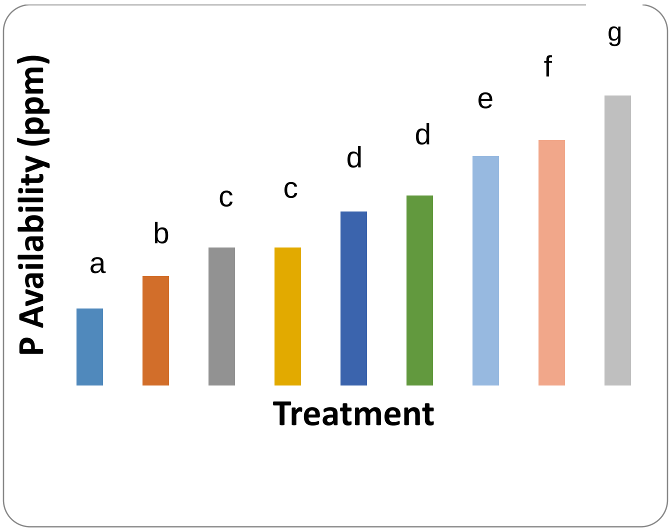


Figure 2. P-available in soi when sago pith waste granular compost was administered with phosphate fertilizer in the inceptisols soil.

Figure 2 shows that the treatment interaction that gave the greatest influence on P-available was P2KGES2. The provision of sago pith waste granular compost along with phosphate fertilizers can improve the soil P-available better than the treatment without phosphate fertilizer. Even without SP-36 fertilizer, ela sago compost significantly improved P-available in soil.

SP-36 fertilizer treatments of 120 $kg.ha^{-1}$ and 240 $kg.ha^{-1}$ with or without compost treatments were significantly different from treatments without SP-36 in increasing P- available in soil. Provision of SP-36 fertilizer with doses of 120 and 240 $kg.ha^{-1}$ without any compost raised the P-available in soil by 1.8 and 3.367 ppm, respectively. The figures were 3.1 and 6.566 ppm, respectively, when 40 $tons.ha^{-1}$ of compost was introduced, and were 2.834 and 6.0 ppm when 80 $tons.ha^{-1}$ of compost was introduced. It was seen that the higher dose of compost administered along with the addition of SP-36 fertilizer into the soil, the greater the P-available in the soil.

Sago pith waste granular compost can improve soil P-availability, as the decomposition of organic matter will release P into the soil. The compost will also reduce Al_e, soil pH, maximum P adsorption, retention of P, and the fractions of Al-P and Fe-P, also lower the active surface of soil components in binding P (Kaya, 2003; Potter, 1993) (Licudine, 1995).

Plants Phosphate Uptake

The experimental results show that the interaction between sago pith waste granular compost with phosphate fertilizer had no significant effect on the uptake of phosphate by plants (Figure 3).

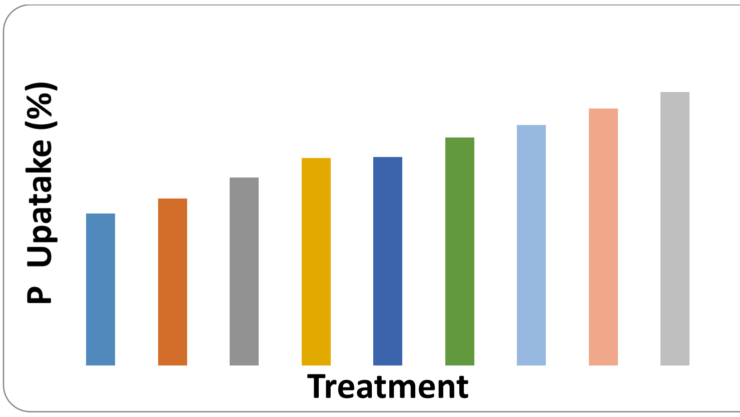


Figure 3. Phosphate uptake by corn plant when sago pith waste granular compost and phosphate fertilizers were added to the inceptisol soil they were growing.

Sago pith waste granular compost could contribute P to the soil from the decomposition, thus increasing plant P-uptake. Increased P-uptake by the plants was followed by an increase in dry corn grain yield. Sago pith waste granular compost in the soil will undergo decomposition process that produces organic acids that can reduce the activity of Al, Fe, and Mn in Inceptisol soil. Therefore, the adsorbed P by the three ions are released and become available. The process will also affect changes in soil conditions (soil pH increased) so that the plant roots will be able to absorb phosphates. In addition, the increase in P-uptake due to the increase P-availability in the soil can also be caused by the mineralization of P in the compost by soil microorganisms (Lahabi, 2007) (Minardi et al., 2007b). Sago pith waste granular compost increases water holding power of the soil and reduces soil density. Reduced soil density in turn eases plant roots to penetrate the soil, thus make them larger. This affects the reach range of roots that increases the ability of plant roots to absorb nutrients, including phosphor. In addition, the increasing power of the soil to hold water influences the water content of the soil thus increases the diffusion of phosphate ions from the soil to plant root surface. Similarly, phosphate fertilizer together with sago pith waste granular compost can improve plant P-uptake due to an increase in P-available in the soil. The raise in soil P-available and the elongated roots increase the contact between plant roots and the P in the soil so that more P is uptaken by plants. Chemical and biological processes in the root rhizosphere not only determine nutrient mobilization and acquisition of soil P and microbial dynamics, but also control the P nutrient use efficiency by plants, thus greatly affect crop productivity (Hinsinger et al., 2009; Richardson et al., 2009; Wissuwa et al., 2009; Zhang et al., 2010).

Corn Yields (Dry Grain Weight)

Experimental results show that the interactions between compost and phosphate fertilizer significantly affect the weight of dry corn grains (Figure 4).

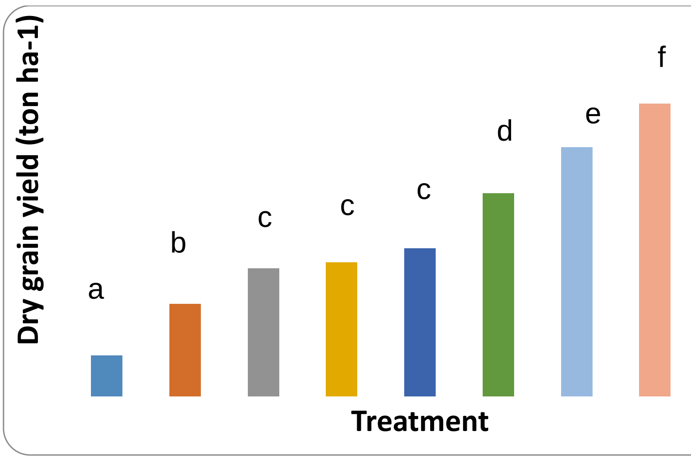
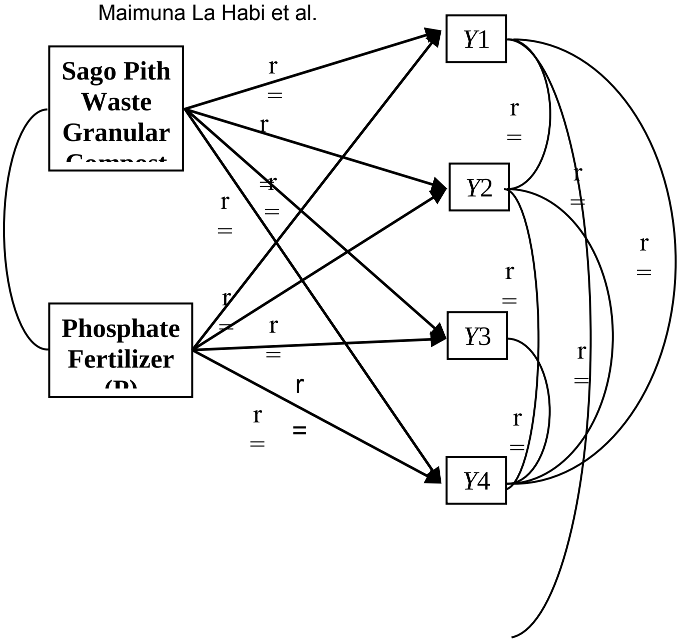


Figure 4. Dry corn grain yield when compost was introduced with phosphate fertilizers in inceptisol soil.

Figure 4 shows that the combination of compost and phosphate fertilizer can increase the corn yield (weight of dry grains) much higher than the treatment without phosphate fertilizer. Treatments without SP-36 fertilizer when combined with sago pith waste granular compost treatment either of 40 tons.ha^{-1} and 80 tons.ha^{-1} were significantly different in producing dry corn grains weight compared to no compost treatment, whereas both compost weights did not give a difference, although there was an increase. SP-36 fertilizer treatments of 120 kg.ha^{-1} and 240 kg.ha^{-1} with or without compost treatments resulted in significantly different in increasing dry corn grains yields. 120 kg.ha^{-1} and 240 kg.ha^{-1} of SP-36 fertilizer without compost treatments produced 1.19 and 2.67 tons.ha^{-1}, respectively. The increase when 40 tons.ha^{-1} compost was introduced were 1.73 and 3.87 tons.ha^{-1}, respectively, and were 2.66 and 4, 77 tons.ha^{-1} when 80 tons.ha^{-1} compost was introduced.

Based on the analysis, the relationship between soil pH and P-available was 0.67, the relationship between pH and P-uptake was positive (r = 781), the relationship between P-available and the dry corn grains weight was positive (r = 0.984), the relationship between P-uptake and the dry grains weight was positive (r = 0.894), and the relationship between the pH and the dry grains weight was also positive (r = 0.632) as depicted in Figure 5.



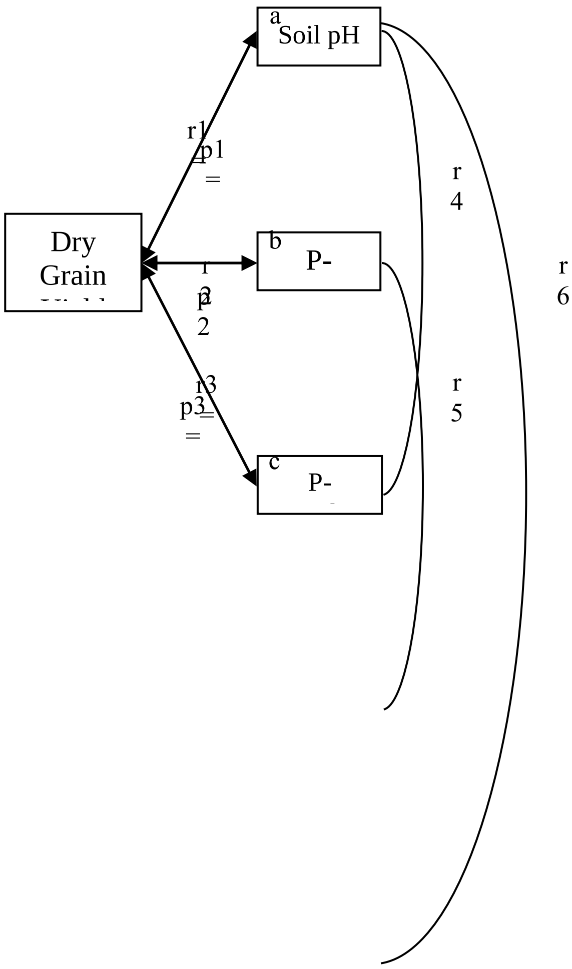


Figure 5: The relationship between soil pH, P-available, P-uptake and yield of dry corn grains. *Y*1 = soil pH, *Y*2 = P-uptake, Y3 = P-available, Y4 = dry grain yield, and *r* = effect of total grain yield to each factor.

The total effect of pH on the grain yield through the P-available and P-uptake was p = 0.951, where the direct influence of pH on the dry grain weight was at -0.123. This means that if the pH acts alone it will negatively affect the dry grain weight results. But when the pH acts together with the P-available and P uptake it will have a positive influence on the dry grain weight results. The effect of P-available on the dry grain weight results through pH and P-uptake was 0.982, where direct influence of P-available on the dry grain weight results was 0.875. So it could be said that if the P-available was applied together it will give a greater influence than individual application. The total P-uptake influenced the dry grain weight results at 0.894, where direct influence of P-uptake on the dry grain weight results was 0.214. It can be concluded that if the P-uptake was applied together then it will give a greater influence than when it was applied individually. Observations on three direct influences, i.e. pH on the dry corn grain weight results, P-available on the dry corn grain weight results, and P-uptake on the dry corn grain weight results, showed that the P-available gave the greatest effect (p = 0.875) compared with pH and P-uptake. Similarly, the total effect of the P-available on the dry corn grain weight results through pH and P-uptake gave the greatest influence (p = 0.982) compared to the total effect of the others.Sago pith waste granular compost improves the chemical properties of the soil, especially the increase of P-available in the soil and its pH. The higher the P-available in soil, the higher the P-uptake by plant roots and the dry corn grain result.

4. Conclusion

Sago pith waste granular compost combined with phosphate fertilizers can increase soil pH and available phosphate that resulted in plant roots are capable of absorbing phosphate properly, so that the results of the dry corn grain weight also increased. Sago pith waste granular compost dose of 80 $tons.ha^{-1}$ together with phosphate fertilizer dose of 120 $kg.ha^{-1}$ increased the soil pH to 6.7, while with phosphate fertilizer dose of 240 $kg.ha^{-1}$ improved the P-available in soil to 16.233 ppm. Besides, compost dose of 80 $tons.ha^{-1}$ and phosphate fertilizer dose of 240 $kg.ha^{-1}$ was also able to independently increase the P-uptake of plants by 0.168% and 0.169%, respectively. About 80 $tons.ha^{-1}$ of compost and 240 $kg.ha^{-1}$ of P fertilizer was the best dose combination to improve the results of the dry corn grain weight yield at 7.85 $tons.ha^{-1}$. The results of the study apply to all types of soil, not only Inceptisols and for further researchers, it is better to examine the chemical and biological properties of the soil as well because it is related to soil quality and sustainable organic agriculture.

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