

Mechanism in Using Commercial High Efficient Zeolite-Base Greenfeed Slow Release Fertilizers

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Abstract

Fertilizer issues such as overuse, leaching and soil degradation are becoming severe in worldwide plantation areas. To secure current food production, prevention measures on these issues are relatively limited on agricultural production areas. Slow release fertilizer is prevailing over past years due to its significant effects on prevention of fertilizer leaching and less harm to soil and underground water. We presented here the mechanisms of a novel zeolite-based slow release fertilizer including its properties as reservoirs of nutrients, pH balancer and also water retainer in soil. By providing sufficient nutrients to soil, this fertilizer has commercially proven to give better growing environment to grower as well as labor saving and cost saving.

Keywords

Ion Gradient, Slow Release Fertilizer, Soil, Zeolite

1. Introduction

To meet the requirements on food demands, elements such as nitrogen and phosphorus and potassium in fertilizer are essential for living crops. Global consumption on fertilizer is steadily increasing in response to the growing population and this has led to overuse of fertilizers in many areas [1]. Leaching of nitrate can happen through inappropriate use of nitrogen fertilizers and become a major cause of soil acidification, degradation and underground water pollution [2] [3]. The need to seek high efficient utility rate of commercial fertilizer is very much stronger over years. So far, the appearance of controlled release fertilizer, or the so-called time-release fertilizer has improved the nutrients use efficiency [4], however, these resin-coated or polymer-coated fertilizers may cause some other environmental issues due to the resin waste remained after nutrients re-

leased and also, temperature-regulated characteristic of these fertilizers is always a restriction factor to its release.

Zeolite is a group of highly crystalline hydrated aluminosilicate minerals with porous structure with diameters of pore between 0.3 - 1 nm [5] [6] [7]. It is widely used as molecular sieve materials that can absorb ions based on their sizes [7] [8]. This enables zeolite to retain cation elements such as NH_4^+ , K^+ , Ca^{2+} and so on [7]. The release of adsorbed cations on the surface zeolites due to ionic gradient in soil ensures its slow-release characteristics [9] [10] [11]. The use of zeolite-based fertilizer has been reported in crops such as paddy and banana [12] [13].

Commercial zeolite-regulated slow release fertilizer presented by Greenfeed Agro Company in Malaysia has made significant progress over years in global market. Greenfeed® slow release fertilizer (GSRF), a compressed and pelletized nugget forming in averagely 16 g per piece, has the absorptive mechanism that plays a definitive role to the nutrient release and availability for plant's utility (Figure 1). This specialty compound fertilizer is zeolite integrated to prevent nutrient losses, regulate cations exchange capacity (CEC) in soil and also preservation of water [10] [11] [14]. Moreover, zeolite is also helping to improve pH level, while the slight-alkaline nature of Greenfeed slow release fertilizer contains liming materials which is able to optimize the soil pH around the applied area. We summarized here the mechanism may involve on the performance of this high efficient slow release fertilizer.

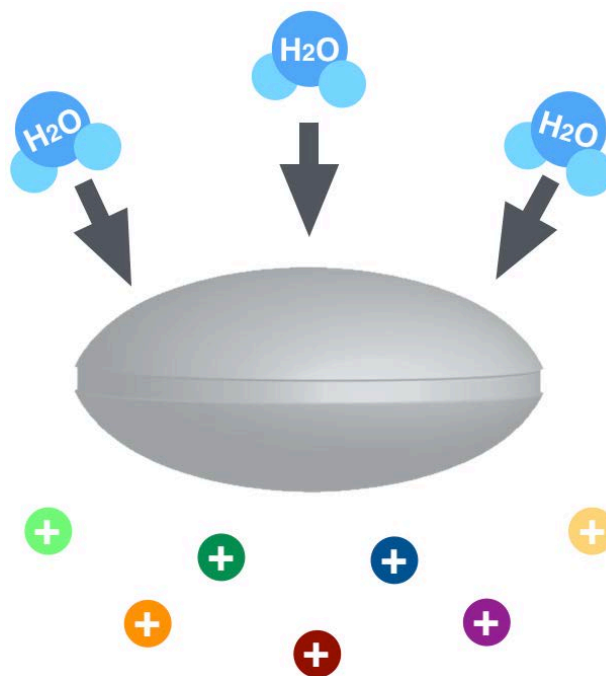


Figure 1. Schematic diagram on the Greenfeed® Slow Release Fertilizer release mechanisms. Water first into contact with the nugget. The outer layer then will start releasing nutrients into the soil environment based on the ionic gradient.

2. Reservoir and Release of Elements by Ionic Gradient

Zeolite is natural occurring mineral known as a suite of porous, fine-grained minerals commonly found in certain near surface, sediment rocks, having special physical and chemical properties that could make them valuable for agricultural practices [10] [11]. Some of the characteristics of zeolites that potentially make them desirable for improving the properties of soils are a large internal porosity that results in water retention, a uniform particle-size distribution that allows them to be easily incorporated, and high cation-exchange capacity that retains nutrients [15]. Abdi [16] reported that zeolite capabilities on the improvement of soil physical environment particularly in sandy and clay poor soil. This report also stated that the application of zeolite increased the available nitrogen, phosphorus, calcium and magnesium of the soil. Other study also proves that by using zeolite as soil amendment will improve the soil cation exchange capacity as stated by DeSutter and Pierzynski [17]. Zeolite also has a positive influence on nitrate leaching, nitrogen use efficiency and yield of crop [18]. The benefits of slow release fertilizer are not just limited to nitrogen alone. It also applies to other nutrient as well. As an example, Bley *et al.* [19] also proved the positive impact of potassium (K) slow release fertilizer.

The activated zeolite included within GSRF's formulation provides the lasting nutrient reservoirs through the adhesive characteristic that zeolite has; resulting in longer period of nutrient availability for the plant's uptake. The nutrient release is carried out according to the ionic gradient difference between the fertilizer and the soil. This will ensure that the nutrient released is being carried out synergistically to the soil environment surrounding the fertilizer, which is relatively affected by the root's absorption rate. Such process promotes the efficient nutrient release into the soil and based on the plant demand. The breakdown of GSRF in soil is summarized into three directive processes, which are rehydration, reactivation and equivalence control. The rehydration process is the movement of soil moisture to the surface of the fertilizer. After the hydration process taken, nutrients are reactivated and turn into ionic form and ready to be released from the zeolite carrier. The third equivalence process occurs based on the ionic gradient within the fertilizer and the soil. The nutrients are released via transfusion based on the differences in the ionic gradient between the fertilizer and the soil, hence, resulting in a controlled and efficient nutrient releasing mechanisms that defines this high efficient fertilizer. Its performance on crops such as banana and paddy were reported by Ng *et al.* In banana applied GSRF, the foliar content of macro-elements nitrogen, phosphate, and potassium in Greenfeed® group was 12.5%, 10% and 34.8%, respectively, higher than the conventional compound fertilizers and photosynthesis rate was found 10.5% - 32% higher [12]. Paddy yield was found increased from 6100 kg/ha to 8000 kg/ha, with 33% increment [13].

3. pH Balancer

Leaching of nitrogen in the nitrate form is a very important factor in soil acidity.

Nitrate is a major nutrient for plant growth however, wastage of fertilizer from this processes are tremendous [20]. When there are more nitrates than the plant can use, the nitrate is at risk of leaching below the plants roots and into the ground water system. Every nitrogen element that cannot be absorbed by the plant will potentially leach and bring down the soil pH [21]. Leaching of nitrate can happen through inappropriate use of nitrogen fertilizers and intensive production of crops that required heavy applications of nitrogen fertilizers are examples of practices that may increase the risk of nitrate leaching. Hence, proper fertilizer selection and proper practice are crucial for minimize this issue. Leaching losses is high in poor soil with low clay content. **Table 1** shows the summary of the nitrogen fertilizer loss in different type of soil presented by Foong [22].

Numerous studies have shown that the application of slow release fertilizer can significantly reduce the amount of nutrient leaching. Nitrogen is one of the nutrients that are most prone to leaching. Nitrogen leaching into groundwater poses serious environmental hazards that result from the lack of oxygen available to organisms [23]. Zarebyaneh & Bayatvarkeshi [20] shows that the application of slow release fertilizer reduces the nitrate leaching improve nitrogen use efficiency and increase yield production. Slow release fertilizers reduce nitrate leaching up to 35.75% and increase plant available nitrogen in the soil during growing season [20]. Uptake and assimilation of NH_4^{4+} is a proton generating process and usually leads to a decrease in the external pH and in the contents of carboxylates in the roots, whereas NO_3^{3-} uptake and assimilation is a proton-consuming process and usually leads to an increase in external pH and in the contents of carboxylates in the roots [24]. Hence, the cytoplasmic pH must be maintained in a fairly constant at or near neutral pH, in order not to disrupt the cellular processes which are sensitive to pH [25] [26].

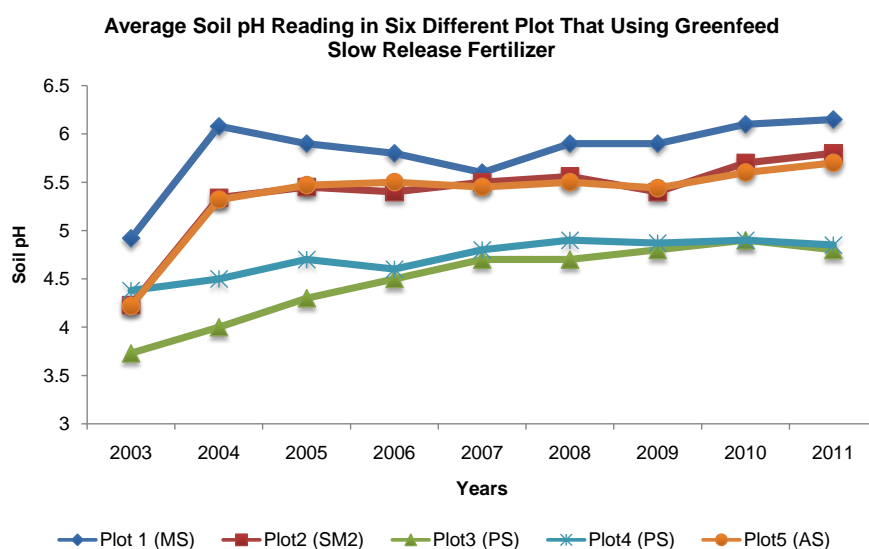
Many research and studies has indicated the use of zeolite can improve pH level of acid soils, thus reducing the need for applications of lime. Apart from that, GSRF has a slight-alkaline characteristic that derived from the liming material contained within that have the ability to improve the soil pH around the applied area. **Table 2** and **Figure 2** demonstrate the effect of using GSRF on soil pH over a period of 9 years. The soil pH was gradually improved (internal study not published). Problem like soil hardening also much altered. The lower

Table 1. Percentage of nitrogen leaching in different type of soil.

Soil group	Soil situation	Leaching losses % nutrient lost in fertilizer	Balance % nutrient available to oil palm
1	Clayey > 8% slope	10	50
2	Sandy > 8% slope	43	29
3	Clayey > 8% slope	10	60
4	Sandy > 8% slope	43	38
5	Peat	56	29

Table 2. Data on the average pH reading of six different planting ages of oil palm in Malaysia.

Planting year	pH value (2003)	pH value (2004)	pH value (2005)	pH value (2006)	pH value (2007)	pH value (2008)	pH value (2009)	pH value (2010)	pH value (2011)
2000 (S. Clay. S)	4.92	6.08	5.90	5.80	5.60	5.90	5.90	6.10	6.15
2002 (Sandy. S)	4.23	5.34	5.45	5.40	5.50	5.56	5.40	5.70	5.80
2005 (Peat. S)	3.73	4.00	4.30	4.50	4.70	4.70	4.80	4.90	4.80
2006 (Peat. S)	4.38	4.50	4.70	4.60	4.80	4.90	4.87	4.90	4.85
2006 (Aluvir. S)	4.22	5.32	5.47	5.50	5.45	5.50	5.44	5.60	5.70

**Figure 2.** Average soil pH in six different plots that using Greenfeed® Slow Release Fertilizer.

salt accumulation in the subsurface soil or root zone may offer a reduced salt stress on plants. Thus, an application of zeolite may filter harmful salts from the root zone, thereby creating a favorable environment for plant growth and soil ecosystem.

4. H₂O Retainer

Climate change especially rainfall becoming variable in worldwide regions and extreme weather is expected to increase abiotic and biotic stress on plants [27]. Soil moisture determines nutrients availability for plant uptake including ion transport, nutrient supply and uptake by plants is influenced by water content of a soil [28]. These mechanisms supply a significant proportion of nutrients that are present at high concentrations in soil solution or are almost exclusive in the

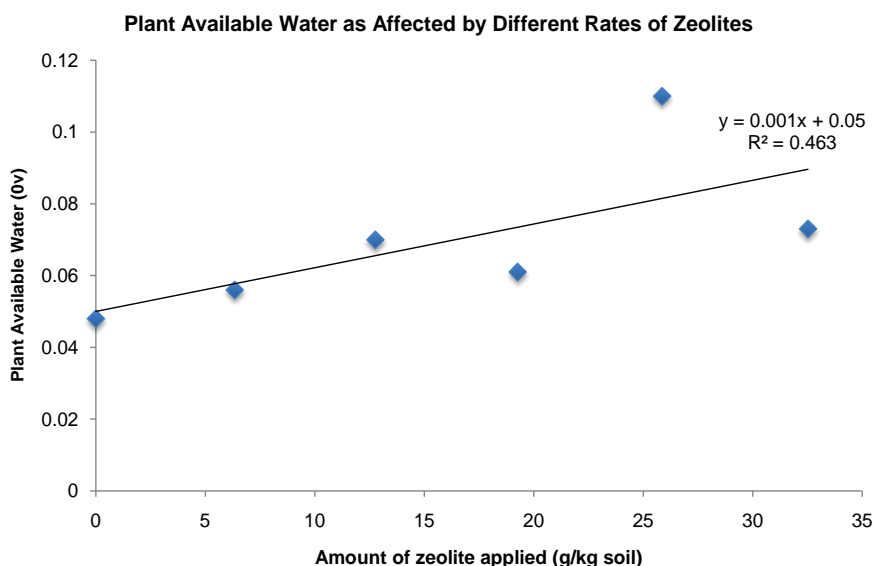


Figure 3. Plant available water as affected by different rates of zeolite.

solution phase in order for the nutrients to be taken up by the plant [29] [30].

Zeolites have been proposed to improve the water holding capacity and drainage control [31] [32] [33], eventually prevention on nutrient leaching. **Figure 3** shows that for every gram of zeolite added to a kilogram of soil, there is a significant 0.12% increase in the plant available water [34]. Integrated zeolite inside Greenfeed® Slow Release Fertilizer has the ability to retain moisture is another positive aspect to be use as a soil amendment. Zeolites can hold up to 60% of their weight in water due to the high porosity of their crystalline structure [9] [10] [11]. Zeolite acts as a non-form changing, permanent water reservoir, which provides prolonged moisture during dry periods as well as promoting rapid re-wetting and improved lateral spread in the root zone during irrigation. This in turn reduces the quantities of water needed for irrigation [9] [10] [11].

5. Conclusion

Commercial slow release fertilizer from Greenfeed® has demonstrated various advantages over past decades in many crops. The mechanisms involved in the product action can be summarized into characteristics as ion-gradient reservoir, pH balancer and water retainer. During nutrient release, it is released based on ionic gradient difference between the fertilizer and the soil. This will ensure that the nutrient released is being carried out synergistically to the soil environment. GSRF displays a slight-alkaline characteristic that has the ability to improve the soil pH around the applied area. By using of GSRF, soil pH was gradually improved. Application of GFSF may filter harmful salts from the root zone, thereby creating a favorable environment for plant growth and soil ecosystem. Zeolites integrated GSRF has the ability to retain moisture which is another positive aspect to be used as a soil amendment. With these mentioned mechanisms occurred during its application, we hope this may interpret clearly for its further promotion and po-

pularization in other regions.

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