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*Research article*

# Effect of Eggshell Wastes from Different Bird Species on Growth and Yield of Peanut

**Nittaya Phakamas[1]*, Phonthip Gatewit[1], Maythavee Kongsamret[1], Pornpen Somchit[2] and Chorkaew Aninbon[1]**

[1]*Department of Plant Production Technology, School of Agricultural Technology, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand*
[2]*Chachoengsao Provincial Agricultural Extension Office, Chachoengsao, Thailand*

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## Abstract

Eggshell wastes from various bird species may be used as an alternative calcium source for peanut production. The purpose of this experiment was to determine the effects of eggshell waste from chicken, duck and quail on the growth and yield of peanut. Five treatments consisting of no gypsum control, three eggshell wastes from chicken, duck and quail, and commercial gypsum were laid out in completely randomized design with four replications during December 2020 to April 2021. Peanut variety KK 6 was planted in cement plots. Gypsum and eggshell wastes were applied at the rate of 312.5 kg/ha at 25 days after planting. Data were collected for growth parameters, pod yield and yield components at harvest. Analysis of variance was performed for all parameters, and means were separated by least significant difference at the 0.01 probability level. Eggshell wastes from chicken, duck and quail did not show significant effects for leaf dry weight, stem dry weight, total dry weight and 100 seed weight, but they significantly increased pod dry weight, seed yield, filled seed, shelling percentage and harvest index. All eggshell wastes produced higher growth and yield of peanut than commercial gypsum. Eggshell waste from duck seemed to be better than the other sources in terms of yield increase in KK 6 peanut.

**Keywords**

peanut;

gypsum;

calcium;

seed filling

## 1. Introduction

Calcium deficiency during the vegetative phase is highly detrimental to the pod yield of peanut (*Arachis hypogaea* L.), and calcium in the soil should be monitored closely in peanut production. High levels of calcium are needed for peanut growth and development, and calcium deficiency can result in unfilled pods called "pops", as well as reductions in yield and grade. Calcium uptake by

*Corresponding author: Tel.: (+66) 023298512 Fax: (+66) 023298512
E-mail: nittaya.ph@kmitl.ac.th

the peanut plant is unique because most calcium is absorbed directly through the peanut pods from the soil solution instead of being taken up by the roots [1].

Application of calcium on the peanut plant pod zone increased the number of pods per plant, and the use of calcium in the form of gypsum between 10 to 30 days after penetration of gynophores into the soil increased the percentage of developed pods [2]. According to Cheema *et al*. [3], calcium is a yield-enhancing nutrient in peanut, and it is needed for both good vegetative growth and normal healthy fruit development. Deficiency of both calcium and phosphorus, particularly calcium, is a possible cause of low yield in peanut production, and calcium deficiency leads to a high percentage of aborted seeds (empty pods or pops) and improperly filled pods [4, 5]. Therefore, gypsum is widely used as a source of calcium for peanut production worldwide because peanut is highly responsive to calcium application [6].

Gypsum provides calcium to plants, and it is also a source of sulfur. Several sources of gypsum are utilized in the peanut production system including mined gypsum from geologic deposits, phosphogypsum from wet-acid production of phosphoric acid from rock phosphate, recycled casting gypsum from various manufacturing processes, recycled wallboard gypsum, and flue gas desulfurization (FGD) gypsum from power plants. FGD gypsum is a new and large volume source and is produced in the coal-fuel production of electricity, heat, or other forms of energy [7].

At present, gypsum for agricultural use is derived from both mined and synthetic sources. Industrial by-products such as FGD gypsum can potentially be a more economic source of gypsum as well as providing additional agricultural benefits by supplying nutrients (calcium and sulfur) for plants, ameliorating sodic and acidic soils, improving soil physicochemical properties, and reducing soil and nutrient (phosphorus) losses [8].

However, there are also concerns about heavy metal contamination which can harm consumers if gypsum by-products from power plants are used in peanut production systems [9, 10]. Therefore, if a natural source of gypsum could be substituted for synthetic gypsum, it could reduce concerns about heavy metal contaminants in peanut production and be environmentally friendly.

An alternative source of calcium carbonate ($CaCO_3$) is the eggshells with substantial underutilized volume found as wastes in households and hatchery of poultry industries [11]. Eggshells contain calcium and trace amounts of other elements, i.e. magnesium, boron, copper, iron, manganese, molybdenum, sulfur, silicon and zinc. Calcium carbonate makes up approximately 94% of the eggshells of most bird species [12]. It is a much better source of calcium than limestone or coral sources [13]. Besides, the eggshells of the eggs of different birds contain varying percentages of calcium content [14]. However, there are few reports of studies comparing different types of eggshells as calcium sources for use in peanut production. Therefore, the objective of this study was to compare the influence of different eggshell types on the growth and yield of peanut, and to find a way to use eggshell gypsum instead of synthetic gypsum for sustainable peanut production and environmental friendliness.

## 2. Materials and Methods

### 2.1 Location and experimental design

The experiment was conducted in cement containers under open environment at the Department of Plant Production Technology, School of Agricultural Technology, King Mongkut's Institute of Technology Ladkrabang, Thailand, during December, 2020 to April, 2021. The KK 6 peanut variety was treated with five calcium source treatments; no gypsum (control), chicken eggshell, duck eggshell, quail eggshell and commercial gypsum. The treatments were assigned in a completely randomized design with four replications.

### 2.2 Eggshell preparation

Three kinds of eggshell wastes, chicken, duck and quail, were kindly donated from food shops near King Mongkut's Institute of Technology Ladkrabang. They were sun-dried and crushed into a powder. All finely ground eggshell wastes were analyzed for chemical properties in laboratory, and the chemical properties of these eggshell wastes are presented in Table 1.

### 2.3 Soil preparation and planting

Soil was obtained from a rice field in Ban Sang district, Prachinburi province. The soil was dried under shade for a week and crushed into small particles. The dry soil (150 kg) was loaded into cement plot, each of which had a diameter of 1 m and height of 0.40 m. There were 20 plots in total. The soil sample was also analyzed for physical and chemical properties before planting (Table 2).

Ethephon 2-chloroethylphosphonic acid 52% W/V was applied to the peanut seed at the rate of 6 mL per 20 L of water to overcome possible dormancy of the seed as the KK 6 had seed dormancy parents in its pedigree. A fungicide, phthalimide N-(trichloromethylthio) cyclohex-4-ene-1.2-dicarboximide 50% WP, was applied to the seed at the rate of 5 g per kg of seed to control soil borne diseases. Seed was also treated with *Rhizobium* spp. before planting to enhance symbiotic nitrogen fixation as the soil did not have a history of peanut cultivation.

The seed was planted at a spacing of 25 × 25 cm on four hills for each cement plot at the seed rate of 2-3 seeds for sufficient seedlings at emergence, and the seedlings were later thinned to obtain 1 plant per hill at 14 days after planting.

All gypsum treatments were applied to the crop at 25 days after planting (flowering stage) at the rate of 312.5 kg/ha. Manual weed control was carried out 2 times, at 15 and 20 days after planting. Irrigation was applied by a sprinkler system twice day.

### 2.4 Plant data collection and data analysis

The plants were harvested at maturity of approximately 103 days after planting when 60% of the pods had brown inner shells. As the researchers had difficulty to get access to the experimental site because of the work from home policy of the campus due to Covid 19 pandemic, two plants were sampled from each cement plot, and harvest time was delayed for a week. Stems, leaves and pods were separated and oven-dried at 80ºC for 48 h or until the dry weight was consistent.

The pods were shelled to separate shell and seeds, and the shells and seeds were weighed. The hundred seed weight was recorded, and shelling percentage was calculated. The pods were also counted for filled pods and unfilled pods. The data were subjected to analysis of variance according to a completely randomized design, and the differences among treatment means were compared by least significant difference (LSD) at 0.05 and 0.01 probability levels using M-STATC software from Michigan State University.

## 3. Results and Discussion

### 3.1 Soil properties

The soil was acidic with a pH value of 4.66, but it was not saline, with electrical conductivity (EC) value of 0.58 mS/cm (Table 2). Organic matter (OM) was intermediate, being 2.55%. Available phosphorus (P), exchangeable potassium (K), exchangeable calcium (Ca), exchangeable magnesium (Mg), extractable sodium (Na), extractable iron (Fe), extractable manganese (Mn), extractable zinc

**Table 1.** Chemical properties of commercial gypsum and eggshell wastes from chicken, duck and quail

| Chemical property | Eggshell | | | Commercial gypsum |
|---|---|---|---|---|
| | Chicken | Duck | Quail | |
| Total carbon (%) | 13.04 | 15.53 | 13.05 | nd |
| Total nitrogen (%) | 0.79 | 1.85 | 0.87 | nd |
| Total sulfur (%) | 0.11 | 0.24 | 0.17 | 0.44 |
| Total phosphorus (g/kg) | 1.26 | 3.48 | 1.81 | 150.13 |
| Total potassium (mg/kg) | 792 | 1,609 | 183 | 136.69 |
| Total calcium (g/kg) | 329 | 314 | 346 | 148.49 |
| Total magnesium (g/kg) | 3.62 | 5.93 | 1.12 | 45.21 |
| Total iron (mg/kg) | nd | nd | 159 | 40.75 |
| Total manganese (mg/kg) | nd | nd | 1.00 | 1.15 |
| Total zinc (mg/kg) | nd | nd | nd | 0.03 |
| Total copper (mg/kg) | 0.13 | 1.84 | 13.12 | 0.00 |
| Total boron (mg/kg) | 4.47 | 2.10 | 4.08 | 7.91 |
| Total sodium (g/kg) | 1.41 | 2.17 | 0.87 | 129.67 |

nd = not detected

(Zn) and extractable copper (Cu) were sufficient for the plant with values of 15.47, 222.18, 1,803.46, 638.81, 327.41, 95.67, 23.77, 2.68 and 1.50 mg/kg, respectively. It should be noted here that exchangeable Ca was higher than the other elements.

### 3.2 Eggshell and gypsum compositions

Eggshell wastes had higher total carbon, total nitrogen, total potassium and total calcium than commercial gypsum, whereas commercial gypsum had higher total sulfur, total phosphorus, total magnesium, total iron, total manganese and total sodium than eggshell wastes (Table 2). Among the eggshell wastes, waste from duck eggs was highest for total carbon, total nitrogen, total sulfur, total phosphorus, total potassium and total magnesium, and the waste from quail eggs had the highest total calcium, total iron, total manganese and total copper.

In this study, eggshell wastes from different bird species were evaluated as potential sources of calcium in the peanut production system. According to King'ori [13], eggshell wastes from different bird species contained calcium and trace amounts of other elements such as magnesium, boron, copper, iron, manganese, molybdenum, sulfur, silicon and zinc. These nutrients are essential for the growth and yield of peanuts. Eggshells are also easily obtained from household and food industry waste.

**Table 2.** Soil chemical properties before planting

| Soil properties | |
|---|---|
| pH (1:1) | 4.66 |
| Electrical conductivity (EC) (1:5) (mS/cm) | 0.58 |
| Total carbon (%) | 1.29 |
| Total nitrogen (%) | 0.12 |
| Total sulfur (%) | 0.77 |
| Organic matter (OM) (%) | 2.55 |
| Available phosphorus (mg/kg) | 15.47 |
| Exchangeable potassium (mg/kg) | 222.18 |
| Exchangeable calcium (mg/kg) | 1,803.46 |
| Exchangeable magnesium (mg/kg) | 638.81 |
| Extractable sodium (mg/kg) | 327.41 |
| Extractable iron (mg/kg) | 95.67 |
| Extractable manganese (mg/kg) | 23.77 |
| Extractable zinc (mg/kg) | 2.68 |
| Extractable copper (mg/kg) | 1.50 |

Eggshell wastes from different bird species are different in their appearance characteristics such as color and thickness. They are also different in the physical and chemical properties that may affect the growth and yield of peanut. In this study, eggshell wastes from chicken, duck and quail were analyzed for their chemical properties. Eggshell waste from quail contained higher calcium than those from chicken and duck. Ajayan *et al*. [15] reported that eggshell wastes with a dark color (quail eggshell) contained higher calcium than those with brown color (chicken eggshell) and white color (duck eggshell), indicating that eggshell wastes of darker color were stronger than those with lighter color [16]. Our results were consistent with those reported in previous studies.

However, duck eggshell waste had higher total carbon, total nitrogen, total sulfur, total phosphorus, total potassium, total magnesium and total sodium than those from chicken and quail. Contrasting results were reported in a previous study. Shen and Chen [17] found that duck eggshell waste had higher calcium and lower magnesium than eggshell waste from chickens. The differences in the results from different studies were likely due the differences in environments and breeds of bird species.

According to Kadirimangalam *et al*. [18], calcium uptake by peanut plants from the soil remains in the plant tissues and will not be transported back to developing pods which have a high calcium requirement. The subterranean growth of peanut pods can absorb calcium from the soil directly. Therefore, application of calcium before the pod development stage in the peanut plant is required in order to have sufficient calcium available to the pods. Such pre-supplied calcium can help increase in yield of up to 20-30%.

### 3.3 Growth and yield of peanut

Different sources of calcium did not produce significant differences for leaf dry weight, stem dry weight and total dry weight, but they produced significant differences ($P \leq 0.01$) for pod dry weight (Table 3). However, it was likely that chicken eggshell waste as the source of calcium produced the highest leaf dry weight of peanut at 6.71 t/ha followed by duck eggshell, gypsum, quail eggshell and control treatment with leaf dry weights of 5.54, 5.49, 4.76 and 4.43 t/ha, respectively. Waste from chicken eggshell was also highest for stem dry weight (9.17 t/ha), and control treatment was lowest (5.74 t/ha).

All eggshell wastes had high pod dry weights, ranging from 9.76 to 10.78 t/ha, but they were not significantly different from the no gypsum control (6.95 t/ha). However, they were significantly higher than commercial gypsum (4.53 t/ha). Although the differences were not significant, all wastes from eggshell had higher total dry weight (20.76 to 26.25 t/ha) than the no gypsum control (17.12 t/ha) and commercial gypsum (17.81 t/ha).

It is well known that calcium is an important element for peanut pod development. Although eggshell waste from quail had the highest calcium, it tended to have lower pod yield than the eggshell wastes from chicken and duck. This may be due to the calcium absorbed by the roots not being translocated to the developing pods, whereas calcium required for pod formation is absorbed directly from soil solution because of the subterranean nature of the peanut pods [6]. Besides, the availability of nutrients at different soil pH levels is also a relevant factor in determining fertilizer source and effectiveness [19, 20].

Application of gypsum may not be effective at low soil pH because of low availability and short residence time for absorption. At the recommended soil pH level range of 5.8-6.2, the application of large quantities of calcium can influence peanut growth and development when needed, but can also impact concentrations of other cations that are important in peanut growth [21, 22]. In this study, the soil pH was lower than the recommended soil pH, thus possibly causing the pod yield of peanut treated with eggshell waste from quail to be lower than that treated with eggshell waste from duck. Another possible reason for higher pod yield in eggshell waste from duck was that higher potassium may have had an effect on translocation of assimilates into developing pods.

**Table 3.** Means for leaf dry weight, stem dry weight, pod dry weight and total dry weight of KK 6 peanut variety as affected by different sources of calcium from eggshell wastes

| Treatment | Dry weight (t/ha) | | | |
|---|---|---|---|---|
| | Leaf | Stem | Pod | Total |
| No gypsum | 4.43 | 5.74 | 6.95$^{ab}$ | 17.12 |
| Chicken eggshell | 6.71 | 9.17 | 10.38$^{a}$ | 26.25 |
| Duck eggshell | 5.54 | 7.13 | 10.78$^{a}$ | 23.45 |
| Quail eggshell | 4.76 | 6.46 | 9.76$^{a}$ | 20.76 |
| Commercial gypsum | 5.49 | 7.79 | 4.53$^{b}$ | 17.81 |
| F-test | ns | ns | ** | ns |
| C.V. (%) | 25.84 | 25.48 | 21.83 | 21.95 |

ns and ** = non-significant and significant difference at 0.01probability level by LSD, respectively. Means in the same column followed by the same letter are not significantly different.

Calcium sources were significantly different (P≤0.01) for seed yield, filled pod, un-filled pod, shelling percentage and harvest index, but they were not significantly different for 100-seed weight (Table 4). All eggshell wastes produced significantly higher values than commercial gypsum for seed yield, filled pod, shelling percentage and harvest index, but they were significantly lower than commercial gypsum for un-filled pod. However, all eggshell wastes were similar to the no gypsum control for seed yield, filled pod, un-filled pod, shelling percentage, harvest index, and 100-seed weight.

In the comparison of the eggshell wastes, all eggshell wastes showed similar performance for seed yield, percentage of filled seed, shelling percentage and harvest index. However, duck eggshell waste was more likely to have higher seed yield, percentage of filled seed, shelling percentage, and harvest index than the eggshell wastes from chicken and quail. Better performance of eggshell waste from duck for these traits was probably due to higher potassium in duck eggshell waste (1,609 mg/kg) compared to eggshell wastes from chicken (792 mg/kg) and quail (183 mg/kg). Higher performance in eggshell waste would be largely due to higher potassium content as potassium is known to enhance pod and grain filling in pulse and grain crops [23]. In peanut, potassium and calcium work in synergistic manner for yield increase. Both of these nutrients are abundant in duck eggshell. Therefore, the use of duck eggshell waste may well improve the growth and yield of peanut. Moreover, the eggshells can have high content of other various growth promoting compounds such as amino acids which can also have a significant stimulatory effect on plant growth, yield and quality [20, 24, 25].

In addition, this study found that different calcium sources did not significantly affect 100-seed weight, and 100-seed weight was highest in chicken eggshell waste (70.3 g) and lowest in commercial gypsum (51.4 g) (Table 4). Our results were in agreement with those in previous studies. According to Ajayan *et al*. [15], peanut treated with eggshell wastes from chicken and duck showed better performance for yield and agronomic traits than peanut supplied with commercial gypsum. Higher calcium and better-balanced nutrients in eggshell wastes may result in better performance of peanut treated with those wastes.

**Table 4.** Means for seed yield, filled pod, un-filled pod, shelling percentage, harvest index and 100-seed weight of KK 6 peanut variety as affected by different sources of calcium from eggshell wastes

| Treatment | Seed yield (t/ha) | Filled pod (%) | Un-filled pod (%) | Shelling (%) | Harvest index | 100-seed weight (g) |
|---|---|---|---|---|---|---|
| No gypsum | 4.58$^{ab}$ | 96.13$^{a}$ | 3.87$^{b}$ | 65.6$^{a}$ | 0.26$^{a}$ | 54.5 |
| Chicken eggshell | 6.77$^{a}$ | 97.40$^{a}$ | 2.61$^{b}$ | 65.1$^{a}$ | 0.25$^{a}$ | 70.3 |
| Duck eggshell | 7.09$^{a}$ | 97.69$^{a}$ | 2.31$^{b}$ | 66.0$^{a}$ | 0.30$^{a}$ | 63.6 |
| Quail eggshell | 6.19$^{a}$ | 96.76$^{a}$ | 3.24$^{b}$ | 63.2$^{a}$ | 0.29$^{a}$ | 68.1 |
| Commercial gypsum | 1.81$^{b}$ | 90.30$^{b}$ | 9.71$^{a}$ | 40.1$^{b}$ | 0.10$^{b}$ | 51.4 |
| F-test | ** | ** | ** | ** | ** | ns |
| C.V. (%) | 25.74 | 2.76 | 60.71 | 11.32 | 19.98 | 16.61 |

ns and ** = non-significant and significant difference at 0.01probability level by LSD, respectively. Means in the same column followed by the same letter are not significantly different.

## 4. Conclusions

Application of eggshell wastes from chicken, duck and quail gave higher dry weight, yield components and yield of peanut than application of commercial gypsum. It was also likely that the application of duck eggshell waste was superior to application of wastes from chicken and quail. Therefore, eggshell wastes from chicken, duck and quail can be used as an alternative calcium source for peanut production.

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