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Effects of rock phosphate and vermicompost on off-season longan production

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Abstract Results showed that applying rock phosphate and vermicompost to longan plants, as partial replacement of chemical fertilizer prior to the $KClO_3$ application, showed effectiveness in off-season longan production. Application of rock phosphate and vermicompost to longan plants at a 4:8 kilogram per plant level, resulted in the best off-season longan production quality. Yield quality in terms of fruit number, fruit weight and total fruit weight were highest, significantly higher than other levels and control group ($p \leq 0.05$). It also resulted in highest in inflorescences, flowers numbers and total soluble solids content (°Brix). These findings benefit to longan producers by reducing chemical fertilizers and also helps to improve soil quality as well, since soil pH improved in the experimental group.

Keywords: Off-season longan production, Rock phosphate, Vermicompost

Introduction

Longan (*Dimocarpus longan* Lour) is an economically important fruit crop of Thailand. The Ministry of Agriculture and Cooperative and Ministry of Commerce has regarded Longan as one of the "Product Champion" (Jealviriyapan *et al*., 2000; Ramingwong *et al*., 2005). Thailand has appropriate topography and technology development which can produce longan year-round. Its production not only generates good household income, but its export also generates high Country income. Currently, longan is the second largest exported fruit in Thailand, in terms of value, after durian (Office of Agricultural Economics, 2022). In 2021, all types of longan product, were exported to international markets, accounting for 633,131 tons valued at US$ 722.91 million (Office of Agricultural Economics, 2022). The major longan growing area is in the northern region of Thailand, including Lamphun, Chiang Mai, Chiang Rai, Nan, Phra Yao, Lampang, Phrae (Choo, 2003; Charoensri *et al*., 2005). Longan growing areas are beginning to spread around Thailand, such as in Chanthaburi, Sakaeo and Samut Sakhon provinces. Longan production in the country

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comes from two sectors, in-season and out off-season. Longan production from off-season is becoming more popular because its price is much better than during the in-season harvest (Samart, 2021). The ratio between on-season and off-season longan production has dramatically increased in the past ten years, with off-season longan production now comprising approximately 50 percent of the total longan production. Chanthaburi province is well-known for its off-season production, with yields there accounting for 20 percent of the country's longan output (Jaroenkit and Monochai, 2020).

Flower and fruit shedding in longan are correlated to the environment. Poor flowering, occurs when winter temperature, are higher than average (usually ≤ 18°C, Suttitanawat *et al*., 2012). Temperature is the main constraint to successful longan production. Floral induction technique is now used to promote off-season flowering, for commercial longan in Thailand, using potassium chlorate ($KClO_3$) and sodium chlorate ($NaClO_3$) (Jaroenkit and Monochai, 2020). However, the use of this chemical alone is not sufficient enough to produce quality yields for off-season longans; proper nutrient management is also necessary. Phosphorus is the nutrient element reported to be important for fruit growth and development (Chen *et al*., 2021).

Generally, plants including longans, have a high phosphorous demand during flowering, pollination and fruiting set. Off-season longan farmers prefer to use chemical fertilizers high in phosphorus, such as the formula N:P:K, 8-24-24. Unfortunately, these chemical fertilizers are high priced, resulting in higher production cost and can deteriorate soil quality. Using rock phosphate to replace the phosphorus fertilizer is an attractive alternative, because not only is it a source of phosphorus to longans, but it also has calcareous properties that helps improve soil acidity. Vermicompost is a nourishing organic fertilizer, containing most nutrients in plant-available forms and provide improvements to the micronutrient levels in the soil (Jaikishun *et al*., 2014). Adding vermicompost to the soil also improves physical quality of the soil, to be porous, crumbly, having ability to absorb water, and help absorb plant nutrients from being lost by leaching water (Azarmi *et al*., 2008). Faculty teacher of Agronomy (1983) suggested that using vermicompost, combined with rock phosphate, will increase the benefits of phosphorus. Unfortunately, up to now there are no other research reports on effects of rock phosphate combined with vermicompost to off-season longan production. In this study, the effects of the usage rate, in combination between rock phosphate and vermicompost, on off-season longan productivity was investigated.

Materials and methods

Experimental design

This experiment was carried out on longan plot of Agro-Industry Technology Faculty, located in Rajamangala University of Technology Tawan-ok, Chanthaburi Campus. It was done, based on randomized complete block design (RCBD), consisting of 5 treatments and 4 replications. Details of each treatment are shown in Table 1.

Table 1. Application of treatments

Treatments	Usage levels (kilogram per plant)		
	Chemical fertilizer (Formula 15-15-15)	Rock phosphate	Vermicompost
T_1 (control)	0.5	-	-
T_2	0.5	1	2
T_3	0.5	2	4
T_4	0.5	3	6
T_5	0.5	4	8

Preparation of experimental longan trees

Forty longan trees, three-years-old from initial planting, grown in field condition with 8x8 meter spacing and having canopy diameter less than 1 meter, were used for this experimental unit. The trees were subjected to formative pruning to obtain 'open' canopy, allowing good light penetration. Only limited numbers of main branches were retained, to obtain the desired tree structure. Other branches, incomplete twigs or shaded branches, were also removed. After pruning, approximately 60 percent of canopy branches remained. A water distribution system, using a sprinkler, was provided for each longan tree. Chemical fertilizer formula 46-0-0 and 16-16-16, with a ratio of 1:1, was applied to all longan trees, using the rate of 0.5 kg per a tree, initiated immediately at the end of pruning.

Application of experimental fertilizer

Commercial rock phosphate, a product of mining and smelting processes, contain phosphorus (approximately 12-15 percent phosphorus) and, was obtained from a fertilizer supply store in Chanthaburi province. Vermicompost was obtained from locally raised earthworms (*Perionyx excavates*), fed with organic waste. Application of experimental fertilizer was divided into two times. The first application was carried out 30 days after pruning. The second application was applied 30 days after the first application. Schedule for experimental fertilizer application is shown in Table 2.

Table 2. Schedule for experimental fertilization

Fertilization	Amount (kilogram per plant)				
	T_1 (control)	T_2	T_3	T_4	T_5
First application					
N:P: K; 15-15-15	0.5	0.5	0.5	0.5	0.5
Rock phosphate	-	0.5	1.0	1.5	2.0
Vermicompost	-	1.0	2.0	3.0	4.0
Second application					
N:P: K; 15-15-15	0.5	0.5	0.5	0.5	0.5
Rock phosphate	-	0.5	1.0	1.5	2.0
Vermicompost	-	1.0	2.0	3.0	4.0

Application of fertilizer was done by making a shallow circular ditch (15-20 cm depth and 15-25 cm width) around the tree canopy, with fertilizer placed in the ditch, then covered up with soil, followed by watering.

Flowering induction

Flowering induction in longan was performed three times, with $KClO_3$. Thirty days after second application of experimental fertilizer, 0.025 g/L $KClO_3$ was spread into the ditch, for the first time. Seven days later, 0.75 g/L $KClO_3$ was sprayed onto the leaves, for the second application, and five days following, 0.75 g/L $KClO_3$ was also sprayed onto the leaves, for the third application.

Fertilizer application to improve yield quality

When inflorescence emergence was observed, the chemical fertilizer formula 15-15-15 was applied to all experiment trees, using a rate of 0.5 kilogram per plant. To promote shell formation, after fruit setting, the chemical fertilizer formula 15-5-20 was applied to all experiment trees, using a rate of 0.5 kilogram per plant. Thirty days later, the chemical fertilizer formula 15-15-15 was applied to all experiment trees, using a rate of 0.5 kilogram per plant. The following thirty days a mixture of chemical fertilizers, formula 15-15-15 and 0-0-60, with 1:1 ratio, was applied to all experiment trees, using a rate of 0.5 kilogram per plant, to increase yield quality.

Longan tree maintenance during the experiment

Each experimental longan tree was watered every 3 days through a sprinkler. Area surrounding the canopy was always maintained and clean.

Pesticides were injected into the experimental trees once a month until the end of the experiment.

Data collection

Days to first flower bud initiation were recorded. When longan flowers were in full bloom, the number of inflorescences per tree and the number of flowers per inflorescences were counted (female only). Four inflorescences were randomly sampled from each experimental tree, and measured for their length and diameter. Length was measured from base to end of the inflorescences, while diameter was measured from the widest side, using vernier calipers.

Longan fruit production was harvested, after 7 months from the onset of flowering induction. Data was collected on harvesting date, including height of each tree and diameter of the canopy from 4 directions, measured using bamboo sticks together with measuring tape. Four inflorescences were randomly sampled from each tree to determine fruit number per inflorescence. Four fruits were taken from each bouquet to measure their total soluble solids content (℃Brix), using Brix refractometer (ATAGO 2313 Master series).

Statistical analysis

Data collected from each treatment was subjected to statistical analysis, through a one-way analysis of variance (ANOVA). Also, significantly different means were separated by Duncan' s New Multiple Range Test (DMRT), at 5% levels of probability.

Results

Use of rock phosphate, in combination with vermicompost, at five different levels had an effect on flowering period and growth of longans. Results indicated that longan trees fertilized with rock phosphate and vermicompost at a rate of 3:6 kilogram per plant, took shortest period for flowering. However, there was no significant difference from using 1:2 kilogram per plant level or 2:4 kilogram per plant level ($p>0.05$) (Table 3). The longest flowering period was found in the control group. Largest canopy diameter was found in longan tree fertilized with rock phosphate combined with vermicompost at 4:8 kilogram per plant level. However, there was no significant difference when using 2:4 kilogram per plant and 3:6 kilogram per plant level ($p>0.05$). There was also no significant difference in height of all experimental plant ($p>0.05$).

Table 3. Flowering period and growth of longan tree, which received five different levels of rock phosphate and vermicompost

Treatments	Ratio between Rock phosphate: vermicompost (Kilogram per plant)	Flowering period (days)	Plant height^{ns} (cm)	Plant Canopy diameter (cm)
T_1	Control Unit	27.3 ±0.5^{b}	163.0 ± 9.4	119.0 ±5.2^{b}
T_2	1:2	26.8 ±0.5^{bc}	164.5 ±6.7	119.8 ±5.6^{b}
T_3	2:4	26.8 ±1.0^{bc}	165.5 ±5.3	123.3 ±3.0^{ab}
T_4	3:6	25.5 ±1.3^{c}	169.3 ±4.2	124.3 ±4.3^{ab}
T_5	4:8	28.8 ±1.3^{a}	171.5 ±2.4	126.0 ±2.2^{a}

Note: Mean (±SD.**),** followed by different letters in the same column differs significantly ($p \leq 0.05$), ns = not significant different

There was no difference in length and diameter of inflorescence among all treatments. Number of inflorescences and number of flowers, found in longan tree fertilized with rock phosphate combined with vermicompost at 4:8 kilogram per plant level was higher than control and a 1:2 kilogram per plant level ($p \leq 0.05$). However, there was no significant difference when using 2:4 kilogram per plant or 3:6 kilogram per plant levels ($p > 0.05$) (Table 4).

Table 4. Length and diameter of inflorescence, number of inflorescence and flowers of longan tree receiving five different levels of rock phosphate and vermicompost

Treatments	Ratio between Rock phosphate: vermicompost (kg/plant)	Length of inflorescence (cm) ^{ns}	Diameter of inflorescence (cm) ^{ns}	Number of inflorescences (per plant)	Number of flowers (per an inflorescences)
T_1	Control Unit	23.8 ±2.2	17.5 ±4.4	49.8 ±13.2^{b}	23.8 ±2.6^{c}
T_2	1:2	23.8 ±4.3	18.8 ±5.1	50.0 ±7.9^{b}	26.8 ±7.0^{bc}
T_3	2:4	24.8 ±2.2	18.8 ±3.9	56.0 ±10.7^{ab}	33.8 ±6.3^{ab}
T_4	3:6	25.0 ±2.2	20.0 ±2.4	61.9 ±6.1^{ab}	34.3 ±4.8^{ab}
T_5	4:8	26.3 ±1.7	20.3 ±3.4	68.4 ±7.6^{a}	36.5 ±3.7^{a}

Values are expressed as mean ± standard deviation,
Mean followed by different letters in the same column differs significantly ($p \leq 0.05$)
ns = not significant different

Different levels of rock phosphate and vermicompost, had an effect on yield of longan fruit and their quality (Table 5). Highest fruit number per an inflorescence and average yield was found in longan tree fertilized with

rock phosphate combined with vermicompost at 4:8 kilogram per plant level, which was significantly higher than other treatments ($p \leq 0.05$). Highest fruit weight and total soluble solids content was also highest in longan tree fertilized with rock phosphate, combined with vermicompost at 4:8 kilogram per plant level ($p \leq 0.05$). However, there was not significant difference when using 3:6 kilogram per plant level ($p > 0.05$) (Table 5).

Table 5. Yield quality of longan tree receiving five different levels of rock phosphate and vermicompost

Treatments	Ratio between Rock phosphate: vermicompost (kg/plant)	Total fruit number in an inflorescences (fruit)	Total fruit weight in an inflorescences (g.)	Mean production (kg/plant)	TSS (% Brix)
T_1	Control Unit	28.3 ± 4.2^{b}	412.3 ± 54.7^{c}	20.4 ± 5.3^{c}	17.8 ± 0.5^{c}
T_2	1:2	34.0 ± 5.2^{b}	427.6 ± 59.7^{c}	21.2 ± 2.7^{c}	18.3 ± 0.5^{c}
T_3	2:4	35.5 ± 7.7^{b}	471.2 ± 22.5^{bc}	29.1 ± 2.8^{b}	19.8 ± 0.5^{b}
T_4	3:6	36.0 ± 6.7^{b}	533.3 ± 63.9^{ab}	29.6 ± 4.5^{b}	20.8 ± 1.3^{ab}
T_5	4:8	49.3 ± 10.9^{a}	558.3 ± 32.5^{a}	38.0 ± 2.3^{a}	21.5 ± 1.0^{a}

Values are expressed as mean ± standard deviation, Mean followed by different letters in the same column differs significantly ($p \leq 0.05$)

In addition, this study found that higher levels of rock phosphate and vermicompost, improves soil pH (Table 6). Highest pH increases in soil of longan trees fertilized with rock phosphate, combined with vermicompost at 3:6 and 4:8 kilogram per plant level. However, there was no significant difference when using 2:4 kilogram per plant level ($p > 0.05$).

Table 6. pH value of the soil before and after the experiment

Treatments	Ratio between Rock phosphate: vermicompost (kg/plant)	pH of soil	
		Before ^{ns}	After
T_1	Control Unit	4.0 ± 0.0	4.5 ± 0.0^{b}
T_2	1:2	4.0 ± 0.0	4.7 ± 0.3^{b}
T_3	2:4	4.0 ± 0.0	5.3 ± 0.9^{ab}
T_4	3:6	4.0 ± 0.0	5.6 ± 0.6^{a}
T_5	4:8	4.0 ± 0.0	5.9 ± 0.3^{a}

Values are expressed as mean ± standard deviation,
Mean followed by different letters in the same column differs significantly ($p \leq 0.05$)

Discussion

Induction of flowering and fruiting of longan, by nutrient manipulate and $KClO_3$ application, is a desirable economic goal, particularly, for off-season longan production. Results indicated that an optimal amount of phosphorus allows earliest flowering of longans; however, excessive amounts will have the opposite effect. The study found that three-year-old longan trees, fertilized with rock phosphate and vermicompost at levels of 3:6 kilogram per plant, were most quick to flower; while, when fertilized at levels of 4:8 kilogram per plant, were slowest to flower. It is assumed that when phosphorus is excessive, that longan trees grow leaves and branches, more than producing flower buds. This is consistent with applications of rock phosphate and vermicompost at levels of 4:8 kg per tree, where longan trees produced the largest canopy diameters.

Research finding indicated that applications of rock phosphate and vermicompost, levels of 4:8 kilogram per plant, resulted in best off-season longan quality, when compared to other levels ($p \leq 0.05$). The number of inflorescences and the number of flowers is indicator of the amount of yield to be obtained, when the crop is harvested. This study found that numbers of inflorescences and numbers of flowers in an inflorescence tended to increase, when levels of rock phosphate and vermicompost increased, with highest results found when applying levels of 4: 8 kg per plant. Number of flowers depended on the length of the inflorescence. In this study, there was no significant difference in inflorescence length for all experimental groups (inflorescence length 23.8-26.3 cm). Results were similar to the study by Jarassamrit *et al*. (2019) who used only chemical fertilizer; but lower than found in the study by Sruamsiri *et al*. (2005), who used both chemical and bio-organic fertilizer.

Application of rock phosphate and vermicompost to longan trees was at a level of 4:8 kilogram per plant resulted in smallest fruit size (average 11.27 gram per fruit); due to this. They also had highest total fruit numbers and total fruit weight in an inflorescence, meaning that they were more fruitful than other treatments. On the other hand, longans in the control group, showed largest fruit size (average 14.71 gram per fruit); since it had lower total fruit numbers and total fruit weight in an inflorescence. Fresh fruit weight of longans obtained from this study, was in a range of 12.35 to 14.71 gram, higher than weights found in the study by Sruamsiri *et al*. (2005) and Jarassamrit *et al*. (2019). They were in a range of 6.40 to 9.46 gram and 8.39-9.35 gram, respectively.

In addition, this study found that in all treatment groups, the longan which obtained rock phosphate and vermicompost, had higher TSS (%brix), than the control group ($p<0.05$). This is likely due to accumulation of potassium from vermicompost and potassium, affecting the TSS of crop yields (Young *et al*., 1993; Lumpkin, 2005; Khan *et al*., 2019). Total

soluble solids value of longan fruit in this study, 17.8-21.5 %brix was higher than the study by Sruamsiri *et al*. (2005) which was in a range of 16.15-17.86 %brix. In general, when rock phosphate was added directly into the soil, phosphorus content was difficult to dissolve. It does, however, dissolve well in acidic conditions (Maseena, 1988). Before this study commenced, soil in the experimental plot was determined as acidic, with soil pH of approximately 4. At the end of the experiment, the soil pH in the experimental groups increased, as the level of rock phosphate increased.

The study clearly confirmed that using rock phosphate and vermicompost to longan plants, as partial replacement of chemical fertilizer in a period of plant preparation, prior to the $KClO_3$ application, have effectiveness for off-season longan production. Averaged yield in terms of fruit number, fruit weight and total production was higher than using chemical fertilizers alone. Application of rock phosphate and vermicompost not only reduced the use of chemical fertilizer but also improved soil quality, positively affecting growth and quality of crops.

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