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# Effects of Trinexapac-ethyl in Combination with Nitrogen Fertilizer on Growth and Yield of Three Rice Varieties

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***Abstract:*** - Application of excess nitrogen fertilizer is one factor contributing to rice lodging. Trinexapac-ethyl is a plant growth regulator that reduces stem elongation and helps strengthen cell walls. The objective was to find the optimum rate of nitrogen fertilizer to use together with trinexapac-ethyl foliar spray for increasing yield and reducing lodging. A split plot in RCB with 3 rice varieties: PT 1, PT 80 and PT 200 as main plot and 4 rates of nitrogen application: 0, 62.5, 125, and 187.5 kg/ha as subplot was performed. Trinexapac-ethyl foliar spray was applied at a concentration of 100 ppm two times, at seedling and tillering stage, at the same time as nitrogen application. The results showed that plant height, chlorophyll content, leaf area, internode length, panicle and seed numbers were not significantly different among 3 rice varieties under trinexapac-ethyl treatment combined with various nitrogen rates, but statistical significance were noted in yield, 1,000-grain weight, filled grain percentage, harvest index, cellulose, and lignin content. Application of nitrogen at different rates resulted in significant differences in plant height, chlorophyll content, internode length, yield, panicle numbers, harvest index, and cellulose content but did not show significant differences in leaf area, seed number per panicle, 1,000-grain weight, filled grain percentage and lignin content. From these results we can conclude that spraying trinexapac-ethyl 100 ppm two times at seedling and tillering stage together with nitrogen at the rate of 125 kg/ha results in the highest yield for PT200 variety, and the rice plants tend to be stronger and resist lodging.

***Keywords:*** Rice Variety, Trinexapac-Ethyl, Nitrogen Fertilizer Rate

## I. INTRODUCTION

Rice (*Oryza sativa* L.) is still one of the most important economic crops in Thailand, as 66% of Thai farmers grow rice. In 2019-2020, there were 9.76 million hectares under rice cultivation in Thailand with annual production of about 24 million tons, 6.6 million tons of which were exported for a value of 123 billion baht. The average yield is 465 kg/rai (1 rai = 1,600m$^2$). Rice exports are a significant part of Thailand's national foreign currency earnings (Office of Agricultural Economics, 2021). Rice is an extremely important part of the Thai economy and Thai society. Rice production faces many problems at present so that the rice varieties that farmers use cannot reach their full production potential. One of the problems that causes economic losses is lodging. When rice stems fall over and break, yields are decreased. Duwayri et. al. (2000) found that lodging caused loss in yield of about 26 kg/hectare. Many factors caused lodging, such as susceptible rice variety, high planting density, method of planting and irrigation as well as fertilization application method (especially overuse of nitrogen fertilizer) (Hui, 2018). Approaches to solving the problem of lodging included selecting rice varieties with a short life cycle, short-stemmed varieties, using a transplanting method instead of broadcast seeding, using the appropriate amount and timing of nitrogen fertilizer and using plant growth regulators to reduce plant height (Jatuporn, 1997). The appropriate use of plant growth regulators is one alternative to prevent farmers' losses from rice lodging. Trinexapac-ethyl is a available synthetic plant growth regulator that can be used to limit plant growth by inhibiting gibberellin GA) biosynthesis. Exogenous trinexapac-ethyl application caused the plants to have thicker cell walls and shorter stems so the plants are more resistant to breakage in heavy wind and rain. It also had the beneficial side effects of increasing photosynthetic rate and strengthening the root system so plants cloud absorb water and nutrients more efficiently from the soil (Subedi et. al., 2021; Matysiak, 2006). Several studies have been published on the use of trinexapac-ethyl to prevent lodging. Rolston et. al. (2010) reported that trinexapac-ethyl had been used to improve

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ryegrass seed yields by reducing lodging. They wrote that the main mechanism of action was causing the ryegrass stems to be shorter and stronger by inhibiting the synthesis of gibberellic acid (Rademacher, 2000). Trinexapac-ethyl application was found to limit gibberellin formation, resulting in reduced stem elongation, and plants with shorter height and stronger stems (Rademacher, 2018). Another field study confirmed these results. Borm and van den Berg (2008) showed that trinexapac-ethyl reduced stem length and lodging in perennial ryegrass (Lolium perenne L.), which caused an average yield increase of approximately 10%. Application of trinexapac-ethyl (around 150 g a.i. ha-1) to rye plants at the 6th visible node on the main stem was shown to result in reduced plant height, and this in turn resulted in a reduced lodging index for the crop, facilitating the harvest of high-quality grains (Pinheiro et al., 2021). Fagherazzi et. al. (2018) showed a significant reduction in height of corn plants (Zea mays) following trinexapac-ethyl application. In their study they also compared applying trinexapac-ethyl at different growth stages and found that application was more efficacious when applied between stages V2-V7, compared to stages V2-V6. Another study on rice by Corbin et al. (2016) concluded that trinexapac-ethyl could be used to decrease rice plant height and lodging on both clay and silt loam soils, but grain yield under trinexapac-ethyl treatment varied with soil texture and nitrogen fertilizer management method.

Nitrogen is the main growth-limiting factor in plants. When plants do not get enough nitrogen, they exhibit nitrogen deficiency symptoms like stunted growth and leaf yellowing. However, when plants absorb too much nitrogen, they may appear excessively leafy with unusually dark green leaves, with larger and more numerous cells, larger and more numerous leaves, and they may flower and fruit more slowly than normal (Marschner, 2012; Ohyama and Sueyoshi, 2010). In some cases, excessive rates of nitrogen application have been implicated as the cause of lodging. There was evidence to show that high use of nitrogen fertilizer resulted in poor lodging resistance in both rice and wheat (Zhang. et al., 2016). Quang et. al. (2004) proposed that a way to improve lodging resistance in rice was to use sparse planting density and smaller amounts of nitrogen fertilizer in the seedling stage.

Considering the attributes of trinexapac-ethyl, we decided to test using trinexapac-ethyl to prevent lodging by strengthening the plant cell walls, with an aim to increase rice yield. In this study, we combined trinexapac-ethyl with different levels of nitrogen fertilizer to find the optimum level for growth and yield increases of 3 different rice varieties.

## II. Method

*1 Experimental design*

The experiment was a split-plot in Randomized Complete Block Design with 4 replications.

The main plot was the 3 varieties of rice: Pathumthani 1(PT1), Pathumthani 80 (PT80) and Pathumthani 200 (PT200).

The subplot was 4 rates of nitrogen fertilizer: 0, 62.5, 125, and 187.5 kg/ha.

*2 Method*

Seeds of Pathumthani 1, Pathumthani 80 and Pathumthani 200 rice varieties were pre-soaked for 12 hours, then left to sit for 24 hours to begin sprouting before being broadcast in pre-plowed 3x5-meter seedling plots at a rate of 25 kg of seed per 1,600 $m^2$. Nitrogen fertilizer at the rate as mentioned in subplot was applied twice, first when the seedlings were 25-30 days old, and the second time when the rice plants were tillering at 45-50 days old. Trinexapac-ethyl foliar spray was applied at a concentration of 100 ppm two times, at the same time nitrogen fertilizer was applied. All required cultural practices as rice growing recommendation were performed. Rice was harvested at 115-120 days after planting.

*3. Data recording*

1. Plant height; 10 plants were randomly selected from each plot, and the tallest leaf from each plant was measured from base (soil level) to tip and averaged.
2. Chlorophyll analysis; 10 plants were randomly sampled and 3 leaves from each plant. were randomly combined and chlorophyll was extracted with N N-Dimethyl formamide (Moran and Porath, 1980).
3. Internode length; 10 plants were randomly selected from each plot and the length between nodes was measured and averaged
4. Grain weight; All the rice seeds harvested from a 2x2.5- meter area in each plot were weighed to calculate yield.
5. Panicle numbers; The number of panicles were counted in a 1x1 meter area in each plot.

6. Leaf area; 10 plants were randomly selected from each plot and leaf area was measured using a desktop Leaf Area Meter (WinDias3 by Delta-T Device) and averaged to be Leaf area/plant.
7. Seed number per panicle; 10 panicles were randomly selected from each plot and the number of seeds per panicle was counted and averaged to be seed number per panicle
8. 1,000-grain weight; 1,000 grains were randomly selected from each plot and weighed.
9. Filled grain percentage; total grains of 10 panicles from each plot were together weighed, then the filled gains were separated from the unfilled grains and weighed again to calculate percent filled grain using the following formula:

$$\text{(\%) Filled grain} = \frac{\text{weight of filled grains x 100}}{\text{weight of total grains}}$$

10. Harvest index (HI); the total economic yield was weighed, and then it was divided by the dry weight of the biological yield to calculate the harvest index according to the following formula:

$$\text{HI} = \frac{\text{Economic yield}}{\text{Biological yield}}$$

11. Cellulose, hemicellulose and lignin percentage were analyzed using the method of Mansor et. al. (2019)
All the data according to the experimental design were statistically analyzed to find analysis of variance (ANOVA) using STAR software (IRRI, 2014) and means were compared by calculating Least Significant Difference (LSD).

## III. Results And Discussion

### *1. Plant height and chlorophyll content*

Trinexapac-ethyl treatment combined with nitrogen fertilizer at the different concentrations did not have a statistically significant effect on plant height and chlorophyll content in the 3 rice varieties tested. This might be because the plant type of 3 rice varieties were rather similar so they responded similarly to the treatments. These results are consistent with those reported by Matysiak (2006), who found that chlorophyll content in winter wheat leaves was not affected by trinexapac-ethyl application. Meanwhile, Głąb et. al. (2021) revealed that trinexapac-ethyl effects were usually observed at 7, 14 and 21 days after application, and later, the effects disappeared. The tallest plant height was observed in the plots with nitrogen fertilizer applied at the rate of 125 kg/ha, but it was not a statistically significant difference compared to the plots with nitrogen fertilizer applied at the rates of 187.5 and 62.5 kg/ha. The application of trinexapac-ethyl was expected to have an inhibitory effect on plant growth that masked the effect of nitrogen fertilizer application, because trinexapac-ethyl works by blocking the final step in the biosynthesis of gibberellins, resulting in slower shoot growth (Pannacci et al., 2004; McCann and Huang, 2007). The highest chlorophyll content was observed in the plots with nitrogen fertilizer applied at the rate of 187.5 kg/ha, but it was not a statistically significant difference compared to the plots with nitrogen fertilizer applied at the rate of 125 kg/ha. The lowest chlorophyll content was observed in the plots with zero nitrogen fertilizer applied. This is probably because nitrogen is an important part of the chlorophyll molecule that is necessary for photosynthesis (Zhang et.al, 2020). When more nitrogen is available, plants can synthesize more chlorophyll. This is consistent with the findings of Uysal (2018), who found that increasing doses of nitrogen increased the chlorophyll content of the leaves. Chlorophyll content is related to plant nitrogen nutrition (Ya-wei et .al. , 2019). Chlorophyll in leaves was observed in plants subjected to a high nitrogen treatment (Roca et al., 2018). In the present study, no interaction was observed between rice variety and amount of nitrogen fertilizer applied on plant height and chlorophyll content (Table 1,2).

**Table1.** Effects of foliar trinexapac-ethyl in combination with various nitrogen rates on plant height of three rice varieties**.**

| Rice variety | Plant height (cm.) | | | | Average |
|---|---|---|---|---|---|
| | Nitrogen rate (kg/ha) | | | | |
| | 0 | 62.5 | 125 | 187.5 | |
| Pathum Thani 1 | 88.7 | 94.4 | 93.90 | 95.1 | 93.4 |
| Pathum Thani 80 | 89.5 | 89.5 | 95.45 | 92.1 | 91.6 |
| Pathum Thani 200 | 92.3 | 94.9 | 97.32 | 95.8 | 95.1 |
| Average | 90.1 | 92.9 | 95.6 | 94.3 | |
| LSD.05 (M) | ns | | | | |

| | |
|---|---|
| LSD.05 (S) | 2.94 |
| LSD.05 (M*S) | ns |
| CV (M) (%) | 8.24 |
| CV (S) (%) | 3.77 |

**Table2** Effects of foliar trinexapac-ethyl in combination with various nitrogen rates on chlorophyll content of three rice varieties.

| Rice variety | Chlorophyll content (mg/g fresh wt.) | | | | Average |
|---|---|---|---|---|---|
| | Nitrogen rate (kg/ha) | | | | |
| | 0 | 62.5 | 125 | 187.5 | |
| Pathum Thani 1 | 3.55 | 3.78 | 3.93 | 4.21 | 3.86 |
| Pathum Thani 80 | 3.57 | 3.66 | 3.71 | 3.89 | 3.70 |
| Pathum Thani 200 | 3.34 | 3.70 | 3.87 | 4.23 | 3.78 |
| Average | 3.49 | 3.72 | 3.84 | 4.11 | |
| LSD.05 (M) | ns | | | | |
| LSD.05 (S) | 0.28 | | | | |
| LSD.05 (M*S) | ns | | | | |
| CV (M) (%) | 10.78 | | | | |
| CV (S) (%) | 3.77 | | | | |

*2.Leaf area and internode length*

There was no statistically significant difference in leaf area and internode length among the three rice varieties when trinexapac-ethyl was applied with nitrogen fertilizer at different concentrations. No statistically significant difference was found on leaf area when comparing different concentrations of nitrogen fertilizer, but there was a statistically significant effect on internode length. The longest internode length was observed in the plots with nitrogen fertilizer applied at the rate of 187.5 kg/ha. However, this was not significantly different from the treatment with nitrogen applied at the rate of 125 kg/ha. This is similar to the results of Singh Bar and Singh (2016), who reported that the internode length of okra (*Abelmoschus esculentus* (L.) Moench) increased gradually with the increasing level of nitrogen. In plots where nitrogen fertilizer was applied at the lowest rate of 62.5 kg/ha, internode length of the rice plants was not significantly different from that in the plots in which zero nitrogen fertilizer was applied. Because trinexapac-ethyl inhibits cell elongation, it is not surprising that the internode length in experimental plots was not very long, even when nitrogen fertilizer was applied. Interestingly, Zagonel et al. (2002) found that trinexapac-ethyl decreased internode length, but increased stem diameter of wheat. In the present study, no statistically significant interaction was observed between rice variety, amount of nitrogen fertilizer applied on leaf area and internode length (Table 3,4).

*3. Yield and panicle numbers*

Application of trinexapac-ethyl combined with different concentrations of nitrogen fertilizer to the 3 rice varieties resulted in statistically significant differences in yield, but had no effect on number of panicles. Pathum Thani 200 variety gave the highest yield of 5,613 kg/ha, but it was not significantly different from the yield of Pathum Thani 80 variety. Pathum Thani 1 variety had the lowest yield of 4,625 kg/ha. The Pathum Thani 200 and Pathum Thani 80 varieties performed well because more photosynthates were transported from the leaves and stems to the grain in these varieties (they had high harvest indexes) and they also had higher percentages of filled grains compared to Pathum Thani 1 variety. These two factors contributed to higher yield. Our results showed that yield was highest when nitrogen fertilizer was applied at the rate of 125 kg/ha. At that rate the yield was significantly higher than the yield in plots with nitrogen fertilizer applied at the rate of 62.5 and 187.5 kg/ha. This is probably because supplying nitrogen at the appropriate rate promotes stem and leaf growth, and when there is more dry weight accumulation in the vegetative parts of the plant, nutrients are subsequently translocated to the grain resulted in high yield. The highest number of panicles was observed in the plots with nitrogen fertilizer applied at the rate of 187.5 kg/ha, but it was not a statistically significant difference compared to the plots with nitrogen fertilizer applied at the rate of 125 kg/ha. This is consistent with the findings of Can et.al. (2021), who concluded that "with the decrease of nitrogen application, the yield decreased gradually due to the decrease of panicle number and spikelet number per panicle. In addition, Corbin *et al.* (2016) found that in terms of yield, the response of rice plants to the application of trinexapac-ethyl was dependent on soil properties and nitrogen fertilizer management. Reporting the results of a study on Giant Rice, Zhange *et al*. (2020) wrote that yield increased with increasing rates of nitrogen fertilizer. In the present study, no statistically significant interaction was observed between rice variety, amount of nitrogen fertilizer applied on grain yield and panicle numbers (Table 5,6).

**Table 3** Effects of foliar trinexapac-ethyl in combination with various nitrogen rates on leaf area of three rice varieties

| Rice variety | Leaf area (cm2.) | | | | Average |
|---|---|---|---|---|---|
| | Nitrogen rate (kg/ha) | | | | |
| | 0 | 62.5 | 125 | 187.5 | |
| Pathum Thani 1 | 120.02 | 131.12 | 137.57 | 149.92 | 134.65 |
| Pathum Thani 80 | 134.15 | 140.60 | 154.07 | 151.97 | 145.19 |
| Pathum Thani 200 | 145.37 | 159.22 | 134.65 | 145.75 | 146.24 |
| Average | 133.18 | 143.64 | 142.09 | 149.21 | |
| LSD.05 (M) | ns | | | | |
| LSD.05 (S) | ns | | | | |
| LSD.05 (M*S) | ns | | | | |
| CV (M) (%) | 26.80 | | | | |
| CV (S) (%) | 20.00 | | | | |

**Table 4** Effects of foliar trinexapac-ethyl in combination with various nitrogen rates on internode length of three rice varieties

| Rice variety | Internode length (cm.) | | | | Avera ge |
|---|---|---|---|---|---|
| | Nitrogen rate (kg/ha) | | | | |
| | 0 | 62.5 | 125 | 187.5 | |
| Pathum Thani 1 | 5.66 | 6.31 | 6.93 | 7.54 | 6.61 |
| Pathum Thani 80 | 6.02 | 6.05 | 6.43 | 6.34 | 6.21 |
| Pathum Thani 200 | 6.43 | 5.99 | 6.92 | 6.82 | 6.54 |
| Average | 6.03 | 6.12 | 6.76 | 6.90 | |
| LSD.05 (M) | ns | | | | |
| LSD.05 (S) | 0.41 | | | | |
| LSD.05 (M*S) | ns | | | | |
| CV (M) (%) | 13.23 | | | | |
| CV (S) (%) | 7.64 | | | | |

**Table 5** Effects of foliar trinexapac-ethyl in combination with various nitrogen rates on panicle numbers of three rice varieties

| Rice variety | Panicle numbers/m2 (panicle) | | | | Average |
|---|---|---|---|---|---|
| | Nitrogen rate (kg/ha) | | | | |
| | 0 | 62.5 | 125 | 187.5 | |
| Pathum Thani 1 | 762 | 840 | 897 | 947 | 861.50 |
| Pathum Thani 80 | 702 | 817 | 790 | 793 | 775.50 |
| Pathum Thani 200 | 712 | 806 | 817 | 915 | 812.50 |
| Average | 725 | 821 | 835 | 885 | |
| LSD.05 (M) | ns | | | | |
| LSD.05 (S) | 51.10 | | | | |
| LSD.05 (M*S) | ns | | | | |
| CV (M) (%) | 10.41 | | | | |
| CV (S) (%) | ns | | | | |

Table 6 Effects of foliar trinexapac-ethyl in combination with various nitrogen rates on yield of three rice varieties

| Rice variety | Grain yield | | | | Average |
|---|---|---|---|---|---|
| | Nitrogen rate (kg/ha) | | | | |
| | 0 | 62.5 | 125 | 187.5 | |
| Pathum Thani 1 | 3490 | 4490 | 5660 | 4860 | 4625 |
| Pathum Thani 80 | 4140 | 5530 | 6660 | 5990 | 5580 |
| Pathum Thani 200 | 3940 | 5850 | 6460 | 6200 | 5613 |
| Average | 3857 | 5290 | 6260 | 5683 | |
| LSD.05 (M) | 377.25 | | | | |
| LSD.05 (S) | 476.75 | | | | |
| LSD.05 (M*S) | ns | | | | |
| CV (M) (%) | 8.27 | | | | |
| CV (S) (%) | 0.80 | | | | |

*4. Seed numbers and 1,000-grain weight*

Application of trinexapac-ethyl combined with different concentrations of nitrogen fertilizer to the 3 rice varieties had no statistically significant effect on the number of seeds per panicle, but statistically significant differences were noted in 1,000-grain weight. The highest 1,000-grain weight of 26.88 g was observed in Pathum Thani 80 variety. This was higher than the 1,000-grain weight of Pathum Thani 1 variety (22.20 g) to a statistically significant degree, but was not significantly different from the 1,000-grain weight observed in Pathum Thani 200 variety (26.14 g). This might be because the percentage of filled grains of Pathum Thani 80 variety was high and the number of seeds per panicle was lower than the other two varieties, which could result in higher 1,000-grain weight. In contrast, the percentage of filled grains and harvest index of Pathum Thani 1 variety were rather low, which could result in lower 1,000-grain weight. When considering only the different rates of nitrogen fertilizer applied, this factor did not result in significant differences in number of seeds per panicle and 1,000-grain weight. In contrast, Bhuyan et al (2015) proposed that foliar application of nitrogen might enhance accumulation of assimilate in the grains, resulting in heavier grains of rice. The 1,000-grain weight and seeds yield of *Leymus chinensis* were significantly influenced by nitrogen addition (Chen et al., 2013). In the present study, no statistically significant interaction was observed between rice variety, amount of nitrogen fertilizer applied on seed numbers per panicle and 1,000-grain weight (Table 7,8).

**Table 7.** Effects of foliar trinexapac-ethyl in combination with various nitrogen rates on seed numbers/panicle of three rice varieties.

| Rice variety | Seed numbers/panicle (seed) | | | | Average |
|---|---|---|---|---|---|
| | Nitrogen rate (kg/ha) | | | | |
| | 0 | 62.5 | 125 | 187.5 | |
| Pathum Thani 1 | 100.57 | 95.22 | 108.47 | 108.07 | 103.08 |
| Pathum Thani 80 | 79.62 | 94.52 | 104.20 | 106.00 | 96.08 |
| Pathum Thani 200 | 85.15 | 107.95 | 101.72 | 99.90 | 98.68 |
| Average | 88.44 | 99.23 | 104.79 | 104.65 | |
| LSD.05 (M) | ns | | | | |
| LSD.05 (S) | ns | | | | |
| LSD.05 (M*S) | ns | | | | |
| CV (M) (%) | 9.56 | | | | |
| CV (S) (%) | 17.22 | | | | |

**Table 8** Effects of foliar trinexapac-ethyl in combination with various nitrogen rates on 1,000-grain weight of three rice varieties

| Rice variety | 1000-grain weight (g) | | | | Average |
|---|---|---|---|---|---|
| | Nitrogen rate (kg/ha) | | | | |
| | 0 | 62.5 | 125 | 187.5 | |
| Pathum Thani 1 | 21.16 | 22.15 | 23.84 | 21.68 | 22.20 |
| Pathum Thani 80 | 27.63 | 28.07 | 25.91 | 25.93 | 26.88 |
| Pathum Thani 200 | 27.05 | 25.88 | 26.90 | 24.74 | 26.14 |
| Average | 25.28 | 25.36 | 25.55 | 24.11 | |
| LSD.05 (M) | 1.88 | | | | |
| LSD.05 (S) | ns | | | | |
| LSD.05 (M*S) | ns | | | | |
| CV (M) (%) | 7.19 | | | | |
| CV (S) (%) | 5.18 | | | | |

*5. Filled grain and harvest index*

Application of trinexapac-ethyl combined with different concentrations of nitrogen fertilizer to the 3 rice varieties resulted in statistically significant differences in filled grain percentage and harvest index. Pathum Thani 80 variety had the highest percentage of filled grains and the highest harvest index and Pathum Thani 1 variety had the lowest percentage of filled grains and the lowest harvest index. A variety that has a high percentage of filled grains indicates that the plants are efficient at translocating assimilates from the leaves and stem to the grains, resulting in a high harvest index. In our results, the different rates of nitrogen fertilizer application did not have any statistically significant effect on filled grain percentage. This is consistent with the results of Jing et al. (2021), who found that nitrogen applications prolonged the duration of both superior and inferior grain filling and were positively correlated with chalky kernel rate, chalkiness, and amylose content. However, our data showed the different rates of nitrogen fertilizer application did have a statistically significant effect on harvest index. The plots with zero nitrogen fertilizer applied had the highest harvest index of 0.67, which was not significantly different from the harvest index in plots with nitrogen fertilizer applied at the lowest rate of 62.5 kg/ha (0.66). The lowest harvest index of 0.57 was observed in the plots with nitrogen fertilizer applied at the highest rate of 187.5 kg/ha. This is consistent with the findings of Kamithi *et. al.,* (2009), who reported that the harvest index of chick pea (*Cicer arietinum* L.) decreased with increasing rates of nitrogen fertilizer. In another study on rice, it was found that when nitrogen fertilizer was applied at the rate of 125 kg/ha, the harvest index was approximately 50 % lower compared to when nitrogen fertilizer was applied at the rate of 62.5 kg/ha (Nantachan et. al., 2016). In the present study, no statistically significant interaction was observed between rice variety, amount of nitrogen fertilizer applied on filled grain percentage and harvest index (Table 9,10).

**Table 9.** Effects of foliar trinexapac-ethyl in combination with various nitrogen rates on filled grain percentage of three rice varieties

| Rice variety | Filled grain (%) | | | | Average |
|---|---|---|---|---|---|
| | Nitrogen rate (kg/ha) | | | | |
| | 0 | 62.5 | 125 | 187.5 | |
| Pathum Thani 1 | 79.78 | 82.95 | 85.32 | 85.67 | 83.43 |
| Pathum Thani 80 | 90.96 | 92.34 | 87.41 | 89.36 | 90.02 |
| Pathum Thani 200 | 89.09 | 90.07 | 86.66 | 85.07 | 87.73 |
| Average | 86.61 | 88.46 | 86.46 | 86.70 | |
| LSD.05 (M) | 2.07 | | | | |
| LSD.05 (S) | ns | | | | |
| LSD.05 (M*S) | ns | | | | |
| CV (M) (%) | 2.76 | | | | |
| CV (S) (%) | 4.35 | | | | |

**Table 10.** Effects of foliar trinexapac-ethyl in combination with various nitrogen rates on harvest index of three rice varieties

| Rice variety | Harvest index | | | | Average |
|---|---|---|---|---|---|
| | Nitrogen rate (kg/ha) | | | | |
| | 0 | 62.5 | 125 | 187.5 | |
| Pathum Thani 1 | 0.61 | 0.62 | 0.58 | 0.53 | 0.59 |
| Pathum Thani 80 | 0.68 | 0.68 | 0.63 | 0.58 | 0.65 |
| Pathum Thani 200 | 0.71 | 0.68 | 0.62 | 0.58 | 0.65 |
| Average | 0.67 | 0.66 | 0.61 | 0.57 | |
| LSD.05 (M) | 0.03 | | | | |
| LSD.05 (S) | 0.02 | | | | |
| LSD.05 (M*S) | ns | | | | |
| CV (M) (%) | 6.36 | | | | |
| CV (S) (%) | 5.86 | | | | |

*6. Cellulose and lignin*

Application of trinexapac-ethyl combined with different concentrations of nitrogen fertilizer to the 3 rice varieties resulted in statistically significant differences in lignin content and cellulose content. Pathum Thani 200 variety had the highest cellulose content at 0.686%. Pathum Thani 1 variety had the highest lignin content at 0.520%, but it was not significantly different from the lignin content of Pathum Thani 200 variety at 0.404%. Pathum Thani 80 variety had the lowest cellulose content and the lowest lignin content. Looking at the nitrogen fertilizer factor, different rates of nitrogen fertilizer application resulted in different percentages of cellulose content, but had no significant effect on lignin content. Nitrogen fertilizer application at the rates of 62.5 kg/ha and 125 kg/ha resulted in higher cellulose content, but cellulose content tended to be lower when application of nitrogen fertilizer was increased to the rate of 187.5 kg/ha. This is consistent with the findings of Zhang et. al. (2017) who reported that in treatments where more N was applied, both cellulose and especially lignin content was noticeably less. Plants that had more available N were able to build up thicker secondary walls in the sclerenchyma and vascular bundle cells, where lignin was deposited. When culm lodging-resistant index (CLRI) was measured, the data showed that there was a significant positive correlation between lignin content, cellulose content and CLRI. In the present study, a statistically significant interaction was observed between rice variety, amount of nitrogen fertilizer applied, and both cellulose and lignin content. That is, Pathum Thani 200 variety had the highest cellulose content when treated with the combination of trinexapac-ethyl and nitrogen fertilizer at the rate of 125 kg/ha and Pathum Thani 1 variety had the highest lignin content when treated with the combination of trinexapac-ethyl and nitrogen fertilizer at the rate of either 125 kg/ha or 187.5 kg/ha (Table 11,12).

**Table 11.** Effects of foliar trinexapac-ethyl in combination with various nitrogen rates on cellulose of three rice varieties

| Rice variety | Cellulose (%) | | | | Average |
|---|---|---|---|---|---|
| | Nitrogen rate (kg/ha) | | | | |
| | 0 | 62.5 | 125 | 187.5 | |
| Pathum Thani 1 | 0.243 | 0.539 | 0.577 | 0.365 | 0.431 |
| Pathum Thani 80 | 0.086 | 0.075 | 0.087 | 0.084 | 0.083 |
| Pathum Thani 200 | 0.563 | 0.743 | 0.821 | 0.615 | 0.686 |
| Average | 0.297 | 0.452 | 0.495 | 0.355 | |
| LSD.05 (M) | 0.0875 | | | | |
| LSD.05 (S) | 0.0874 | | | | |
| LSD.05 (M*S) | 0.0874 | | | | |
| CV (M) (%) | 11.04 | | | | |
| CV (S) (%) | 10.21 | | | | |

**Table 12.** Effects of foliar trinexapac-ethyl in combination with various nitrogen rates on lignin percentage of three rice varieties

| Rice variety | Lignin (%) | | | | Average |
|---|---|---|---|---|---|
| | Nitrogen rate (kg/ha) | | | | |
| | 0 | 62.5 | 125 | 187.5 | |
| Pathum Thani 1 | 0.547 | 0.247 | 0.659 | 0.626 | 0.520 |
| Pathum Thani 80 | 0.166 | 0.18 | 0.15 | 0.187 | 0.171 |
| Pathum Thani 200 | 0.452 | 0.544 | 0.32 | 0.300 | 0.404 |
| Average | 0.388 | 0.324 | 0.376 | 0.371 | |
| LSD.05 (M) | 0.159 | | | | |
| LSD.05 (S) | ns | | | | |
| LSD.05 (M*S) | 0.144 | | | | |
| CV (M) (%) | 23.01 | | | | |
| CV (S) (%) | 16.92 | | | | |

## IV. Conclusion

In this present study, we can conclude that spraying trinexapac-ethyl 100 ppm two times at seedling stage (25-30 days old) and at tillering stage (45-50 days old) together with nitrogen fertilizer at the rate of 125 kg/ha resulted in the highest yield for all rice varieties tested, especially Pathum Thani 1 variety had the most positive response and the rice plants tend to be stronger and resist lodging.

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