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Enhancing the use of coated urea fertilizer and assessing its effect on growth and yield performance in grain corn

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Abstract

Use of urea fertilizer is currently increasing to meet the agricultural demand. However, the efficiency and optimization of urea application in agriculture is uncertain. Therefore, this study was conducted to compare the efficacy of slow-release urea and standard urea fertilizer. Reductions in the N rate of the slow release was assessed by measuring the different growth performance and yield at the field. A 25% reduction in N content using coated urea gave similar growth performance and yield compared to standard practice The findings indicated that there was no significant difference in stem diameter, number of leaves and chlorophyll content between the control treatment and slow-release urea. Grain yield and yield components like cob length, number of grains per cob, weight of grain per cob and 1000 grain weight obtained in the field was similar when applying the slow-release urea with the yield and yield components obtained from standard practice as a control. We conclude that this slow-release urea can be used in extensive cropping of corn while promising at least the same yields than standard practices with reducing impact on environment and nitrogen losses in the soil.

Keywords: Grain Corn; Coated Urea; Plant Growth; Corn Yield; Chlorophyll Content

1. Introduction

Corn (*Zea mays L.*) is the most widely grown cereal crops in the world provides food, silage, and biofuel. Corn can be categorised into two types, which are sweet corn and grain corn. Grain corn widely used for livestock feed industry in Malaysia. According to FAO, grain production has increased by 25% since 2010. Statistics showed that the importation of grain corn for Malaysia has tripled in the past 30 years from 1.196 million tons (mt) in 1985 to 4.1 mt in 2016 (USDA, 2017). Despite increase in global population and continuous demand for food and meat consumption, then the demand for grain and nutrients is expected to triple by 2050 (Bahar et al, 2019). Hence, the future of the development of grain corn industry needs to be emphasized in increasing total crop production capacity (Li et al., 2022), facing food security for growing population and thus reducing the dependency on the imported products.

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Malaysia has started commercial planting grain corn in 1980 and new cultivar of grain corn, Suwan 1 was introduced in 1985. However, the average actual yield obtained was 2 metric tonne per hectare (mt/ha) was lowered than the average of experimental yield recorded was 4.25 mt/ha and average yield of others neighbouring countries about 5 to 6 mt/ha (FAOSTAT, 2021). The factor contributing different in yield can be attributed to the management practices. As the result, the project was terminated by the government due to their lack of interest to continue the production of grain corn in Malaysia and finally it becomes a major obstacle for the corn industry evolves in Malaysia after 1995's.due to high cost of grain production.

Fertilizer is one of major inputs to sustain food production system and ensure food security. Approximately 70 % of food grain production will be dependent on fertilizers (Bahar et al., 2019). Most widely applied plant nutrient is nitrogen (N) fertilizer in achieving high yield of crop. According to report from Department of Agriculture (2003), annual nitrogen consumption in Malaysia increased from 3.33 mt in 2000 to 3.51 mt in 2002 which consequently increases food production costs. One of the nitrogenous sources of nitrogen is urea. Urea is the most widely used fertilizer due to its high N content (46%) and ease of application to the crop. However, urea is easily volatilized to the environment due to runoff or leaching after fertilization. High losses tend to occur at the beginning of N fertilization and estimated at 30 to 60% in the tropical soil, thus resulted in poor crop performance (Ognyan, 2016). This loss leads in economic loss, low plant nutrient use efficiency and environmental change (Balaganesh et al., 2021). Therefore, minimise N fertilization need to be studied to ascertain whether it will produce maximum return with minimal N losses in a grain corn production.

A few management strategies have been proposed to improve N fertilizer efficiency in agricultural systems (Shamsuzzaman et al., 2016). The use of slow release or controlled release fertilizer is one approach to reduce N losses in soil. Research has been done and showed that controlled release fertilizer can significantly improve rice production (Kiran, 2010), corn (Zhao, 2009) and other crops yield. Limited studies had been done in Malaysia to determine efficiency of slow-release fertilizer especially on grain corn in increasing grain corn yields. In addition, the effects are still unclear across shorter periods, which affects our understanding in temporal response. The idea of this research is based on improving the yield of the grain corn from past research by applying only the amount of fertilizer needed for crop development. Therefore, the overarching goals of this experiment were to evaluate the effect of a coated urea fertilizer with commercial fertilizer on growth performance and grain yield of grain corn.

2. Materials and methods

2.1. Study Site

The research was conducted at the Malaysian Agriculture Research and Development Institute, Serdang Malaysia. Size of experimental plot was 399m^2 (21.0 m ×20.5 m). The planting distance was 75 cm between rows and 25 cm between plants in each plot size. The planting depth was set at 15 cm.

2.2. Planting management

Sprinkler system used to water the plants two times in a day. Ground Magnesium Limestone (GML) applied 10 days before sowing and organic fertilizer was applied 7 days before planting.

2.3. Experimental Design

The experimental design consisted of four treatment (Table 1) were arranged in a randomized completely block design with four replications. Three conventional fertilisers were used: urea (46% N) as nitrogen, superphosphate (6.1% P) as phosphorus, and potassium sulphate (41.5% K) as potassium fertiliser, respectively according to standard agricultural practices (MARDI, 2019; 2022). Urea was coated nitro humic acid at rate 8% in continuous rotation granulator drum according to the method has been describe by Muhammad Syahren et al. (2008; 2009). Seeds were planted at 20 kg seeds /ha. Weeds were controlled with a preemergence application of atrazine (2-chloro-4-ethylamino-6-isopropylamino-s-triazine) at 2 Liter/ha and Metachlor at 2L/ha, followed by post emergence Glyphosinate at 2L/ha.

Table 1 Treatment and experimental design description

Treatment	Treatment details
T1	120:60:60 $NP_2O_5K_2O$ ha^{-1}, N applied from normal urea at two splits at basal and 30 DAP
T2	120:60:60 $NP_2O_5K_2O$ ha^{-1}, N applied from normal urea at a basal
T3	90:60:60 $NP_2O_5K_2O$ ha^{-1}, N applied from coated urea at two splits at basal and 30 DAP
T4	90:60:60 $NP_2O_5K_2O$ ha^{-1}, N applied from coated urea at basal

2.4. Treatments

2.4.1. Data Collection and Measurements

All the growth parameters were measured at 15, 30, 45, 60, 75 and 90 days after planting (DAP). Plant height was measured from the soil surface to the top of the plant by height pole. Stem diameter was measured from 10 cm from the soil surface using calliper. Chlorophyll levels were measured by using a portable SPAD 502 Chlorophyll Meter (Minolta Co. Ltd.) Each plant cob sample was harvested manually. The yield and yield components of corn was measured at the harvesting stage after 110 DAP using the standard ruler and weighing machine. The crop cutting test (CCT) area was 4m x 1m (4m^2) per plot. Grain yield was converted to 14 percent of grain moisture content, and moisture content is measured using Agratronix MT-16 grain moisture tester. Cob length was measured by using standard ruler. Cob diameter was measured using calliper. Number of grains were measured using a seed counter and weight of grains were measured by digital balance.

2.5. Data Analysis

Statistical analyses were analysed using SAS (SAS Institute, 1997). Analysis of variance (ANOVA) was performed to compare the effect of the different treatments followed by Least Significant Difference (LSD) tests to assess the differences between treatments means.

3. Results

3.1. Plant height

Observation of plant height during the study showed that there was significant difference between the treatments starting from 15 days after planting (DAP) to 90 DAP (Table 2). The highest results in plant height observations were achieved from T2 which were 82.7cm (15DAP) and 145.0 cm (30 DAP). The increase in plant height for T2 was thought due high ammonium ion in the soil for plant uptake in boosting internodes elongation. Meanwhile, the maximum plant height was obtained in T1 (235.8 cm) showing significant difference among treatments at 60 DAP. Plant height for all treatments is at maximum height at 75 DAP before gradual decline after silking stage at 90 DAP. Data in Table 2 shows the tallest plant was recorded from T1 followed by T2<T4<T3. The increase in plant height can be attributed to the fact that nitrogen as an essential nutrient for the plant promotes plant growth by increasing the number and length of internodes which results in increase in plant height.

3.2. Stem diameter

Stem diameter was significantly difference at 15 DAP (Table 2). The biggest results in stem diameter observations were achieved from T2 which were 20.9 cm. The plant height due to high ammonium ion in the soil for plant uptake in promoting stem elongation. However, the treatments were not significantly different at 30 and 45 DAP. For the stem diameter at 30 DAP, the largest stem diameter (22.9 cm) was obtained with the application of coated urea in T2, and the smallest stem diameter (20.3 cm) was from T4. Meanwhile, the largest stem diameter (18.9 cm) was recorded from T1, and the smallest stem diameter (17.2 cm) was from T4 at 45 DAP. However, the trend of stem diameter attained maximum girth at 60 DAP and leads to slowly decrease 75 and 90 DAP. This due to inhibition of stem elongation when the physiological maturity is reached for the plant at that stage.

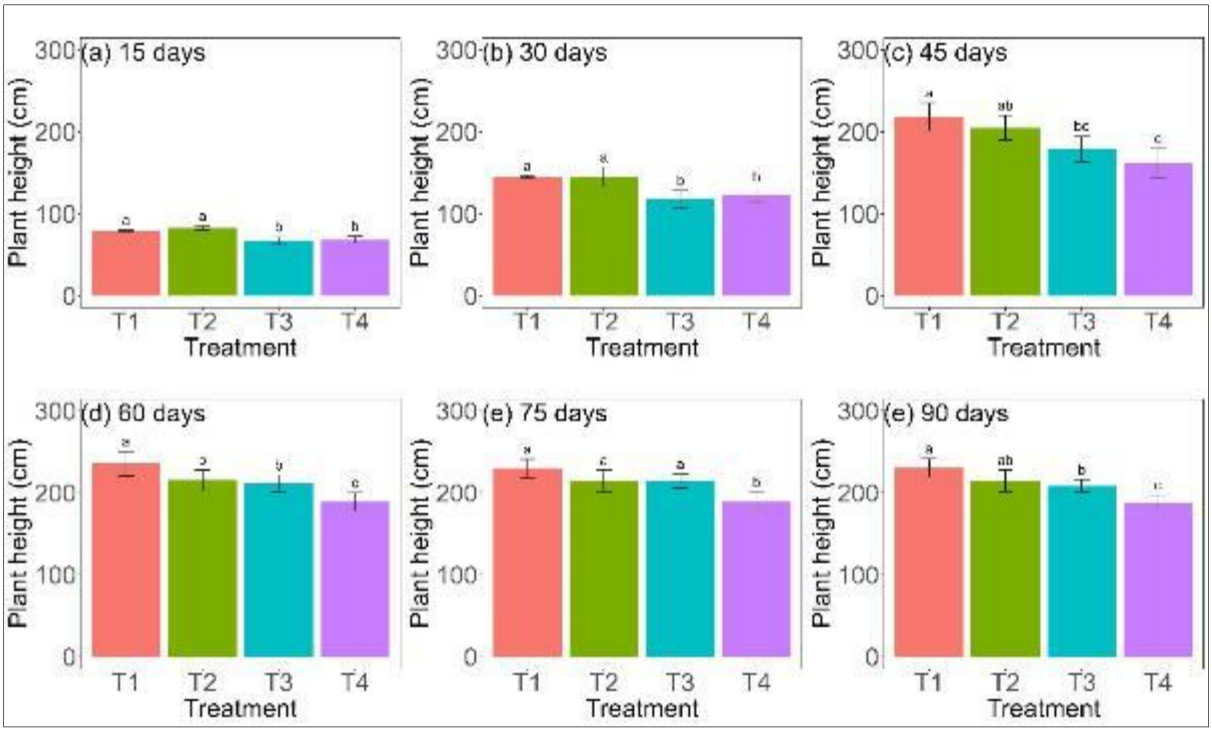

Figure 1 Trend on the effect of treatment on plant height measured by number of days.

3.3. Number of leaves per plant

As shown in Table 4, the number of leaves per plant is significantly increased when fertilized with 120 kg/ha of nitrogen in T1 and T2. Whereas reducing the rate of nitrogen produced the lower number of leaves as shown in T3 and T4. The highest number of leaves was recorded in T2 at all stages of crop growth. This might be due to application high amount of nitrogen during basal thus promoting number of leaves at early stages of plant growth. It was reported that application of nitrogen fertilization increases the number of leaves because of increasing the number of nodes and internodes and subsequently more production of leaves (Jhones et al., 1995). For the number of leaves at 45 DAP, the highest leaves produced were obtained from T1 even though no significant difference was observed among treatments. Similar mean numbers of leaves produced were found in T1 and T2 at 75 and 90 DAP.

3.4. Chlorophyll content

The trend of SPAD reading values was high in early stages and then gradually declined from 15 DAP to 90 DAP except for T1 and T3 (Table 4). This due to additional application of N fertilization for treatments during vegetative stage. The variation of SPAD readings values was higher in early stages of maize development with average from 32.4 to 38.6 at 15 DAP for all treatments. This shows that nitrogen (N) taken up by plants was enough to produce other plant structures during early development stages. SPAD readings were only significant between treatment at 45 and 60 DAP. At this stage, the higher SPAD reading values were 39.9 and 38.4 at 45and 60 DAP, respectively, obtained from T1. SPAD readings was found increased in T1 and T3 at 75 DAS because there was more nitrogen in the soil until reproductive stages. Our result show that the amount of nitrogen is sufficiently available in the soil for the corn development in T3.

Table 2 Mean squares of analysis for plant height and stem diameter under various fertilizer treatments

Source	df	Plant height (cm)						Stem diameter (cm)					
		15 DAP	30 DAP	45 DAP	60 DAP	75 DAP	90 DAP	15 DAP	30 DAP	45 DAP	60 DAP	75 DAP	90 DAP
Rep	3	153.4**	1667.0***	2786.2**	1991.7***	1604.0**	1328.6**	10.8**	5.7ns	1.8ns	5.7**	5.9**	10.6**
Trt	3	226.4***	796.7**	2536.1**	1469.3**	1175.0**	1267.3**	28.4***	4.6ns	2.6ns	8.2**	9.8*	6.1*
Mean		74.3	132.8	191.2	213.0	212.3	210.4	18.03	21.8	17.7	18.1	16.9	16.9
Cv (%)		4.9	7.1	11.7	5.8	5.4	5.9	5.29	14.9	14.5	6.0	7.8	7.2

Note: *Significant at p < 0.1; **Significant at p <0.05; ***Significant at p<0.001; ns= not significant. df=degree of freedom

Table 3 Mean comparison of plant height and stem diameter under various fertilizer treatments

Treatment	Plant height (cm)						Stem diameter (cm)					
	15 DAP	30 DAP	45 DAP	60 DAP	75 DAP	90 DAP	15 DAP	30 DAP	45 DAP	60 DAP	75 DAP	90 DAP
T1	78.7±1.6a	144.7± 1.6a	218.3±17.1a	235.8±14.9a	230.1±11.2a	230.7±11.0a	19.7±0.7a	22.2±1.1a	18.9±0.7a	18.9±0.8ab	18.1±0.9a	17.6±1.1ab
T2	82.7±2.6a	145.0±12.2a	205.1±15.2ab	215.4±12.7b	214.5±13.1a	214.4±13.4ab	20.9±0.7a	22.9±1.2a	17.5±1.9a	19.8±0.7a	18.5±0.9a	18.4±1.2a
T3	67.4±4.8b	118.1±10.3b	179.4±15.4bc	211.7±10.0b	214.4±8.7a	208.8±7.0b	15.3±1.1b	21.7±2.1a	17.3±0.8a	16.7±0.7c	15.5±0.7b	16.1±0.7b
T4	68.6±4.0b	123.3±9.8b	162.3±17.6c	189.0±11.4c	189.4±11.3b	187.6±9.9c	16.2±1.1b	20.3±1.5a	17.2±0.7a	17.3±0.8bc	15.7±0.7b	15.8±0.9b

Note: Mean with different letter indicate statistically significant different at p <0.05

Table 4 Mean squares of analysis for leaf area various fertilizer treatments

Source	df	Number of leaves plant^{-1}					Chlorophyll content (SPAD unit)				
		15 DAP	30 DAP	15 DAP	30DAP	15 DAP	30 DAP	15 DAP	30 DAP	15 DAP	30 DAP
Rep	3	2.1**	2.47**	2.1**	2.47**	2.1**	2.47**	2.1**	2.47**	2.1**	2.47**
Trt	3	1.0*	0.63ns	1.0*	0.63ns	1.0*	0.63ns	1.0*	0.63ns	1.0*	0.63ns
Mean		9.2	10.5	9.2	10.5	9.2	10.5	9.2	10.5	9.2	10.5
Cv (%)		0.5	6.9	0.5	6.9	0.5	6.9	0.5	6.9	0.5	6.9

Note: *Significant at p < 0.1; **Significant at p < 0.05; ***Significant at p < 0.001; ns= not significant. df = degree of freedom.

Table 5 Mean comparison of analysis for leaf area, photosynthetic rate, and stomatal conductance under various fertilizer treatments

Trt	Number of leaves plant^{-1}					Chlorophyll content (SPAD unit)				
	30 DAP	45 DAP	60 DAP	75 DAP	90 DAP	30 DAP	45 DAP	60 DAP	75 DAP	90 DAP
T1	9.4 ± 0.3^{ab}	10.9± 0.6^{a}	15.9± 0.4^{a}	15.5± 0.3^{a}	15.5± 0.2^{a}	15.2± 0.1a	38.2± 2.0^{a}	27.9± 1.8^{a}	39.9± 2.9^{a}	35.8± 2.6^{a}
T2	9.7 ± 0.4^{a}	10.8± 0.6^{a}	16.0± 0.5^{a}	15.5± 0.6^{a}	15.5± 0.3^{a}	15.2± 0.3^{a}	38.6± 2.3^{a}	26.0± 2.8^{a}	25.0± 2.9^{b}	27.4± 1.4^{b}
T3	8.6 ± 0.5^{b}	10.0± 0.5^{a}	14.2± 0.8^{a}	13.7± 0.7^{b}	14.8± 0.5^{a}	14.3± 0.5^{b}	32.4± 4.0^{a}	25.9± 2.4^{a}	34.3± 1.0^{a}	34.5± 1.6^{a}
T4	8.9 ± 0.5^{ab}	10.3± 0.2^{a}	14.2± 0.7^{a}	14.5± 0.5^{b}	14.8± 0.4^{a}	14.6± 0.5^{ab}	32.6± 3.7^{a}	26.7± 1.3^{a}	24.5± 1.2^{b}	26.5± 0.5^{b}

Note: Mean with different letter indicate statistically significant different at p <0.05

3.5. Grain yield

The highest grain yield was recorded in T1 (8509.9 kg/ha) though insignificant difference from T3 (7726.4 kg/ha) (Table 6). This shows that reduction of nitrogen rate with coated urea gave similar yield obtained from commercial fertilizer. However, reduction in N rate significantly gave the lowest grain yield (5590.5 kg/ha) as shown in T4. Furthermore, application high N rate during one time as shown in T2 gave the low grain yield (6813.5kg). It proven that application of high N rate in one time application at sowing time resulted low yield of grain production. This might be due to volatilization of nitrogen and the loss of soil inorganic nitrogen after application. The results agreed with those found by Feng et al. (2021) suggest that crops require less nitrogen in the early stages of growth and nitrogen demand significantly increase in the middle and late stages of growth for producing high yield of maize.

3.6. Cob length and diameter

Cob length was significantly affected by treatments (Table 6 and 7). The comparing average results showed that the maximum cob length was observed in T1 and T3 treatments 144.8 and 134.7 cm, respectively which was not significantly difference between both treatments. This shows that the nitrogen in soil adequate to translocate the nitrogen from leaves to grain during reproductive stage. However, the minimum cob length was observed in T2 and T4 with an average 122.2 cm and 126.7 cm, respectively.

The cob diameter was significantly affected by treatments. This is evident in Table 6 and 7 which shows a reduction of nitrogen rate with coated urea gave larger cob diameter was 43.6 cm in T3. This value gave similar diameter obtained from commercial fertilizer in T1, while the smallest cob diameter was observed was 38.9 cm in T4.

3.7. Number of rows and grains per cob

Number of rows per cob was significantly affected by treatments (Table 6 and 7). The maximum number of rows per cob was observed in T2 which was not significantly difference from T3; however, the minimum number of rows was obtained in T1.

Number of grains per cob was affected by treatments (Table 6 and 7). Comparing the average results showed that the maximum number of grains per cob was observed in T1 with an average 483 grains, however no difference between treatments T3 with an average 466 kernels. The minimum number of grains per cob was observed in T4 with an average 390.5 grains. The decrease of nitrogen from 120 to 90 kg/ha did not lead to the decrease of number of grains in a row.

3.8. Weight of grains per cob and 1000 grain weight

Weight of grains per cob was significantly affected by treatments (Table 6 and 7). Comparing the average results showed that the maximum weight of grains per cob was observed in T1 and T3; however, the minimum weight was obtained in T2 and T4. In other words, reduction of N rate with coated urea not significantly difference from conventional fertilizer. Treatment effect on grain weight was significant at $p \leq 0.05$. The lowest grain weight (106.2 g) obtained from T4 was significantly different from T1 and T3. The highest grain weight recorded from T1 (151.5 g) was not significantly different from T3.

1000-grain weight was significantly not affected by treatments (Table 6 and 7). Comparing the average results showed that the maximum 1000-grain weight was observed in T3 which was not significantly difference from T1 and T4; however, the minimum amount was observed in T2 with an average of 287.8g.

Table 6 Mean squares of analysis for yield and yield components of grain corn under various fertilizer treatments

Source	df	Grain yield (kg/ha)	Cob length (cm)	Cob diameter (cm)	No. of row/cob	No. of grain/cob	Weight of grain/cob (g)	1000grain weight (g)
Rep	3	3916342.8**	183.0^{ns}	9.6^{ns}	0.2*	7164.0*	758.4*	246.0^{ns}
Trt	3	6301900.1**	392.8*	17.4*	0.1*	6970.8*	1717.8**	503.5^{ns}
Mean		7160.0	132.1	40.7	13.8	440.7	130.6	296.9
Cv (%)		10.3	7.6	6.1	1.7	10.2	11.1	13.8

Note: *Significant at $p<0.1$; **Significant at $p<0.05$; ***Significant at $p<0.001$; ns = not significant. df = degree of freedom.

Table 7 Mean comparison of analysis for yield and yield components under various fertilizer treatments

Source	Grain yield @ 14% (kg/ha)	Cob length (cm)	Cob diameter (cm)	No. of row/ cob	No. of grain/ cob	Weight of grain/cob (g)	1000 grain weight (g)
T1	8509.9± 597.1^{a}	144.8± 3.2^{a}	40.7± 1.2^{ab}	13.6± 0.2^{b}	482.7± 9.8^{a}	151.5± 5.9^{a}	296.6± 3.9^{ab}
T2	6813.5± 726.5^{b}	122.2± 1.7^{b}	39.6± 1.2^{b}	14.0± 0.1^{a}	423.4± 20.9^{ab}	121.2± 10.0^{bc}	287.8± 9.1^{b}
T3	7726.4± 186.4^{ab}	134.7± 7.7^{ab}	43.6± 1.2^{a}	13.9± 0.0^{a}	466.1± 20.7^{a}	143.4± 7.5^{ab}	312.8± 5.2^{a}
T4	5590.5± 248.25^{c}	126.7± 6.9^{b}	38.9± 1.6^{b}	13.7± 0.1^{ab}	390.5± 48.5^{b}	106.2± 12.5^{c}	290.2± 9.0^{b}

Note: *Significant at $p<0.1$; **Significant at $p<0.05$; ***Significant at $p<0.001$; ns= not significant. df = degree of freedom.

4. Discussion

Our results from the study showed that reduction of 30 N kg/ha using coated urea not highly contributed to improve plant height, stem diameter, number of leaves and chlorophyll content. This is due to all the plants in the treatments gradually increase according to their crop stage (Dambreville et al., 2015). However, the treatment proved to achieve similar yield as commercial fertilizer and no significant difference was observed from the yields after reduction N rate from 120 N kg/ha to 90 N kg/ha. Our results in consistent with Modhej et al. (2014) found that application of minimal N rate 90 kg/ha showed no significant difference between yield 180 and 260 kg/ha on the corn. Another study reported by Amir et. al. (2015) found that coated urea applied at a rate of 90 kg/ha resulted in higher grain yields of maize compared to the use of commercial urea at both 90 and 120 kg/ha. They achieved a grain yield of 3521 kg/ha using coated urea at a rate of 90 kg/ha, while with commercial urea fertilizer, the yields were 2445 kg/ha and 3377 kg/ha at application rates of 90 kg/ha and 120 kg/ha, respectively.

In fact, research conducted by Trenkel (2010) reported that application of slow-release fertilizers has the potential to reduce the use of fertilizer doses by 20-30% recommended from the conventional fertilizers while getting same yields on corn hybrid evaluated in the field. In the same way N rate can be modified within a cropping system to utilize the residual nitrogen present in the soil (Nasima et al., 2010).

In addition, our finding showed that reduction of N with coated urea was not affected on yield components of grain corn. Whereas it produces maximum cob length, cob diameter, number of rows per cob, number of grains per cob, weight of grain per cob and 1000-grains weight as conventional practice. Our finding similar with Modhej et. al. (2014) reported that the number of seeds, the number of plants rows, 1000-seed weight and corn yields was significantly affected when decreasing N rate from 260 to 90 kg/ha by slow-release fertilizer.

Moreover, applying a high nitrogen rate during one time is not recommended, as it can lead to low grain yield due to nitrogen volatilization of nitrogen and the loss of soil inorganic nitrogen after application. The results agreed with Feng et al. (2021), indicating that crops require less nitrogen in the early growth stages and nitrogen demand significantly increase during the middle and late stages of growth to achieve high yield of maize. Therefore, providing an appropriate amount of nitrogen at the right time will enhance corn yield (Khaveh et. al, 2015). However, nitrogen not absorbed by the plant may be lost through to denitrification, runoff, sublimation, and leaching. Therefore, controlling soil nitrogen loss can be achieved by coating suitable fertilizers to reduce nutrient release into water.

5. Conclusion

The standard application of 120 kg/ha of nitrogen has been shown to promise high grain yield, however these studies reveal no significance difference in yields when reducing the nitrogen rate to 90kg/ha N by using coated urea. Therefore, to protect the natural environments from excessive amount of N in the soil and to lower the agricultural expenses, it is recommended to reduce quantity of nitrogen applied. Certainly, the decrease of nitrogen application rate leads to reduced fertilization cost and highly promising for application in large scale grain corn cultivation. This finding could be used as a recommendation toward the implementation of planting grain corn in Malaysia. However, additional research will be required to enhance the effectiveness of the coating material in regulating the release of nutrients to the plants after application.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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