

Effect of different Nitrogen fertilization on cabbage (*Brassica oleracea*) and development of diamondback moth (*Plutella xylostella*)

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Article history:

Received: 24 October 2018

Received in revised form: 7 December 2018

Accepted: 19 December 2018

Available Online: 23 December 2018

Keywords:

Development, Fertilization, Insect-Plant interaction, Nitrogen

DOI:

Abstract

Cabbage (*Brassica oleracea* var. *capitata*) contains highly nutritional values compared to other leafy vegetables in tropical areas. This vegetable requires an adequate amount of plant nutrients for growth and development. Nitrogen (N) fertilization can improve plant qualities, but at the same time, it may also lead to higher levels of pest damage to crops. Diamondback moth (DBM) is one of the major insect pests attacking cabbage thus reducing the profitable cabbage production. This study is to demonstrate the effect of N on the plant growth and response of the insect pest towards higher N fertilization. Cabbage were applied with different N level; control; 50 mg/L, 100 mg/L, 150 mg/L, 200 mg/L and 300 mg/L at 2nd and 4th week after transplanting. At 6th week, treatment with higher N enhances the growth and development of cabbage and fastens the development of DBM. Glucosinolate content in cabbage was higher at 6th week compared to 9th and 12th weeks. It was further concluded that N fertilizer can increase cabbage productivity and understanding to learn chemical ecology and insect behaviour are crucial to develop pest control approaches.

1. Introduction

Cabbage (*Brassica oleracea* var. *capitata* L.) from family Cruciferae has been recognized as one of the top twenty vegetables and significant food sources around the world. Currently, cabbage has risen as main valued fresh market and widely marketed as minimally processed product. In Malaysia, its total production is about 101,258 metric tonnes (DOA, 2016). Cabbage is rich with nutritional values such as vitamin C, minerals and a small amount of protein with good caloric value (Singh *et al.*, 2006) and glucosinolate (Song and Tornalley, 2007). To achieve marketable with high nutritional quality cabbage, the agronomic practices which highly dependent on N fertilizer is required. Lack of N causes stunted growth or leaves discoloration in green cabbage. However, excessive applied of N fertilizer contributes to nitrate build up in soil and vegetables (Manchali *et al.*, 2012).

Diamondback moth, *Plutella xylostella* L. (Lepidoptera: Plutellidae) is the most damaging insect pest of cruciferous crops in the world (Talekar and

Shelton 1993; Grzywacz *et al.*, 2010) and one of the major constraints to high profitable cabbage production. Total loss of the plant caused by DBM worldwide has increased per annum (Furlong *et al.*, 2013). In Malaysia, DBM is among major pest of crucifer in Cameron Highlands and in the lowlands since 1941 (Corbett and Pagden, 1941). To meet the demand by consumers, farmers often applied excess fertilizer to obtain high yields in the form of nitrogen-based fertilizers and thus influencing the preference and performance of insect pest on the plant. In addition, almost 90% of the farmers utilize insecticides as primary control to combat DBM infestation on cruciferous crop. Consequently, these practices cause arising environmental problem and lead DBM to resistant as well as the rejection of harvested crops by consumer due to highly pesticide residue in crucifer. The objectives of this study were to determine the effects of different N levels on the growth and development of cabbage and its major pest DBM.

2. Materials and methods

2.1 Plant growth experiment

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Cabbage plants were grown individually in a round pot (12 cm x 11 cm) using topsoil: sand: organic matter with ratio 3:2:1 as a potting medium. Experimental plants were laid out in a split plot design (SPD) with six different levels of N treatments (T1: Control; T2: 50 mg/L; T3: 100 mg/L; T4: 150 mg/L; T5: 200 mg/L and T6: 300 mg/L) at 2nd and 4th weeks after transplanting (WAT). The treatments were replicated five times. Plant growth data parameters including root length, leaf area, dry weight of root and leaves were collected subsequently chemical analysis of N and glucosinolate were analysed on 6, 9 and 12 WAT.

2.2 DBM development experiment

DBM larva and pupae were collected from a private organic farm in Semenyih and was cultured on cruciferous plants in glasshouse. The cotton wool was dipped with 10% of honey solutions as food sources to adult DBM. 10 neonates of DBM were put on sixth-week old plants to observe the duration required of DBM to change from larva, pupae and adult. All the experiments were conducted with five replications.

2.3 Statistical analysis

The N effect on cabbage growth was evaluated by analysis of variance (ANOVA), the mean differences were tested with Duncan Multiple Range Test (DMRT) at $P < 0.05$. The effect of N on DBM growth was evaluated by analysis of PROC GLM for split-plot design.

3. Results and discussion

3.1 Effects of nitrogen fertilization on cabbage growth

The effect of N treatment had a significant difference on the root length ($P < 0.05$) (Figure 1). It demonstrated that higher N uptake responds to the root elongation by increasing root length of cabbage with 27.97 cm after applied with 300 mg/L of N compared to other treatments. A similar result was reported by Petridis *et al.* (2012) showed that higher N treatments on lettuce

had the longest root length compared to lower N treatments. This may explain that high N application plays a role in root elongation by absorbing mineral nutrients which is fundamental in metabolism. There was also a significant interaction between root length and different harvest week of cabbage ($P < 0.05$). Longest root length was measured at week 12 with 36.98 cm after treated with 300 mg/L of N.

Figure 2 shows that the roots dry weight were significantly different after grown with different N treatments ($P < 0.05$). Similarly, Shormin and Kibria (2018) found that dry root weight of Indian spinach (*Basella alba* L.) increased positively with increasing levels of N. There was a significant interaction between N level and different harvest week on the dry weight of roots ($P < 0.05$) at Figure 2. Cabbage which grown with 300 mg/L of N at week 6 and 12 while 50 mg/L at week 9 gave higher roots dry weight.

There was a significant difference ($P < 0.05$) among the N treatments on the dry weight of the leaves in Figure 3. Cabbage treated with 300 mg/L of N shown the highest dry leaf weight followed by 150 mg/L and 200 mg/L of N. Previous study found application of higher N with increased leaves dry weight of lettuce (Boroujerdnia and Ansari, 2007). Tabeke *et al.* (1995) suggested that increasing leaf dry weight because of the N is combined with plant constituents of compounds during photosynthesis such as glucose, ascorbic acid, amino acid and protein. Moreover, increasing N fertilizer rate affected the leaf dry weight because N enhances plant photosynthesis, thus increasing dry matter production (Novoa and Loomis, 1981). There was also a significant interaction between N level and harvesting week on leaf dry weight in Figure 3. At the final stage of harvesting was shown highest leaf dry weight followed by week 9 and 6 where 300 mg/L of N had the highest leaves dry weight compared to other treatments.

A significant difference was observed between effect N treatments on the leaves area ($P < 0.05$) in Table 1.

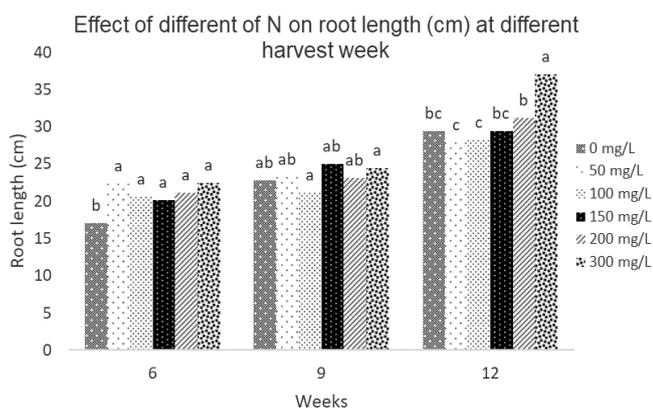


Figure 1. Means of cabbage root length (cm) at week 6, 9 and 12 of harvesting after treated with different N level

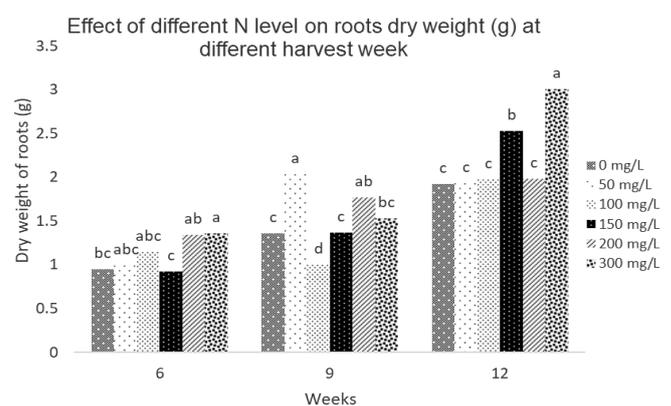


Figure 2. Means of roots dry weight of cabbage at week 6, 9 and 12 of harvesting after treated with different N level

Higher N application resulted in the leaf expansion in the treated plants compared to control plants. An increase leaf development of swiss chard (*Beta vulgaris* L. var. *cicla* L.) with an increase in N level was also reported by Miceli and Miceli (2014). There was also a significant interaction found between N treatments and different harvesting week on leaf area ($P < 0.05$) in Table 1. This trend implied that higher N fertilizer promoted leaf expansion rate which is a dominant factor in determining the leaf area maturity. Thus, these resulted that cabbage required adequate amount of N at early growth of each development mainly use in the process enlargement of leaves. Well-developed of leaves contributed to the better head formation of cabbage.

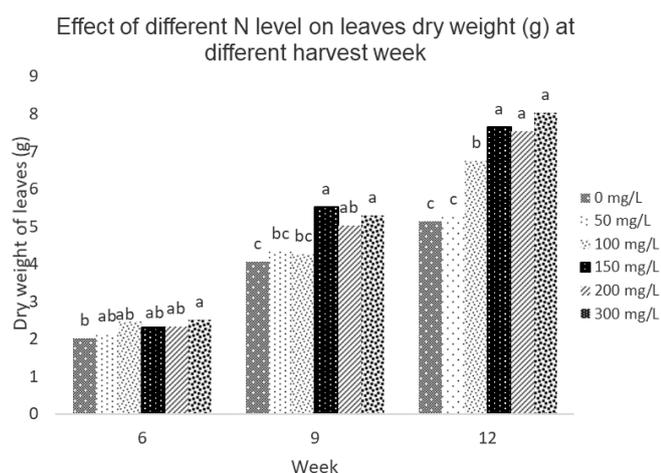


Figure 3. Means of leaves dry weight of cabbage at week 6, 9 and 12 of harvesting after treated with different N level

3.2 Chemical analysis

Table 2 showed that there was a significant effect of different N level on N content in leaves cabbage. Leaves treated with high level of N had higher N content than unfertilized plants. Engelbrecht *et al.* (2010) found that N content was higher in *Beta vulgaris* var *cicla* leaves after treated with high dose of N. Leong *et al.* (2004) also found that higher N had the highest percentage of N in cabbage compared to the lowest N rate. There was a significant interaction between N content in leaves and different harvesting week in Table 2. This due to the N content in leaves tissue declined as the stage of development progressed. It indicated N had absorbed at the early growth stages and reutilize for expansion leaves at the latter growth stages. Kamarudin *et al.* (2014) also revealed N concentration was higher at early stages of plant growth. Thus, the age of plant tissue is an important factor to determines N content.

Table 3 shows there was significant interaction of different N different between glucosinolate content in leaves and different harvesting weeks of cabbage. Glucosinolate content was greater on 6-week-old plants compared to 9 and 12 weeks after treated with different

N level. Young leaves contained higher levels of glucosinolate and reduce after maturation (Porter *et al.*, 1991; Badenes-Perez *et al.*, 2014). However, 150 mg/L of N shown the highest glucosinolate on 6-week-old in leaves cabbage. Velasco *et al.* (2007) revealed that higher N produces a decrease in total glucosinolates. Thus, glucosinolates content in plants varied among ontogenetic state of plant and agronomic factors related to its growth.

3.3 DBM development

Table 4 shows the application of N had a significant effect on DBM growth. N fertilization significantly reduced larva period compared to no treatments. The higher the amount N, the shorter is the larva period. Similarly, DBM larvae developed faster when fed on cauliflower grown with higher dose of N (Bansode and Purohit, 2013). Hwang *et al.* (2008) reported that larvae fed on higher nutrient leaves had increase growth rate and reduce development time compared to larvae that fed on low nutrient leaves. Even though the mechanisms N fertilization increase DBM larva growth and modified larval feeding preference still unknown, N supply may alter the balance of plant's protein to carbohydrate ratio (P:C), or decrease levels of plants defensive, or a combination of the two (Simpson and Raubenhiemer, 1993; Bede *et al.*, 2007). Therefore, balanced of (P:C) is essential for growth and development of many phytophagous insects.

During pupa period, treatments of 200 mg/L and 300 mg/L of N had significantly shorter days compared to no treatment with the shortest pupa stage to only 2.4 days, compared to 3.78 days at no treatment. DBM pupal period varied after grown in cauliflower plant with different level of N fertilization that required 3.79 to 4.24 days. This is due to the plant availability had significantly affected the pupal durations of *P. canidia* (Hwang *et al.*, 2008).

The adult DBM longevity was shown to be significantly longer with higher N treatment. Besides, total DBM development time shows that treatments 100 mg/L, 200 mg/L and 300 mg/L gave significantly shorter at 15.59, 15.68 and 15.18 days respectively. Wang *et al.* (2000) found that *Peregrinus maidis* (Ashmead) responded to N fertilizer by shortening development and longer adult longevity period on corn plants grown in high N level. Similarly, Jauset *et al.* (2000) found that there was significantly different on the development time of immatures (from egg laying to adult emergence) of greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood) after treated with different nitrogen level (308, 140 and 84 ppm) on tomato plants, *Lycopersicon esculentum* (Miller). Subsequently,

Table 1. Means of leaves area of cabbage at week 6, 9 and 12 of harvesting after treated with different N level

N treatments (mg/L)	Leaves area (cm ²)		
	Week 6	Week 9	Week 12
0	530.51±93.09 ^a	754.13± 115.53 ^c	715.57±132.05 ^d
50	580.76±100.70 ^d	798.25±129.62 ^c	763.91± 102.85 ^d
100	652.74±74.70 ^c	770.54±133.70 ^c	892.61±77.36 ^c
150	727.03± 108.52 ^b	824.3± 143.22 ^b	895.84±100.59 ^c
200	745.6±129.57 ^b	885.15±86.51 ^b	970.11±83.70 ^b
300	825.56±90.23 ^a	947.81±86.51 ^a	1038.21±114.79 ^a

*Columns and rows with the same letter were not significantly different based on Duncan's multiple range tests at $\alpha=0.05$

Table 2. Effect of different N level on nitrogen content in leaves at 6, 9 and 12 (WAT).

N treatments (mg/L)	N content (%)		
	Week 6	Week 9	Week 12
0	1.205±0.341 ^d	0.356±0.12 ^d	0.363±0.057 ^c
50	1.66±0.41 ^{bc}	0.51±0.22 ^c	0.379±0.048 ^c
100	1.423±0.421 ^{cd}	0.597±0.175 ^c	0.428±0.111 ^{bc}
150	1.52±0.484 ^c	0.713±0.335 ^b	0.457±0.233 ^{ab}
200	1.87±0.57 ^{ab}	0.908±0.424 ^a	0.512±0.172 ^a
300	2.02±0.344 ^a	0.924±0.42 ^a	0.513±0.176 ^a

*Columns and rows with the same letter were not significantly different based on Duncan's multiple range tests at $\alpha=0.05$

Table 3. Effect of different N level on glucosinolate content in leaves at 6, 9 and 12 (WAT).

N treatments (mg/L)	Glucosinolate content (ppm)		
	Week 6	Week 9	Week 12
0	26.32±0.22 ^b	5.19±0.18 ^d	4.8±0.19 ^c
50	20.32±0.31 ^c	13.60±0.44 ^b	12.29±0.05 ^a
100	15.68±0.05 ^d	3.24±0.15 ^c	4.54±0.28 ^c
150	35.41±0.20 ^a	10.22±0.22 ^c	2.19±0.07 ^d
200	12.58±0.35 ^c	3.24±0.21 ^c	6.45±0.32 ^b
300	20.22±0.57 ^c	18.51±0.25 ^a	12.6±0.24 ^a

*Columns and rows with the same letter were not significantly different based on Duncan's multiple range tests at $\alpha=0.05$

Table 4. Effect of N levels on development period of *P. xylostella*

N treatments (mg/L)	Larva period (Days)	Pupa period (Days)	Adult longevity (Days)	Development time (Days)
0	8.25 ^a	3.78 ^a	4.68 ^c	16.78 ^a
50	5.5 ^b	3.91 ^{ab}	5.60 ^b	17.48 ^a
100	5.25 ^b	3.83 ^{ab}	5.95 ^b	15.59 ^b
150	5.6 ^b	3.98 ^a	6.05 ^b	17.40 ^a
200	5.38 ^b	3.39 ^b	5.87 ^b	15.68 ^b
300	4.3 ^c	2.4 ^c	7.00 ^a	15.18 ^b

*Columns and rows with the same letter were not significantly different based on Duncan's multiple range tests at $\alpha=0.05$

the composition in plant tissue influenced insect herbivores. Throop and Lerda (2004) reported that N deposition may also affect the quantity of food available to herbivores, either by altering the total amount of plant tissue available or plant phenology and altering the timing of the availability of specific tissues.

4. Conclusion

The development of cabbage was apparently affected by higher N application. Higher N resulted in greater root length at week 6, 9 and 12. Moreover, dry weight of cabbage leaves and root increased greatly when applied with 300 mg/L of N. The higher N application has increased cabbage leaves area. The leave tissue increased with the increasing of nutrient solution. At week 6, glucosinolate content in leaves was higher after treated with higher N level compared to 9 and 12 WAT.

Besides, development of DBM was positively influenced with N fertilization. Increasing N level significantly shorten the larva development. Higher N content also significantly increase the life expectancy of DBM adult. This shown that larvae on high N consumed food and utilized N more efficiently than larvae on low N plants. Although higher N fertilization resulted in the growth of plant but susceptible to insect pests. As a conclusion, higher N fertilization can strongly affect the host plant growth and performance of insect herbivores.

Acknowledgment

The authors would like to acknowledge the financial support provided by Ministry of Science, Technology and Innovation of Malaysia.

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