



RESEARCH ARTICLE

# Effect of zeolite on the growth and yield of broccoli in the dry season

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## Abstract

Broccoli (*Brassica oleracea* var. *italica* Plenck) growth and yield are impacted in warmer climates, especially during the dry season. Broccoli gives low yield and quality although it is heat-tolerant cultivars. Zeolite is an organic material recognized as suitable for dry season plant growth because it can adsorb cations, nutrients and water and release on demand from the plant. Application of zeolite in the soil may improve broccoli growth and yield during the dry season. The trial preparation followed a randomized complete block design (RCBD) with four replications involving five amounts of zeolite at 0, 1.56, 3.12, 4.68 and 6.24 t ha<sup>-1</sup> using broccoli cultivar 'Top Green'. Results showed that zeolite applications of 4.68 and 6.24 t ha<sup>-1</sup> improved growth and yield parameters including plant width, stem diameter, time to 50% flowering and harvest, head diameter and head weight better than the other treatments. Application of zeolite at 6.24 t ha<sup>-1</sup> gave high total broccoli yield of 8.45 t ha<sup>-1</sup> but not significantly different ( $p \leq 0.05$ ) from 4.68 t ha<sup>-1</sup> that gave 7.89 t ha<sup>-1</sup>. Results indicated that application of zeolite at 4.68 t ha<sup>-1</sup> was optimal for reducing drought stress and enhancing effective growth and yield of broccoli.

## Keywords

Broccoli, Zeolite, Drought stress

## Introduction

Broccoli belongs to the Brassicaceae family which consists of the Cole crops viz., cauliflower, cabbage and kale (1) that originated from the Mediterranean region (2). Broccoli is a popular vegetable that is cultivated in many countries including Australia, New Zealand, Japan, Canada, Germany, the Netherlands, the United States of America and Thailand (3). Broccoli has high nutritional value and many health benefits from contained antioxidant substances that ameliorate the onset of some types of cancer (4, 5). In Thailand, broccoli cultivation has recently expanded, with increased production to satisfy the requirements of domestic consumers (6). The most suitable temperature for broccoli cultivation is between 10 and 20°C (1). Therefore, in Thailand, broccoli is generally cultivated in northern areas where temperatures are lower or northeastern regions during the cool season (3, 7). Southern areas are humid with no cool season and unsuitable for broccoli growth, while local consumers generate high product demand (8). To meet consumption demands in the south, heat-tolerant broccoli cultivars such as 'Green Queen', 'Yok Kheo' and 'Top Green' have been developed as better adapted to humid tropical weather (9).

Drought stress is one of the most important environmental factors that influence plant cultivation in the dry season (10). Drought causes stress in plants because the soil cannot accumulate enough moisture necessary for plant growth (11). Broccoli is most sensitive to drought stress (12) causing decreasing growth and yield in the dry season (6, 13). The shading technology under greenhouse is recommended for broccoli farmers. It was reported that broccoli cultivated under shading in southern Thai greenhouses during the dry season showed higher growth and yield than in open fields (14). However, the high costs for greenhouse construction are prohibitive for southern farmers. It was already reported (15) that addition of zeolite to the soil improved plant growth and yield under drought stress for canola, wheat, amaranthus (16) and sorghum (11). Reports are also on the zeolite application improved shoot yield and follow oil yield of peppermint in the dry season (17). Zeolite also contains macronutrients and micronutrients including N, K, Ca, Mg, Zn, Mn and Cu (18), which counterbalance the loss of nutrients in the soil (19). The influence of zeolite in improving dry season growth and yield of broccoli in Southern Thailand was investigated.

## Materials and Methods

### Plant material and experimental

Broccoli cultivar 'Top Green' was selected for this experiment as a heat-tolerant cultivar that can produce high yield in Southern Thailand (8). A randomized complete block design using four replications was used to carry out the experiment at Songkhla Rajabhat University, Muang Songkhla District, Songkhla Province, Thailand, latitude 7° 12' 27" N, longitude 100° 35' 48" E and altitude 4 m above sea level (Fig. 1) (20) between March and May, 2016. Experimental therapies comprised zeolite addition at five amounts as 0 (control), 1.56, 3.12, 4.68 and 6.24 t ha<sup>-1</sup> (21). The soil was prepared for planting by plowing, disking and leveling. Raised-beds with plot size of 1.0 m width, 5.0 m length and 0.20 m height were manually prepared. One week before broccoli planting, each treatment of zeolite was incorporated into the plots (22). One-month-old broccoli seedlings were transplanted into the plots with plant and row spacing of 0.30 and 0.60 m respectively. Each plot consisted of 2 rows with 16 plants in each row. Broccoli plants were watered frequently using a sprinkler in the morning and the afternoon, excluding rainy days. Fertilizer 21N-0P-0K was applied three times at 2, 3 and 4 weeks after transplantation, while fertilizer 15N-6.5P-12.5K was used 5 and 6 weeks after transplantation. At 2 and 4 weeks after transplantation, the plots were weeded using a hand hoe (7).

### Data collection

Seedling survival rate at 30 days after transplanting (%) was determined. Plant height (cm) was measured for 10 random plants in the plot by taking the distance from the soil surface to the longest top leaf, plant width (cm) was measured for 10 random plants in the plot by taking the distance from the longest leaf on one side to the other

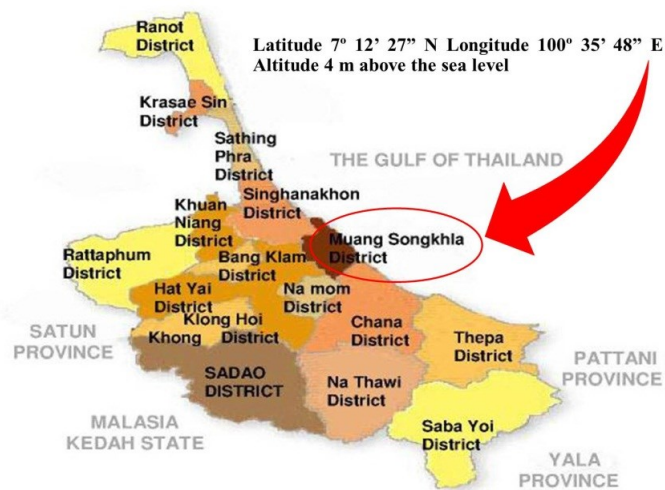


Fig. 1. District map of Songkhla Province showing the study area (20).

longest one on the opposite side and stem diameter (cm) was measured for ten random plants in the plot using a digital caliper (Insize series 1108, U.S.A.) at time to 50% flowering stage. The number of days from transplanting to the beginning of 50% flowering and harvest (DAT) was recorded. Other data were recorded from harvested plants in the plot: stalk length (cm), head diameter (cm), head weight (g) and total yield (t ha<sup>-1</sup>) (7). Soil samples in each plot were extracted at a depth of 0-20 cm and evaluated for total nitrogen (total N), organic matter (OM), available phosphorus (avail. P), available potassium (avail. K), available calcium (avail. Ca), available magnesium (avail. Mg) and pH.

### Statistical analysis and experimental

Data were assessed using analysis of variance (ANOVA), with means determined utilizing Duncan's Multiple Range Test (DMRT) with  $p \leq 0.05$ .

## Results

### Growth parameters

Application of zeolite did not significantly affect broccoli seedling survival (Fig. 2A) and height compared to the control, with values of 72.65 to 82.02% and 42.09 to 44.76 cm respectively. On the other hand, zeolite application at all levels significantly increased plant width 60.61 to 65.31 cm compared with the control at 58.48 cm. Highest stem diameter at 4.85 cm was obtained from application of zeolite at 6.24 t ha<sup>-1</sup>, followed by 4.68, 3.12 and 1.56 t ha<sup>-1</sup> with stem diameter of 4.26 to 4.44 cm, whereas lowest stem diameter was obtained from the control at 4.04 cm (Fig. 2B). Earliest times to 50% flowering and harvest were obtained from applications of 4.68 and 6.24 t ha<sup>-1</sup> of zeolite, with values of 41.50 to 41.75 DAT and 51.75 to 52.00 DAT respectively. The most recent periods to 50% flowering and harvest were gained from 1.56 and 3.12 t ha<sup>-1</sup> zeolite applications and control with values of 45.50 to 45.87 DAT and 55.50 to 56.37 DAT respectively (Fig. 2C).

### Yield parameters

All zeolite application levels did not significantly affect broccoli stalk length compared with the control (Fig. 3A),

with values of 36.88 to 40.01 cm. However, zeolite treatments significantly affected head diameter, head weight and total yield. Highest head diameter was obtained from 6.24 t ha<sup>-1</sup> zeolite application at 13.25 cm, which was only slightly dissimilar ( $p \leq 0.05$ ) from the 4.68 t ha<sup>-1</sup> zeolite application at 13.07 cm. Lowest head diameter was obtained from the control, 1.56 and 3.12 t ha<sup>-1</sup> of zeolite applications with values of 10.53 to 11.08 cm (Fig. 3A). Highest head weight was obtained from 4.68 and 6.24 t ha<sup>-1</sup> zeolite applications with values of 268.93 and 282.64 g respectively that were not significantly different ( $p \leq 0.05$ ), followed by 3.12 and 1.56 t ha<sup>-1</sup> zeolite applications. Lowest head weight was obtained from the control at 225.18 g (Fig. 3B). Highest total yield was obtained from 6.24 t ha<sup>-1</sup> of zeolite application with a value of 8.45 t ha<sup>-1</sup>, which was only slightly dissimilar ( $p \leq 0.05$ ) to 4.68 t ha<sup>-1</sup> zeolite application, giving a yield of 7.84 t ha<sup>-1</sup>. Lowest total yield was obtained from the control at 6.51 t ha<sup>-1</sup>, which was only slightly dissimilar ( $p \leq 0.05$ ) to 1.56 and 3.12 t ha<sup>-1</sup> zeolite applications, with yields of 6.88 to 7.11 t ha<sup>-1</sup> (Fig. 3C).

## Discussion

Zeolite application promoted higher growth parameters of broccoli grown in the dry season than the control for plant width, stem diameter, time to 50% flowering and time to 50% harvest. Similar results were reported in canola (15) and soybean (23). This occurred because zeolite decreased electrolyte leakage in plants (24) and increased soil retention and water absorption to 100% in dry soils with slow

nutrient release (25) This improved plant growth under water deficit stress (24). Broccoli with added zeolite in the soil produced higher head diameter, head weight and total yield than the control. Similar results were reported in carrots, cowpea, eggplant and potatoes grown in soil mixed with zeolite, with significantly increased yield compared with the control; 5 t ha<sup>-1</sup> of zeolite application yielded the best results for these crop cultivations (18). Moreover, applications of 4 to 8 t ha<sup>-1</sup> zeolite significantly increased wheat, eggplant and apple crops by 13-15%, 19-55% and 13-38% respectively (26) because zeolite boosted the accessibility to important nutrient elements such as nitrogen, phosphorus, potassium, calcium, magnesium and micronutrients was the main factors for plant growth (27). Zeolite retains nutrients in the root zone that are then used by plants when required (28, 29). Positive effects of zeolite application on plant growth and yield were related to increased increments of soil nitrogen efficiency by 10 to 22% and prevention of nitrogen leaching by 86 to 99% (30, 31). These findings concurred with analysis results of soil properties in the experimental plots, as shown in Table 1.

## Conclusion

Adding zeolite to the soil had a significantly positive effect on growth and yield of broccoli grown in the dry season. Utilization of 4.68 t ha<sup>-1</sup> of zeolite was recommended for farmers because this improved effective growth and yield compared with other treatments.

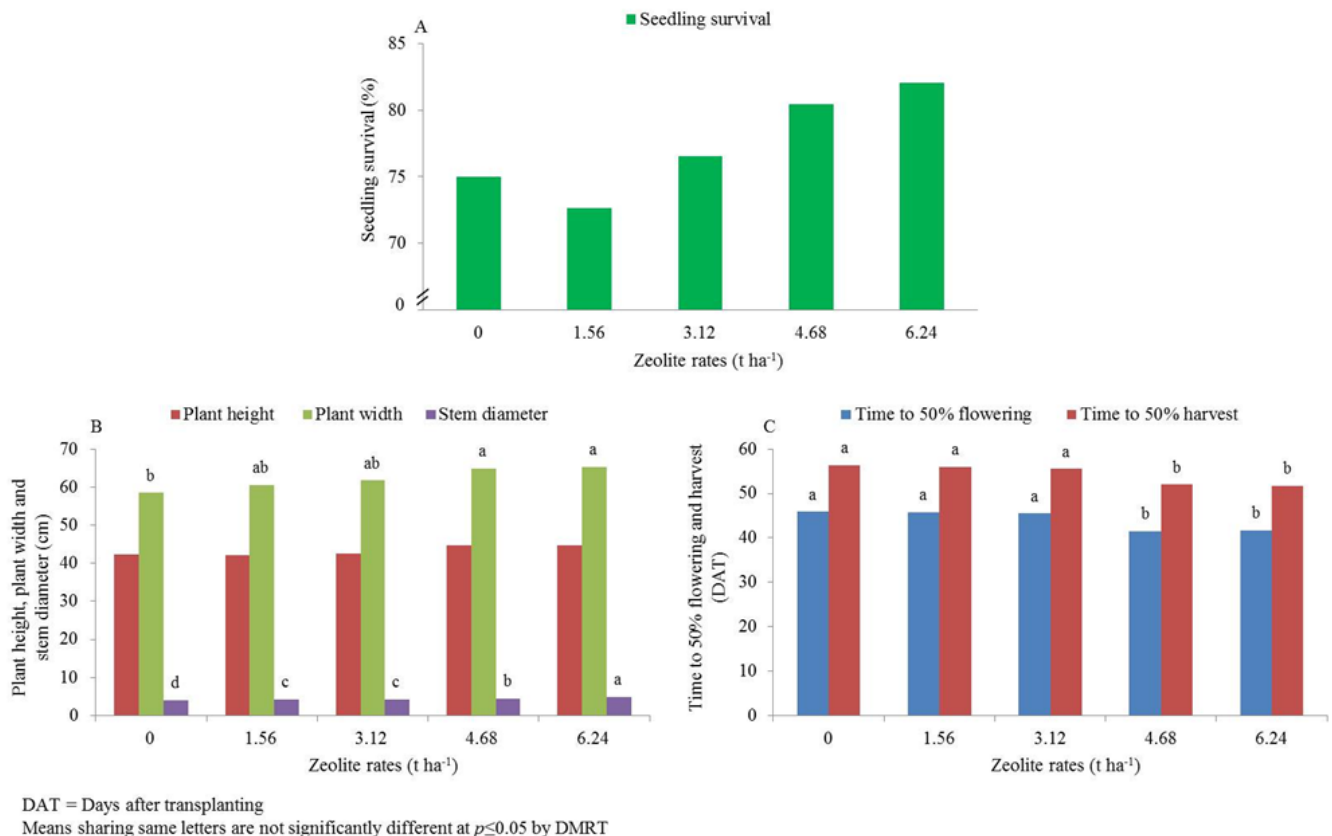
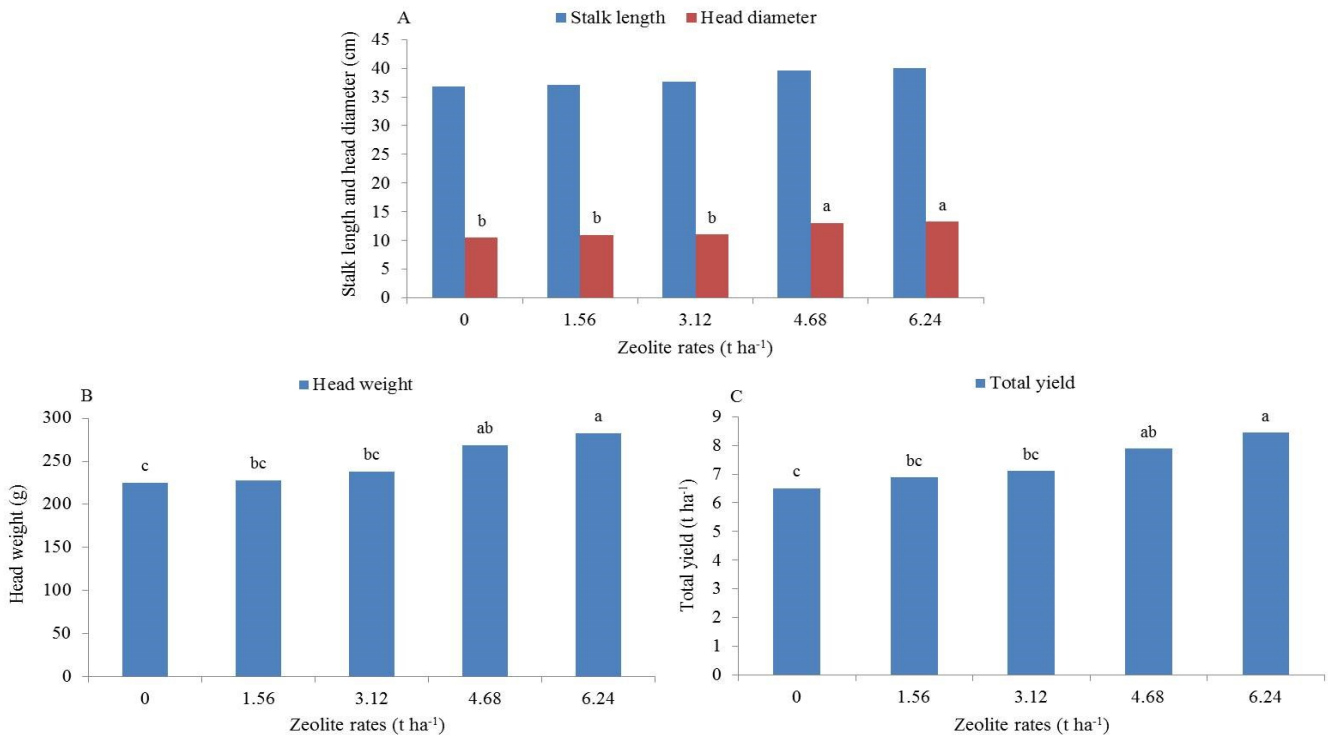


Fig. 2. Growth parameters of broccoli with different rates of added zeolite.



Means sharing same letters are not significantly different at  $p \leq 0.05$  by DMRT

**Fig. 3.** Yield parameters of broccoli with different rates of added zeolite.

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## Compliance with ethical standards

**Conflict of interest:** The authors do not have any conflict of interests to declare.

**Ethical issues:** None.

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**Table 1.** Experimental soil properties

Soil property	Addition of zeolite to the soil (t ha <sup>-1</sup> )					Analysis method
	0	1.56	3.12	4.68	6.24	
Total N	0.11	0.13	0.15	0.15	0.17	McKenzie method (%)
OM	2.52	2.56	2.61	2.70	2.74	Walkley-Black method (%)
Avail. P	158.12	162.66	172.65	185.41	194.84	Bray II (mg/kg)
Avail. K	254.11	268.66	275.09	286.74	336.41	NH <sub>4</sub> OAc extract (mg/kg)
Avail. Ca	1743.90	1854.70	1916.96	2334.33	2942.88	NH <sub>4</sub> OAc extract (mg/kg)
Avail. Mg	245.77	264.32	266.62	284.11	341.72	NH <sub>4</sub> OAc extract (mg/kg)
pH (H <sub>2</sub> O)	6.42	7.16	7.33	7.43	7.52	pH meter method

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