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Cauliflower Growth, Yield and Quality Response to Nitrogen Fertilization and Micronutrients Foliar Application in Newly Reclaimed Areas

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ABSTRACT

Two field experiments were carried out during 2017/2018 and 2018/2019 seasons, at the Experimental Farm, Faculty of Agriculture, New Valley University, New Valley governorate, Egypt, to study the effect of nitrogen levels (30, 45 and 60 kg/fed.) and micronutrients foliar application: control (B 0 + Mo 0), boron at 100 ppm (B 100), molybdenum at 50 ppm (Mo 50) and combined boron and molybdenum (B 100 + Mo 50) on cauliflower vegetative growth, yield, and quality parameters in the recently reclaimed areas, especially New Valley governorate as a promising area for agriculture expansion in Egypt. The results revealed that nearly all traits showed a gradual increment with increasing the nitrogen level; whereas the application of high level of nitrogen (60 kg/fed.) significantly increased vegetative growth, curd yield and curd quality of cauliflower and significantly decreased total phenols content and has no effect on number of days to maturity. Also, the results of this study reported promotional effects of either B or Mo foliar application on growth, yield and quality of cauliflower curds compared with untreated plants; nevertheless the combined application of B and Mo together was more effective than application of B or Mo when they separately applied. Moreover, inorganic nitrogen at 60 kg/fed. was more effective in the presence of B and Mo at 100 and 50 ppm, respectively, than the other combinations and achieved the highest curd yield with top quality.

Keywords: *Brassica oleraceae,* nitrogen level, boron, molybdenum

INTRODUCTION

Cauliflower *(Brassica oleracea* L. var. *botrytis)* is an important cool season vegetable crop and belongs to Brassicaceae family. It is one of the highest antioxidative activity vegetables because of its high content of phytochemicals, such as glucosinolates, vitamins, phenolic compounds and fibers, which are principals for digestive system health (Podsedek, 2007; Picchi *et al*., 2012). The health promoting properties of cauliflower have been strongly emphasized and were referred to its high content of sulphoraphane, indole-3-carbinol and 2-propenyl isothiocyanates, which are the breakdown products of glucoraphanin, glucobrassicin and sinigrin, respectively (Agerbirk *et al*., 2009). Therefore, cauliflower has been shown to be very effective in protecting against the risk of several types of cancer (Lee *et al*., 2008; Tang *et al*., 2008).

Like other crops, plant nutrition is one of the key principals for getting high yield of cauliflower. It is well known to be a heavy feeder crop and has the capacity to absorb high amount of macronutrients, particularly nitrogen (Abdel-Razzak *et al*., 2008 a; Bianco *et al*., 2015). Nitrogen (N) significantly affects the crop productivity as well as quality attributes (Konstantopoulou *et al*., 2010; He-xi *et al*., 2011), through controlling the synthesis of several key products in plant cell, such as nucleic acids, proteins, phospholipids and other secondary metabolites (Amtmann and Armengaud, 2009). The optimum supply of N enhances plant growth and crop productivity (Collins and McCoy, 1997); however, the excessive and overuse of N fertilization may increase the accumulation of compounds such as nitrates and non protein nitrogen in the edible parts, which may be harmful to human health and cause several environmental pollution and economical losses (Lisiewska and Kmiecik, 1996; Elia *et al*., 1998; Rani and Mallareddy, 2007; Elwan and El-Shatoury, 2012). Pervious investigations have showed that curd yield and quality of cauliflower and broccoli are greatly influenced by N application (Abdel-Razzak *et al*., 2008 a and b; Yoldas *et al*., 2008; Abd El-All and EL-Shabrawy, 2013; Singh *et al*., 2018). Therefore, supply of proper N must be ensured during cauliflower cultivation.

In addition, micronutrients are essential elements for normal plant growth, development and productivity of plants as they play important roles in the meristematic development, chlorophyll formation, photosynthesis and transpiration as well as tannin and phenolic compound development (Sharma, 2006; Tripathi *et al*., 2015). Boron (B) is very important for growth and development of crops as it is involved in cell division, root elongation, calcium metabolism, auxin synthesis, sugar metabolism translocation of solutes and protein synthesis (Tariq and Mott, 2007; Camacho-Cristóbal *et al*., 2018). Molybdenum (Mo) is also an important micronutrient for plant growth and development. It is an essential component of major enzyme, nitrate reductase, which converts the nitrate to nitrite, which is the first stage of the incorporation of nitrogen to proteins (Kaiser *et al*., 2005; Bambara and Ndakidemi, 2010).

Some vegetable crops have higher demand micronutrients than others and should be applied in optimum rates. Cauliflower has a high micronutrients requirement, particularly B and Mo. Several previous studies reported that both B and Mo are important elements in attributes of cauliflower and broccoli productivity and quality (Thapa *et al*., 2015; Hassain *et al*., 2018; Sarker *et al*., 2018). Unfortunately, B and Mo deficiency has been reported very frequently in cauliflower and caused several anatomical, physiological, and biological changes, such as browning of curd and hollow stem as well as whiptail disorders, sword like leaves, malformation of growing tip and delaying curd formation (Mehrotra and Mishra, 1974; Shelp and Liu, 1992; Sharma, 2002). In addition, the affected heads become irregular in shape, smaller in size, and bitter in taste, which adversely affects the market demand of the crop. Nevertheless, several researchers reported that B and Mo deficiency could be overcome by application of B and Mo, either as soil application or as foliar spray, and enhanced the cauliflower growth and productivity (Ahmed *et al*., 2011; Ningawale *et al*., 2016; Farooq *et al*., 2018). Therefore, application of B and Mo is a crucial factor for yield and quality of cauliflower.

In last decades, the rapid growth of population is one of the main challenges facing Egypt. In order to overcome this problem, policy makers are trying to expand the arable land, which represents only 3.5 % of total area, into the new rejoins such as recently reclaimed areas over all the country. However, information regarding the standard cultural practices such as fertilization requirements is still meager in these zones. Keeping this view in perspectives, the following field experiments were performed with a view to find out the optimum level of N and foliar application of B and Mo for obtaining maximum growth, yield and quality of cauliflower in newly reclaimed area in the south-west part of Egypt.

MATERIALS AND METHODS

Plant materials and treatments

Two field experiments were performed out in consecutive winter seasons of 2017 and 2018 at Experimental Research Farm of the Faculty of Agriculture, New Valley University, New Valley governorate, Egypt in order to study the effect of N levels and foliar application of micronutrients: B and Mo as well as their interaction on vegetative growth, yield, quality and chemical components of cauliflower "cv. Amshiry". N was supplied as ammonium sulphate at level of 30, 45 (according to recommendation of Agriculture Ministry of Egypt) and 60 kg N/fed. Four micronutrients treatments were supplied: (1) control (B 0 + Mo 0), (2) B at 100 ppm (B 100; borax was used as source for boron), (3) Mo at 50 ppm (Mo 50; ammonium molybdate was used as a source for molybdenum) and (4) boron at 100 ppm plus molybdenum at 50 ppm together (B 100 + Mo 50). Both treatments and their interactions were arranged in a split plot in randomized complete block design with three replications. N levels were applied at three doses; the first dose was applied after four weeks from transplantation and the rest doses were supplied with three weeks intervals. The treatments of micronutrients with three drops of tween-twenty were sprayed four times.

The first micronutrient treatment was applied at age 30 after transplantation with two weeks intervals on the whole foliage in the morning (10–11 am). The plants that were treated with combined application of B + Mo were firstly sprayed with B and in the next day were sprayed with Mo. Depending on plant development stage, the volume of sprayed solution ranged from 20 ml to 50 ml per plant each time with a manual pump. The same amount of double distilled water plus three drops of tween-twenty was sprayed to the control plants.

Experimental design

Each replicate consisted of 12 treatments representing all combinations among the three levels of nitrogen and four treatments of micronutrients. The main plots were assigned to levels of nitrogen levels, while micronutrients treatments occupied as sub-plot and were placed randomly in each main plot. The experimental unit area (plot) was 11.2 m^2 in size and contained 4 ridges (with 4 m in length and 0.7 m in width for each ridge) and included 40 plants. A guard row was left without planting to separate each two adjacent sub-plots to protect against border effects.

Soil analysis

Before plantation, five soil samples were randomly collected at depth of 0.0–40.0 cm and then homogenized together in order to determine the physicochemical and chemical characteristics (Jackson, 1973; Chapman and Pratt, 1978; Klute, 1986). The soil physicochemical and chemical characteristics of the experimental site are presented in Table (1).

Table 1. Physicochemical and chemical characteristics of the experimental site in growing seasons.

Soil characteristics	Season 2107/2018	Season 2018/2019
Silt (%)	12.77	12.54
Clay (%)	7.85	7.80
Sand (%)	79.38	79.66
Texture	Sandy	Sandy
PH	8.15	8.20
E.C dsm	0.98	0.95
Organic matter (%)	0.51	0.54
$CaCo_3$ (%)	4.97	5.05
Available N (mg/kg)	48.80	51.24
Available P (mg/kg)	5.16	4.95
Available K (mg/kg)	133.70	142.36
Ca^{++} (meq/100g)	0.98	0.95
Mg^{++} (meq/100g	0.66	0.40
Na^{+} (meq/100g)	3.15	3.21
CO_3^{--} (meq/100g)	-	-
HCO_3^{-} (meq/100g)	1.13	1.10
Cl^{-} (meq/100g)	2.97	2.85
SO_4^{--} (meq/100g)	0.92	0.88

Agricultural practices

Seeds of cauliflower cv. "Amshiry" were firstly sown in 209-cell styrophom trays in greenhouse to produce the transplants. Trays were filed with soil mixture (peatmoss and vermiculite mixes in 1:1). The germination conditions were 22-26 ^oC and 85-90% relative humidity. During the seedling growth in the greenhouse, the experimental sites were prepared by adding 20 m^3 of cattle manure in addition to 200 kg/fed. of calcium super phosphate (15.5% P_2O_5). Later, the soil was cleared, ploughed, harrowed and divided into plots. After 30 days, healthy cauliflower seedlings with 3-4 true leaves were transplanted by hand on one side of the ridge at a distance of 40 cm on October 17^{th} and 12^{nd} in 2017 and 2018 seasons, respectively. All cultural practices (i.e. irrigation, weed and pest control) used for the cauliflower production were performed according to instructions of the Egyptian Ministry of Agriculture for cauliflower field production.

Measurements

At maturity stage, five plants were randomly selected from each experimental unit (plot) and data were recorded as follows:

A. Vegetative growth parameters:

- Plant height, number of leaves, leaf area (cm^2), leaves fresh weight (g), leaves dry matter (%).

B. Yield parameters:

- Curd fresh weight (g), curd diameter (cm), curd dry matter (%), total curd yield/fed. (ton), number of days to maturity

C. Curd chemical quality parameters:

- Ascorbic acid (mg/100 g FW) was measured according to the method described by A.O.A.C. (1975).
- Carbohydrates content (%): It was determined according to Mazumdar and Majumder (2003).

- Total phenols content (mg/100 g FW): It was determined according to Mazumdar and Majumder (2003).
- Soluble solids content (SSC %) was measured by a digital refractometer (Atago N1, Japan).
- Nitrate content (ppm) was measured according to Cataldo *et al*. (1975).
- Sulphur content (ppm) was estimated according to Novozamsky and Van Eck (1977).

D. Total Chlorophyll content and mineral composition in leaves:

- Total chlorophyll content (mg/g FW) was measured spectrophotometrically according to Lichenthaler and Wellburn (1983).
- N (%) was measured according to method of Baethgen and Ally (1989).
- P (%) was determined as described by Jackson (1973).
- K (%) was determined as described by Page (1982).
- B (ppm) was determined by method of Dible *et al*. (1954).
- Mo (ppm) was determined by methods of Johnson and Arkley (1954).

Statistical analysis

The collected data were subjected to statistical analysis using two-ways analysis of variance (ANOVA) procedures as implemented in Co-Stat Software computer program for statistics (2004). Means for nitrogen levels and micronutrients treatments as well as their interactions were compared according to Duncan's multiple range test at a significance level α of 0.01.

RESULTS AND DISCUSSION

Results

Effect of nitrogen levels as well as B and Mo on vegetative growth

The nitrogen levels significantly affected all vegetative growth parameters of cauliflower in both growing seasons (Table 2). Results convincingly reported that the significant highest plant height, leaves number, leaf area, leaves fresh weight and leaves dry matter were associated with nitrogen supplementation at level 60 kg/fed. compared with other levels; 30 and 45 kg/fed. Cauliflower plant growth was also significantly influenced by the main effect of micronutrients treatments (Table 2). Either B or Mo treatments had high vegetative growth comparing with non-treated plants; however, the application of molybdenum was more effective than boron for enhancing plant growth. In addition, the foliar spray of B next to Mo achieved the maximum values of all vegetative parameters in both growing seasons (Table 2); however, no significant difference between the addition of B and Mo together and addition of Mo alone was detected for number of leaves in both growing seasons. Cauliflower plants that were fertilized with 60 kg and sprayed with 100 and 50 ppm B and Mo together, respectively, had the highest plant growth parameters compared with other combinations.

Table 2. Main effects of nitrogen levels, micronutrients treatments and their interactions on vegetative growth parameters of cauliflower

Treatments	2017/2018 season				2018/2019 season			
	N1	N2	N3	Mean	N1	N2	N3	Mean
				Plant height (cm)				
B 0 + Mo 0	47.27 i	48.26 hi	48.64 hi	48.05 D	47.91 j	48.62 ij	50.20 hi	48.91 D
B 100	49.75 gh	51.01 fg	52.30 ef	51.02 C	50.64 hi	51.95 gh	53.03 fg	51.87 C
Mo 50	53.68 de	55.96 cd	58.57 ab	56.07 B	54.24 ef	56.98 cd	59.61 ab	56.94 B
B 100 + Mo 50	54.79 d	57.34 bc	60.47 a	57.53 A	55.27 de	58.67 bc	61.72 a	58.55 A
Mean	51.37 C	53.14 B	54.99 A		52.01 C	54.05 B	56.14 A	
				Number of leaves/plant				
B 0 + Mo 0	17.33 f	18.00 ef	18.33 ef	17.88 C	17.66 f	18.33 ef	19.33 de	18.44 C
B 100	18.33 ef	19.00 de	19.00 de	18.77 B	19.33 de	19.66 d	20.00 d	19.66 B
Mo 50	19.66 cd	20.33 bc	21.33 ab	20.44 A	20.00 d	21.33 bc	22.33 ab	21.22 A
B 100 + Mo 50	20.00 cd	20.33 bc	21.66 a	20.66 A	20.33 cd	21.33 bc	22.66 a	21.44 A
Mean	18.83 C	19.41 B	20.08 A		19.33 C	20.16 B	21.08 A	
				Leaf area/plant (cm^2)				
B 0 + Mo 0	7012.60 j	8621.39 i	9023.65 hi	8219.21 D	8022.20 h	8815.25 gh	9132.99 gh	8656.81 D
B 100	9935.34 gh	10910.25 fg	11478.13 ef	10774.57 C	10138.15 fg	10963.01 ef	11504.70 ef	10868.62 C
Mo 50	12388.84 de	13410.77 cd	15514.11 ab	13771.24 B	12509.73 de	13925.85 cd	16060.72 ab	14165.43 B
B 100 + Mo 50	12687.17 de	14589.83 bc	16757.27 a	14678.09 A	13363.07 d	15312.67 bc	17695.58 a	15457.11 A
Mean	10505.99 C	11883.06 B	13193.29 A		11008.29 C	12254.19 B	13598.50 A	
				Fresh weight of leaves/plant (g)				
B 0 + Mo 0	1117.16 j	1141.00 ij	1222.86 ij	1160.34 D	1128.63 i	1199.64 hi	1332.62 gh	1220.30 D
B 100	1276.92 hi	1373.13 gh	1436.43 fg	1362.16 C	1357.83 g	1457.73 fg	1522.28 f	1445.95 C
Mo 50	1527.00 ef	1694.65 cd	1851.10 ab	1690.91 B	1581.38 ef	1746.96 cd	1899.25 ab	1742.53 B
B 100 + Mo 50	1593.77 de	1786.38 bc	1963.27 a	1781.14 A	1666.03 de	1836.58 bc	1998.27 a	1833.62 A
Mean	1378.71 C	1498.79 B	1618.42 A		1433.47 C	1560.23 B	1688.10 A	
				Dry matter of leaves/plant %				
B 0 + Mo 0	8.46 g	9.36 f	9.82 ef	9.21 D	9.29 f	9.78 ef	10.42 ef	9.83 D
B 100	9.94 ef	10.27 de	10.33 de	10.18 C	10.62 de	10.67 de	10.73 de	10.67 C
Mo 50	10.40 de	11.45 c	12.64 ab	11.50 B	10.81 de	12.14 bc	13.02 ab	11.99 B
B 100 + Mo 50	10.97 cd	11.80 bc	13.28 a	12.02 A	11.77 cd	12.77 bc	13.98 a	12.84 A
Mean	9.94 C	10.72 B	11.51 A		10.62 C	11.34 B	12.04 A	

Values are the means of three replicates. Values followed by the same letters within a column for each genus are not significantly different at the 1% level of probability according to Duncan's multiple range test. N1= 30 kg nitrogen/fed., N2= 45 kg nitrogen/fed., N3= 60 kg nitrogen/fed., B 0 + Mo 0= control, B 100= 100 ppm of boron, Mo 50= 50 ppm of molybdenum and B 100 + Mo 50= 100 ppm of boron combined with 50 ppm of molybdenum.

Effect of nitrogen levels as well as B and Mo on yield and yield parameters

Data in Table (3) clearly show that all yield traits had gradual increment with increasing nitrogen level up to 60 kg/fed. in both growing seasons except number of days to maturity. With regard to the main effect of micronutrient treatments, Table (3) shows that all yield traits were statistically affected by the application of all micronutrient treatments except number of days to maturity. The significant highest values of curd fresh weight, curd diameter, curd dry matter and curd yield were observed in plants subjected to B and Mo together, followed by the plant that received Mo at 50 ppm alone. Nevertheless, the difference between these two treatments was not significant for curd diameter and curd dry matter in both growing seasons. Regarding to the interaction effect between nitrogen levels and micronutrient treatments, the results showed that cauliflower plants fertilized with 60 kg N/fed. and foliar sprayed with combined application of B and Mo at 100 and 50 ppm, respectively, had the significant highest curd fresh weight, curd diameter, curd dry matter and curd yield in comparison with other combinations; however, this combination had no effect on the number of days to maturity. The above-mentioned treatment enhanced curd yield by 73.06% and 74.27% in season of 2017/2018 and 2018/2019, respectively.

Table 3. Main effects of nitrogen levels, micronutrients treatments and their interactions on yield and yield components of cauliflower.

Treatments	2017/2018 season				2018/2019 season			
	N1	N2	N3	Mean	N1	N2	N3	Mean
				Curd fresh weight (g)				
B 0 + Mo 0	1128.92 h	1289.40 gh	1367.57 fg	1261.96 D	1246.92 h	1293.02 gh	1368.33 gh	1302.75 D
B 100	1402.91 fg	1488.78 ef	1508.14 ef	1466.61 C	1425.39 fg	1541.51 f	1587.01 ef	1517.97 C
Mo 50	1576.69 de	1683.81 cd	1859.86 ab	1706.79 B	1711.19 de	1804.15 cd	1974.12 ab	1829.82 B
B 100 + Mo 50	1625.08 de	1799.74 bc	1980.17 a	1801.66 A	1758.81 d	1929.03 bc	2099.11 a	1928.98A
Mean	1433.40 C	1565.43 B	1678.93 A		1535.57 C	1641.92 B	1757.14 A	
				Curd diameter (cm)				
B 0 + Mo 0	18.69 g	18.92 g	20.16 fg	19.26 C	19.26 g	19.45 g	20.57 fg	19.76 C
B 100	20.53 fg	22.01 ef	22.52 de	21.69 B	20.60 fg	22.07 ef	22.74 e	21.80 B
Mo 50	22.81 de	25.45 c	27.45 ab	25.24 A	23.70 de	25.49 cd	27.59 ab	25.59 A
B 100 + Mo 50	24.37 cd	26.21 bc	28.34 a	26.30 A	25.18 cd	26.45 bc	28.75 a	26.79 A
Mean	21.60 C	23.15 B	24.62 A		22.18 C	23.36 B	24.91 A	
				Curd dry matter (%)				
B 0 + Mo 0	14.24 k	14.51 jk	14.82 ij	14.52 C	15.03 j	15.32 ij	15.37 ij	15.24 C
B 100	15.10 hi	15.36 gh	15.67 fg	15.38 B	15.63 hi	15.95 gh	16.20 fg	15.93 B
Mo 50	15.97 ef	16.54 cd	17.12 ab	16.54 A	16.49 ef	17.09 cd	17.72 ab	17.10 A
B 100 + Mo 50	16.25 de	16.83 bc	17.35 a	16.81 A	16.80 de	17.41 bc	17.95 a	17.38 A
Mean	15.39 C	15.81 B	16.24 A		15.99 B	16.44 AB	16.81 A	
				Curds yield (tone/fed.)				
B 0 + Mo 0	13.14 f	13.31 f	13.43 f	13.29 D	13.16 f	13.84 f	14.21 ef	13.73 D
B 100	14.01 ef	14.63 ef	15.94 de	14.86 C	14.28 ef	15.05 ef	16.45 de	15.26 C
Mo 50	16.41 de	18.92 bc	21.04 ab	18.79 B	16.61 de	19.17 bc	21.53 ab	19.10 B
B 100 + Mo 50	17.75 cd	20.23 bc	22.74 a	20.24 A	18.48 cd	20.32 bc	22.93 a	20.58 A
Mean	15.33 C	16.77 B	18.29 A		15.63 C	17.09 B	18.78 A	
				Days to curd maturity				
B 0 + Mo 0	92.54 a	93.00 a	93.33 a	92.96 A	94.00 a	94.00 a	94.00 a	94.00 A
B 100	91.85 a	92.33 a	94.33 a	92.84 A	93.67 a	94.00 a	94.00 a	93.89 A
Mo 50	92.00 a	92.67 a	94.00 a	92.89 A	93.67 a	95.00 a	94.33 a	94.33 A
B 100 + Mo 50	92.10 a	92.33 a	93.33 a	92.59 A	93.33 a	94.00 a	94.00 a	93.78 A
Mean	92.12 A	92.58 A	93.75 A		93.67 A	94.25 A	94.08 A	

Values are the means of three replicates. Values followed by the same letters within a column for each genus are not significantly different at the 1% level of probability according to Duncan's multiple range test. N1= 30 kg nitrogen/fed., N2= 45 kg nitrogen/fed., N3= 60 kg nitrogen/fed., B 0 + Mo 0= control, B 100= 100 ppm of boron, Mo 50= 50 ppm of molybdenum and B 100 + Mo 50= 100 ppm of boron combined with 50 ppm of molybdenum.

Effect of nitrogen levels as well as B and Mo on quality parameters

Table (4) shows that all quality parameters were significantly increased by increasing the level of N in both seasons, except total phenols content. In this line, the highest level of nitrogen; 60 kg/fed. was more effective for enhancing all studied traits, except total phenols content than the other lower levels: 30 and 45 kg/fed. Table (4) also shows that the response of all cauliflower quality parameters was significantly affected by foliar application of both B and Mo either individually or together. The maximum content of ascorbic acid, carbohydrates, SSC and sulfur were recorded with foliar combined application of B at 100 ppm and Mo at 50 ppm, followed by application of B at 100 ppm only. However, the highest content of total phenols and nitrate content were recorded in cauliflower un-treated plants in both growing seasons. Concerning the interaction between N levels and foliar application of micronutrients, data given in Table (4) demonstrate that the high level of N (60 kg/fed.) in combination with the foliar application of B and Mo together at 100 ppm and 50 ppm, respectively, achieved the best records for all quality traits except total phenols and nitrate content.

Effect of nitrogen levels as well as B and Mo on chlorophyll content and mineral composition

Data regarding to the main effects of nitrogen level and micronutrient treatments as well as their interaction effect on chlorophyll content and mineral contents (N, P, K, B and Mo) in cauliflower leaves are presented in table (5). The results undoubtedly indicated that the content of chlorophyll and all minerals were significantly affected by nitrogen level and micronutrient application. All studied traits were increased with increasing the nitrogen level up to the highest level (60 kg/Fed.) in both seasons. Also, the content of chlorophyll and all measured minerals was strongly affected by the micronutrient application; whereas, the highest records of total chlorophyll, N, P, K, B and Mo were found in sprayed plants with 100 and 50 ppm of B and Mo together, respectively, in both growing seasons. Table (5) reveals that the interaction treatment between the high level of N (60 kg/fed.) combined with the foliar application of B and Mo (100 and 50 ppm, respectively) had a significant effect on total chlorophyll, N, P, K, B and Mo concentrations in both seasons.

Table 4. Main effects of nitrogen levels, micronutrients treatments and their interactions on bio-chemical compounds in curds of cauliflower.

Treatments	2017/2018 season				2018/2019 season			
	N1	N2	N3	Mean	N1	N2	N3	Mean
				Ascorbic acid (mg/100g F.W)				
B 0 + Mo 0	36.13 i	36.76 hi	37.59 gh	36.83 D	37.63 j	38.63 ij	39.16 hi	38.47 D
B 100	40.20 de	40.26 de	41.53 cd	40.66 B	41.90 ef	42.63 de	43.36 cd	42.63 B
Mo 50	38.10 gh	38.80 fg	39.63 ef	38.84 C	39.93 gh	40.43 gh	41.10 fg	40.48 C
B 100 + Mo 50	42.33 bc	43.20 ab	43.73 a	43.08 A	44.08 bc	44.83 ab	45.40 a	44.77 A
Mean	39.19 B	39.75 B	40.62 A		40.88 C	41.63 B	42.25 A	
				Carbohydrate (%)				
B 0 + Mo 0	13.54 h	13.72 gh	13.81 gh	13.69 D	13.84 i	14.02 hi	14.18 gh	14.01 D
B 100	14.43 de	14.56 cd	14.75 bc	14.58 B	14.75 de	14.84 cd	14.97 cd	14.85 B
Mo 50	13.96 fg	14.14 ef	14.27 de	14.12 C	14.23 gh	14.38 fg	14.54 ef	14.38 C
B 100 + Mo 50	14.86 bc	15.02 ab	15.32 a	15.07 A	15.15 bc	15.29 ab	15.46 a	15.30 A
Mean	14.20 B	14.36 AB	14.54 A		14.49 B	14.63 AB	14.78 A	
				Total phenols (mg/100g F.W)				
B 0 + Mo 0	397.00 a	391.33 ab	386.66 bc	391.66 A	376.66 a	370.33 ab	363.66 bc	370.22 A
B 100	362.33 ef	353.66 fg	351.33 gh	355.77 C	347.00 ef	342.33 fg	339.00 gh	342.77 C
Mo 50	382.33 bc	378.66 cd	372.00 de	377.66 B	358.33 cd	352.33 de	349.33 ef	353.33 B
B 100 + Mo 50	348.33 gh	341.66 hi	335.33 i	341.77 D	332.00 h	322.66 i	318.33 i	324.33 D
Mean	372.50 A	366.33 AB	361.33 B		353.50 A	346.91 B	342.58 B	
				SSC (%)				
B 0 + Mo 0	6.76 f	6.85 f	6.94 ef	6.85 D	6.78 i	6.86 hi	6.97 hi	6.87 D
B 100	7.29 cd	7.37 cd	7.46 bc	7.37 B	7.36 ef	7.43 de	7.58 cd	7.45 B
Mo 50	6.98 ef	7.12 de	7.19 de	7.10 C	7.06 gh	7.19 fg	7.28 ef	7.18 C
B 100 + Mo 50	7.51 bc	7.65 ab	7.77 a	7.64 A	7.64 bc	7.82 ab	7.92 a	7.79 A
Mean	7.14 C	7.24 B	7.34 A		7.21 C	7.32 B	7.44 A	
				NO_3-N (ppm)				
B 0 + Mo 0	134.20 bc	139.70 ab	143.33 a	139.07 A	136.63 bc	142.50 ab	144.13 a	141.08 A
B 100	118.06 ef	123.53 de	129.20 cd	123.60 B	128.16 d	131.50 cd	133.60 cd	131.08 B
Mo 50	103.80 hi	108.53 gh	113.13 fg	108.48 C	105.63 fg	109.46 ef	114.20 e	109.76 C
B 100 + Mo 50	89.26 j	94.80 ij	99.26 i	94.44 D	94.56 h	99.46 gh	103.40 fg	99.14 D
Mean	111.33 B	116.64 AB	121.23 A		116.25 B	120.73 AB	123.83 A	
				S (ppm)				
B 0 + Mo 0	0.076 i	0.088 hi	0.097 h	0.087 D	0.077 g	0.096 fg	0.109 f	0.094 D
B 100	0.142 e	0.153 de	0.164 cd	0.153 B	0.143 de	0.163 cd	0.172 c	0.159 B
Mo 50	0.104 gh	0.119 fg	0.134 ef	0.119 C	0.109 f	0.131 e	0.142 de	0.127 C
B 100 + Mo 50	0.176 bc	0.187 ab	0.197 a	0.187 A	0.177 bc	0.194 b	0.259 a	0.210 A
Mean	0.124 C	0.137 B	0.148 A		0.126 B	0.146 AB	0.171 A	

Values are the means of three replicates. Values followed by the same letters within a column for each genus are not significantly different at the 1% level of probability according to Duncan's multiple range test. N1= 30 kg nitrogen/fed., N2= 45 kg nitrogen/fed., N3= 60 kg nitrogen/fed., B 0 + Mo 0= control, B 100= 100 ppm of boron, Mo 50= 50 ppm of molybdenum and B 100 + Mo 50= 100 ppm of boron combined with 50 ppm of molybdenum.

Table 5. Main effects of nitrogen levels, micronutrients treatments and their interactions on total chlorophyll, macronutrients and micronutrients in leaves of cauliflower.

Treatments	2017/2018 season				2018/2019 season			
	N1	N2	N3	Mean	N1	N2	N3	Mean
				Total chlorophyll (mg/g F.W)				
B 0 + Mo 0	0.904 h	0.931 g	0.946 fg	0.927 D	0.948 j	0.971 ij	0.982 hi	0.967 D
B 100	1.024 d	1.047 c	1.060 c	1.044 B	1.052 de	1.069 cd	1.084 c	1.068 B
Mo 50	0.963 ef	0.983 e	1.007 d	0.984 C	1.001 gh	1.019 fg	1.035 ef	1.018 C
B 100 + Mo 50	1.088 b	1.107 ab	1.127 a	1.107 A	1.094 bc	1.118 ab	1.136 a	1.116 A
Mean	0.995 C	1.017 B	1.035 A		1.023 B	1.044 A	1.059 A	
				N (%)				
B 0 + Mo 0	0.85 j	0.90 j	0.98 ij	0.91 D	0.98 g	1.05 g	1.13 fg	1.05 D
B 100	1.27 ef	1.38 de	1.44 cd	1.36 B	1.46 d	1.51 cd	1.62 bc	1.53 B
Mo 50	1.04 hi	1.13 gh	1.21 fg	1.13 C	1.20 f	1.28 ef	1.36 de	1.28 C
B 100 + Mo 50	1.53 bc	1.62 ab	1.67 a	1.61 A	1.68 b	1.75 ab	1.84 a	1.76 A
Mean	1.17 B	1.26 AB	1.33 A		1.33 B	1.40 AB	1.49 A	
				P (%)				
B 0 + Mo 0	0.102 i	0.110 hi	0.122 gh	0.111 D	0.120 g	0.128 g	0.138 fg	0.129 D
B 100	0.153 de	0.159 cd	0.167 cd	0.160 B	0.176 cd	0.180 cd	0.192 bc	0.183 B
Mo 50	0.128 fg	0.135 fg	0.142 ef	0.135 C	0.148 ef	0.158 e	0.167 de	0.157 C
B 100 + Mo 50	0.171 bc	0.187 ab	0.192 a	0.183 A	0.200 b	0.208 ab	0.219 a	0.209 A
Mean	0.138 C	0.148 B	0.155 A		0.161 B	0.168 AB	0.179 A	
				K (%)				
B 0 + Mo 0	1.25 j	1.31 ij	1.40 hi	1.32 D	1.26 h	1.39 gh	1.41 gh	1.35 D
B 100	1.58 ef	1.65 de	1.72 cd	1.65 B	1.77 de	1.86 cd	1.93 cd	1.85 B
Mo 50	1.46 gh	1.48 gh	1.53 fg	1.49 C	1.51 fg	1.58 f	1.67 ef	1.58 C
B 100 + Mo 50	1.81 bc	1.88 ab	1.98 a	1.89 A	2.02 bc	2.10 ab	2.19 a	2.10 A
Mean	1.52 B	1.58 B	1.65 A		1.64 B	1.73 A	1.80 A	
				B (ppm)				
B 0 + Mo 0	33.70 h	34.80 gh	36.13 fg	34.87 C	35.56 i	36.86 hi	37.86 hi	36.76 C
B 100	40.53 cd	42.73 bc	44.80 ab	42.68 A	42.70 de	45.10 bc	47.36 ab	45.05 A
Mo 50	37.26 ef	38.16 ef	39.26 de	38.23 B	39.10 gh	40.23 fg	41.46 ef	40.26 B
B 100 + Mo 50	41.53 c	44.00 b	46.33 a	43.95 A	43.86 cd	46.20 b	48.73 a	46.26 A
Mean	38.25 C	39.92 B	41.63 A		40.30 C	42.10 B	43.85 A	
				Mo (ppm)				
B 0 + Mo 0	0.68 i	0.85 i	1.08 hi	0.87 C	0.88 h	1.04 gh	1.25 gh	1.06 C
B 100	1.36 gh	1.63 fg	1.90 ef	1.63 B	1.47 fg	1.74 ef	1.97 de	1.72 B
Mo 50	2.14 de	2.61 bc	3.05 ab	2.60 A	2.17 de	2.64 bc	3.09 ab	2.63 A
B 100 + Mo 50	2.40 cd	2.82 bc	3.31 a	2.84 A	2.41 cd	2.86 bc	3.39 a	2.88 A
Mean	1.64 B	1.98 B	2.33 A		1.73 C	2.07 B	2.42 A	

Values are the means of three replicates. Values followed by the same letters within a column for each genus are not significantly different at the 1% level of probability according to Duncan's multiple range test. N1= 30 kg nitrogen/fed., N2= 45 kg nitrogen/fed., N3= 60 kg nitrogen/fed., B 0 + Mo 0= control, B 100= 100 ppm of boron, Mo 50= 50 ppm of molybdenum and B 100 + Mo 50= 100 ppm of boron combined with 50 ppm of molybdenum.

Discussion

Cauliflower is one the vegetable crops that need nitrogen in optimum level, because inadequate dose of nitrogen may lead to a decay in curd formation and quality parameters (Bianco *et al*., 2015). Therefore, the current research was primarily performed out to study the effect of different levels of N (30, 45, and 60 kg/fed.) to determine the optimum level of N in newly reclaimed areas, especially New Valley governorate as a promising area for agricultural expansion in Egypt. The results of this research reported that all vegetative traits; plant height, number of leaves, leaf area, fresh weigh of leaves and dry matter of leaves gradually increased with the increasing level of N. Similarly, it has been previously reported that vegetative growth parameters of cauliflower were significantly influenced by different N fertilization (Farahzety and Siti Aishah, 2013). Also, our results show that all yield traits were increased linearly with increasing level of mineral N up to 60 kg/fed. except number of days to maturity. Similar results were obtained by previous reports, which declared that curd weight, diameter and dry matter were generally responsive to mineral N application (Farrag *et al*., 2000; Abdel-Razzak *et al*., 2008 a and b).

Moreover, our study clearly show that all quality parameters: vitamin C, carbohydrates, soluble solids content, nitrate and sulfur content were increased with increasing the inorganic N level with exception of total phenols. In this direction, Abdel-Razzak *et al*. (2008 b) reported that inorganic N has a great influence on cauliflower curd quality related traits.

Generally, this study clearly confirmed that nearly all vegetative growth, yield and quality traits showed significant differences due to N application in both growing seasons; whereas the highest level of N (60 kg/fed.) gave the maximum records of most of studied traits in the current study (Table 2, 3, and 4). This promotional effect of N in enhancing the growth, yield and quality of cauliflower might be explained by the fact that N is one of the most critical constitutes for all biochemical and physiological functions that are running during the cauliflower growth. For instance, N is an essential constitute in synthesis of chlorophyll, amino acids, protein, nucleic acids and hormones, which might rabidly enhance the synthesized carbohydrates that critical for more dry matter accumulation in plant organs (Russel, 1973; Leghari *et al*., 2016). In our study, nitrogen application had a positive effect on the total chlorophyll content (Table 5); whereas, the N fertilized plants with the highest level (60 kg/fed.) had recorded the highest total chlorophyll content (1.035 and 1.059 mg/g FW) and carbohydrates content (14.54 and 14.78 %) in the first and second seasons, respectively. In the same regard, Mitra *et al*. (1990) reported that chlorophyll content was increases by increasing N application from 56 to 224 kg/ha in broccoli. In addition, the observed nitrogen promotional effect in this study might be due to the role of N in improving the mineral content of macronutrients and micronutrients in leaves of cauliflower as shown in Table (5). Where, the highest content of macronutrients (N, P and K) and micronutrients (B and Mo) were recorded in leaves of treated plants with 60 kg/fed. Similarly, inorganic and organic N application have improved of cauliflower curds of macronutrients and micronutrients. Together, the positive effect of mineral N application on mineral contents of cauliflower appeared to enhance cauliflower growth by enhancing photosynthetic activities as well as minerals uptake and availability, which ultimately leads to more assimilation of carbohydrates and their translocation to the reproductive tissues, namely curds (Sharma *et al*., 2002).

Besides N, micronutrients application also play an important role in plant nutrition, particularly cauliflower. Therefore, another aim of current study was to find out necessity of micronutrient, B and Mo, in cauliflower cultivation. Generally, the results showed positive effects of using either B or Mo on cauliflower curds yield and quality characters compared with untreated plants. However, combined foliar application of 100 ppm of B and 50 ppm of Mo recorded the highest values of vegetative, yield and quality parameters. Similarly, several recent studies confirmed that application of B and Mo strongly affected the growth, yield and quality of cauliflower (Thapa *et al*., 2016; Hossain *et al*., 2018; Sarker *et al*., 2018, Hassan *et al*., 2018). Micronutrients deficiency often occur in plants grown in sandy soil and new reclaimed areas (Shaaban, 2010). However, plant crop species greatly vary in their demand to micronutrients. Cauliflower is sensitive to B and Mo and it often shows B and Mo deficiency. The promotional effects of B and Mo might be referred to their critical roles in synthesis and metabolism of carbohydrates as well as enhancing photosynthetic process, where Tables 4 and 5 show the combined application of B and Mo recorded the maximum values of carbohydrates content and total chlorophyll in the first (15.07% and 1.107 mg g/FW) and second seasons (15.30 % and 1.116 mg g/FW). In this regards, Lewis (1980) reported that B controls the metabolic reactions of carbohydrates by controlling several enzyme activities, such as α and β amylase. Also, Ahmed *et al*. (2014) stated a positive effect for external B addition on chlorophyll content in cotton plants.

Excessive nitrate is harmful for human health, particularly for children and patients nutrition (Makovic and Djurovka, 1990); therefore, it is considered an important characteristic to be monitored in agricultural products in response to nitrogen fertilization. As expected, the highest level of nitrate content was recorded in plant treated with inorganic N at 60 kg/fed. with a maximum of 121.23 and 123.83 ppm in the first and second seasons, respectively, which is still in the safe level for human consumption. The same result was indicated by Abdel-Razzak *et al*. (2008 b), who found that the content of nitrate in cauliflower head was increased by increasing N fertilization dose from 40 to 120 kg N/fed. Nevertheless, the application of B and Mo significantly decreased the nitrate content in cauliflower plants over the three levels of N (Table 4). The highest reduction in nitrate content was achieved by foliar spray of combined B and Mo, followed by Mo only. The reduction in nitrate content in this study might be explored by the role of Mo in controlling the activity of nitrate reductase that converts the nitrate to nitrite, which is the first step of the integration of nitrogen to proteins (Kaiser *et al*., 2005; Bambara and Ndakidemi, 2010). These results confirm the role of B and Mo in improving quality parameters in cauliflower curds through decreasing the nitrate content and increasing other quality parameters, such as vitamin C, carbohydrate and SSC.

Interestingly, neither nitrogen levels nor micronutrient application had altered the trait of number days to maturity (Table 2) over the two growing seasons. Contrary, Singh *et al*. (2017) reported that soil application of Borax (20 kg/ha) combined with Sodium molybdate (2 kg/ha) as sources of B and Mo, respectively, accelerated the early mature yield of cauliflower. However, insignificant effects of nitrogen, micronutrient application and their interaction on number of days to maturity might be due to its high heritability, whereas, it was reported that number of days to budding is a highly heritable trait (86 and 94%), which indicates that this trait is stable and not strongly affected by environmental factors (Yousef *et al*., 2015; Thorwarth *et al*., 2018).

Increasing the total phenolic is an advantage for human health, where those phytochemicals possess many biologically significant functions, such as protection against oxidative stress, and degenerative diseases (Forni *et al*., 2019). Another interesting finding of this research is the insignificant effect of N and micronutrients application on the phenolic compounds in cauliflower curds. In crux, both N and micronutrients treatments had negative effect on total phenols content in this study, which in contradiction to results of Abdel-Razzak *et al*. (2008 b), who reported that addition of different levels of inorganic N fertilizer caused gradual increase in phenolic content of cauliflower curds. However, the high concentration of total phenols in control plants compared with treated plants may indicate that these plants were subjected to nutrient deficiency, which leads to an increase in the activity of phenylalanine ammonialyase (PAL) , leading to a significant increase in total phenols in the stressed plants (Chishaki and Horiguchi, 1997; Liakopoulos and Karabourniotis, 2005).

CONCLUSION

From the current study, it was stated that for the better production value of cauliflower, the soil application of high nitrogen and foliar spray of B and Mo are necessarily needed and the results confirmed that application of N at 60 kg/fed. as well as foliar spray of B and Mo at 100 ppm and 50 ppm, respectively are optimum for effective yield in newly reclaimed area in the south-west part of Egypt. Briefly, the application of N at 60 kg/fed. combined foliar application of B and Mo at 100 ppm and 50 ppm, respectively, improved the growth and yield of cauliflower plants grown in sandy soils through enhancing the chlorophyll and carbohydrate content; while they increase the cauliflower quality through reducing the nitrate content.

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إستجابة نمو ومحصول وجودة القنبيط للتسميد النيتروجيني والرش الورقي بالعناصر الصغرى فى المناطق المستصلحة حديثاً

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تم إجراء تجربتين حقليتين فى المزرعة البحثية لكلية الزراعة جامعة الوادى الجديد بمحافظة الوادى الجديد لدراسة تأثير التسميد بمستويات مختلفة من النيتروجين (٣٠ ، ٤٥ و ٦٠ كجم/فدان) والرش الورقى بالعناصر الصغرى (٠ عناصر صغرى ، ١٠٠ جزء فى المليون بورن ، و ٥٠ جزء فى المليون موليبدنم ، و ١٠٠ جزء فى المليون بورن + ٥٠ جزء فى المليون موليبدنم) على صفات النمو الخضري والمحصول وجودة الأقراص الزهرية للقنبيط النامى فى الأراضى المستصلحة حديثا ً، خاصة فى محافظة الوادى الجديد كمنطقة واعدة فى زيادة التوسع الزراعي بمصر. أوضحت نتائج هذه الدراسة أن معظم الصفات أظهرت زيادة تدريجية بزيادة مستوى النيتروجين حيث أن إضافة النيتروجين بمعدل ٦٠ كجم/فدان أدى إلى زيادة معنوية فى صفات النمو الخضري والمحصول وجودة الأقراص الزهرية ، كما أدى إلى نقص فى محتوى الفينولات الكلية ولم يكن لها تأثير على صفة عدد الأيام حتى النضج. كما أوضحت نتائج هذه الدراسة أن الرش الورقي بالبورن أو الموليبدنم أدى إلى تحسين نمو ومحصول وجودة الأقراص الزهرية للقنبيط مقارنة بالنباتات غير المعاملة ، لكن كانت نتائج إضافة البورن والموليبدنم معاً أفضل من إضافة البورن أو الموليبدنم بصورة منفردة. هذا بالإضافة إلى أن التسميد النيتروجيني بمعدل ٦٠ كجم/للفدان كان أفضل فى حالة وجود البورن (١٠٠ جزء فى المليون) والموليبدنم (٥٠ جزء فى المليون) معاً من باقى المعاملات محققاً أعلى محصول من الأقراص الزهرية بأعلى صفات جودة.