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Nitrogen Fertilization and Foliar Application with Mn and Cu in Green Pea (*Pisum sativum* L.) Using ^{15}N Stable Isotope

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ABSTRACT

Pea crop grown on sandy soil under field conditions was fertigated by three rates of nitrogen i.e. 138.1, 172.6 and 207.1 kg N ha^{-1} and treated with four treatments of foliar applied Cu and Mn includes control. The results revealed that all experimental treatments significantly enhanced the crop yield and growth attributes (pods fresh weight, pods dry weight, seeds dry yield, pods cover dry weight and shell out). Similarly, it improves the chemical composition like protein content in dry seeds, content and uptake of N, Mn and Cu. These effects were more pronounced especially at higher N rate (N_3, 207.1 kg N ha^{-1}) except shell out % where the highest value was detected at N_1 (172.6 kg N ha^{-1}). In the same time, spraying with Mn has a significant effect on pea plants for example dry matter yield of pea seeds recorded 2.77 Mg ha^{-1} higher than the untreated control. Similarly, either N or Mn and Cu uptake were enhanced by foliar application of Mn as a micronutrient source comparable to the untreated control. In this respect, Mn plus Cu induced the best values of pea growth and yield and nutrients uptake comparing to individual treatments. Application of isotope dilution technique showed that the portion of N gained by seeds of pea crop from chemical N fertilizer and NUE were higher under N_3S_3 (207.1 kg N ha^{-1}, 240 g Mn ha^{-1} and 240 g Cu ha^{-1}) treatment than other treatments.

Keywords: Nitrogen; Mn; Cu; ^{15}N isotope; N-efficiency; Pea; Sandy soil

INTRODUCTION

Green pea (*Pisum sativum* L.) is one of the important vegetable crops in Egypt. It has high contents of protein (278 gkg^{-1}), carbohydrates (427 gkg^{-1}) and antioxidants (Urbano *et al.*, 2003). Nitrogen (N) an essential macronutrient taken up by plants at a relatively high amounts compared with other nutrients (Marschner, 1995). It is required for the vegetative growth of plants and needed for synthesis of starch and amino acids. Micronutrients are essential for vegetables to get maximum yield with high quality. There are seven micronutrients among them Mn and Cu are essential for many plants metabolic processes (Brady and Weil, 2002).

Mn is involved in plant metabolic processes such as photosynthesis, respiration, hormone activation and amino acid synthesis (Inani *et al.*, 2015 and Lidon *et al.* 2004). It plays an important role in redox processes, such as electron transport in photosynthesis and detoxification of oxygen-free radicals (Romheld, and Marschner, 1991). It is important for some enzyme reactions including phenylalanine ammonia- lyase (PAL), enzymes of the tricarboxylic acid cycle and the chloroplast RNA polymerase (Marschner, 1995). Its application showed an increase in photosynthetic activity, plant growth, and yield (Lidon and Teixeira and 2000 and Sultana *et al.*, 2001).

Cu is an essential micronutrient involved in many physiological and biochemical reactions in growth and development in plants (Yuan *et al.*, 2016). It functions in regulating plant growth and development, including chlorophyll formation and seed production (Viera *et al.* 2019). Also, involved in electron transport, cell wall metabolism and oxidative stress protection (Yruela, 2009); and important in absorption of water and nutrients (Mahler, 2015). It is required for pollen and seeds (Havlin *et al.*, 2015). It acts as a structural element and participates in oxidative stress response, and hormone signaling (Raven *et al.*, 1999). Plants were positively responded to foliar application of many nutrients (Pandev *et al.*, 2016). In this respect, foliar application of Mn and Cu found to be more practical than application through the soil (Sarkar *et al.*, 2007 and Wissuwa *et al.*, 2008).

In addition to the abovementioned knowledge, and excellent review written by Farooq et al., (2012) indexed that copper (Cu) is involved in carbon assimilation and nitrogen metabolism; its deficiency results in severe growth retardation. Cu is also involved in lignin biosynthesis, which not only provides strength to cell walls but also prevents wilting (Taiz and Zeiger, 2010).

Therefore, the present study aimed to evaluate and select the proper management of nitrogen fertilizer either individually or in association with Cu and Mn representing micronutrient that classified as an important and beneficial for growing the green pea on low fertile sandy soil. Interaction between N, Cu and Mn and its effects on growth attributes, yield and nutrient composition were also taken into consideration.

MATERIALS AND METHODS

A field experiment was conducted on pea (*Pisum sativum* L. cv. Master-B) at the experimental farm of Nuclear Research Center, Atomic Energy Authority, Abou-Zaable, Egypt during the 2020/2021 winter season under drip irrigation system on a sandy soil (Table 1), following a randomized complete block design in two factors with three replicates. Factor N: Nitrogen fertilizer was applied at three levels, i.e. 138.1 kg N

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ha^{-1} (N_1); 172.6 kg N ha^{-1} (N_2) and 207.1 kg N ha^{-1} (N_3) in labeled urea form (46% N) enriched with 2% ^{15}N atom excess. Factor S: Representatives of micronutrients, Cu and Mn were sprayed on plant foliage in four treatments: untreated control (S_0); 240 g Mn ha^{-1} (S_1); 240 g Cu ha^{-1} (S_2) and 240 g Mn ha^{-1} + 240 g Cu ha^{-1} (S_3). Copper and manganese were sprayed in sulfate form. All plots received the recommended rates of 24 kg P as Ca-superphosphate (68 g P kg^{-1} fertilizer) during soil preparations while 80 kg K ha^{-1} as potassium sulfate was splitted into two equal doses; applied after 4 and 7 weeks from sowing according to Ministry of Agriculture and Land Reclamation. Basically, chelates of Fe and Zn were sprayed at 1200 L ha^{-1}. Before sowing, seeds of pea were coated with Rhizobium Spp. as biofertilizers mounted on peat-moth carrier and marketed as commercial fertilizers by the Agriculture Research Center, Giza, Egypt. A saccharide solution was used as sticking material for sticking the inoculant on the seeds surface three hours before seeding. In each plot (10 m^2), a 2 m^2 micro-plot was allocated for applying ^{15}N urea with 2% ^{15}N atom excess to get samples for $^{14}N/^{15}N$ ratio analysis. The duration of experiment started at December, 27th, 2020 and plants were harvested at March, 29th, 2021 (growth lasted 93 days).

Table 1. physical and chemical properties of the experimental soil

Physical properties			Chemical properties					
% Sand	% Silt	% Clay	pH (1:2.5)	EC (dS m^{-1})	OM (g kg^{-1})	Total N (g kg^{-1})	Total Mn (g kg^{-1})	Total Cu (g kg^{-1})
95.9	4.0	0.1	7.14	0.23	0.34	0.42	0.013	0.021

Before cultivation, soil samples were taken and analyzed according to methods cited by Carter and Gregorich (2008). At harvest 93-day after sowing, plants were harvested, and samples were taken, oven dried at 70ºC and digested using sulfuric acid (H_2SO_4) and hydrogen peroxide solution then analyzed according to Estefan *et al.* (2013). Nitrogen was determined using Kjeldahl apparatus Model Behr S1, while Mn and Cu were determined using atomic absorption Model Buck 210.

$^{14}N/^{15}N$ ratio analysis:

Plant samples were taken and subjected to ^{15}N analysis using emission spectrometer model Fischer NOI-6PC. Estimation of portions of nitrogen derived from fertilizer (%Ndff), ^{15}N uptake (kg ha^{-1}) and ^{15}N recovery were carried out according to standard equations of IAEA (2008), Bruulsema *et al.* (2004) and Hirel *et al.* (2011). The standard equation used are as following:

$$\%Ndff = \frac{15N_{a.e.}\,in\ sample}{15N_{a.e.}\,in\ fertilizer} \times 100 \quad \textbf{......... (1)}$$

$$\mathrm{Ndff\,(g\,kg^{-1}) = \%\,Ndff \times Total\ N\ content\,(g\,kg^{-1})} \quad \textbf{..... (2)}$$

$$\%\mathrm{Ndfs} = 100 - \%\mathrm{Ndff} \quad \textbf{.................. (3)}$$

$$Nydff\,(kg\,ha^{-1}) = \%Ndff \times N\ uptake\,(kg\,ha^{-1}) \quad \textbf{.......... (4)}$$

$$\%FNR = \frac{Ndff\ (kg\ ha^{-1})}{Rate\ of\ applied\ N\ (kg\ ha^{-1})} \times 100 \quad \textbf{......... (5)}$$

$$NUE\ (kg\ seed\ yield\ per\ kg\ N\ applied) = \frac{Seed\ yield\ (kg\ ha^{-1})}{Rate\ of\ applied\ N\ (kg\ ha^{-1})} \quad \textbf{..... (6)}$$

Where: Ndff, Nitrogen derived from fertilizer; Ndfs, Nitrogen derived from soil; Nydff, Nitrogen yield derived from fertilizer; FNR, Fertilizer nitrogen recovery and NUE, Nitrogen use efficiency.

Shell out % of dry pods was calculated using the following equation (Abdel-Aziz and Ismail, 2016):

$$\text{Shell out (\%)} = \frac{\text{Weight of dry seeds}}{\text{Weight of dry pods}} \times 100 \quad \textbf{......... (7)}$$

Statistical analysis:

All experimental data were subjected to ANOVA analysis to estimate the least significant differences (LSD) at $p \leq 0.05$ to compere the variation between treatments using MSTAT-C program software version 1.42 (Fisher, 1960).

Results and discussion:

Yield and its attributes:

Pods fresh and dry weight:

As presented in Table 2, application of high N rate (N_3, 207.1 kg N ha^{-1}) combined with S_2 (240 g Cu ha^{-1}) resulted in the highest pod (containing seeds) fresh and dry weights accounting for 9.54 Mg ha^{-1} and 4.90 Mg ha^{-1}, respectively. On the other hand, the lowest pod (containing seeds) fresh and dry weight accounted for 1.46 and 0.79 Mg ha^{-1}, respectively were induced by the lowest N rate (138.1 kg N ha^{-1}) combined with 240 g Cu ha^{-1} (N_1S_2). These results indicated that increasing N fertilizer rates interacted with foliar spray of both Mn and Cu led to increase pods fresh and dry yield. Impact of N fertilization rates on pods fresh weight followed the next pattern, $N_3>N_2>N_1$ and reflected a relative increase by about 73.9 and 271.2% over N1 for N_2 and N_3, respectively, while the relative increases in pods dry weight accounted for 70.8 and 167.3% over N_1 for the same sequence. This pattern indicated that the most positive effect was due to high N rate followed by the medium one. Similarly, the comparison held between application treatments of Mn and Cu indicated that both nutrients has the pattern of $S_2>S_3>S_2>S_0$ concerning the pods fresh weight. In the same time, there were no significant differences between S_2 and S_3 and between S_0 and S_1. Contrary, there was a significant difference between S_3 or S_2 and S_0 or S_1. The main effect of Cu and Mn on pods dry weight the pattern of S3>S2>S1>S0 indicating that foliar application of combined Mn and Cu contributed in increasing pods dry matter yield.

Pods cover dry weight:

Dry weight of pods cover was differentially affected by interaction between nitrogen added rates and micronutrient applied treatments (Table 2). In this regard, the lowest pods cover dry matter yield was estimated under N_1S_0, while the highest pods cover dry matter yield was resulted from N_3S_2 application treatment. This treatment achieved a relative increase by about 478.9% over N_1S_0. Increasing N fertilization with or without Mn and Cu foliar application gave a significant increasing in pods cover dry matter yield. N fertilization main effect gave a pattern of $N_3>N_2>N_1$ with an increase about 79.3 and more than two folds over N_1 due to N_2 and N_3, respectively, while Mn and Cu main effect gave a pattern of S3>S2>S1>S0 recording a relative increase averaging 20.6, 28.4, 32.4% over S_0 due to S_1, S_2 and S_3, respectively.

Seeds dry yield:

Under all N fertilization rates, seeds dry yield was increased by spraying Mn and Cu either individually or in combination. Similarly, seeds dry yield was increased by increasing N fertilization rate under all foliar application treatments. The lowest seeds dry yield was accounted for 0.41 Mg ha^{-1} induced by N_1S_0. The highest yield of pea dry seeds was 2.77 Mg ha^{-1} given by the treatment received high rate of N fertilization and foliar application of combined Mn and Cu. There was a significant relative increase caused by the highest N rate accounted for 145.1% over N_1S_0. N fertilization main effect gave a pattern of $N_3>N_2>N_1$ with a relative increase by about 67.3 and 73.1% over N_1 due to N_2 and N_3, respectively, while the main effect of Mn and Cu gave a pattern of S_3>S_2>S_1>S_0 which reflected a relative increases averaging 24.5, 39.9, 50.3% over S_0 due to S_1, S_2 and S_3, respectively.

Shell out:

Shell out pea are the pea you grow for seeds. The results of shell out in dry seeds ranged from 51.64 to 69.64% by N_1S_0 and N_1S_3, respectively. Under conditions of 138.1 kg N ha^{-1} the shell out of dry pods percentage was in significant increase with a combined with Cu and Mn spraying. Shell out was decreased by increasing the rate of nitrogen fertilizer and this is due to seeds dry yield.

Protein content in dry seeds:

The protein content in seeds depends on their nitrogen content. The lowest protein content in seeds was achieved by N_1S_3 treatments recording 9.40%. The highest protein content in dry seeds was 13.43% given by N_2S_3 with an increase about 42.9% over N_1S_0 compared with the lowest protein content in dry seeds. N fertilization main effect gave a pattern of N3>N2>N1 with a significant increase due to N1 and N3 compared with low N rate. MN main effect gave a pattern of S_3>S_0>S_1>S_2 with no significant differences between all MN treatments.

Gooding and Davies (1992) and El-Azab (2016) showed that the spraying with macronutrients beside micronutrients decrease the losses of nitrogen by any means compared to the nitrogen applied in soil. Spraying of NPK with micronutrients increased the concentration and the uptake from phosphorus that increased the absorption of phosphorus compared with the phosphorus in the soil which become fixed in soil and unavailable to plant (Srivastava and Gupta, 1996 and El-Azab, 2016). Our results were disagree (specially under Egyptians sandy soil conditions) with Gul *et al.* (2006) Who found that to get the better plant growth and higher fresh pod yield, 80 kg N ha^{-1} in two split applications, 25% at sowing and 75% at flowering is recommended for agro-climatic conditions of Dera Ismail Khan.

Table 2. Yield and growth traits of pea crop fertigated with different N rates and sprayed Cu and Mn treatments.

Treatment		Pods fresh weight (Mg ha^{-1})	Pods dry weight (Mg ha^{-1})	Seeds dry yield (Mg ha^{-1})	Pods cover dry weight (Mg ha^{-1})	Shell out (%)	Protein content in dry seeds (%)
				Nitrogen fertilization rates (kg N ha^{-1})			
N_1		2.26	1.71	1.13	0.58	63.85	10.32
N_2		3.93	2.92	1.89	1.04	64.70	11.43
N_3		8.39	4.57	2.50	2.07	54.66	11.95
LSD 0.05		0.39	0.06	0.03	0.05	0.058	0.79
				Mn and Cu (g ha-^{1})			
S_0		4.23	2.45	1.43	1.02	57.76	11.31
S_1		4.57	3.01	1.78	1.23	61.16	10.80
S_2		5.40	3.30	2.00	1.31	62.33	11.28
S_3		5.24	3.50	2.15	1.35	63.03	11.55
LSD 0.05		0.45	0.07	0.03	0.05	0.68	ns
				Combined treatments			
N_1	S_0	1.46	0.79	0.41	0.38	51.64	9.94
	S_1	2.27	1.83	1.22	0.60	66.93	11.46
	S_2	2.39	1.94	1.31	0.64	67.21	10.47
	S_3	2.94	2.27	1.58	0.69	69.64	9.40
N_2	S_0	3.14	2.45	1.66	0.79	67.65	11.64
	S_1	3.97	2.85	1.81	1.04	63.56	10.20
	S_2	4.28	3.06	1.98	1.08	64.65	10.47
	S_3	4.34	3.33	2.10	1.24	62.94	13.43
N_3	S_0	8.09	4.12	2.22	1.89	53.99	12.35
	S_1	7.49	4.37	2.32	2.05	52.99	10.74
	S_2	9.54	4.90	2.70	2.20	55.14	12.89
	S_3	8.43	4.90	2.77	2.13	56.51	11.81
LSD 0.05		0.79	0.12	0.05	0.09	1.17	1.59

Notes: N_1, 138.1; N_2, 172.6; N_3, 207.1 kg ha^{-1} and S_0, 0 Cu or Mn; S_1, 240 g ha^{-1} Cu, S_2, 240 g ha^{-1} Mn; S_3, 240 g ha^{-1} of each of Cu plus Mn

Concentration and uptake of N, Mn and Cu in pea dry seeds:

N content and uptake in pea dry seeds:

N content in pea dry seeds agree with protein content in main effects of each factor and interaction effect between N fertilization and MN spraying (Table 3). Nitrogen uptake is the product of nitrogen content in pea dry seeds × seeds dry yield. The highest N uptake in pea dry seeds was 55.74 kg ha^{-1} obtained by N_3S_2 with no significant increases between the second high N uptakes in pea dry seeds which obtained by N_3S_3. This means that at the highest rate of nitrogen fertilization, a negative interaction occurs between manganese and copper, which leads to a decrease in nitrogen absorption. It was found that at the medium and lowest rates of nitrogen fertilization, nitrogen uptake increases by the interaction between manganese and copper in the spray solution.

Content and uptake of Mn and Cu in pea dry seeds:

The highest Mn uptake and Mn content in pea dry seeds were 1.779 g kg^{-1} and 4.920 kg ha^{-1}, respectively obtained by N_3S_3. The lowest Mn content and Mn uptake in pea dry seeds were 0.755 g kg^{-1} and 0.308 kg ha^{-1}, respectively given by N_1S_0 with a decrease of 57.6 and 93.7% due to Mn content and Mn uptake. The highest Cu uptake and Cu content in pea dry seeds were 0.092 g kg^{-1} and 0.254 kg ha^{-1}, respectively obtained by N_3S_3. The lowest Cu content and Cu uptake in pea dry seeds were 0.021 g kg^{-1} and 0.009 kg ha^{-1}, respectively given by N_1S_0 with a decrease of 77.2 and 96.5% due to Cu content and Cu uptake. N fertilization main effect was agree in cases of Mn content, Mn uptake, Cu content and Cu uptake and gave a pattern of N_3>N_2>N_1. MN main effect was also agree in cases of Mn content, Cu content and Cu uptake and gave a pattern of $S_3>S_2>S_1>S_0$ but disagree in case of Mn uptake and gave a pattern of $S_2>S_3>S_1>S_0$.

Spraying micronutrients (single nutrient or mixed) increased plant growth. It can be explained that foliar feeding is a rabid technique in correcting the nutritional disorders through applying such nutrients directly to the location of demand in which quickly absorption will be happened (Romheld and El-Fouly, 1999). Foliar feeding with mixed micronutrients (Fe+ Zn+ Mn) was better than foliar feeding with individual element for counteracting the hazard effect of salinity and improving nutrients uptake. Also, it is better to judging the nutritional status of the plants through calculating the nutrients uptake than depending on nutrients concentration (El-Fouly and Abou El-Nour, 2021). Additional Nitrogen application to pea plants during growth and development of crop can improve their nutrient balance, which may in tern lead to an increase in growth and yield (Pandey *et al.,* 2017).

Table 3. Nitrogen, copper and manganese content and uptake by seeds of pea crop fertigated with different N rates and sprayed Cu and Mn treatments.

Treatment		N content (g kg^{-1})	N uptake (kg ha^{-1})	Mn content (g kg^{-1})	Mn uptake (kg ha^{-1})	Cu content (g kg^{-1})	Cu uptake (kg ha^{-1})
Nitrogen fertilization rates (kg N ha^{-1})							
N_1		16.5	18.61	0.890	1.050	0.030	0.030
N_2		18.29	34.64	1.280	2.460	0.060	0.120
N_3		19.12	47.94	1.680	4.220	0.080	0.210
LSD $_{0.05}$		1.27	1.75	0.065	0.114	0.008	0.008
Mn and Cu (g ha-^{1})							
S_0		18.09	27.08	1.110	1.830	0.049	0.090
S_1		17.28	30.55	1.200	2.290	0.058	0.110
S_2		18.04	36.91	1.360	3.290	0.059	0.130
S_3		18.47	40.38	1.470	2.910	0.066	0.150
LSD $_{0.05}$		Ns	2.02	0.076	0.131	0.009	0.009
Combined treatments							
N_1	S_0	15.90	6.48	0.755	0.308	0.021	0.009
	S_1	18.33	22.30	0.851	1.040	0.031	0.038
	S_2	16.76	21.87	0.868	1.132	0.029	0.038
	S_3	15.04	23.78	1.100	1.737	0.030	0.047
N_2	S_0	18.62	30.81	1.008	1.670	0.050	0.083
	S_1	16.33	29.55	1.110	2.010	0.060	0.109
	S_2	16.76	33.14	1.491	2.945	0.065	0.129
	S_3	21.48	45.07	1.525	3.198	0.076	0.160
N_3	S_0	19.76	43.94	1.574	3.499	0.078	0.172
	S_1	17.19	39.79	1.651	3.824	0.083	0.191
	S_2	20.62	55.74	1.721	4.652	0.085	0.230
	S_3	18.90	52.30	1.779	4.920	0.092	0.254
LSD $_{0.05}$		2.54	3.50	0.131	0.227	0.017	0.017

For details, see note of Table 2

Efficient use of nitrogen using ^{15}N labeled fertilizer:

The impact of nitrogen fertilization rates combined with manganese and copper foliar application on portion of nitrogen derived from fertilizer (Ndff), soil (Ndfs), nitrogen yield derived from fertilizer (Nydff), nitrogen recovery and nitrogen use efficiency (NUE) were presented in Table 4.

Table 4. Effect of nitrogen fertilization and micronutrients spraying on different portions of N derived to plants and efficient use of nitrogen using ^{15}N tracer technique.

Treatment		Ndff (%)	Ndff (g kg^{-1})	Ndfs (%)	Nydff (kg ha^{-1})	N Recovery (%)	NUE (kg kg^{-1})
Nitrogen fertilization rates (kg N ha^{-1})							
N_1		26.84	4.41	73.16	5.10	2.79	8.18
N_2		36.66	6.75	63.34	12.89	7.47	10.93
N_3		45.73	8.74	54.28	21.98	10.61	12.08
Mn and Cu (g ha-^{1})							
S_0		33.57	6.19	66.43	10.26	5.31	7.77
S_1		35.27	6.06	64.73	11.36	5.94	10.17
S_2		36.70	6.75	63.30	14.69	7.61	11.32
S_3		40.10	7.53	59.90	16.97	8.96	12.32
Combined treatments							
N_1	S_0	24.6	3.91	75.4	1.59	0.87	2.95
	S_1	25.15	4.61	74.85	5.61	3.06	8.85
	S_2	26.05	4.36	73.95	5.70	3.11	9.45
	S_3	31.55	4.74	68.45	7.50	4.10	11.45
N_2	S_0	32.35	6.02	67.65	9.97	5.77	9.61
	S_1	35.25	5.75	64.75	10.42	6.04	10.49
	S_2	37.45	6.27	62.55	12.41	7.19	11.46
	S_3	41.6	8.94	58.4	18.75	10.86	12.15
N_3	S_0	43.75	8.65	56.25	19.23	9.28	10.74
	S_1	45.4	7.80	54.6	18.07	8.72	11.18
	S_2	46.6	9.61	53.4	25.97	12.54	13.05
	S_3	47.15	8.91	52.85	24.66	11.91	13.36

For details, see note of Table 2. Values are averages and no statistical analysis was done

Nitrogen fertilizer applied individually resulted in an increase in Ndff, Ndfs, Nydff, N recovery and NUE. In case of interaction between nitrogen and spraying with manganese and copper, it was found that the increasing rate of nitrogen fertilizer, whether with or without spraying with manganese or/and copper, leads to an increase in nitrogen uptake, whether from fertilizer or soil, and an increase in nitrogen recovery using the ^{15}N isotope technique. Spraying with individual manganese and copper showed that both of them led to an increase in Ndff, Ndfs, Nydff, N recovery and NUE. Similar trend was noticed in case of increasing nitrogen rates. As for the efficiency of nitrogen fertilizer, it was calculated without using ^{15}N technique. Fertilizer N use efficiency is one of the parameters which measures the efficiency of using the fertilizer in terms of crop production. It is determined according to the equation No. 6 expressing the efficiency as the amount of excess yield (kg ha^{-1}) obtained because of application of the rate of fertilizer N (kg ha^{-1}) (Dobermann, 2007), and expressed as kilograms of grains per kg applied N. It was also found that the efficiency of nitrogen fertilizer took the same direction as in the rest of the measurements that were calculated using ^{15}N.

The direct method on ^{15}N add is the most adequate to determine the recovery efficiency of N derived from fertilizer (Araújo *et al.,* 2019 and Hekal *et al.,* 2021). The capture of N by crop cover was generally higher with the mineral fertilizer than with the manure, which has been reported in other studies (Li *et al.*, 2015; Thilakarathna *et al.,* 2015). This could be explained by higher N losses through ammonia volatilization following manure application than with the mineral fertilizer used (Chantigny *et al.*, 2007 and Langelier *et al.*, 2021).

CONCLUSION

Nitrogen fertilization combined with Mn and Cu significantly increased pea yield and its attributes (Pods fresh weight, pods dry weight, seeds dry yield, pods cover dry weight and shell out) as well as chemical composition (protein content in dry seed, nitrogen, manganese and copper content and uptake). Interaction effect between nitrogen fertilization and Cu and Mn as representatives of microelement showed a promotive effect on all studied attributes. Additionally, the highest N rate resulted in the highest values of all studied parameters.

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التسميد النيتروجينى والرش الورقي بالمنجنيز والنحاس فى نبات البازلاء الخضراء باستخدام النظير الثابت للنيتروجين ن15

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الملخص

تم تسميد محصول البازلاء المنزرع في تربة رملية تحت ظروف الحقل بثلاثة مستويات من التسميد النيتروجينى وهى 138.1، 172.6 و 207.1 كجم نيتروجين/هكتار وتم الرش الورقى بأربعة معاملات من النحاس والمنجنيز بالإضافة إلى معاملة المقارنة. أوضحت النتائج أن جميع المعاملات التجريبية عززت معنوياً إنتاجية المحصول وصفات النمو (الوزن الرطب للقرون، الوزن الجاف للقرون، محصول البذور الجافة، الوزن الجاف لقشرة القرون ونسبة البذور للقرون). وبالمثل، فإنه تم تحسين التركيب الكيميائي مثل محتوى البروتين في البذور الجافة ومحتوى وإمتصاص النيتروجين والمنجنيز والنحاس. كانت هذه التأثيرات أكثر وضوحًا خاصة عند أعلى معدل نيتروجين (207.1كجم/هكتار) باستثناء النسبة المؤية للبذور فى القرون كانت أعلى قيمة عند 172.6 كجم/هكتار. في نفس الوقت، كان للرش بالمنجنيز تأثير معنوي على نباتات البازلاء على سبيل المثال، سجل إنتاج المادة الجافة لبذور البازلاء 2.77 ميجاجرام/هكتار. وبالمثل، تم تحسين إمتصاص كل من النيتروجين والمنجنيز والنحاس بواسطة الرش الورقى بالمنجنيز كمغذى دقيق. في هذا الصدد، أعطى الرش بالمنجنيز+ النحاس أفضل قيم لنمو البازلاء والمحصول وامتصاص العناصر الغذائية مقارنة بالمعاملات الفردية. أظهر تطبيق تقنية التخفيف النظائرى أن نسبة النيتروجين الممتصة بواسطة بذور البازلاء من السماد النيتروجينى أيضاً كفاءة استخدام السماد كانوا أعلى عند المعاملة N_3S_3 (207.1كجم نيتروجين/هكتار، 240جم منجنيز/هكتار +240 جم نحاس/هكتار) عن المعاملات الأخرى.

الكلمات المفتاحية: النيتروجين، المنجنيز، النحاس، النظير الثابت للنيتروجين، كفاءة النيتروجين، البازلاء، التربة الرملية