Turkish Journal of Agricultural and Natural Sciences
Special Issue: 1, 2014

TÜRK
TARIM ve DOĞA BİLİMLERİ
DERGİSİ

TURKISH
JOURNAL of AGRICULTURAL
and NATURAL SCIENCES

www.turkjans.com

Effect of Foliar Fertilization on Nodulation and Grain Yield of Pea (*Pisum sativum* L.)

Gencho MILEV
Dobrudzha Agricultural Institute (DAI) – General Toshevo, 9520 Bulgaria
Corresponding author: milev2013@abv.bg

Abstract

During 2011 – 2013, a field experiment with pea (*Pisum sativum L.*) was carried out in the trial field of Dobrudzha Agricultural Institute. The aim was to find out what is the effect of foliar fertilization with liquid fertilizers on the nodulation ability and the grain yield from a new fodder pea variety. The soil in the trial field was slightly leached chernozem (*Luvic phaeozem*) with very good agro physical and agro chemical properties. The experiment was designed according to the block method in four replications. The variants were the following: 1) check; 2) treatment with liquid fertilizer Bo-La containing boron and molybdenum; 3) treatment with liquid fertilizer Potassium thiosulfate (PTS) containing potassium and sulfur; 4) treatment with liquid fertilizer High-Phos containing phosphorus, potassium and magnesium. Based on the obtained results it was found out that the parameters of nodulation (number, dry weight and life cycle) improved significantly. The value of the changes depending on the applied foliar fertilizers was highest for the index number of nodules per plant – up to 17.1 %, followed by the indices life cycle of the nodules – up to 15.9 %, and dry weight of the nodules – up to 15.8 %. The Mo-B-containing fertilizer Bo – La had highest significance of the effect. The other two fertilizers had lower and almost equal significance. The positive effect of the tested fertilizers was expressed in a similar way on grain yield, too. The increase of grain yield was highest after foliar treatment with B0-La – 11 %, followed by High-Phos – 8 %, and PTS – 5 %.

Key words: peas, nodulation, nodulation indices, grain yield

Introduction

Fodder pea is a valuable crop in the field rotations due to the fact that it fixates symbiotically with the nodule bacteria considerable amounts of atmospheric nitrogen. According to the researches of a number of authors, this amount may reach 80-100 kg ha^{-1} (Posapanov and Kniazeva 1975). The fixation of this nitrogen depends on multiple factors, the most important of which are: availability of specific and virulent strains of nodule bacteria on pea, condition and type of soil (pH reaction, moisture, nutrition regime), level of the agronomy practices used for growing of the crop (Donchenco 1991; Vlasova and Gorbacheva, 2011). Fertilization, soil tillage, control of pests on the nodules of the plant, weeds, etc, are important factors which affect the formation of efficient symbiotic apparatus (Browning and George, 1981; Gurjev, 2014; Tricot et al. 1997). The genetic potential for fixation of atmospheric nitrogen often varies considerably within a set of cultivars (Kevin, 1992). Some chemical elements such as molybdenum, boron, sulfur, phosphorus, potassium, etc., have significant effect on the process of fixation of atmospheric nitrogen (Popov et al., 1994; Vasileva et al., 2007). Their effect is related to the normal growth and development of both the macro and the micro symbiotes. The enzyme complex nitrogenase is directly responsible for the fixation of atmospheric nitrogen, and the availability of these elements in the flow of photo assimilates is crucial.

Under certain unfavorable conditions for soil nutrition of plants, the foliar treatment with fertilizers containing the above chemical elements is a very useful agronomy practice. These fertilizers help to overcome the specific occurrence of stress and as a result the nutrition of the plants and the indices of nodulation are restored to normal.

In relation to the above notes, a field experiment was carried out in the trial field of DAI with the aim of determining the effect of the foliar treatment with selected liquid fertilizers on the nodulation ability and the grain yield from a new released fodder pea cultivar.

Material and Methods

During 2011 – 2013 in the trial field of Dobrudzha Agricultural Institute – General Toshevo (North-East Bulgaria) a field experiment was carried out with fodder pea (*Pisum sativum L.*) variety Michelle. The trial was designed by the block method in four replications on harvest plot of 12 m^2. The variants of the experiment were the following: 1) check; 2) treatment with liquid fertilizer Bo-La containing boron (B) and molybdenum (Mo); 3) treatment with liquid fertilizer Potassium thiosulphate (PTS) containing potassium and sulfur (K, S); 4) treatment with liquid fertilizer High-phos containing phosphorus, potassium and magnesium (P, K, Mg).

The treatment with the above liquid fertilizers was done at vegetative stage V3 (the third true leaf has unfolded at the third node, tendril present) of the crop, in the early hours of the day, at working solution rate of 300 l ha^{-1}. The doses applied for the respective fertilizers were as follows: Bo-La - 2 l ha^{-1}; PTS - 5 l ha^{-1}; High-phos-5 l ha^{-1}.

The soil in the trial field was slightly leached chernozem (*Luvic phaeosem*) with agro physical and agro chemical properties very favorable for development of pea (Table 1). The natural strains of nodule bacteria on peas *Rhisobium. leguminosarum.* biovar. *vicea* were widespread in the trial field and had good virulent ability. The method of the most probable number (MPN, Vincent, 1970) was applied to determine their number immediately before sowing.

The reading of the number of nodules was done at reproductive stage R2 (first open flower at one or more nodes) on 5 plants in three replications. Soil monoliths with length including the 5 plants, width 12 cm and depth 15 cm were carefully cut, taken out and sifted through a set of sieves, the last of which was with 1.5 mm apertures. The dry weight of the nodules was determined at temperature 70^o C till constant weight.

Pea was sown on the entire surface of the trial plot. Interspacing was 12 cm, and the sowing norm was 120 germinating seeds m^{-2}. Sowing was done in the second decade of March, the optimum date for this agro ecological region. Pea was grown in crop rotation with winter wheat treated with low nitrogen norms (60 kg ha^{-1}). Direct fertilization on pea was not used. The herbicide Aphalon at dose 2.5 kg ha^{-1} was applied for control of weeds. Harvesting of pea was direct, at stage full maturity (R7), and was done with plot micro combine.

The obtained results were processed with the help of the statistical software SPPS 13.

Table 1. Agro chemical characteristics of the soil in the trial field

Indices	Value
NH_4-N +NO_3-N, mg kg^{-1}	16.55
*P_2O_5, mg 100 g^{-1}	5.48
*K_2O, mg 100 g^{-1}	22.66
Humus, %	3.32
pH_{KCl}	5.39
Number of nodule bacteria in 1 g dry soil	8.10^4

** according to Ivanov, 1984*

The vegetation rainfalls (March – June) were most abundant in 2012 – 198.4 mm, and lowest in 2013 – 95.3 mm (Table 2). The rainfalls in May, which are decisive for the formation of vegetation mass, were highest in 2012: 118.9 mm, and most scarce – in 2013: 23.0 mm. The rainfalls in June, when the reproductive organs are formed, were considerably below the respective referential amounts for the long-term period, averaged for three years: 24.66 mm as compared to 64.00 mm.

The autumn-and-winter rainfalls during the same period also conceded to the rainfalls for the 60-year period, 246.7 mm as compared to 294.0 mm, respectively. Concerning the total vegetation rainfalls and their effect on the growth and development of pea in the rest of the years, they can be defined as follows: years 2011 and 2012 – favorable; year 2013 – unfavorable.

The temperature regime during the growth season of pea in all three years of the investigation did not deviate significantly from the mean long-term temperature regime.

Results and Discussion

Nodulation during the first two years began 12-14 days after emergence and coincided with vegetative stage V2 (the second true leaf has unfolded at the second node, tendril present). During the third year, which was characterized with lower soil moisture, the first nodules on the pea roots appeared a little earlier – in 10-12 days. The delay during the first two years in the appearance of the first nodules in comparison to the third year was most probably due to the lower soil temperature and aeration as a result from the more abundant rainfalls in this period.

Table 2.Vegetation rainfalls, mm

Months	Years			Averaged for 3 years	Averaged for 60 years
	2011	2012	2013		
March	20.6	11.8	25.3	19.2	46.5
April	49.2	40.1	35.7	41.6	48.3
May	80.4	118.9	23.0	74.1	49.6
June	35.1	27.6	11.3	24.6	64.0
Amount for March - June	185.3	198.4	95.3	159.6	208.4
Autumn-and-winter rainfalls, October-March	206.4	283.0	250.8	246.7	294.0

The mean duration of the nodules' life cycle was highest in 2012 – 50.7 days, and lowest in 2013 – 33.5 days (Table 3). Among the variants with foliar fertilization, the variant with Bo-La had the highest effect on this index - 43.6 days (15.9 %) followed by the variant with High-phos – 42.3 days (12.5 %) and PTS – 41.6 days (10.6%), respectively. The value of this index was directly proportional to the vegetation rainfalls during the respective years.

Table 3. Duration of the life cycle of nodules, days

Variants	Years			Averaged for 3 years	Variation
	2011	2012	2013		%
Control	36	47	30	37.6	100.0
Bo-La	42	54	35	43.6	115.9
PTS*	40	52	33	41.6	110.6
High-phos	41	50	36	42.3	112.5
Averaged for the year	39.7	50.7	33.5		

PTS*- Potasium thiosulphate

The index number of nodules per plant, which, as a rule, characterizes the infection ability of the local strains of nodule bacteria, was highest during the first year of the investigation – 40.5 nodules plant ^{1} (Table 4). During the dry growing season of 2013, lowest number of nodules per plant was read – 34.7. The effect of the fertilizers was again highest for the Mo-B-containing fertilizer Bo-La – 41.0 nodules plant^{-1} (17.1 %).

The effect of PTS was higher on this index (11.4%) than the effect of High-phos (7.4%), in contrast to the reverse situation with the index life cycle of nodules. Moisture content in soil in this case, too, was decisive for the higher values of the index. The roots of pea expanded intensively under such conditions and a much greater number of nodules formed on the main and lateral branches.

Table 4. Number of nodules, plant^{-1}

Variants	Years			Averaged plant^{-1}	Variation, %
	2011	2012	2013		
Control	36	38	31	35.0	100.0
Bo-La	41	42	40	41.0	117.1
PTS*	46	38	33	39.0	111.4
High phos	39	39	35	37.6	107.4
Averaged for the year	40.5	39.2	34.7		

PTS*- Potasium thiosulphate

The dry weight of the nodules gives a general idea about their size (Table 5). Nodules had highest dry weight in the year with the highest moisture reserves available in soil (2012) and vice versa – their dry weight was lowest during the dry year 2013 (57.7 mg plant^{-1}). The effect of the tested foliar fertilizers on dry weight was similar to the effect on the index number of nodules per plant. According to this effect, the fertilizers can be ranked in the following ascending order: PTS>High-phos>Bo-La.

Table 5. Dry weight of nodules, mg plant^{-1}

Variants	Years			Averaged for 3 years	Variation, %
	2011	2012	2013		
Control	60	72	52	61.3	100.0
Bo-La	70	81	62	71.0	115.8
PTS*	68	72	57	65.6	107.0
High-phos	69	75	60	68.0	110.9
Averaged for the year	66.7	75.0	57.7		

PTS*- Potasium thiosulphate

The degree of variation depending on the applied foliar fertilizers was highest in the index number of nodules per plant – up to 17.1%, followed by the indices life cycle of nodules – up to 15.9 %, and dry weight of nodules – up to 15.8 %.

The dispersion analysis of the results indicated variations in the three indices under the effect of the applied variants of the trial (Table 6). Most significant was the effect of the Mo-B-containing fertilizer Bo-La. The other two fertilizers had lower and almost equally significant effect. The conditions of the respective year had highly significant influence, mainly due to the availability if sufficient moisture in soil.

Table 6. Dispersion analysis of the results

Factors	Life cycle of nodules, days	Number of nodules, plant^{-1}	Dry weight of nodules, mg plant^{-1}
A. Variants			
Control	37.6	35.0	61.3
Bo-La	43.6***	41.0***	71.0***
PTS*	41.6**	39.0**	65.6**
High-phos	42.3**	37.6*	68.0***
B. Years			
2011	39.7	40.5	66.7
2012	50.7***	39.2^{NS}	75.0***
2013	33.5*	34.7***	57.7***

*,**, *** Significance at p= 5%, 1% and 0.1%;
NS-not significant, PTS*- Potasium thiosulphate

The effect of the tested foliar fertilizers on grain yield was the same as the model of effect on the indices of nodulation (Table 7). Again foliar fertilizer Bo-La had the highest effect – 11.4 % more grain according to the check variant. The foliar fertilizer PTS had lowest effect on grain yield – 5.5 %.

The analysis on the obtained results undoubtedly demonstrated the positive effect of the application of selected foliar fertilizers on nodulation of pea. This positive effect was due to the important role of the chemical elements they contained. Thus for example molybdenum contained in the foliar fertilizer Bo-La is included in the enzyme complex nitrogenase which is directly responsible for fixation of nitrogen from the atmosphere. The element B regulates water content in cells, reproduction and pollen formation. Magnesium is very important for the process of photosynthesis and is involved in the chlorophyll structure, respectively in the delivery of assimilates to the plant. Sulfur increases the resistance of the plants to diseases through the synthesis of amino acids. All these useful effects of the above elements contained in the respective tested foliar fertilizers make them very suitable for application in the growing technology of pea.

Table 7. Grain yield from pea averaged for 3 years, kg ha^{-1}

Variants	Value, kg	Variation, %
Control	3613	100.0
Bo-La	4026	111.4**
PTS*	3803	105.5*
High-phos	3936	108.9**

*,**, *** Significance at p= 5%, 1% and 0.1%,
PTS* - Potasium thiosulphate

Conclusion

The effect of the applied foliar fertilizers on nodulation of pea was positive. The degree of variation was highest for the index number of nodules per plant – up to 17.1 %, followed by the indices life cycle of the nodules – up to 15.9 % and dry weight of nodules – up to 15.8 %.

Among the tested foliar fertilizers, the Mo-B-containing fertilizer Bo-La had highest significance of the effect. The other two fertilizers, PTS and High-phos, had lower and almost equally significant effect.

The conditions of the respective year had very good significant effect which was mainly due to the sufficient moisture available in soil.

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