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Root Mass Accumulation after Different Fertilization and Soil Cultivation of Alfalfa (*Medicago sativa* L.)

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ABSTRACT

Effect of mineral fertilization and soil cultivation practices on root mass accumulation of alfalfa was studied. Field trial was conducted in the Institute of Forage Crops, Pleven, Bulgaria on leached chernozem subsoil type and no irrigation. The next treatments were tested: (1) For fertilization as follows: N0P0K0 (control), N60P100K80 (an accepted technology), N23P100K35 (nitrogen was applied 1/2 in first year of growing, 1/2 in third year), N23P100K35 (nitrogen was supplied pre-sowing), N35P80K50 and Amophose, calculated at fertilizing rates N27P120K0 and (2) For soil cultivation as follows: soil loosing 10-12 cm, plough at depth 12-15 and 22-24 cm (an accepted technology), 18-22 and 30-35 cm. It was found that alfalfa plants accumulated the biggest amount of dry root mass (4550 kg ha^{-1}) at the plough at the depth of 18-22 and fertilization at N35P80K50. Supplying of plants with an initial amount of nitrogen was essential for the root mass formation in shallow soil cultivation practices. Both, mineral fertilization and soil cultivation had effect on root mass accumulation of alfalfa.

Key words: Root mass, alfalfa, fertilization, soil cultivation

INTRODUCTION

Alfalfa (*Medicago sativa* L.) is one of the most important forage legume species. It is valuable protein source for animals with high nutritive value and rich in minerals (Keskin *et al*., 2009). This crop is important for the formation of a higher fertility of the soil on which is grown (Pachev *et al*., 2007). This occurs because every time when plants are cut a corresponding amount of the root system dies back thus providing soil with organic matter that can be immediately degraded by soil micro organisms.

As a legume, alfalfa is nitrogen fixing crop and the potential for nitrogen fixation through symbiosis is about 450 kg ha^{-1} $year^{-1}$ (Heichel and Henjum, 1991; Starchenkov and Kot's, 1992; Dubach and Russelle, 1994). The issue of the additional introduction of nitrogen to alfalfa is debatable in the literature (De Oliveira *et al*., 2004; Werner and Newton, 2005).

Many authors support the thesis for application of nitrogen fertilization and its positive effects on growth and productivity (Kot's *et al*., 1990; Cihacek, 1994; Petkova, 1994; Sharma and Sharma, 1995; Raun *et al*., 1999; Trepachev, 1999; Delgado *et al*., 2001; Vasileva *et al*., 2006, 2011). Significantly increase of dry mass yield of alfalfa after 23 kg ha^{-1} N application was found by Pachev (2001). The need of nitrogen fertilization was confirmed by Raun *et al*. (1999). After additional applying of nitrogen fertilizer (once in the spring) they found enhanced dry mass productivity in the cuts, harvested later, which is in line with declined then nitrogen fixation capacity.

In the same time high doses of mineral nitrogen inhibit the biological fixation process (Steerer and Wong, 1998; Kot's *et al*., 1990, 1996; Kot's, 2001).

Alfalfa has the ability to accumulate significantly more nitrogen than other legumes through its deep rooting system Jarvis (2005). Root mass accumulation is an important agronomic characteristic (Hakl *et al*., 2007, 2011, 2012). It was considered that 70% of root mass of alfalfa is situated into the depth of 40 cm (Campbell *et al*., 1997). They found 4830 kg ha^{-1} root mass of alfalfa in field trial. Maximum root mass of 9000 kg ha^{-1} in Sweden was measured by Pettersson and Hansson (1990).

By accumulating root mass into the soil alfalfa contributed to enhancing the soil fertility. It was concluded that decaying alfalfa roots are good source of plant available nitrogen (Dubach and Russelle, 1994). They determined 15.36 kg ha^{-1} N was available from decaying alfalfa roots (for comparing -3.47 kg ha^{-1} N was available from decaying birdsfoot trefoil roots), thus alfalfa roots added significant amount of nitrogen to an agro ecosystem.

In this study, we aimed to analyze the root mass accumulation in alfalfa after different mineral fertilization and soil cultivation practices.

MATERIALS AND METHODS

The experiment was carried out in the experimental field of the Institute of Forage Crops, Pleven, Bulgaria (2003-2006) on leached chernozem soil subtype without irrigation. Alfalfa variety Obnova 10 was sown at sowing rate of 25 kg ha^{-1}. Long plot method was used and plots size was 10 m^2. Most important agrochemical characteristics of the soil were as follows: N, 31.5/1000 g soil; P (P_2O_5), 5.19 mg/100 g soil; K (K_2O), 25.4 mg/100 g soil; pH (H_2O), 6.95 and humus, 1.77%.

The treatments being 4-times replicated were: (1) For fertilization as follows: N0P0K0 (control), N60P100K80 (by accepted technology), N23P100K35 (nitrogen was applied 1/2 in first year of growing, 1/2 in third year and P and K supply); N23P100K35 (nitrogen was supplied pre-sowing, K supply, P by 1/3 in the first, second and third year of growing); N35P80K50 and Amophose, calculated at fertilizing rates N27P120K0, (2) For soil cultivation as follows: soil loosing 10-12 cm, plough at depth 12-15 and 22-24 (an accepted technology), 18-22 and 30-35 cm.

Soils from soil profile from 4 replications were taken (20/30/40 cm), root mass were washed with tap water (Beck *et al*., 1993) and measured: (1) For the first year of growing: Root Mass Density (RMD) as g cm^{-3} = Roots fresh weight (g)/roots volume (cm^3), root volume was measured using fresh roots of each plant by the water displacement method, using graduated cylinder (Saleh and Gritton, 1988) Specific Root Length (SRL) as cm g^{-1} = Root length (cm)/root weight (g), (2) For the whole period of growing (four years) dry root mass (kg ha^{-1}) was calculated from fresh mass and dry matter percentage (dried at 60°C).

One cut were obtained in the first experimental year and two cuts were obtained every year of 2004, 2005 and 2006. Experimental data was averaged and statistically processed using SPSS software program (2012).

RESULTS AND DISCUSSION

Agro meteorological conditions during the first year of study were unfavaourable for the growing of alfalfa (Table 1). Prolonged drought period occurred in the late April to the mid-May. There was a lack of rainfall during the first 10 days of May and high mean monthly average air temperatures (20.5°C). Small amount of precipitation (12.8 mm) and high average temperature (23.9°C) were typical in June.

During the second experimental year despite the large amount of rainfall in May and June, early spring drought occurred in April (6.9 mm) also adversely effects both, growing and development of alfalfa.

Over the next year when the vegetation advanced the higher amount of rainfall were favourable for alfalfa growing. There were small amount of precipitation during the spring of the last experimental year (rainfall in May and June -31 and 33 mm). Precipitation in July contributed the improvement of soil water regime, but the associated high daily average temperature and earlier spring drought inhibit plants growth.

Alfalfa does not develop its potential for the root mass formations during the first year of vegetation and a large part of mineral fertilizers remain unused, especially in dry soils.

Table 1: Agro meteorological conditions for the period of study (2003-2006)

	2003		2004		2005		2006	
Months	Temperature (°C)	Rainfall (mm)	Temperature (°C)	Rainfall (mm)	Temperature (°C)	Rainfall (mm)	Temperature (°C)	Rainfall (mm)
January	-0.1	53.4	-2.2	26.1	2.4	55.0	-2.9	8.8
February	-3.4	27.6	3.2	23.9	-1.7	46.3	0.6	121.0
March	4.7	10.2	7.4	41.6	5.1	75.8	6.8	176.0
April	10.9	83.6	13.1	6.9	12.4	57.4	13.2	30.9
May	20.5	74.5	16.1	87.5	17.5	101.0	17.8	33.2
June	23.9	12.8	20.3	70.3	19.8	95.9	21.0	47.3
July	23.7	49.7	23.5	38.5	22.6	115.0	23.0	78.4
August	25.5	1.4	22.6	82.4	21.4	156.0	23.2	63.4
September	17.7	67.6	18.4	42.2	17.4	225.0	18.7	48.5
October	10.7	107.0	14.0	14.6	17.4	25.5	17.4	25.5
November	7.4	24.8	7.9	21.6	5.1	24.0	5.1	24.0
December	1.2	28.2	2.6	43.3	2.7	41.7	3.3	32.5
Aver/sum	11.9	540.8	12.2	498.9	11.8	1018.6	12.3	689.5

Table 2: Dry root mass after different fertilizing rates and soil cultivation of alfalfa

	Dry root mass (kg ha^{-1})					
	Soil loosing (cm)			Plough (cm)		
Treatments	12-15	12-15	22-24	18-22	30-35	Av. for soil cultivation
N0P0K0	3184	3185	3202	3833	3368	3354
N60P100K80	3500	3397	3007	3699	3216	3364
N23P100K35*	3080	2826	3566	3799	3997	3454
N23P100K35**	3243	2889	3222	3730	3831	3383
N35P80K50	3300	3344	3912	4550	3907	3803
Amophose	3445	3062	4003	3483	3840	3566
Av. for fertilization	3292	3117	3485	3849	3693	
SE (p = 0.05)	64	95	166	148	130	

*Nitrogen was applied 1/2 in first year of growing, 1/2 in third year and P and K supply, **Nitrogen was supplied pre-sowing, K supply, P by 1/3 in the first, second and third year of growing

In the 15-30 cm layer in the first year of production of alfalfa (range of 1900-3580 kg ha^{-1} root mass, average of 2450 kg ha^{-1}) and in the second year (range of 1920-3660 kg ha^{-1} root mass, average of 2800 kg ha^{-1}) was measured (Bolinder *et al*., 2002). Significant less amount of 928-1556 kg ha^{-1} dry root mass accumulated in alfalfa after 5 year growing was found by Biederbec *et al*. (2005).

An amount of 4017-5196 kg ha^{-1} dry root mass of alfalfa after mineral nitrogen fertilization was recorded where fertilized treatments significant exceeded the control (Vasileva and Kostov, 2015). Positive correlation has been found between root biomass and forage yield of alfalfa by Lamb *et al*. (2000) and Hakl *et al*. (2008). The amount of nitrogen accumulated in alfalfa roots was observed to be much higher than that in other legumes according to Kusvuran *et al*. (2014). High quality of forage after fertilizing of alfalfa with rates N35P80K50 was found by Naydenova and Pachev (2009).

In this study, dry root mass accumulation was different for soil cultivation practices studied (Table 2). When soil loosing at the depth of 12-15 cm was applied the largest amount of dry root mass (3445-3500 kg ha^{-1}) was accumulated for Amophose and N60P100K80 treatments, significantly exceeding unfertilized control.

For the shallow soil cultivation practices the supply of alfalfa with starting amount of nitrogen was important. Dry root mass in this study varied in relatively narrow limits when plough at the depth of 12-15 cm was applied and the biggest accumulation were observed for the doses N60P100K80. According to Hartwig and Soussana (2001), alfalfa used the soil or fertilizer nitrogen during the initial development of the plants, since nitrogen assimilation needs lower levels of CO_2 and energy as compared to nitrogen fixation process, therefore requires applying nitrogen.

This data is in agreement with Hartwig and Soussana (2001), who considered that alfalfa plants without nitrogen fertilization had a significantly lower root dry mass than plants with nitrogen fertilization.

When plough at the depth of 22-24 cm was applied dry root mass accumulation for N35P80K50 was 3912 kg ha^{-1} and exceeded the control by 22.2%, but for the Amophose, 4003 kg ha^{-1} or by 25.0% over the control. The biggest amount of dry root mass (4550 kg ha^{-1}) alfalfa plants accumulated in the variants with plough at the depth of 18-22 cm and N35P80K50.

Nitrogen fertilization had more influence on nodulation ability of alfalfa as compared to soil cultivation practices was found by Vasileva and Pachev (2009).

In studies of Hanackova and Slamka (2004), higher dry mass yield from alfalfa was measured after plough at the depth of 20-25 cm comparing with plough at the depth of 12-14 cm.

Root mass was formed in very dry conditions during the year of establishment of alfalfa and it showed small differences in the characteristics studied (Table 3). Root mass density varied in a narrow limit (0.1922-0.2118 g cm^{-3}) and significant differences between the variants did not found. Similar were the findings in other study (Vasileva and Kostov, 2015).

Meteorological conditions under where root system of alfalfa was formed influenced the specific root length. At the shallow soil cultivation (loosing at the depth of 12-15 cm) specific root length was highest at the best supplying with nitrogen (N60P100K80) (Table 4). Plants from the unfertilized control for all the experimental depths of plough showed the lowest values of specific root length.

These results suggest that for the primary development of the plants alfalfa need nitrogen to avoid the retention of root development.

Specific root length showed the highest values the plough depth of 12-15 cm and N23P100K35. Similar results were reported by Vaughan *et al*. (2002). When plough at the depth of 18-22 cm was applied the values of this characteristic were close at N23P100K35 and N35P80K50 and the highest specific root length showed the roots at the Amophose fertilizing. We assume that it was due to the phosphorous

Table 3: Root mass density of alfalfa during the first growing year

	Root mass density (g cm^{-3})					
	Soil loosing (cm)			Plough (cm)		
Treatments	12-15	12-15	22-24	18-22	30-35	Av. for soil cultivation
N0P0K0	0.2006	0.1995	0.1957	0.1968	0.2024	0.1990
N60P100K80	0.2000	0.2004	0.1968	0.1943	0.2015	0.1986
N23P100K35*	0.2000	0.1966	0.1978	0.1965	0.1964	0.1975
N23P100K35**	0.2118	0.1945	0.1930	0.1966	0.1980	0.1988
N35P80K50	0.2000	0.1968	0.1944	0.1922	0.1953	0.1957
Amophose	0.2012	0.2013	0.1949	0.2012	0.2012	0.2000
Av. for fertilization	0.2023	0.1982	0.1954	0.1963	0.1991	
SE (p = 0.05)	0.0019	0.0010	0.0007	0.0012	0.0012	

*Nitrogen was applied 1/2 in first year of growing, 1/2 in third year and P and K supply, **Nitrogen was supplied pre-sowing, K supply, P by 1/3 in the first, second and third year of growing

Table 4: Specific root length of alfalfa during the first growing year

	Root length (cm g^{-1})					
	Soil loosing (cm)			Plough (cm)		
Treatments	12-15	12-15	22-24	18-22	30-35	Av. for soil cultivation
N0P0K0	4.106	3.529	3.529	2.865	3.188	3.443
N60P100K80	4.274	4.130	4.237	3.611	4.563	4.163
N23P100K35*	4.154	3.830	4.126	4.067	4.048	4.045
N23P100K35**	3.086	5.063	4.615	4.082	4.011	4.172
N35P80K50	3.824	4.142	4.126	4.085	4.217	4.079
Amophose	4.154	4.418	4.196	4.255	4.261	4.257
Av. for fertilization	3.933	4.185	4.138	3.827	4.048	
SE (p = 0.05)	0.18	0.21	0.14	0.21	0.18	

*Nitrogen was applied 1/2 in first year of growing, 1/2 in third year and P and K supply, **Nitrogen was supplied pre-sowing, K supply, P by 1/3 in the first, second and third year of growing

imported with fertilizer. Alfalfa plants supplied with phosphorus showed better nodulating ability according to Vasileva and Pachev (2009) and higher dry mass productivity according to Fan *et al*. (2015).

CONCLUSION

Alfalfa plants accumulated the biggest amount of dry root mass (4550 kg ha^{-1}) at the plough at the depth of 18-22 cm and fertilization at N35P80K50. Supplying of alfalfa plants with an initial amount of nitrogen was essential for the root mass formation in shallow soil cultivation practices.

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