Effects of a Super Absorbent Polymer on Ryegrass (*Lolium multiflorum* lam.) Forage Production Under Rain-fed Conditions in the Region of Korça, in South-eastern Albania

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Abstract

Ryegrass (*Lolium multiflorum* Lam.) is a promising forage crop for animal feeding and animal production in Albania, used as fresh or dry mass. The study was carried out in the late season (August 15 - November 20), under rain-fed conditions only, during three consecutive years, 2010-2012, at the Experimental Base of the Agricultural Faculty, University "Fan S. Noli", Korçë, situated in Southeastern Albania, using different rates (0, 20, 50, 80 and 100 kg/ha) of a superabsorbent polymer. Mean total precipitation was 232.7 mm in 14 rainy days. There were determined biomass production and quality indicators of ryegrass. Application of superabsorbent polymer at different rates affected forage production indicators of ryegrass. For the treatment application of 50 kg/ha SAP, the aboveground mowing biomass was increased significantly (48.1%) compare to control. The number of panicles and tiller fertility rates, as well as relative water content, crude protein content and relative feed value, were also increased. The optimum application rate was 50 kg/ha SAP. Other rates did not significantly affect the forage production indicators. Use of superabsorbent polymer could be an effective means for ryegrass forage production in rain-dependent and not irrigated regions of Albania and the other regions with similar climate conditions.

KEYWORDS: forage, indicator, *Lolium multiflorum* Lam., superabsorbent polymer (SAP), southeastern Albania.

INTRODUCTION

Ryegrass (*Lolium multiflorum* Lam.) is a promising forage crop for animal feeding and animal production in Albania, used throughout the year as fresh or dry mass. Ryegrass can be planted on early spring (March), when production can be used for hay (dry mass) production, or late summer (August), when production can be used for fresh mass. Shortage of agricultural land and irrigation water are the main limiting factors for growth and yield of agricultural crops, especially forages, in mountainous and hilly southeastern and northeastern regions of Albania. In these regions, the forage crop cultivation, and ryegrass as well, is rain-dependent.

In different regions of the world, intensive researches on water management are being carried out considering the use of superabsorbent polymers (SAP) for the increase of water use efficiency in crops (Lentz & Sojka, 1994; Lentz *et al.*, 1998). SAP-s can be used effectively in areas of rain-fed agriculture and sprinkler irrigation, as well (Ben-Hur *et al.*, 1989; Levy *et al.*, 1992; Shainberg & Levy, 1994). The application of SAP for stabilizing soil structure resulted to increased infiltration and reduced water use and soil erosion in a furrow irrigated field (Trout et al., 1995). Superabsorbent polymers have been used as water-retaining materials in the agricultural and horticultural fields (Johnson, 1984; Mikkelsen, 1994; Yazdani *et al*., 2007) because when incorporated with soil, they can retain large quantities of water and nutrients, which are released slowly as required by the plant to improve growth under limited water supply (Huttermann *et al*., 1999).

Johnson (1984) has reported 171% to 402% increase in the water retention capacity of sandy soils when polymers were incorporated in coarse sand. Addition of a polymer to peat decreased water stress and increased the time to wilt (Gehring & Lewis, 1980).

Other reports show that the incorporation of superabsorbent polymer with soil improved sandy soil physical properties (Gehring & Lewis, 1980), enhanced seed germination and emergence of desert soils (Azzam, 1983), crop growth and yield of soybean under drought stress conditions (Yazdani et al., 2007), reduced irrigation requirements of plants (Flannery & Busscher, 1982), and increased nutrient and water availability *to Ligustrum lucidum* (Taylor & Halfacre, 1995). The use of hydrophilic polymer materials as carrier and regulator of nutrient release was helpful in reducing undesired fertilizer losses, while sustaining vigorous plant growth (Mikkelsen, 1994) and of the reducing surface sealing (Shainberg *et al*., 1990). Three classes of SAP are commonly used and classified as natural, semi-synthetic and synthetic polymers (Mikkelsen, 1994). Superabsorbent polymer (SAP) used for this study was a synthetic polyacrylamide with potassium salt base (a cross linked polymer) developed to retain water in agricultural and horticultural crops. It was imported by an Albanian agricultural inputs company from China. Until the late 2000, superabsorbent polymers were not used in Albania, due to their high prices, even though these polymers can retain soil moisture and have positive impact on the other soil characteristics up to 3-5 years after application (Johnson, 1984). Recently, the application of SAP in agricultural field has become a necessity of water-saving technology for many farmers in mountainous and hilly southeastern and eastern areas with water shortage conditions in Albania, as well as all over the world.

MATERIAL AND METHODS

The main objective of the study was the evaluation of the effects of different rates of superabsorbent polymer (0, 20, 50, 80 and 100 kg/ha) on growth, biomass production, and quality of the forage Italian ryegrass in sandy-clay field in southeastern Albania.

Plant material and growth conditions of ryegrass. The study was conducted under field conditions at the Experimental Base of the Agricultural Faculty, University “Fan S. Noli”, Korçë, Albania, in a sandy-clay land in Korça District, situated on a plateau of 850 m (2.789 ft) above sea level, on latitude 40°27'-40°57'N and longitude 21°4'-20°19'E, in southeastern Albania. The field capacity of the soil was 36.3 ± 0.7% water by weight and the permanent wilting point was 22.1 ± 0.2%; thus, only 14.2% of the water is available to the plants. The soil contained 0.4 g/kg organic carbon, 0.7 g/kg total nitrogen, 0.18 g/kg K, 7.5 g/kg Ca and 0.04 g/kg available phosphorus. The soil pH was slightly basic (pH 7.6) with an electric conductivity of 0.36 mS/cm. Plots were marked out with normal pre-planting land preparation, and a basal fertilizer with phosphates (300 kg/ha) was applied in sowing rows during seeding. A standard seed rate of 30 kg/ha and row spacing of 15 cm were used. Superabsorbent polymer was applied in the row during seed sowing at low (20 kg/ha), medium (50 kg/ha), high (80 kg/ha) and very high (100 kg/ha) application rates. For control plot no superabsorbent polymers was applied. All variants were treated twice with a complex granular fertilizer (NPK 15:15:15), in a dose of 100 kg/ha. Ryegrass was cultivated each year in the late season, under rain-fed conditions, during three consecutive years, 2010-2012. Treatments were arranged into a randomized complete block design with five variants (different SPA rates) and three replications, with a plot area of 25 m^2 (5 m × 5 m). Seeds were sown in August 15 and biomass was mowed in November 20.

Soil and forage tests were carried out at the Analytical and Microbiological Lab of the Agricultural Technology Transfer Center of Fushë Kruja, Albania, according to specific protocols.

Phenological measurements and calculations. Determination of plant growth indicators, such as plant height (cm), number of tillers (tillers fertility rate - %) and the number of panicles per unit area (m^2) was carried out on 100 randomly tagged plants of each variant on each replication.

Relative water content (RWC) was measured on flag leaves at anthesis, 14 weeks after sowing (WAS). Immediately after cutting the base of lamina, leaves were sealed in plastic bags and transferred to the laboratory. Fresh weights were determined within 1 hour of excision.

Turgid weights were obtained after soaking leaves with distilled water in test tubes for 16 to 18 hours at room temperature (about 20ºC) under low light condition. After soaking, leaves were carefully blotted dry with blotting paper to determine turgid weight.

The RWC (%) and dry weights were obtained after oven-drying of 100 g fresh mass for 72 hours at 70ºC. The RWC (%) was calculated according to the equation (Schonfeld *et al.*,1988):

$$\text{RWC (\%)} = [(\text{fresh weight} - \text{dry weight})(\text{turgid weight} - \text{dry weight})] \times 100 \quad (1)$$

The tiller fertility rate (TFR) was calculated according to Singh (1988) and Balasubramaniyan et al. (2001), as follows:

$$\text{TFR (\%)} = (\text{number of fertile tillers}/\text{total number of tillers}) \times 100 \quad (2)$$

At maturity (15 WAS), a sample of 5 m^2 area for each plot on each replication was harvested for the aboveground mowing biomass (AGMB) converted on dry matter yield (quintal/ha) and forage quality determination. Dry weight was recorded after oven drying of 100 g fresh mass for 72 hours at 70ºC.

Forage quality determination. Different parts (leaf, stem and grain) of dried samples were ground through a 1 mm sieve before analysis. Nitrogen content (%) was determined by the Kjeldahl method (AOAC, 1990) and crude protein (CP) content was obtained by multiplying the Kjeldahl N values by 6.25. Neutral detergent fiber (NDF) was determined according to Van-Soest *et al.* (1991). Acid detergent fiber (ADF) was analyzed according to the official procedures for feed analysis (AOAC, 1990). Digestible dry matter (DDM) was obtained based on feeding trials and ADF by the equation:

$$DDM = 88.9 - (0.779 \times \%\ ADF)\ (3)$$

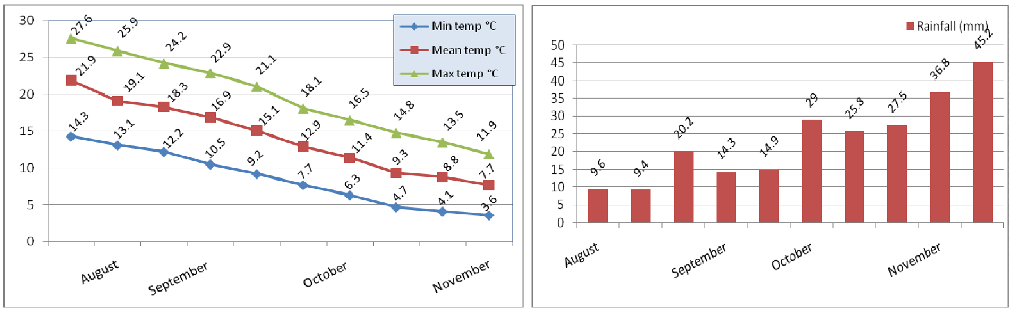
Dry matter intake (DMI) was calculated based on feeding trials and NDF, according to the formula:

$$DMI = 120/\%\ NDF\ (4)$$

The relative feed value (RFV) as a composite estimate of both intake and digestibility potential of forage was calculated by the equation:

$$RFV = (DDM \times DMI)/1.29\ (5)$$

Climatic data. Climatic data were recorded using an automatic weather station which was installed in the experimental field to record daily air temperature and rainfall during ryegrass growing period for three years of the study (Fig. 1/a, b). During the experimental period (15th August to 20th November), the mean air temperature ranged from 7.7 to 21.9°C, with a mean temperature of 14.4°C, and the total precipitation was 232.7 mm in 14 rainy days. No irrigation was applied.



a) b)

Figure 1. Daily air temperature (^{o}C) and rainfall (mm) during late ryegrass growing season, from August 15 to November 20 (three years mean)

Statistical analysis. An analysis of variance was performed using the STATEVIEW software to statistically partition the effect of superabsorbent polymer rate. Treatment means were compared using the Fisher's protected least significant differences at the 95% level of probability.

RESULTS AND DISCUSSION

Plant height (cm). There were observed significant differences between treatments for the plant height. Plant height ranged from 58 cm (control) to 65.1 cm (50 kg ha^{-1} SPA - medium rate). There were no observed significant differences between control and low SAP rate, and between high and very high SAP rate. Medium rate SAP application increased mean plants height by 12.4% compare to control (Table 1).

Number of panicles per unit area (PA - m^2). The number of panicles per unit area differed significantly between treatments (Table 1). SAP application increased significantly the number of panicles per unit area by 17.3% (low SAP application rate), 45.5% (medium SAP application rate), and 21.2% (high application rate). The very high application rate did not affect significantly PA, compare to control.

Tiller fertility rate (TFR - %)**.** Tiller fertility rate was significantly affected by SAP application rate. The highest increase by 29.3% was noted for the medium SAP application rate, while for high SAP application rate it was 18.7%, 10.4% for very high SAP application rate, and 9.83% for low SAP application rate. There were no significant differences between low and very high SAP application rates (Table 1).

Relative water content (RWC - %)**.** The relative water content in flag leaves at anthesis (14 WAS) was increased significantly for the medium SAP rate (9.8%), while low SAP application rate showed no significant effect on RWC, but high and very high SAP application rates reduced RWC, by 1.7% and 4.1%, respectively, compare to control (Table 1).

Table 1. Effect of different superabsorbent polymer application rates on plant height, number of panicles per unit area (PA), tiller fertility rate (TFR - %), and relative water content (RWC - %) (three years mean values, different letters indicate significant difference at $P<0.05$).

Treatments	Plant height (cm)	PA (m^2)	TFR (%)	RWC (%)
Control (0 kg/ha SAP)	58.0 c	189 c	52.9 d	77.9 b
20 kg/ha SAP (low)	58.3 c	222 b	58.1 c	78.1 b
50 kg/ha SAP (medium)	65.1 a	275 a	68.4 a	85.6 a
80 kg/ha SAP (high)	62.2 b	229 b	62.8 b	76.6 b
100 kg/ha SAP (very high)	61.7 b	191 c	58.4 c	74.7 c
LSD	<0.05**	<0.05**	<0.05**	<0.05**

Aboveground mowing biomass (AGMB) or dry matter yield (kv ha-^{1}). There were applied three mowings, in intervals of 33 days. There were observed significant differences in aboveground mowing biomass (AGMB) production between treatments (different SAP rates). AGMB was increased significantly for medium, high and low SAP application rates by 48.1%, 29.5%, and 15%, respectively, while for very high SAP application rate there was observed a not significant raise (only 3.1%), compare to control (Figure 2).

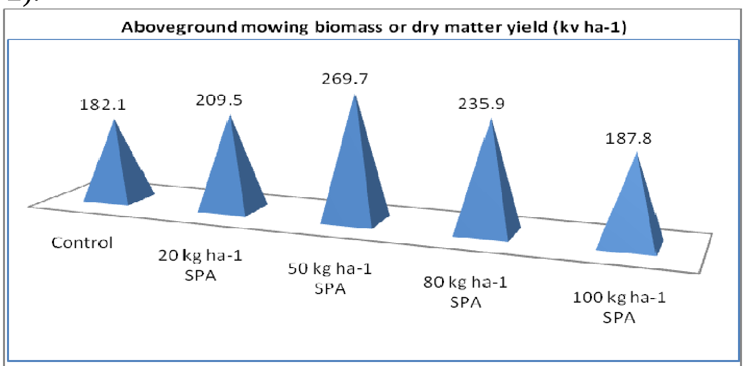


Figure 2. Aboveground mowing biomass or dry matter yield (kv ha-^{1}) of ryegrass at different superabsorbent polymer rates.

Forage quality indicators

Crude protein content (CP - %). The application of SAP increased the crude protein content in plants parts (leaves and stem) of the ryegrass plants. Some previous reports[13,14] have shown that SAP can efficiently prevent nutrient-leaching losses and improve yield quality in different plants. Leaf crude protein (CP) content increased by 28.6%, 38.8%, 36.7% and 43.6% for low, medium, high and very high SAP application rates, respectively, compare to control. Crude protein content in the stem increased by 27.3% at the low SAP application rate, 54.5% at the medium SAP application rate, 43.2% at the high SAP application rate and 34.1% at the very high SAP application rate, compare to control (Table 2). Total protein content would be higher for medium application because it increased both biomass and protein content, followed by high and very high SAP application rates.

Acid detergent fiber (ADF - %). The acid detergent fiber content in the leaves decreased slightly with the application of SAP by 0.5 to 2.4% and lowest value was obtained at the very high SAP application rate, but differences were not significant. The acid detergent fiber content in the stem increased not significantly with low SAP rate (0.5%), but it was increased significantly for medium, high and very high SAP application rates. The highest value was obtained at the very high application rate by 11.6% more than control. There were not significant differences between low SAP application rate and control, and medium and high SAP application rate (Table 2).

Neutral detergent fiber (NDF - %). NDF contents (%) in the leaves decreased significantly with SAP application. NDF content decreased by 4.2%, 9.5%, 5.3%, and 3.5% for low, medium, high and very high SAP application rates, respectively, compare to control.

The neutral detergent fiber content in the stem (Table 2) increased slightly with increasing of SAP application rates, ranging from 0.2% at the low rate to 2% at the very high rate, but it was not statistically confirmed.

Relative feed value. Relative feed value of the leaves increased with the SAP application from 4.5% (at the low rate) to 15.8% (at the medium rate). There were not found significant differences between low, high and very high SAP application rates. RFV for of the stem decreased slightly with the SAP application, but significantly at high and very high SAP application rates (Table 2).

Table 2. Effect of different rates of superabsorbent polymer on forage quality indicators: crude protein content (CP - %), acid detergent fiber (ADF - %), neutral detergent fiber (NDF - %) and relative feed value (RFV) of ryegrass leaves and stem (three years mean values, different letters indicate significant difference at P<0.05).

Plants parts/Treatments	CP (%)	ADF (%)	NDF (%)	RFV
Leaf				
Control (0 kg/ha SAP)	6.3 d	37.9 a	54.7 a	95.3 c
20 kg/ha SAP (low)	8.1 c	37.7 a	52.4 b	99.6 b
50 kg/ha SAP (medium)	8.74 b	37.2 a	49.5 c	110.4 a
80 kg/ha SAP (high)	8.61 b	37.3 a	51.8 b	101.3 b
100 kg/ha SAP (very high)	9.05 a	37.0 a	52.6 b	99.8 b
Stem				

Control (0 kg/ha SAP)	4.4 d	42.3 c	64.5 a	74.9 a
20 kg/ha SAP (low)	5.6 c	42.5 c	65.5 a	74.3 a
50 kg/ha SAP (medium)	6.8 a	45.0 b	66.5 a	74.1 a
80 kg/ha SAP (high)	6.3 b	45.1 b	66.7 a	71.5 b
100 kg/ha SAP (very high)	5.9 c	47.2 a	66.5 a	70.6 b

There was found that SAP application had a significant effect on forage ryegrass growth indicators (yield and its qualitative components) in a rain-dependent area and in a soil with limited water resources. Application of SAP at 50 kg/ha gave the best results of ryegrass growth indicators and we suggest this rate as the optimum for application in the study area or other areas with similar soil and climate conditions. Beyond this recommended rate, we noticed negative or only marginal changes in ryegrass growth indicators. Yazdani *et al*. (2007) showed that even a higher SAP rate (225 kg/ha) was required for best growth of soybean under drought stress conditions, while Islam *et al*. (2011) have reported as the optimum SAP rate 60 kg/ha SAP as the best rate for oat cultivation in arid region of northern China.

CONCLUSIONS

Application of SAP in different rates affected significantly the forage quantity and quality of ryegrass in not irrigation conditions of southeastern Albania, but there were not observed significant differences between two sowing seasons. Application of the medium rate SAP (50 kg/ha), seems to be the optimum rate for forage ryegrass growth indicators. The use of superabsorbent polymer could be an effective means for ryegrass forage production in rain-dependent and not irrigated southeastern regions of Albania, and the other regions with similar climate conditions, as well.

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