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# Sheep wool and leather waste as fertilizers in organic production of asparagus (*Asparagus officinalis* L.)

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**ABSTRACT**

Sheep's wool and leather shavings tanned without chromium (III) salts would be suitable for fertilization in organic farming, where is the lack of easily accessible fertilizer nitrogen. This hypothesis was tested in a two-year field experiment growing asparagus at Rogelj organic farm in Kranj (Slovenia). The block designed experiment with three replicates comprised fertilization treatments with sheep's wool (W), leather shavings (L), cattle manure (FYM) and unfertilized (Ø). Doses of fertilizers were relevant to 0 (Ø), 140 (W1, L1), 280 (W2, L2, FYM) and 560 kg (W3, L3) N/ha. Fertilizers were dosed the first year before the start of the vegetation. Within the next year we followed their subsequent effect. The highest soil mineral N was found in the W2, which produced also the highest asparagus yield (non-significant) in the first year. On contrary, $NO_3$-N content in the asparagus crop was small what reflects the good synchrony of N mineralization and consumption of N at W2. Treatments W and L released significantly more N in the next year than the same dose of nitrogen from FYM. The experiment showed that mainly sheep wool represents a quality alternative organic fertilizer.

**Key words:** horticulture, asparagus, leather waste, sheep wool, organic fertilizers, nitrogen

**IZVLEČEK**

**OVČJA VOLNA IN OSTRUŽKI USNJA KOT GNOJILI V EKOLOŠKI PRIDELAVI ŠPARGLJA (*Asparagus officinalis* L.)**

Ovčja volna in ostružki usnja strojenega brez kromovih (III) soli bi bili lahko primerni za gnojenje v ekološkem kmetijstvu, kjer primanjkuje gnojil z lahko dostopnim dušikom. To hipotezo smo preverjali v dvoletnem poljskem poskusu z vzgojo špargljev na ekološki kmetiji Rogelj v Kranju. V bločnem poskusu smo v treh ponovitvah obravnavali gnojenje z ovčjo volno (W), ostružki usnja (L), govejim hlevskim gnojem (FYM) ter negnojeno (Ø). Odmerki gnojil so ustrezali 0 (Ø), 140 (W1, L1), 280 (W2, L2, FYM) in 560 kg (W3, L3) N/ha. Gnojila smo odmerili prvo leto pred začetkom vegetacije, v naslednjem letu pa spremljali njihov naknadni učinek. V tleh je bilo največ mineralnega dušika pri W2, tudi pridelek je bil največji, vsebnost $NO_3$-N v pridelku špargljev pa je bila majhna, kar kaže na dobro sinhronost mineralizacije in porabe N. Obravnavanji W in L sta imeli tudi v naslednjem letu značilno večje sproščanje N kot enak odmerek dušika iz FYM. Poskus je pokazal, da predvsem ovčja volna predstavlja kakovostno alternativno organsko gnojilo.

**Ključne besede:** hortikultura, špargelj, odpadki usnja, ovčja volna, organska gnojila, dušik

## 1 INTRODUCTION

Organic farmers face many constraints, one of which is prohibition of the use of synthetic fertilizers. The result is often a lack of fertilizer with easily accessible nitrogen. Organic fertilizers contain a lot of organic nitrogen, but it is not mineralized fast enough to meet the needs of the plants during critical periods (Pang and Letey, 2000). Therefore, the need for fertilizer to fill this gap and at the same time being allowable and economically accessible for organic farming is high.

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Typical by-products of leather such as leather scraps, and waste sheep's wool are now mostly deposited in landfills, and nutrients they contain can no longer be exploited. More environmentally friendly alternative is to use them as fertilizers. These by-products are richer in organic N (over 5%) and C (30-50%) than manure and compost (Baker, 1991). Sheep wool hydrolyzate improves growing conditions, by increasing contents of total N, C, and P in the soil (Govi et al., 1998). Applied hydrolysed wool also improved emergence and plant growth (Nustorova et al., 2005). The addition of unwashed and cut sheep wool showed similar positive results on mangold and basil (Zheljazkov et al., 2009).

For normal tanning, the chromium (III) salts are used. Thereof a potential risk of oxidation and forming of the carcinogenic chromium (VI) are becoming increasingly problematic in the leather industry (Blackman and Kildegaard, 2003). The same applies to dyes containing heavy metals. In addition to chromium, these are often cobalt, nickel, copper, etc. One ton of salted skin produces about 200 kg of leather and about 600 kg of waste (Cabeza et al., 1998). With the cessation of the use of chrome tanning salts and heavy metal dyes open up other options, such as the use of waste as fertilizer in agriculture, especially in organic farming.

Two types of animal by-products originated of animals raised according to approved organic agriculture rules were tested in a field trial, the organically produced sheep's wool and leather shavings. In a previous pot experiment, carried out by the Centre for Soil and Environmental Science at the Biotechnical Faculty in Ljubljana, they had been proven to be a good source of nitrogen (Hodnik et al, 2008). Due to the technology used in the processing of hides and skins (processing with organic tannins) they do not contain heavy metals or synthetic additives and as such are suitable for use in organic farming.

In this paper the results of a field experiment using these two residues as fertilizers for the production of asparagus are presented. Our hypotheses were that the sheep's wool and leather shavings are a good source of nitrogen in the soil. The yield of asparagus should be higher and nitrate contents in the young asparagus shoots lower compared to standard fertilization with farmyard manure.

## 2 MATERIALS AND METHODS

**Field conditions and experiment design**

The field experiment took place in 2008 and 2009 at 3 years old green asparagus plantation in town Kranj on the properties of the family farm Rogelj, which is engaged in organic production of plants and animals for the last several years.

Soil at the experimental site is /eutric brown soil on gravel and sand (Eutric Cambisols). The texture of the soil is loam. The plough layer contains about 20% of skeleton (sand and gravel > 2 mm in diameter), but with a depth its content increases rapidly. Horizons they appear in the following order: Ap (0 - 25 cm), AB (20 - 40 cm) and BC (40 - 60 cm). Soil in the Ap horizon contains about 7.5% organic matter, pH of the soil is 6.9. The content of "plant-available" (ammonium-lactate extractable) $P_2O_5$ ranges from 51 to 67.5 mg/100g soil and $K_2O$ content from 55 to 61.2 mg/100g soil which is extremely very high, and indicates intensive fertilization with mineral fertilizers prior to switch to organic farming. The soil is airy, structurally stable and well drained without waterlogging. Capacity of soil to retain water is relatively good, but because of the shallowness of the soil and the proportion of the skeleton in the overall profile is very limited. The effective field capacity is approximately 100 mm (Mihelic, 2004).

The average temperature in 2008 and 2009 was higher than the long-term average. The year 2009 had the average temperature of 11.7 °C. Exceptionally warm were April, May and August. The year 2008 was well provided with precipitation (Ljubljana airport - 1592 mm). Rainfall was in 2009 a little above average (1431 mm). After dry winter, the spring and summer were quite wet. In July and August storms provided enough water for good plant growth (ARSO ..., 2010).

In a randomized field experiment with three blocks in three replicates we compared the effects of fertilizers on the growth of green asparagus. Land was relatively homogeneous. In each block the plots were fertilized either with farm-yard manure (FYM), different doses of sheep's wool (W) and leather (L), and unfertilised control plot (Ø). Each plot measured 35 $m^2$ (5 m x 7 m) (Tab. 1).

**Table 1.** Experimental treatments, application rates of fertilizers and corresponding N

| Treatment | Fertilizer | Application rate (t/ha) | Applied N (kg N/ha) |
|---|---|---|---|
| Ø | Unfertilized control | – | 0 |
| FYM | Farmyard manure | 56.00 | 280 |
| W1 | Sheep wool | 1.00 | 140 |
| W2 | Sheep wool | 2.00 | 280 |
| W3 | Sheep wool | 4.00 | 560 |
| L1 | Leather shavings | 1.61 | 140 |
| L2 | Leather shavings | 3.22 | 280 |
| L3 | Leather shavings | 6.44 | 560 |

Fertilization was carried out on 15 March 2008. Doses of sheep wool and leather shavings were sprinkled evenly by hand; manure was scattered as evenly as possible with pitchforks.

After fertilization the soil was tilled with a rotary harrow. Before the start of the asparagus shoots sprouting out of the ground field was again processed by a comb. During the year and at the end of the growth of asparagus again rotary harrow was used to prevent the growth of weeds between the rows of asparagus.

Soil was sampled at a depth of 0-25 cm with a grooved probe. Sample dates are indicated in tab. 2. The samples were put in a paper bag, and then put in a drying chamber at a temperature of 40 °C for 24 hours. Dried samples were crushed in a mill and screened through 2 mm mesh.

**Table 2:** Dates of plots sampling

| Date of sampling | Comment |
|---|---|
| 07/03/2008 | before fertilization, 3 samples – 1 composite sample for each block |
| 04/20/2008 | samples collected at the beginning of the asparagus sprouts harvest |
| 12/06/2008 | after the termination of the collection of asparagus sprouts |
| 12/01/2008 | out of growing season |
| 19/03/2009 | just before a start of the asparagus growing season |
| 14/05/2009 | the time of maximum growth |

Asparagus in 2008 was collected in two periods of 5 days, and in 2009, in one, 4-day period. Thus, we get an average yield in each plot. Every day we pick up all the stems longer than 20 cm. The asparagus sprouts were weighed and counted. Plant samples of each run were cut, dried at 40 °C for 24 hours, grinded in a coffee grinder and stored at room temperature in a dark for further analysis.

**Soil and plant analyses**

Nitrate nitrogen in plant and soil samples, ammonium nitrogen and total soluble nitrogen in air-dry soils was determined using calcium chloride as extracting solution and measured by spectrophotometer (Perkin Elmer, Lambda 2) (SIST ISO 1425). pH of soil was determined according to SIST ISO 10390.

"Plant available" phosphorus and potassium was extracted with ammonium-lactate solution according to a modified method of the Austrian Standard (ÖNORM L 1087). Phosphorus was determined by spectrophotometry (Perkin Elmer, Lambda 2), and potassium by flame photometry (FLAPO 40).

The total N content in dry soil and plant samples was measured after incineration at 900 °C using TCD detector (Thermal Conductivity Detector) on CNS elemental analyser VarioMAX of Elementar Company (ISO 10694, 1995 and ISO 13878, 1995).

Soil organic matter was measured by the oxidation of chromium in sulphuric acid according to standard SIST ISO 14235.

**N-uptake**
Withdrawal of N to the crop was calculated by measurements of total N in plant samples multiplied by the quantity of harvested shoots of each treatment. Withdrawal throughout the season was calculated so that we have assumed that the harvesting season lasted for 60 days, yield considerations were converted into yield per hectare per season.

**Statistical analysis**
For statistical analysis we used the program Statgraphics plus 4: analysis of variance (ANOVA) and LSD test (statistically significant differences). The method used to discriminate among the means is Fisher's least significant difference (LSD) procedure. With this method, there is a 5.0% risk of calling each pair of means significantly different when the actual difference equals 0. We graphically present data using Microsoft Excel.

## 3 RESULTS AND DISCUSSION

**Nitrate nitrogen in the soil**
The average amount of nitrate (over all measurement dates) was the highest at W2 (2.29 mg/100 g soil) and lowest in the control treatment Ø (1.39 mg/100 g of soil). In all treatments, fertilized with leather or wool, the amount of $NO_3$-N was higher than at the Ø, and in most cases, also higher than at the treatment fertilized with FYM (1.61 mg/100 g of soil). Analysis of variance showed a statistically significant difference between treatments (p = 0.00) at 95% confidence level (Fig. 1).

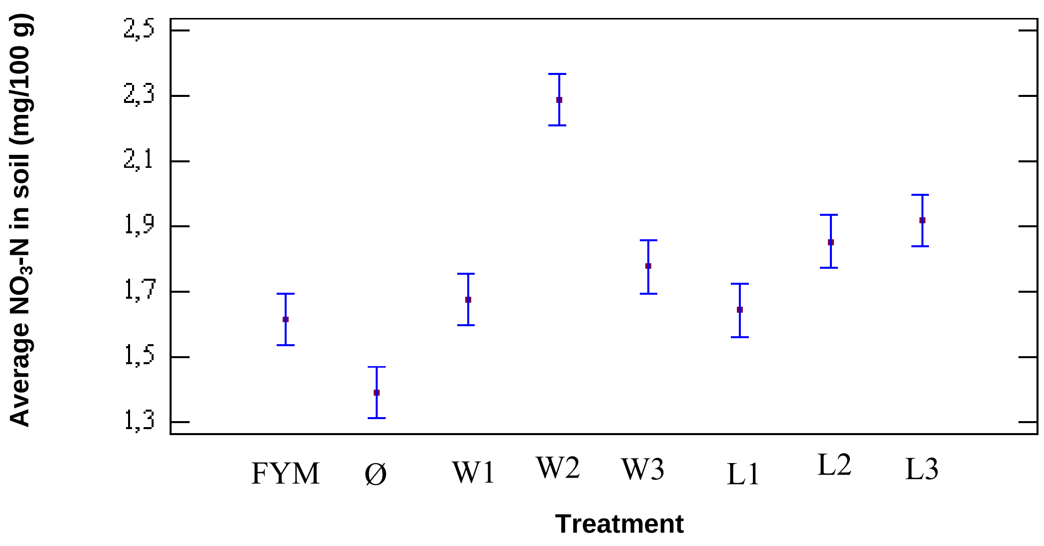


**Figure 1:** $NO_3$-N content in soil (In the figure are presented averages and least significant difference at 5.0% risk; LSD = 0.16)

It was interesting to observe the dynamics of $NO_3$-N in the soil during the experiment. One month after fertilization which was done on 15 March 2008 there was evidence of a nitrification in W2 and L2 in comparison to FYM which released only slightly more nitrate-N compared to non-fertilized control. The concentrations of nitrate-N were very low in FYM and Ø in the mid June 2008, whereas a contrast situation was with W2 and L2. Especially in W2 the $NO_3$-N was very high (3.84 mg/100 g = ca. 125 kg $NO_3$-N/ha in the upper 25 cm of soil) at that time. For a normal growth of field crops (e.g. maize) around 2.0 to 2.5 mg $NO_3$-N/100 g soil is recommended in the technological guidelines for integrated crop production. Above this level side-dressing of maize is generally not needed (Tehnološka navodila…, 2010). This is indication of intensive mineralization and nitrification of organic-N from wool and slightly less intensive from leather chips. Higher nitrate value prevailed at W and L during the entire growing season. On average, the difference was 0.9 mg $NO_3$-N/100 g soil or ca. 30 kg/ha. Towards the end of the year (late autumn), the nitrate from W and L has reached the same level as the non-fertilized soil. Mineralization and nitrification again started more intensively in these treatments the next spring at the end of March. This is an indication of their subsequent N fertilization effect (fig. 2).

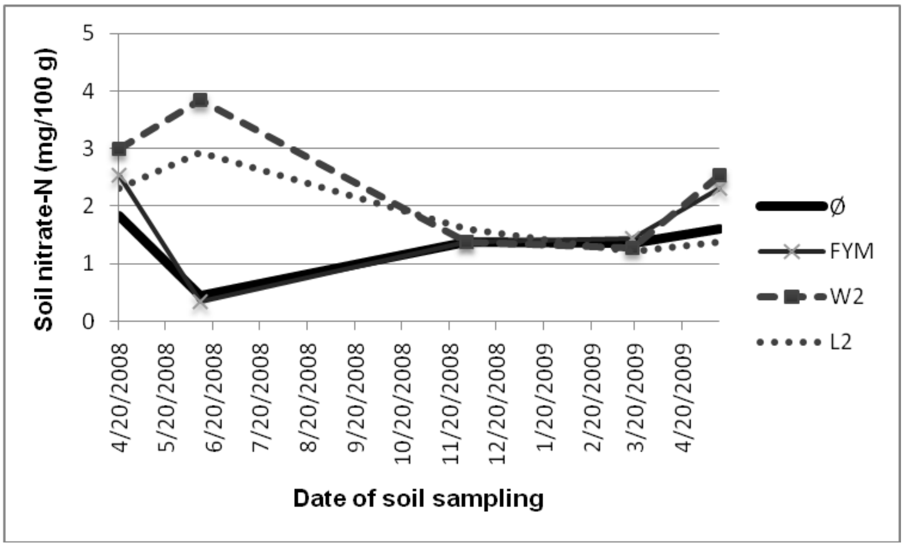


**Figure 2:** Average soil nitrate-N dynamics during the span of the field experiment.
Treatments W1, W3, L1, and L3 are not presented due to clarity of the figure, but their values are in-between those which are presented.

**Ammonium nitrogen in the soil**

Ammonium nitrogen in the soil is a product of mineralization of organic-N. Fast mineralizable organic matter could produce higher amounts of ammonium in the soil. Normally, the ammonium-N content in the soil is from 0.3 – 2.0 mg/100 g (Mihelič, 2004). In our experiment the NH4-N values were always within this range, so there was no accumulation of ammonium in the soil. Apparently, the ammonium produced was consecutively nitrified. The highest average value of $NH_4$-N was at FYM (1.29 mg/100 g soil) and L3 (1.27 mg/100 g of soil). The lowest average value of $NH_4$-N had L1 (1.07 mg/100 g soil) and W2 (1.28 mg/100 g of soil). Low ammonium-N in W2 is in contrast to high nitrate-N values of this treatment during the growing season. Obviously, ammonium-N was concomitantly transformed into nitrate form.

**C/N ratio in the soil**

Soil C/N ratios of fertilized treatments taken 1 month after fertilization were higher compared to the unfertilized control treatment, where C/N level did not change. This may mean that the added organic fertilizers contain a higher C/N ratio as the soil organic matter. In the experiment with the hydrolysed sheep wool Nustorova et al. (2005) have also found that the C/N ratio increased with increasing doses of sheep's wool. This was also reflected by an increased mineralization of hydrolysate by microorganisms in the soil.

**Nitrate nitrogen in vegetation samples**

The plant samples had the lowest average value of $NO_3$-N in W2 (70 mg/kg) and the maximum at L3 (117 mg/kg). The observed differences between treatments were statistically significant (Fig. 3). It is interesting to note that W2 had the lowest nitrate content in plants when the same treatment exhibit the highest $NO_3$-N content in the soil. We can deduce that the relatively high soil nitrate content was not too high for asparagus crop which was able to metabolize the consumed nitrate. Only the highest addition of leather waste (L3) caused a significantly the highest nitrate content in the plant, but also this was not extremely high. Vegetables such as asparagus or onions, including tomatoes, had the lowest concentrations (normally less than 100 mg/kg) (Shalaby, 2004).

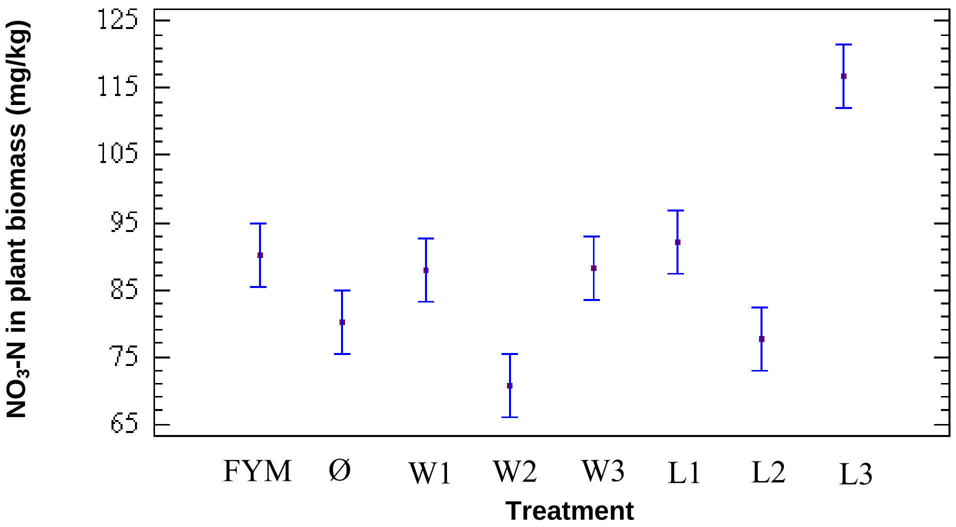


**Figure 3:** Nitrate-N in biomass of harvested asparagus (in the figure are presented averages and least significant difference at 5.0% risk; LSD = 0.16)

**Asparagus yields**

When comparing the yields between the different treatments and blocks there were no major differences. The maximum average yield of the all asparagus collections summed together for the 2008 and 2009 was achieved on a plot of L2 (5.68 kg), and by was 19% higher than the control treatment. The treatment of W2 (5.43 kg) was approximately 13% higher than the control. The highest application rate of leather shavings (L3) gave even 4% less than the controls (mean 4.56 kg). The differences were however not significant (Fig 4, 5).

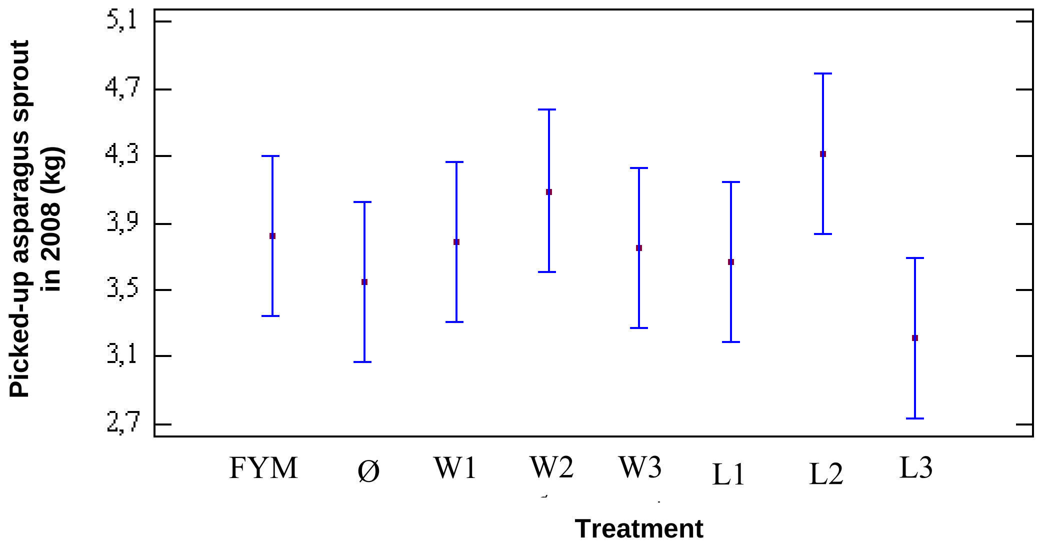


**Figure 4:** The cumulative yields of asparagus in 2008 (in the figure are presented averages and least significant difference at 5.0% risk; LSD = 1.1)

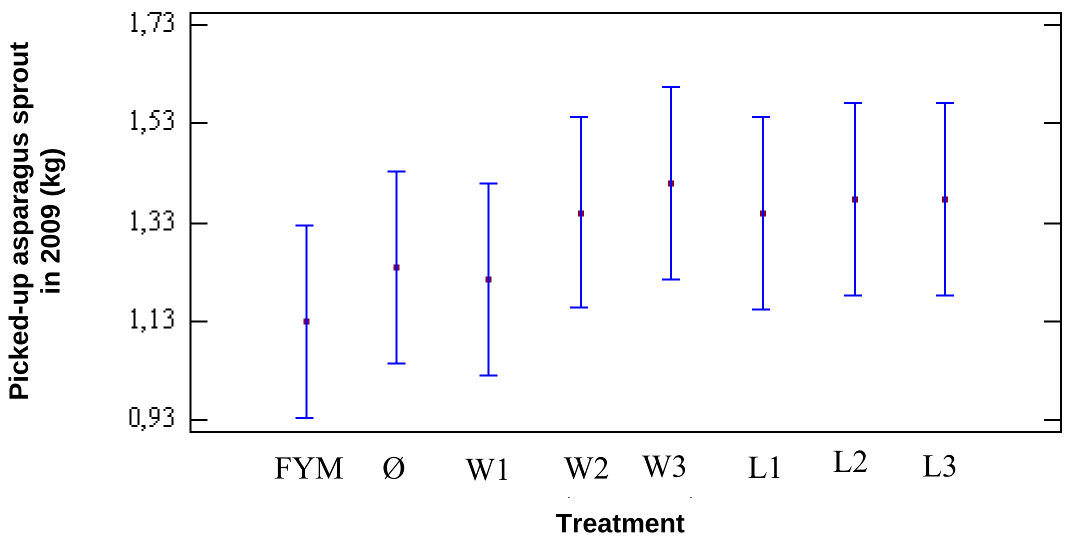


**Figure 5:** The cumulative yields of asparagus in 2009 (in the figure are presented averages and least significant difference at 5.0% risk; LSD = 0.4)

The entire asparagus harvest season lasted for 60 days. The average yields of the entire harvest season in 2008 were from 5.5 t/ha (L3) to 7.4 t/ha (L2), and in 2009 from 4.8 t/ha (G) to 6.0 t/ha (W3). There were no significant differences in yields among treatments. Even the non-fertilized control produced yield on the same level as the fertilized ones. At maximum dose - 560 kg N/ha (treatment W3 and L3) there was a slight depression of the yield. The same was observed in the pot experiment of Hodnik et al., (2008) with the highest doses of sheep wool (tab. 7).

**Table 7:** Asparagus yield

| | Asparagus yield (kg/ha) | | N-uptake (kg/ha) | |
|---|---|---|---|---|
| **Treatment/Year** | **2008** ($LSD_{\alpha=0.05}$ = 1649 kg/ha) | **2009** ($LSD_{\alpha=0.05}$ = 1667 kg/ha) | **2008** ($LSD_{\alpha=0.05}$ = 6.0 kg/ha) | **2009** ($LSD_{\alpha=0.05}$ = 7.7 kg/ha) |
| Ø | 6069 | 5307 | 23,8 | 22,0 |
| FYM | 6543 | 4843 | 24,9 | 20,1 |
| W1 | 6491 | 5185 | 23,9 | 22,2 |
| W2 | 7005 | 5778 | 26,3 | 23,1 |
| W3 | 6420 | 6029 | 23,9 | 25,1 |
| L1 | 6284 | 5771 | 21,6 | 25,6 |
| L2 | 7386 | 5894 | 26,0 | 24,1 |
| L3 | 5504 | 5900 | 19,0 | 24,7 |

Thus we negate the hypothesis of asparagus crop response to the amount of added fertilizer. Small, insignificant differences could be due to the fact that the plants did not respond to specific doses of fertilizer. Even in a pot experiment with asparagus (Shalaby, 2004), different amounts of added nitrogen did not affect the yield. In the Guidelines for expert based fertilization (Mihelič et al., 2010) 40 kg/ha is proposed as a minimal level of soil mineral nitrogen (SMN) and 110 kg SMN/ha as target value for fertilization to achieve 5 t/ha of asparagus yield. The level of SMN in our experiment after fertilization in 2008 during the most intense asparagus growing period was from 50 kg/ha at the control, 90 kg/ha at FYM, and 160 kg SMN/ha at W2 in the upper 25 cm of soil. The SMN content of the other treatments was in between these.

Failure to crop response could also be due to over-fertilization with organic and mineral fertilizers in the past, because the values of the nutrients measured in the soil at the beginning of the experiment were extremely high.

Measurements of $^{15}N$ in asparagus revealed that spring asparagus shoots obtained N mainly by remobilisation of N from the rhizome and roots where it is stored during the dormancy of the plants (Ledgarden et al., 1994). The same experiment also showed that the plants from the soil take N mostly in the summer, and 90% of plant assimilated N at harvested is transferred and stored again into the rhizome and roots in the autumn, from where it is used for the growth of shoots the next season.

## 4 CONCLUSION

Sheep's wool and leather shavings are a good source of nitrogen in the soil. The highest levels of nitrate in the soil were at the treatments W2 (sheep wool; application rate 2 t/ha; soil nitrate level up to 4 mg $NO_3$-N/100 g) and L2 (leather shavings; application rate 3.22 t/ha; soil nitrate level up to 3 mg $NO_3$-N/100 g). Plants however did not respond to fertilization as we expected. Levels of potassium and phosphorus in the soil and humus are suggesting over-fertilisation of the asparagus field before the experiment. In the second year the treatments fertilized with sheep's wool and leather shavings produced a greater amount of asparagus shoots as the unfertilised control and treatment fertilized with manure, however yields were not significantly different from the unfertilized control. Sheep wool (W2) produced the highest content of soil $NO_3$-N; however the content of nitrate-N in the plants was the smallest. W2 also produced high yields of asparagus shoots, which all meant that this treatment represented the best fit between fertilization and the nitrogen needs of the crop.

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