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THE EFFECT OF DIRECT USE OF LAKESIDE BIOMASS AS SOIL AMENDMENT ON THE PRODUCTIVITY OF DRY BEAN CROP

SUMMARY

The riparian areas of the lake Mikri Prespa in the northwest of Greece are surrounded by extensive reedbeds (mainly *Phragmites australis* and *Typha angustifolia* reed) that spread around the perimeter of the lake. The removal of this vegetation is often problematic and imposes difficulties in management and costs. The goal of the present study was to evaluate the effect of the direct use of reed biomass on soil fertility and the performance of common bean (*Phaseolus vulgaris* L.) type "Plake", the main crop in the Prespa region. In a two year field experimentation we tested two fertilization methods, manure and chemical fertilization, combined with three reed biomass doses (0 as a control, 10 tn ha^{-1} and 20 tn ha^{-1}) resulting in five different reed addition treatments (0-0, 10-10, 10-0, 20-20 and 20-0 for the two consecutive years and each fertilization method respectively). Total chlorophyll content measured from start of flowering until physiological maturity was not affected by the incorporation of reed biomass in both fertilization methods. The chemical fertilization significantly affected bean yield exceeding the application of manure in all treatments of reed plant material addition. Reed plant addition treatments affected bean yield with all treatments showing higher values compared to the control (0-0) while the addition of 20 tn ha^{-1} for one year (20-0) significantly exceeded the control regardless of the fertilization method. Further research is needed to explore the best agricultural practice on the effect of reed addition on arable land improvement and the bean crop.

Keywords: Common reed biomass, Soil amendment, Chlorophyll concentration, Bean yield, Prespa area.

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INTRODUCTION

The riparian areas of Lake Mikri Prespa are surrounded by extensive reedbeds that spread almost all around the perimeter of the lake. Different methods have been applied worldwide to manage the overgrowth of mainly *Phragmites australis* and *Typha angustifolia* reed either individually or in combination, including removal of aboveground biomass by cutting, grazing, or burning (Marks *et al.,* 1994; Hazelton *et al.,* 2014; Volesky *et al.,* 2016). The management of common reed cuttings can be accompanied by the exploitation of significant quantities of biomass for energy production and in agriculture. The reed is widely used as animal feed although it has lower nutritional value than other forage crops, it is cheap and easily available (Häkkinen, 2007; Thevs *et al.*, 2007; White, 2009). The harvested biomass of *P. australis* has been exploited for the production of biogas and the sludge which is a by-product of the process is used as organic fertilizer (Hansson and Fredriksson, 2004; Wysocka-Czubaszek *et al.,* 2018).

The production of compost from the removed reed can significantly improve soil composition by increasing organic matter and different plant nutrients but it does not produce any other useful energy and has increased production costs (Mamolos *et al.*, 2011; Hansson and Fredriksson, 2004). Common reed has recently been used to produce biochar (Croon, 2014; Yang and Chen, 2017) a solid, carbon-rich product after pyrolysis of biomass which has been used with positive results for the restoration of cultivated soils in Australia and Canada (Barbiero *et al.*, 2017). *P. australis* has a high N and P uptake capacity (Jiang *et al.*, 2007) with the highest content of nutrients towards the end of the growing period transporting most of them to the rhizomes (Gessner, 2001). The addition of reed after summer cutting directly in the field can improve the structure of the soil, increase the percentage of organic matter and in general the fertility of the soil. However, the addition of nutrients to the crop can be significantly low due to the high C:N ratio (Hansson and Fredriksson, 2004). After decomposition of straw with high C: N ratio, immobilization of N was observed, affecting the growth of corn (Cheshire *et al.,* 1999), while when mainly reed was used as a direct soil conditioner, the growth and yield of corn were not affected due to non-availability of N in the plants (Huijser *et al.,* 2004). The presence of seeds and stolons in the reed pieces may increase the presence of weeds in the field (Prew *et al.,* 1995) but this was not the case when mainly *P. australis* was used as green compost in corn cultivation for two years (Huijser *et al.,* 2004). The transport of cut biomass is the most important obstacle to its utilization (Carson *et al.,* 2018) as low density increases transport costs, however, wetlands often border agricultural land, thus providing an opportunity for cut biomass to be used as a soil conditioner, potentially recycling a significant amount of nutrients.

The aim of the present study was to evaluate the effect of the direct use of reed biomass on the productivity of common bean (*Phaseolus vulgaris* L.) type "Plake", the main crop in the Prespa region regarding the agronomic and physiological behavior of the plants in relation to the soil improvement treatments applied.

MATERIAL AND METHODS

Field experimentation

An experiment was installed for two years (2019 and 2020) in three selected locations in farmer's fields in the area of Prespa in Greece, using a split plot experimental design with fertilizer treatments as the main factor and reed biomass applications as the second factor. We used two fertilization methods, manure at a dose of 50 t ha^{-1} and chemical fertilization based on soil analysis for each experimental field, combined with three reed biomass doses (0 as a control, 10 tn ha^{-1} and 20 tn ha^{-1}) resulting in five different reed addition treatments (0-0, 10-10, 10-0, 20-20 and 20-0 for the two consecutive years and each fertilization method respectively) with three replications. The reed was harvested from the riparian areas of the lake Mikri Prespa during autumn with a special harvester, chopped into 2 mm pieces and spread to the experimental fields with a spreader used to spread manure following the experimental design. Sowing of the experimental fields took place after April 20th until the beginning of May in both years with a local population of climbing indeterminate bean type "Plake". Soil analysis to evaluate the effect of reed addition treatments on soil characteristics was performed in the start of the experimentation and at the end of each cultivation year in all three experimental fields.

Chlorophyll measurements and harvest

Total chlorophyll content was measured with a hand-held dual-wavelength meter (SPAD 502, Chlorophyll meter, Minolta Ltd., Japan) at three developmental stages from start of flowering until physiological maturity (SPAD1 to SPAD3) in twenty-four plants per plot. The measurements were made on developed leaves and the central leaflet, between the central nerve and the leaf blade and were four in total (two on either side), two near the base of the leaf and two in the middle of the leaf in each plant. Harvest was performed with a special harvester after physiological maturity and yield ha^{-1} was estimated. For each sample the 100 seed weight was measured using a seed counter (Contador Pfeuffer, Germany).

Statistical analysis

The statistical analysis of the results was performed with Analysis of Variance (ANOVA) with three factors (location, fertilization and reed addition treatments) while comparison of means was conducted by Least Significant Difference (LSD) at significance level $p < 0.05$.

RESULTS AND DISCUSSION

The analysis of variance of agronomic and physiological parameters measured in all three experimental sites in the final growing season is shown in Table 1. A significant effect of location on yield, 100-seed weight and chlorophyll SPAD levels in the three developmental stages was observed. These differences can be attributed to the initial soil properties of the experimental fields, with the most fertile and with the best soil characteristics experimental field showing the highest yield characteristics and the highest chlorophyll concentration (data not shown).

Table 1. Analysis of variance of different parameters measured in three locations of the lake Mikri Prespa affected by Location (L), Fertilization (F) and the five reed addition treatments (R) (0-0, 10-0, 10-10, 20-20 and 20-0 tn ha^{-1} for the cultivation periods 2019 and 2020 respectively).

Parameter	Location (L)	Fertilization (F)	Reed addition (R)	Lx F	L x R	F x R	L x F x R
df	**2**	**1**	**4**	**2**	**8**	**4**	**8**
Yield	***	**	**	***	***	**	**
100-seed weight	***	NS	*	***	***	NS	NS
SPAD 1	***	NS	*	NS	***	NS	NS
SPAD 2	**	NS	*	NS	NS	NS	NS
SPAD 3	***	NS	NS	NS	NS	NS	NS

df=degrees of freedom, *, **, *** denotes a difference at the levels of P<0.05, P<0.01 and P<0.001 accordingly and NS=no significant

The fertilization factor significantly affected bean yield with the application of chemical fertilization significantly exceeding the application of manure in all reed addition treatments and all three experimental locations. The 100-seed weight and the level of total chlorophyll in all three growing stages measured were not affected by the different fertilization methods but only by the location.

The reed addition affected bean yield with all the treatments showing higher values than the control (0-0 reed material addition for both consecutive years) regardless of the fertilization treatment, with the treatment of 20 tn ha^{-1} for one year (20-0) to have a statistically significant difference in relation to the control (0-0) but not with the other reed addition treatments (Table 2). This could be attributed to the better utilization of water due to the possible improvement of soil water capacity by the addition of plant reed material which was supported from the final soil analysis showing that with higher doses an increase in organic matter mainly in sandy soils could occur. Similarly, wheat straw soil incorporation increased crop yields (Yang *et al.,* 2016), organic matter (Zhu *et al.,* 2014) and soil nutrients (Zhang *et al.,* 2018). Also improved the physical properties of the soil such as hydraulic conductivity and water holding capacity (Mandal *et al.,* 2004; Singh *et al.,* 2007).

Table 2. Effect of fertilization treatment (manure or chemical fertilization) and reed addition treatments (0-0, 10-0, 10-10, 20-20 και 20-0 tn ha^{-1} for the cultivation periods 2019 and 2020 respectively) in agronomic and physiological characteristics of bean crop at three different experimental locations.

Fertil.	Reed addition (2019-2020)	Yield (tn ha^{-1})*	100-seed weight (g)	SPAD 1	SPAD 2	SPAD 3
Manure						
	0-0	4,06b	68,7a	39,8a	40,7a	31,6a
	10-0	4,41ab	68,4a	39,1a	39,8a	31,5a
	10-10	4,36ab	68,7a	38,8a	39,7a	31,5a
	20-20	4,27ab	68,9a	39,0a	41,0a	31,8a
	20-0	4,57a	70,3a	39,8a	41,5a	32,4a

*means in the same column followed by the same letter are not significantly different (t-test, P<0,05)

Chemical fertilization						
	0-0	4,20 b	67,1a	39,6a	40,0a	32,1a
	10-0	4,27ab	68,8a	39,6a	41,1a	32,4a
	10-10	4,60ab	68,1a	38,3a	40,1a	32,8a
	20-20	4,45ab	68,9a	39,9a	40,9a	31,8a
	20-0	4,70a	69,2a	39,5a	41,4a	34,2a

*means in the same column followed by the same letter are not significantly different (t-test, P<0,05)

In addition, the growth of microorganisms was positively affected with the addition of plant biomass (Liu *et al.,* 2010; Zhang *et al.,* 2016). The 100-seed weight did not differ statistically between the reed addition treatments but in the 20-0 treatment there was a slight increase compared to the control. The addition of reed plant material didn't seem to affect the availability of the main nutrients' nitrogen, phosphorus and potassium in both fertilization methods (data not shown). This could explain that the levels of total chlorophyll in the three developmental stages for all the reed addition treatments did not differ from the control in both manure and chemical fertilization treatments (Table 2). After decomposition of straw with very high C: N ratio, immobilization of N was observed, affecting the growth of corn (Cheshire *et al.,* 1999) but when mainly reed plant material was used as a direct soil conditioner, the growth and yield of corn were not affected compared to the control (Huijser *et al.,* 2004).

CONCLUSIONS

The repeated large addition dose of reed in bean cultivated soils of the lake Mikri Prespa slightly increased soil organic matter especially in sandy soils having a possible positive effect on soil water capacity and thus affecting bean yield. This observation could lead to the adoption of practices for continuous and systematic addition of reed. Adding higher doses than those tested in the present study may have had a more significant effect, however this carries the risk of incomplete degradation of the reed and the development of nutritional problems or other dysfunctions in the rhizosphere. Further research would be useful to explore best agricultural practice on the effect of reed addition on arable land improvement in the Prespa area.

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