EFFICIENT WEED CONTROL IN ORGANICALLY GROWN MAIZE BY MEANS OF RED CLOVER AS GREEN MANURE

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Introduction

Cultivation of green manure crops is the main possibility for soil enrichment, especially with N and interest is increasing in recent decades (Travlos et al., 2014). The incorporation of N-rich plant green material into the soil mobilizes N and intensifies microbiological processes, which result in improved plant N content and soil structure (Islam et al., 2018). Regarding legumes, several species (*Trifolium* spp., *Medicago* spp., *Vicia* spp., *Pisum* spp., *Vigna* spp., *Lotus* spp., etc.) have been used and evaluated under diverse conditions (Kumar et al., 2014; Travlos et al., 2014; Karyoti et al., 2018).

Maize (*Zea mays* L.) is globally one of the most popular and productive grain crops. The rapid increase in maize productivity and the high grain yields of the recent decades are mostly due to more productive hybrids and inorganic fertilization (Guo et al., 2010; Travlos et al., 2011). One of the main challenges is to maintain such high yields without adverse environmental impacts and huge costs for farmers, and as a result many studies have recently focused on implementing more environmentally friendly or completely biological practices. (Lamptey et al., 2017).

The beneficial effects of *Trifolium pratense* L. as green manure on the number of grains per corncob and the final maize grain yield have been observed by Tejada et al. (2008). The aim of the present study was to evaluate the effects of this legume as green manure on grain yield and quality characteristics of three organically grown maize hybrids.

Results and discussion

Integrated effects of green manure, hybrid selection and experimental year on yield components of maize and maize grain yield

The results of ANOVA showed that the number of kernels per row as well as the number of kernels per plant and the weight of 1000 kernels were the components of maize grain yield most affected by the different green manure treatments ($P < 0.001$, $P < 0.001$ and $P < 0.01$, respectively). Regarding hybrid selection, its influence on these traits was not clear.

Regarding final yield performance of maize, it was affected by the green manure treatment as well as by hybrid selection during both the experimental years ($P < 0.01$ and $P < 0.001$, respectively). Maize grain yield was not affected by the year factor. Furthermore, neither the interaction between the green manure treatment and hybrids nor the interaction between the factors of hybrid selection and year did put impact on the components of yield and maize grain yield during both the experimental years. The same observation was made regarding the integrated effects of green manure, hybrid selection and year on components of yield and yield performance of maize (Table 1).

	2017-2018	2018-2019
	Kernels row^{-1}	Kernels row^{-1}
Green manure (GM)		
Untreated	25.8222b	26.2889b
Trifolium pratense	30.7111a	30.6000a
Hybrid (H)		
Factor	28.2778a	29.0111a
Dracma	28.1111a	28.0000a
Brasco	29.8111a	29.5111a
P-Values		
Treatment	**	*
Hybrid	ns	ns
T × H	ns	ns

Table 1. Effects of green manure treatment and hybrid selection on the number of kernels per row during the first (2017-2018) and the second (2018-2019) experimental year.
Means followed by different letters within the same column indicate significant differences according to Fisher's Protected LSD test multiple range test (a = 0.05).
*, **Significant at the 0.05 and 0.01 probability levels, respectively; ns: nonsignificant.

	2017-2018	2018-2019
	Kernels plant^{-1}	Kernels plant^{-1}
Green manure (GM)		
Untreated	341.444b	328.000b
Trifolium pratense	387.444a	381.556a
Hybrid (H)		
Factor	391.333a	364.667a
Dracma	363.444a	362.222a
Brasco	376.111a	383.889a
P-Values		
Treatment	***	***
Hybrid	ns	ns
T × H	ns	ns

Table 2. Effects of green manure treatment and hybrid selection on the number of kernels per plant during the first (2017-2018) and the second (2018-2019) experimental year.
Means followed by different letters within the same column indicate significant differences according to Fisher's Protected LSD test multiple range test (a = 0.05).
***Significant at the 0.001 probability levels; ns: nonsignificant.

Effects of green manure on yield components of maize for each experimental year

ANOVA was also carried out to analyze data of each experimental year. Fischer's protected LSD (a = 0.05) multiple range test was used in order to detect the significant differences in maize yield and components of yield between the means of the three experimental treatments as well as between the means of the three maize hybrids. *Trifolium pratense* residuals increased the number of kernels per row by 16% and 14% as compared to control treatment as it was shown from the results of the first and the second year, respectively (Table 2). Similar were the observations regarding the number of kernels per plant. This specific component of yield was increased by 12%-14% due to the use of *T. pratense* green manure, respectively, as compared to untreated control. Incorporating *T. pratense* as green manure instead of leaving the field untreated can result in 11%-15% higher value of weight of 1000 kernels especially as recorded during the second year of the study. The results of the current study showed that green manure can affect components of maize yield and are in line with the results of Dabin et al. (2015), who observed that the number of spikes per hectare under the green manure legume treatment was significantly greater than that recorded under the control treatment. In contrast to these findings, the results of an earlier study indicated that components of yield were unaffected by green manure treatments (Astier et al., 2006).

Effects of green manure on maize grain yield for each experimental year

The main yield components were influenced by the adoption of green manure and consequently these differences had a major influence on the final grain yield of maize. The differences in the yield of maize grains between the various treatments could be largely attributed to the number of kernels produced and their weight, as it is well established that the yield of maize seeds is mainly determined by the number and weight of the kernel (Travlos et al., 2011). Maize yield, in plots where *T. pratense* residuals were incorporated, was increased by up to 6% during the first year of the experiment and almost these results were validated during the second experimental year. The positive effects of green manure legume crops on maize grain yield is in agreement with the findings of Sileshi et al. (2008). The adoption of green manure as a fertilization tactic can increase the yield of maize seeds, enhancing the organic matter content of soil profiles, as well as crop growth parameters (Salahin et al., 2013). In another study, *T. pratense* green manure improved the value of the number of grains per ear and consequently maize grain yield as compared to untreated control (Tejada et al., 2008). The effects of green manure legumes on the yields of the subsequent crop, have also been noticed in wheat and rye crops as well as in oriental sun-cured tobacco (Skuodiene and Nekrosiene, 2007; Travlos et al., 2014). These findings can be explained by the fact that crop yield increases due to the fact that green manure as adds N and has additional beneficial effects on soil properties (Skoufogianni et al., 2013). It is well established that the incorporation of quality organic inputs provides rapid and efficient accumulation of nutrient uptakes for the crop by releasing nutrients in synchrony with plant demands (Martyniuk et al., 2019). The *T. pratense* green manure significantly reduce the weeds density up to 70% compared to the untreated plots in all the three maize hybrids. The results of Dhima et al. (2009) indicated also that green manure of aromatic species can increase the final grain yield by reducing weed infestation in maize crops.

Conclusions

This is one of the first studies evaluating the combined effects of green manure legume crops and hybrid selection on yield performance of maize semi-arid climatic conditions of Greece. The adoption of red clover as green manure crops improved maize grain yield as compared to the corresponding value recorded in untreated plots. Furthermore, the current study also indicated that selecting the appropriate hybrid can lead to increased grain yield. Conclusively, the results of the present study proved that red clover was beneficial for the productivity of maize crop and weeds control under the climatic conditions of Greece.

Matherials and methods

A field experiment was conducted in 2017-2018 (1st year) and repeated in 2018-2019 (2nd year) in the experimental farm of Agricultural University of Athens (37º59′ N, 23º42′ E). The soil of the experimental field is clay loam (CL) with pH 7.29. Typical climatic conditions for Greece were recorded during both experimental years. A split plot design was employed in each growing season in a randomized complete block design with three replicates. Green manure crop were assigned to main plots and maize hybrids were assigned to subplots.

Red clover (*T. pratense* L.) at seed rates of 15 kg ha^{-1} were sown, while an untreated control (without any crop as green manure) was also included. Clover were sown on 19 September 2017 and 24 September 2018. Legume were chopped and ploughed in on 17 March 2018 and 9 March 2019 and the soil was prepared for maize sowing. Three maize hybrids, namely 'Factor' 127-d relative maturity (RM), 'Dracma' 126-d RM, and 'Brasco' 128-d RM were planted on 11 April 2018 and 4 April 2019. The three hybrids have similar biological cycle (FAO 700), plant height (moderate/high) and productivity (stable and high). They were planted in 75 cm rows at an approximate density of about 75 000 seeds ha^{-1}. The size of each subplot was 2.25 m × 3 m. Maize rows were numbered 1 to 4 from left to right. Rows 1 and 4 were border rows, while yield data were collected from rows 3 and no inorganic fertilizers or plant protection products were used. Weed density was measured with small quadrants (0.1m^2), with the dominant weed species being *Chenopodium album*, *Amaranthus retroflexus* and *Echinochloa crus-galli*.

At maize grain maturity (middle of September for both growing seasons), ears of 10 plants of the center rows of each sub plot were hand-harvested and dried at 70 ºC until constant weight was achieved. Grain yield, rows per ear, kernels per row, kernels per plant and 1000 kernel weight were determined while N content was also measured in the grains and protein content determined. All statistical analyses were conducted using the Statsoft software package (Statsoft, Tulsa, Oklahoma, USA).

References & Acknowledgements

1. Adee, E., Roozeboom, K., Balboa, G.R., Schlegel, A., and Ciampitti, I.A. 2016. Drought-tolerant corn hybrids yield more in drought-stressed environments with no penalty in non-stressed environments. Frontiers in Plant Science 7:1534.
2. Ali, K., Munsif, F., Zubair, M., Hussain, Z., Shahid, M., Din, I.U., et al. 2011. Management of organic and inorganic nitrogen for different maize varieties. Sarhad Journal of Agriculture 27:525-529.
3. Astier, M., Maass, J.M., Etchevers-Barra, J.D., Peña, J.J., and González, F. de L. 2006. Short-term green manure and tillage management effects on maize yield and soil quality in an Andisol. Soil and Tillage Research 88:153-159.
4. Dabin, Z., Pengwei, Y., Na, Z., Zheng, W., Changwei, Y., Qunhu, C., et al. 2015. Responses of winter wheat production to green manure and nitrogen fertilizer on the Loess Plateau. Agronomy Journal 107:2361.
5. de Ponti, T., Rijk, B., and van Ittersum, M.K. 2012. The crop yield gap between organic and conventional agriculture. Agricultural Systems 108:1-9.
6. Dhima, K.V., Vasilakoglou, I.B., Gatsis, T.D., Panou-Philotheou, E., and Eleftherohorinos, I.G. 2009. Effects of aromatic plants incorporated as green manure on weed and maize development. Field Crops Research 110:235-241.
7. Guo, S.L., Wu, J.S., Dang, T.H., Liu, W.Z., Li, Y., Wei, W.X., et al. 2010. Impacts of fertilizer practices on environmental risk of nitrate in semiarid farmlands in the Loess Plateau of China. Plant Soil 330:1-13.
8. Inamullah, N.R., Shah, N.H., Arif, M., Siddiq, M., and Mian, I.A. 2011. Correlations among grain yield and yield attributes in maize hybrids at various nitrogen levels. Sarhad Journal of Agriculture 27:531-538.
9. Islam, M.M., Urmi, T.A., Rana, M.S., Alam, M.S., and Haque, M.M. 2018. Green manuring effects on crop morpho-physiological characters, rice yield and soil properties. Physiology & Molecular Biology of Plants 25:303-312.
10. Kadyrov, S., and Kharitonov, M. 2019. Productivity of corn hybrids in relation to the seeding rate. Agronomy Research 17:123-132.
11. Karyoti, A., Bartzialis, D., Sakellariou-Makrantonaki, M., and Danalatos, N. 2018. Effects of irrigation and green manure on corn (Zea mays L.) biomass and grain yield. Journal of Soil Science and Plant Nutrition 18:820-832.
12. Kumar, R., Mahajan, G., Srivastava, S., and Sinha, A. 2014. Green manuring: a boom for sustainable agriculture and pest management-a review. Agricultural Reviews 35:196-205.
13. Lamptey, S., Yeboah, S., Li, L., and Zhang, R. 2017. Dry matter accumulation and nitrogen concentration in forage and grain maize in dryland areas under different soil amendments. Agronomy Research 15:1646-1658.
14. Lichtenberg, E., Shortle, J., Wilen, J., and Zilberman, D. 2010. Natural resources economics and conservation: contributions of agricultural economics and agricultural economists. American Journal of Agricultural Economics 92:469-486.
15. Röös, E., Mie, A., Wivstad, M., Salomon, E., Johannson, B., Gunnarsson, S., Wallenbeck, A., Hoffmann, R., Nilsson, U., Sundberg, C., and Watson, C.A. 2018. Risks and opportunities of increasing yields in organic farming. A review. Agronomy for Sustainable Development 38:14.
16. Salahin, N., Alam, M.K., Islam, M.M., Naher, L., and Majid, N.M. 2013. Effects of green manure crops and tillage practice on maize and rice yields and soil properties. Australian Journal of Crop Science 7:1901.
17. Shah, K.P., and Arif, M. 2000. Management of organic farming: Effectiveness of farmyard manure (FYM) and nitrogen for maize productivity. Sarhad Journal of Agriculture 16:461-465.
18. Sileshi, G., Akinnifesi, F.K., Ajayi, O.C., and Place, F. 2008. Meta-analysis of maize yield response to woody and herbaceous legumes in sub-Saharan Africa. Plant and Soil 307:1-19.
19. Skoufogianni, E., Danalatos, N.G., Dimoyiannis, D., and Efthimiadis, P. 2013. Effects of pea cultivation as cover crop on nitrogen-use efficiency and nitrogen uptake by subsequent maize and sunflower crops in a sandy soil in central Greece. Communications in Soil Science and Plant Analysis 44:1-4.
20. Surma, M., Adamski, T., Banaszak, Z., Kaczmarek, Z., Kuczynska, H., Majcher, M., Lugowska, B., Obuchowski, W., Salmanowicz, B. and Krystkowiak, K. 2012. Effect of genotype, environment and their interaction on quality parameters of wheat breeding lines of diverse grain hardness. Plant Production Science 15:192-203.
21. Tahir, M., Tanveer, A., Ali, A., Abbas, M., and Wasaya, A. 2008. Comparative yield performance of different maize (*Zea mays* L.) hybrids under local conditions of Faisalabad-Pakistan. Pakistan Journal of Life and Social Sciences 6:118-120.
22. Tejada, M., Gonzalez, J.L., García-Martínez, A.M., and Parrado, J. 2008. Effects of different green manures on soil biological properties and maize yield. Bioresource Technology 99:1758-1767.
23. Travlos, I.S. 2010. Legumes as cover crops or components of intercropping systems and their effects on weed populations and crop productivity. p. 151-164. In Greco, A.J. (ed.) Advances in food science and technology. Nova Science Publishers, Hauppauge, New York, USA.
24. Travlos, I.S., Economou, G., and Kanatas, P.J. 2011. Corn and barnyardgrass competition as influenced by relative time of emergence and corn hybrid. Agronomy Journal 103:1-6.
25. Travlos, I.S., Kanatas, P.J., Tsioros, S., Papastylianou, P., Papatheohari, Y., and Bilalis, D. 2014. Effects of legume incorporation and pendimethalin application on oriental sun-cured tobacco. Agronomy Journal 106:1225-1230.
26. Wortman, S.E., Francis, C.A., Galusha, T.D., Hoagland, C., Van Wart, J., Baenziger, P.S., Hoegemeyer, T., and Johnson, M. 2013. Evaluating cultivars for organic farming: Maize, soybean, and wheat genotype by system interactions in Eastern Nebraska. Agroecology and Sustainable Food Systems 37:915-932.