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Relationship between some chemical properties of plant and soil in the cultivation of barley (cv. Torkman) under different fertilization and low-irrigation regimes

S.M. Farahani[a*], M.R. Chaeichi[b]

[a] Department of Crop Production and Plant Breeding, Faculty of Agricultural Sciences, Shahed University, Tehran, Iran.
[b] Department of Crop Production and Plant Breeding, Faculty of Agronomy and Animal Sciences, University of Tehran, Tehran, Iran.

Abstract

The effects of low-irrigation and fertilization systems on some chemical properties of plant and soil under the cultivation of barley were investigated by a split-plot experiment conducted on the basis of a Randomized Complete Block Design in 2007-2008. The main plots were composed of three irrigation levels: no-stress, moderate stress and severe stress. The sub-plots were composed of six fertilization regimes including no-fertilization, the application of Barvar-2 + nitroxin, the application of vermicompost, 50% chemical fertilizer + 50% vermicompost, 50% chemical fertilizer + 50% (Barvar-2 fertilizer + nitroxin), and the application of chemical fertilizer. It was found that the mixture of chemical and organic fertilizer increased soil P content more than other fertilizer combinations. Furthermore, the mixture of fertilizers increased plant N concentration more than other fertilizer treatments. The treatments containing vermicompost increased soil organic C, N and P under all stress levels more than other treatments. Also, this treatment gave rise to higher N concentration in plant under drought stress. Under normal irrigation conditions, biofertilizers increased soil and plant P content more than other fertilization regimes.

Keywords: low-irrigation, vermicompost, biofertilizer, barley, soil properties.

Introduction

Sustained agriculture systems consider the application of organic fertilizers such as vermicompost, manure, and N and P-containing biofertilizers. These fertilizers have been shown to improve soil chemical properties like increasing soil pH, increasing available organic C, K, Ca, P and Mg, and water retention capacity as well as soil biological properties like increasing microbial weight, soil respiration and enzyme activities (phosphatase acid, protease and dehydrogenase) (Oberson *et al.*, 1993; Clark *et al.*, 1998; Berecz *et al.*, 2005; Melero *et al.*, 2006; Courtney and Mullen, 2008; Odlare *et al.*, 2008; Manivannan *et al.*, 2009).

Additionally, soil structure is amended by organic fertilizers or root residues of previous plants and the formation of stable soil particles reduces soil erosion (Emmerling *et al.*, 2000; Ball *et al.*, 2007). Phosphor mineralization occurs more in organically managed soils than in conventional systems (Oehl *et al.*, 2004). Improving chemical properties of soil is mainly related to increasing soil organic matter although Stockdale *et al.* (2002) did not observe any changes in organic matter content of conventional and organically managed systems. Applying P chemical fertilizer (triple-superphosphate), P biofertilizer (cattle manure and biowaste compost) and P combined fertilizer (a combination of P-containing chemical fertilizer and biofertilizer) on a rotation of oilseed rape, barley and wheat, it was found that combined organic-inorganic

*Corresponding author's email: maleki@shahed.ac.ir

Table 1. Physical and chemical properties of soil before the experiment (depth of 0-25 cm)

Bulk density (g cm^{-3})	Organic C (%)	pH	EC (ds m^{-1})	P (mg kg^{-1})	N (%)	K (mg kg^{-1})	Cu (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Fe (mg kg^{-1})
1.58	0.7	8.4	1.02	35.03	0.085	845	2.93	12	12.32	12.2

Table 2. Physical and chemical properties of the studied vermicompost

Organic C (%)	pH	EC (ds m^{-1})	P (mg kg^{-1})	N (%)	K (mg kg^{-1})	Cu (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Fe (mg kg^{-1})
26.90	8.3	7.2	75	2.35	118	55	283	112	3258

fertilization increased soil P content more than other fertilizations (Eichler-Lobermann *et al*., 2007). Furthermore, long-term application of manure and crop residue combined with N fertilizer increased soil organic matter, soil particles stability and soil water retention which were related to the increase in the concentration of humus colloids (Dorado *et al*., 2003). As shown in previous studies, the application of various fertilization systems differently affects soil physical and chemical properties depending on the specific conditions of the region. Since drought stress is known as one of the most important factors threatening the production in Iran and seems to impact soil properties, it is necessary to determine the effect of drought stress on soil chemical properties at different growth stages of barley as a strategic crop in Iran. As shown in previous studies, different chemical, organic and biological fertilizers can differently influence various properties of soil including its chemical, physical and biological characteristics. So far, no study has been carried out on the effect of the application of P supplying bacteria-containing biofertilizers (biofertilizers containing Pseudomonas and Bacillu) and N fixing bacteria-containing biofertilizers (fertilizers containing Azospirillum and Azotobacter) as well as vermicompost organic fertilizer or their combination with chemical fertilizer on soil chemical properties under the condition that the farm is stressed at different growth stages of the plant and farm soil is dried. Assuming that drought stress can differently influence the availability and release of various nutrients from different fertilizer sources, the present study was conducted. Therefore, it was attempted to investigate the effect of low-irrigation and various fertility regimes on chemical properties of soil under the cultivation of barley.

Materials and Methods

The present field study was carried out in research farm of Agriculture and Natural Resources Faculty of Tehran University (Lat. 56°35′ N., Long. 58°50′ E., Alt. 1312 m.) in 2006 and 2007.

The study was a split-plot experiment on the basis of a Randomized Complete Block Design with four replications. The experimental treatments were composed of irrigation as the main plot and fertilization regimes as the sub-plot. The former included three levels of no-stress (normal irrigation up to the end of physiological growth period), moderate stress (irrigation withdrawal from the beginning of anthesis up to the beginning of grain filling) and severe stress (irrigation withdrawal from the beginning of anthesis up to the end of physiological growth period) and the latter included six levels of no fertilization as control (NF), the application of P and N supplying biofertilizers of Barvar-2 and nitroxin (NB), the application of vermicompost at the rate of 5 t.ha-1 (VC), the application of 50% chemical fertilizer + 50% vermicomopst (CV), the application of 50% chemical fertilizer + 50% biofertilizer (CB), and mere application of chemical fertilizer (CF). The normal irrigation was conducted weekly to restore 50% of field capacity in root zone. Irrigation timing was determined by measuring soil moisture percent by weight method. Chemical fertilization levels were calculated according to farm soil analysis (Table 1).

Whole P, K and organic fertilizers and one-third of N fertilizer were added to soil during soil preparation and the remaining of N fertilizer was added as heading during tillering and flowering. Vermicompost as described in Table 2 was added to soil before sowing at the rate of 5 t.ha-1 for mere vermicompost treatment and 2.5 t.ha-1 for

Table 3. Analysis of variance of the effect of year, low-irrigation regime and fertilization on some chemical attributes of plant and soil

Source of variation	df	Means of squares				
		Soil organic C	SoilN	Soil P	Plant N	Plant P
Year	1	0.05 **	0.003 ns	1456.47 **	0.60 **	10.0002 NS
Replication × year	4	0.017	0.0005	8.77	0.009	0.0009
Irrigation regime	2	0.02 ns	0.0002 ns	27.53 ns	0.66 **	0.003 **
Year × irrigation regime	2	0.004 ns	0.0005 *	393.44 **	0.36 **	0.0001 NS
Replication × year × irrigation regime	8	0.007	0.0001	32.06	0.005	0.0004
Fertilizer regime	5	0.004 ns	0.0007 **	94.74 **	0.24 **	0.007 **
Year × fertilizer regime	5	0.004 ns	0.0005 **	49.55 **	0.02 *	0.001 NS
Irrigation regime × fertilizer regime	10	0.007 ns	0.0005 **	81.34 **	0.03 **	0.003 **
Year × irrigation regime × fertilizer regime	10	0.0099 *	0.0006 **	65.17 **	0.03 **	0.003 **
Total error	60	0.004	0.0001	12.55	0.011	0.0005
Coefficient of variations		8.53	13.77	11.46	4.68	6.32

ns: nonsignificant, *: significant at 5% probability level; **: significant at 1% probability level.

combined treatment. The biofertilizers were used as inoculation with seed at sowing date as the prescribed rates.

After the maturity and harvest of plants, combined samples were taken from the soil of the root development zone in order to determine organic C percentage, N percentage and absorbable P concentration of soil. The soil was chemically analyzed in Soil Science Laboratory of Soil Sciences Department of Tehran University, Tehran, Iran. Total N content was measured by Kjeldahl method (Cottenie *et al.*, 1982). P concentration was determined by Vanadate/molybdate yellow method (Page *et al.*, 1982). Combined analysis was conducted on two-year data for analyzing them together. But the coordination of the variances of the studied variables was needed to be uniform before combined analysis for which Bartlett uniformity test was carried out on variances. The results of Bartlett test showed that the calculated Chi-square was lower than table Chi-square in all cases. Therefore, with the assurance that the variances were homogenous, combined analysis was carried out on data. The variance of data was analyzed by SAS software and the significant differences were determined by Duncan method at 5% level.

Results and Discussion

Organic carbon

The effect of year and the interaction between year, irrigation regime and fertilization regimes were significant on soil organic carbon percentage (Table 3). In total, average soil organic carbon was higher at the first year than at the second year which can be related to the mineralization of organic matter in the second year. Drought stress decreased organic matter in NF treatment at the first year which may be associated with the mideralization of organic matter under drought stress. Out of the studied fertilization treatments, the application of vermicompost both alone and mixed with chemical fertilizers (CV and VC treatments) resulted in higher soil organic carbon (Fig. 1).

Also, Pramanik *et al.* (2009) reported that the application of vermicompost increased organic carbon as compared to the application of rock

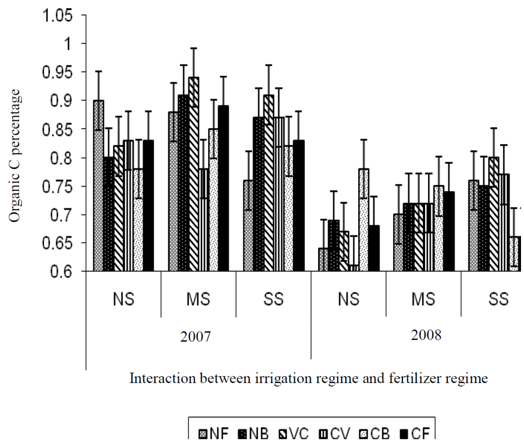

Fig. 1. Interaction between year, irrigation regime and fertilizer regime for soil organic C percentage

NS: no stress (normal irrigation until the end of physiological growth period); MS: moderate stress (irrigation withdrawal from the beginning of flowering until seed filling initiation); SS: severe stress (irrigation withdrawal from the beginning of flowering until the end of physiological growth period); NF: control with no fertilization; NB: application of Barvar-2 fertilizer + nitroxin; VC: application of vermicompost; CV: application of 50% chemical fertilizer + 50% vermicompost; C: application of 50% chemical fertilizer + 50% Barvar-2 and nitroxin; CF: application of chemical fertilizer.

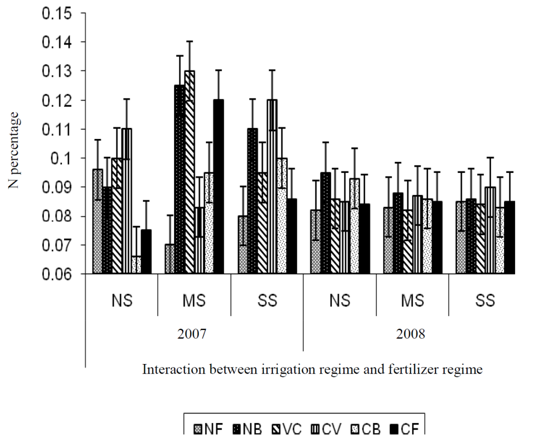

Fig. 2. Interaction between year, irrigation regime and fertilizer regime for soil N percentage

NS: no stress (normal irrigation until the end of physiological growth period); MS: moderate stress (irrigation withdrawal from the beginning of flowering until seed filling initiation); SS: severe stress (irrigation withdrawal from the beginning of flowering until the end of physiological growth period); NF: control with no fertilization; NB: application of Barvar-2 fertilizer + nitroxin; VC: application of vermicompost; CV: application of 50% chemical fertilizer + 50% vermicompost; C: application of 50% chemical fertilizer + 50% Barvar-2 and nitroxin; CF: application of chemical fertilizer.

phosphate alone or no-fertilization control treatment. Soil carbon percentage was increased under all fertilization treatments except combined treatment of biofertilizer and chemical fertilizer and the treatment of chemical fertilizer alone at the second year.

Soil nitrogen

The effect of all factors except year and irrigation regime was significant on soil N percentage (Table 3). Biofertilizer application enhanced soil N content and after that, the combined treatments had the highest soil N content (Fig. 2). N content was lower in the treatment of chemical fertilizer alone under normal irrigation than other fertilizer treatments. N chemical fertilizer can readily dissolve in soil water. The decrease in N content under chemical fertilizer treatment augurs more N leaching under regimes in which chemical fertilizer is applied alone. But, in such treatments as CV and VC where vermicompost was applied N content was higher with the increase in stress than in combined treatment of biofertilizer and chemical fertilizer alone. It appears that higher N content in vermicompost-containing treatments was resulted from more retention of N in soil and lower leaching caused by the increase in organic matter and humus colloids (Dorado *et al.*, 2003).

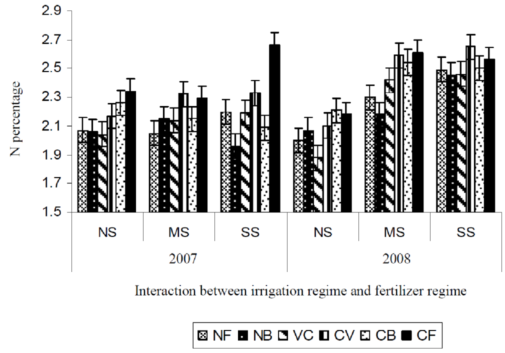

Fig. 3. Interaction between year, irrigation regime and fertilizer regime for plant N percentage

NS: no stress (normal irrigation until the end of physiological growth period); MS: moderate stress (irrigation withdrawal from the beginning of flowering until seed filling initiation); SS: severe stress (irrigation withdrawal from the beginning of flowering until the end of physiological growth period); NF: control with no fertilization; NB: application of Barvar-2 fertilizer + nitroxin; VC: application of vermicompost; CV: application of 50% chemical fertilizer + 50% vermicompost; C: application of 50% chemical fertilizer + 50% Barvar-2 and nitroxin; CF: application of chemical fertilizer.

Plant nitrogen

The effect of all studied factors was significant on plant N percentage (Table 3). As stress was intensified, plant N concentration was increased at both years so that N content was higher at severe stress than at other irrigation regimes under all fertilizer treatments (Fig. 3). At the first year, the application of fertilizer alone increased N concentration in plant (by 2.5%) more than other treatments, but at the second year, plant N concentration was higher under combined fertilizer treatment than other treatments (Fig. 3). The application of organic fertilizers resulted in significant differences in plant N content compared to control at both years.

The application of chemical fertilizer at the first year provided the plants with more available N because of the lower leaching caused by shorter growth period and consequently, N concentration of seeds was increased. But at the second year, more N was leached and the application of chemical fertilizer alone was not able to be as efficient as that at the first year. Therefore, combined fertilization especially combined vermicompost fertilizer (CV) was more efficient in providing plants with N and more nutrients, particularly under stress conditions by increasing soil water retention and more mineralization (higher oxidation rate due to drought or longer

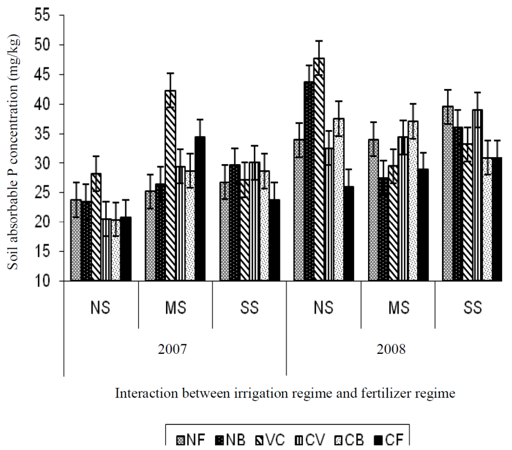

Fig. 4. Interaction between year, irrigation regime and fertilizer regime for soil absorbable P concentration

NS: no stress (normal irrigation until the end of physiological growth period); MS: moderate stress (irrigation withdrawal from the beginning of flowering until seed filling initiation); SS: severe stress (irrigation withdrawal from the beginning of flowering until the end of physiological growth period); NF: control with no fertilization; NB: application of Barvar-2 fertilizer + nitroxin; VC: application of vermicompost; CV: application of 50% chemical fertilizer + 50% vermicompost; C: application of 50% chemical fertilizer + 50% Barvar-2 and nitroxin; CF: application of chemical fertilizer.

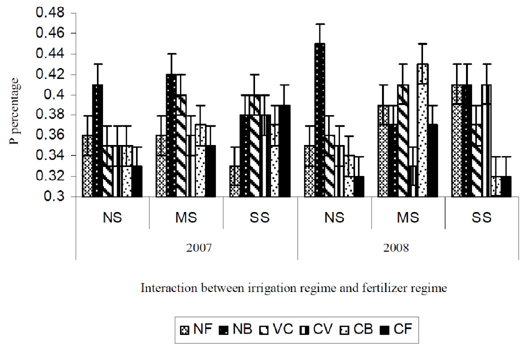

Fig. 5. Interaction between year, irrigation regime and fertilizer regime for plant P concentration

NS: no stress (normal irrigation until the end of physiological growth period); MS: moderate stress (irrigation withdrawal from the beginning of flowering until seed filling initiation); SS: severe stress (irrigation withdrawal from the beginning of flowering until the end of physiological growth period); NF: control with no fertilization; NB: application of Barvar-2 fertilizer + nitroxin; VC: application of vermicompost; CV: application of 50% chemical fertilizer + 50% vermicompost; C: application of 50% chemical fertilizer + 50% Barvar-2 and nitroxin; CF: application of chemical fertilizer.

growth period). The insignificant increase in plant N concentration with the application of organic fertilizers as compared to control implies that these fertilizers provided less N inputs for plants growth which can be associated with lower mineralization rate and/or noncoincidence of N provision with nutritional requirements of the plants in the case of vermicompost fertilization. In the case of biofertilizer, it can be associated with the fact that Azotobacter and Azospirillum of nitroxin biofertilizer are of growth stimulators so they increased barley growth by releasing the hormones with no increase in plant N content. The increase in N concentration under stress has been mentioned by many researchers (Haberle *et al.*, 2008). This increase in grain N concentration is caused by the loss of yield under stress and indeed, shows the dilution of the concentration of nutrients in plant with the increase in yield (Feil *et al.*, 2005).

Soil phosphor

All factors except irrigation regime influenced soil absorbable P concentrations significantly (Table 3). As stress was increased, P content was increased under the treatments of conventional fertilizer, combined vermicompost + chemical fertilizer and control (Fig. 4).

Also, Eichloer-Lobermann *et al.* (2007) found that the application of chemical fertilizer + organic fertilizer in a rotation of rapeseed-barley-wheat increased soil P content as compared to other fertilizer treatments.

Vermicompost-containing fertilizers increased soil P more than other treatments under all stress levels. Biofertilizers increased P content more than other fertilizations under normal irrigation conditions which can be related to soil P dissolution by applied bacteria. Stress decreased P content in this treatment which was probably associated with the decreased activity of bacteria under stress. It seems that the reduced growth and P uptake by plants after the stress resulted in higher soil P. The decreased P content can be related to the deposit of P as insoluble compounds in soil, too.

Plant phosphor

Plant P percentage was influenced by irrigation regime, fertilizer regime, the interaction between irrigation and fertilizer regime, and the interaction among year, irrigation regime and fertilizer regime (Table 3). Fertilizer treatments impacted P content, so that the application of biofertilizers resulted in the highest P content (Fig. 5). At the first year, the increase in stress increase plant P content under all fertilizer treatments except the application of biofertilizer alone and control (Fig. 5). It implies that conventional, combined and vermicompost fertilizer treatments were able to supply the required P under stress at the first year among which vermicompost was especially capable of supplying more P probably due to greater mineralization under severe drought stress and on the other hand, the stunted growth under stress increased P concentration in plants. Higher P content under biofertilizer treatment reveals that Bacillus lentus and Pseudomonas putida of Barvar-2 fertilizer were of phosphate-dissolving bacteria because they increase plant P content. But it did not happen under the combined application of biofertilizer in which higher soil P content caused by the application of chemical fertilizer slowed down the activity of bacteria in this treatment. Canbolat *et al.* (2006) reported similar results. Nonetheless, the efficiency of biofertilizer was decreased under severe stress which can be related to the reduced activity of dissolving bacteria (Rehman and Nautiyal, 2002). These two factors, i.e. higher P content of soil under the combined application of biofertilizer and the reduced activity of bacteria under drought stress, resulted in lower efficiency of this fertilizer under severe stress at both years as compared to moderate stress and to combined application of vermicompost under severe drought stress. The efficiency of conventional treatment and combined application of biofertilizer was lower at the second year than at the first year. It can be related to greater fixation of P in soil in conventional treatment owing to longer growth period.

In total, stress increased P concentration in plants and combined application of vermicompost provided the plants with more P than the conventional treatment. But under normal conditions, biofertilizer resulted in the higher uptake and storage of P (43%) in plant which may show that optimum level of soil P was available for the activity of phosphate-dissolving bacteria; otherwise, this fertilizer would not have an acceptable efficiency (Kirchmann and Ryan, 2004).

Conclusion

Drought stress can enhance soil and plant N by reducing leaching in conventional systems and stimulating the mineralization of organic matters in organic or combined systems. The application of organic fertilizers like vermicompost alone or in combination can prevent nutrients leaching from by increasing its water retention capacity, exchange capacity and N and P content in addition to organic C percentage of soil. Then, it can reduce the contamination of underground waters by enhancing the chemical fertilizers use efficiency. The concentrations of nutrients in soil and plant were shown to be directly related. In total, the comparison of fertilizer treatments revealed that vermicompost-containing fertilizers can provide nutrients for the growth of plants in a wide range of soil conditions. Changing organic matter of soil needs long-term application of fertilizers. As Dorado *et al.* (2003) stated, the positive effects of the application of organic fertilizers on increasing organic matter of soil are realized in their long-term application. Therefore, it seems that restoring low-efficient soils by the application of combined fertilizers can benefit the ecophysiology of plants growth and development in arid and semiarid regions.

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