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Changes of the Growth Rate of Wheat and Canola with Soil Amendments Application in Crop Rotation

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Abstract

Integrated nutrient management in crop rotation conditions (Canola-Soybean-Wheat) is important for farm management. Four years of field experiments were conducted to assess the effects of organic and inorganic soil fertility amendments on crop growth and soil physiochemical properties during 2014–2018. The experiments were carried out based on a randomized complete block design, with the split-plot arrangement of treatments and three replications. Two crop rotations (Canola-Soybean-Wheat; Canola-Wheat) were randomized to the main plot units and nine fertilization management (F_1: urea, F_2: urea + zeolite, F_3: composted manure, F_4: composted manure + zeolite, F_5: urea + composted manure, F_6: urea + composted manure + zeolite, F_7: urea + azocompost, F_8: urea + azocompost + zeolite and F_9: control) were randomized to the sub-plots. The maximum dry matter and the growth rate at linear phase were estimated in F_6 fertilizer treatment for canola (665.05 g m^{-2} and 6.67 g $m^{-2} d^{-1}$) and wheat (716 g m^{-2} and 7.19 g $m^{-2} d^{-1}$), respectively. The maximum soil organic carbon (SOC) was observed in the second year of the experiment by the integrated fertilizing management ($F_6 = 1.26\%$) while the lowest SOC was observed in control ($F_9 = 0.65\%$). Application of zeolite in all of the experimental treatments resulted in higher soil cation exchange capacity (CEC). The maximum soil K (115.23 ppm), P (113.73 ppm), Zn (10.07 ppm) and Mn (12.35 ppm) were observed in organic treatments incorporated with zeolite (F_4). Our study found that application of organic amendments such as azocompost and manure composts incorporated with chemical fertilizer and zeolite can be recommended to improve soil fertility and growth properties of wheat and canola crops.

Keywords Azocompost · Cattle manure compost · Growth analysis · Soil physicochemical properties · Zeolite

Introduction

Soil degradation is the results of intensive agriculture activities without considering environmental cares especially in the semi-arid area regions of Iran. This also negatively influenced sustainable productivity of agronomic crops. SOC is the source of energy for soil microbial activities and processes (Reeves 1997; Woomer et al. 1994). Among the soil management practices, adding organic amendments is important for enhancing the soil quality (Celik et al. 2010). The addition of organic materials such as manure or *Azolla* improves soil chemical, physical and biological properties and hence reduces soil compaction, erosion and degradation (Bandyopadhyay et al. 2010; Yousefzadeh et al. 2013).

Alternative nutrition management, such as integrated nutrient fertilizer management leads to increase crop productivity and minimizes the environmental devastation (Conacher and Conacher 1998; Reganold 1995). Composting manure improves soil structure for root growth and drainage, increases total porosity, soil water retention, soil nutrients, caution exchange capacity, and greater biological activity by supplying carbon and energy to soil organisms (Goladi and Agbenin 1997). Azocompost is the newly amendment used by the producers for enhancing phosphorus and potassium of soil and crop production (Yousefzadeh et al. 2013). Also, the indiscriminate use of chemical fertilizers and the resulting environmental damages made it essential to shift to utilizing organic fertilizers and soil amendments for increasing fertilizer efficiency in sustainable agriculture (Heidarzadeh et al. 2021).

Data Availability Statement The data that support this study cannot be publicly shared due to ethical or privacy reasons and may be shared upon reasonable request to the corresponding author if appropriate.

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Zeolite is a soil enhancer material with high ion-exchange capacity. Application of zeolite in the soil, prevents unnecessary losses of nutrients, besides, they are good carriers and regulators of mineral fertilizers. Some of the properties of zeolite such as high cation exchange capacity, easy incorporation with soil and water retention make them in favor to be used in agricultural farms (Ok et al. 2003; Baghbani-Arani et al. 2017). The researchers also showed that the integration of zeolite in fertilizer management systems preserved nutrients in the rhizosphere (Akbari et al. 2021).

Crop rotation is an agronomic management tool in ecological science. This could play an important role in maintaining soil fertility and sustaining crop production by increasing mineral nitrogen in the soil of the root zone. Crop rotation of legumes-cereals increased the yield and quality of seeds due to the increase of soil nitrogen by legumes (Galantini et al. 2000). Crop sequence improves soil properties such as porosity and structure formation and breaks cycles related to pathogens and weeds (Franzluebbers et al. 1995).

Growth analysis with the physiological parameters is an important tool to establish the nutritional needs of crops. Leaf area index (LAI) is a useful parameter that shows the photosynthetically active radiation rate absorbed by the canopy (Muchow 1988). LAI affects the total amount of CO_2 assimilated; thus, dry matter is a function of the leaf area. To increase dry matter, a larger and a longer duration of LAI are required (Muchow 1988). Thus, crop physiologists with quantifying growth could be understood differences among treatments.

The objectives of this study were evaluated the impacts of different nutrition management on soil physicochemical properties, specify the length of the growth period and quantifying dry matter accumulation and LAI for understanding the differences among fertilization strategies under canola-soybean-wheat crop rotation.

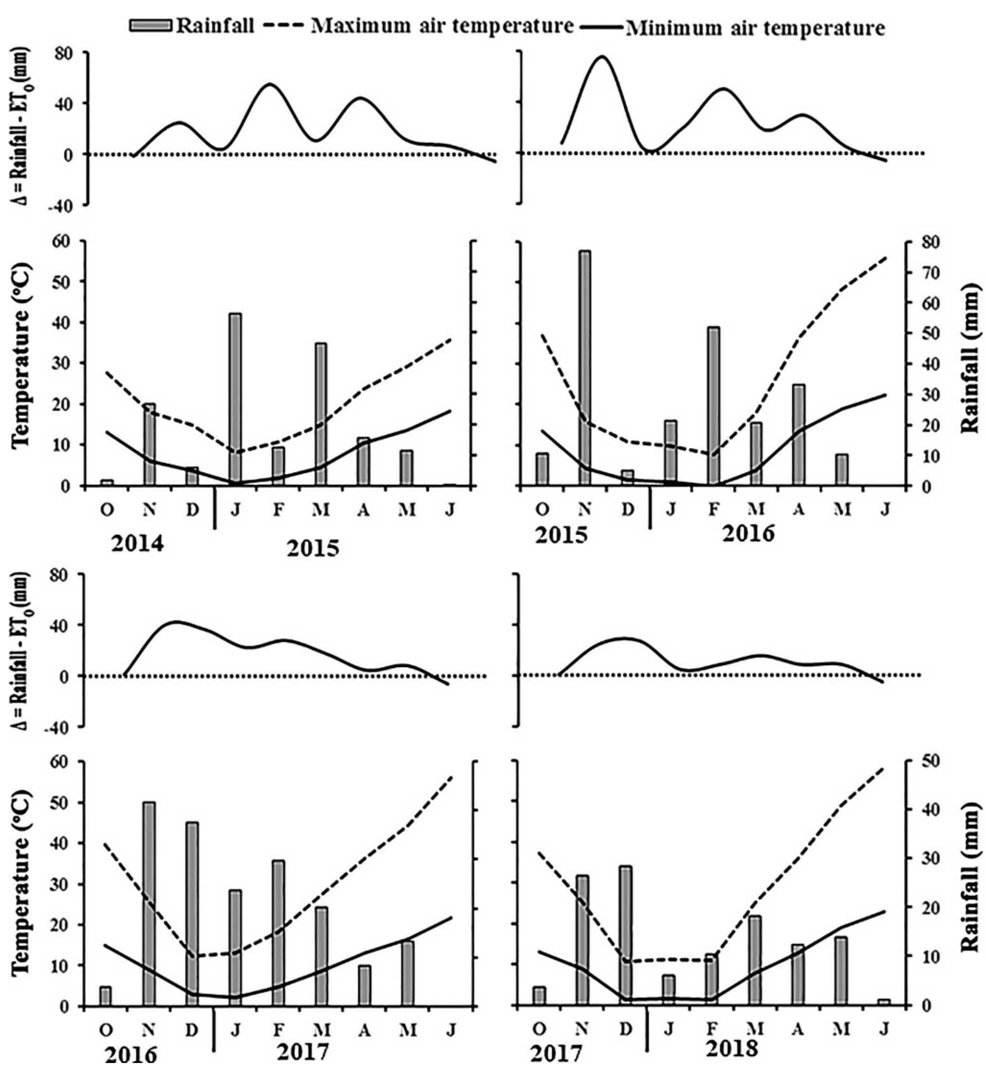

Fig. 1 Rainfall, minimum and maximum air temperature, and Δ (rainfall—evapotranspiration) at the experimental site of the October-July period from 2014/2015 to 2017/2018

Materials and Methods

Site Description; Climate and Soil

The study was conducted during four consecutive growing seasons (from 2014 to 2018) at the experimental farm of Tarbiat Modares University, Tehran, Iran (35°44′ N, 51°19′ E, 1215 ASL) on the poorly drained sandy-loam soil. This site was characterized by a semi-arid climate having relatively hot summers and cold winters with a mean annual precipitation of 289 mm which mostly occurs during the fall and winter seasons. Weather data (minimum and maximum temperatures, precipitation and evapotranspiration) were collected from the nearest meteorological station (Chitgar—Tehran, Iran) (Fig. 1). Soil samples were prepared before cultivation from the depth of 0–30 cm. Samples were mixed together, air-dried, crushed and prepared for the determination of physicochemical properties (Table 1).

Land Preparation and Description of Treatment

Research farm was subjected to shallow plowing in Sep 2014 following disking to be fully prepared for cultivation practice. Chemical weed was controlled by applying Trifluralin (3.5 lit/ha) and then incorporating it into the soil using a disk. The dimension of plots was 12 m^2 (4 m × 3 m), and the distance between each plot was considered 1 m. There were 2 m distance between the blocks and 1 m alley was established between each plot to prevent any interferences. A split-plot experiment was conducted based on a randomized complete block design with three replications. Main plots were two crop rotations including CR_1: Canola-Soybean-Wheat and CR_2: Canola-Wheat. The Subplots were different fertilizer treatments including: 140 and 120 kg ha^{-1} N as urea (F_1); 140 and 120 kg ha^{-1} N as urea plus 8 ton ha^{-1} zeolite (F_2); 140 and 120 kg ha^{-1} N as composted manure (F_3); 140 and 120 kg ha^{-1} N as composted manure plus 8 ton ha^{-1} zeolite (F_4); 70 and 60 kg ha^{-1} N as urea +70 and 60 kg ha^{-1} N as composted manure (F_5); 70 and 60 kg ha^{-1} N as urea +70 and 60 kg ha^{-1} N as composted manure plus 8 ton ha^{-1} zeolite (F_6); 70 and 60 kg ha^{-1} N as urea +70 and 60 kg ha^{-1} N as azocompost (F_7); 70 and 60 kg ha^{-1} N as urea +70 and 60 kg ha^{-1} N as azocompost plus 8 ton ha^{-1} zeolite (F_8) for canola and wheat, respectively, and no organic and chemical fertilization (F_9). Manure compost and azocompost (F_3, F_4, F_5, F_6, F_7 and F_8) were applied in the autumn and incorporated with soil (depth of 15 cm) by hand before planting. Chemical fertilizer was divided into three parts which were applied at three different stages (Plantation, stem elongation and flowering initiation). Based on soil chemical properties, there was no need for phosphorus and potassium fertilizer. Planted cultivars were Okapy (*Brassica napus* L.); Pishtaz (*Triticum aestivum* L.) and Williams (*Glycine max* (L.) Merr.). Planting dates were: Canola: October 12th, 2014 and October 31th, 2016; Wheat: November 5th, 2015 and November 6th, 2017; Soybean in the first crop rotation was planted for four years with planting date of June 18th, 24th, 26th and 25th in 2015, 2016, 2017 and 2018 respectively. Plant density was as followed: Canola: 84 plants m^{-2}; Soybean: 45 plants m^{-2} and wheat 250 plants m^{-2}. Immediately after sowing the soil was irrigated. Polyethylene pipes and counter were used to manage irrigation water.

Table 1 Initial soil chemical and textural properties of the experimental field

Property	Depth 0–30 cm
Soil texture (%)	
Sand	65
Silt	23
Clay	12
Chemical	
pH	7.1
Organic matter (%)	0.86
Electrical Conductivity (dS m^{-1})	0.97
Cation exchange capacity (meq 100^{-1} g)	2.7
Available N (mg kg^{-1})	2.01
Available P (mg kg^{-1})	30.4
Available K (mg kg^{-1})	192.4
Available Fe (mg kg^{-1})	6.9
Available Zn (mg kg^{-1})	1.2
Available Cu (mg kg^{-1})	0.5

Zeolite, Composting Manure and Azocompost

A known amount of fresh manure was placed in some separate rows (12 m long, 3 m width and 1 m height). In order to protect the rows from direct sunlight, all of the rows were covered by herbal straw. Temperature and moisture were daily controlled under aerobic condition until the end composting procedure (day 90th). At the end of the composting process one composite sample of each row was collected

Table 2 Chemical analysis of cattle manure after composting

Parameters	Year 2014	2015	2016	2017
Moisture (%)	7.2	8.1	7.5	6.9
Nitrogen wasting during composting (%)	33	29	30	34
Total N after composting (%)	0.81	0.89	0.77	0.79
Organic nitrogen (%)	0.63	0.80	0.60	0.68
NH_4^+ (%)	0.14	0.11	0.15	0.13
NO_3^- (%)	0.006	0.009	0.002	0.004
Available nitrogen (%)	0.34	0.41	0.31	0.32

Table 3 Physicochemical properties of azocompost

Parameters	Year 2014	2015	2016	2017
pH (H_2O)	8.2	7.9	8.0	7.7
Organic matter (%)	26.7	28.2	30.4	28.8
Organic carbon (%)	15.5	17.1	18.4	17.3
Electrical Conductivity ($dS\,m^{-1}$)	1.9	2.2	2.4	1.7
C:N	12.4	11.0	9.1	10.2
Available N (%)	1.2	1.7	2.1	1.8
Available P (%)	0.53	0.81	0.71	0.59
Available K (%)	0.79	0.90	0.49	0.83
Available Fe (mg kg^{-1})	1177	954	871	923
Available Zn (mg kg^{-1})	28.8	36.7	20.7	31.8
Available Cu (mg kg^{-1})	33.0	23.4	20.7	21.4
Available Mn (mg kg^{-1})	360	440	570	410

and analyzed in each year (Table 2). Azocompost were purchased from Salem Saze Mohite Gil Research Production Company, (Gilan, Iran). The physiochemical analysis of azocompost is shown in Table 3. Zeolite was prepared from the Myaneh mines in the northwest of Iran. Chemical properties of zeolite with X-ray Spectrophotometry are shown in Table 4. Composted manure and azocompost were applied on the basis of the assumption that 20 and 15% of the N in composted manure and azocompost will become available for crops in the first year after application, respectively (Yousefzadeh et al. 2013). The amounts of composted manure, azocompost and zeolite applied for each treatment in each year are given in Table 5.

Dry Matter Accumulation (DMA) and Leaf Area Index (LAI)

With considering the marginal effect, five crops from each plot and each replication were sampled every two weeks from 30 days after emergence to harvesting for measuring DMA and LAI. Leaf area index was measured with a leaf area meter (Delta-T area meter; Delta-T Devices Ltd., Cambridge, UK). Averages of the five crops per plot in two years were used for statistical analysis.

Soil Sampling and Analysis

Three soil samples were collected from 0–30 cm depth at each plot after harvesting crops. Soil samples were composited for each plot and were sealed in plastic bags and transported to the Soil and Plant Laboratory at the University of Tarbiat Modares for analyzing soil chemical and physical properties including: soil organic carbon, phosphorus, cation exchange capacity, electrical conductivity (EC), potassium (Manteghi 1986), and nitrogen, manganese and zinc (Page 1982).

Regression Analysis

In order to describe the trend of dry matter (w) against days after planting (t) the truncated expolinear function was used (Goudriaan and Monteith 1990; Yin et al. 2003):

$$w = \begin{cases} \frac{c_m}{r_m} \ln\left(1 + e^{r_m(x - t_o)}\right) & if \quad x < t_o + w_{\max}/c_m \\ w_{\max} & if \quad x \geq t_o + w_{\max}/c_m \end{cases}$$

where is w_{max} is the maximum dry matter accumulation, the c_m and r_m are maximum growth rate in the linear phase and maximum relative growth rate (RGR) in the exponential phase, respectively and t_o is the lost time when linear phase effectively begins.

The beta function was used for describing the trend of changing in LAI at during the growing season. The beta function was determined as follows (Yin et al. 2003):

$$y = l_{\max}\left[\left(\frac{t_e - x}{t_e - t_m}\right)\left(\frac{x - t_b}{t_m - t_b}\right)^{\frac{t_m - t_b}{t_e - t_b}}\right]^{\delta}$$

where is in this model, x is days after planting, y is the leaf area index, l_{max} is the maximum leaf area index, which is achieved at time t_m, t_b and t_e are times at the beginning and end of the growth period, respectively.

Statistical Analysis

PROC GLM was used to compare the effects of year, crop rotation and fertilizer treatments on soil physiochemical properties. The assumptions of variance analysis were tested by ensuring that the residuals were random, homogenous, and with a normal distribution about the mean

Table 4 Zeolite chemical properties

	CaO %	MgO	Na_2O	Al_2O_3	SiO_2	P_2O_5	TiO_2	MnO	K_2O	Fe_2O_3
Value	2.3	0.1	1.1	12	65	0.01	0.03	0.04	3	1.5

Cation exchange capacity = 200 meq 100^{-1} g

Table 5 The amount of composted manure, azocompost and zeolite application according to soil nitrogen content

Treatments	Available soil nitrogen (kg ha^{-1})				Urea application (kg ha^{-1})				Composted manure application (t ha^{-1})				Azocompost application (t ha^{-1})				Zeolite application (t ha^{-1})			
	2014	2015	2016	2017	2014	2015	2016	2017	2014	2015	2016	2017	2014	2015	2016	2017	2014	2015	2016	2017
F_1	26	25	24	23	247	205	250	210	–	–	–	–	–	–	–	–	–	–	–	–
F_2	26	27	27	25	247	200	244	205	–	–	–	–	–	–	–	–	8	–	8	–
F_3	26	37	41	42	–	–	–	–	18	11	13	10	–	–	–	–	–	–	–	–
F_4	26	38	42	44	–	–	–	–	18	11	13	10	–	–	–	–	8	–	8	–
F_5	26	38	39	40	124	88	109	86	9	5	6.7	5	–	–	–	–	–	–	–	–
F_6	26	44	45	45	124	82	102	80	9	5	6.3	5	–	–	–	–	8	–	8	–
F_7	26	38	40	39	124	88	108	88	–	–	–	–	3	1.5	1.5	1.4	–	–	–	–
F_8	26	44	44	44	124	81	103	82	–	–	–	–	3	1.4	1.5	1.3	8	–	8	–
F_9	26	16	9	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

of zero. Bartlett's tests showed homogeneity of variance for all traits in all year. Means were compared using the LSD test at the probability level of $p \leq 0.01$ and $p \leq 0.05$.

Results and Discussion

Total Dry Matter (TDM) and Leaf Area Index (LAI)

Parameter values of the truncated expolinear function fitted to the dry matter data on the growing seasons are shown in Figs. 2 and 3 for canola and wheat, respectively. The maximum dry matter (w_{max}) and the maximum growth rate in the linear phase (c_m) were estimated in F_6 fertilizer treatment in canola (665.05 g m^{-2} and 6.67 g m^{-2} d^{-1}) and wheat (716 g m^{-2} and 7.19 g m^{-2} d^{-1}), respectively (Figs. 2 and 3). In addition, t_0 was lower in F_6 and F_8 than the other chemical, organic and integrated fertilizer treatments in both crops. The maximum dry matter in the F_6 fertilizer treatment was higher by 13 and 12% compared with the F_2 fertilizer treatment in canola and wheat, respectively. Application of zeolite increased the maximum dry matter (w_{max}) by 7% in F_4 and 12% in F_2, F_6 and F_8 (Figs. 2 and 3). The trend of changes in LAI and parameter estimates for the beta function fitted to LAI are shown in Figs. 2 and 3 for canola and wheat, respectively. Using the beta function, the maximum leaf area index (l_{max}), was higher in F_6 than the other fertilizer treatments in canola (4.90) and wheat (5.17). The arriving time to the maximum LAI (t_m) was lower compared to the other treatments in both crops (Figs. 2 and 3). Leaf growth under chemical fertilizer treatments ended earlier compared with the integrated fertilizer treatments. In the other words, canola and wheat had a greater leaf area duration under organic and chemical fertilizer treatments.

A higher significant value obtained for leaf area and dry matter in this study for the integrated nutrient management show that at super-optimal nutrient conditions, these parameters will be increased. In this research, the application of manure compost and azocompost alone or along with inorganic fertilizer promoted soil nutrient availability (Table 7). Therefore, crop fertilized with organic amendments grew better than those fertilized with inorganic fertilizer. These results are consistent with previous studies (Vats et al. 2001). In this study better crop growth observed under integrated nutrient management enables the crops to produce more leaves and leaf area. The previous study suggested that increasing of leaf area index led to higher photosynthetic activities and the more dry matter is produced (Dreccer et al. 2000). Thus, integrated fertilizer treatments combined with zeolite (especially F_6 and F_8) with increasing nutrient availability and leaf area duration led to higher photosynthesis and biomass accumulation.

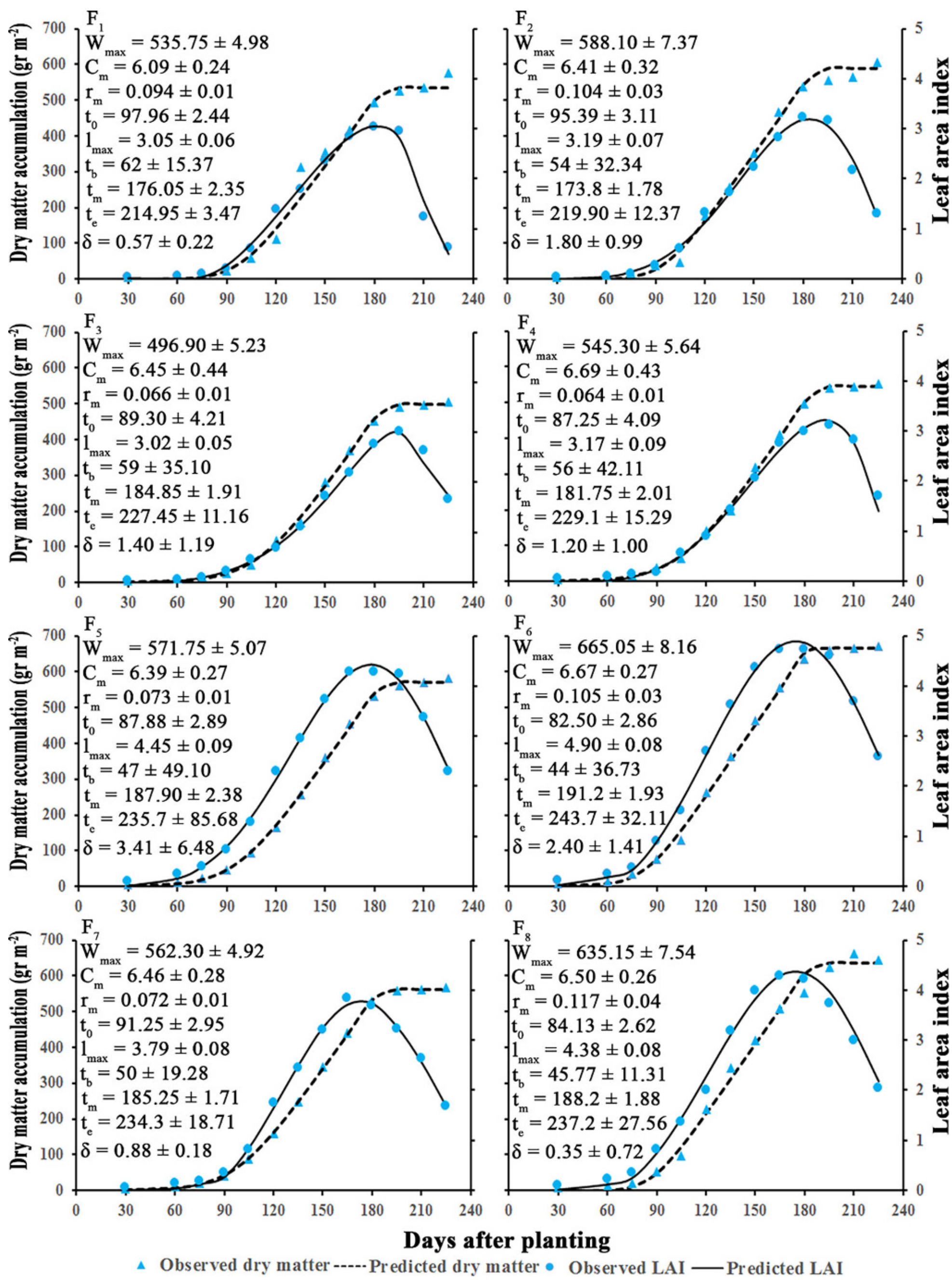

Fig. 2 Parameter estimates, observed and predicted values from the truncated expolinear function and the beta function for dry matter and leaf area of canola (*Brassica napus* L. c.v 'Okapy'), respectively

Soil Organic Carbon (SOC), Cation Exchange Capacity (CEC) and Electrical Conductivity (EC)

SOC, CEC and EC were significantly influenced by the main effect of fertilizer treatments and interaction effects of fertilizer treatments × year (Table 6). The maximum SOC was observed in the second year by the integrated fertilizing management (F_6 = 1.26%) while the lowest SOC was observed in control (F_9 = 0.65%). In all organic and integrated treatments, at the second year of experiments exhibited higher SOC compared to the first year. The highest changes of SOC were observed in F_4 (9%) organic treatment (Table 7). In chemical fertilizers, SOC was reduced by 20% and 11% in F_1 and F_2 respectively. Also, SOC in the control treatment was reduced by 13% in the second year of experiments (Table 7). The maximum CEC was observed in the second year by the F_6 fertilizing management (11.63 meq 100 g^{-1}) while the lowest CEC was observed in control (F_9 = 0.80 meq 100 g^{-1}). There was no significant difference between integrated fertilizer treatments in both years (F_6 and F_8). Application of zeolite in all of the experimental treatments resulted in higher soil CEC. The highest changes in CEC were observed in the F_6 (54%) fertilizer treatment (Table 7). The maximum soil EC was

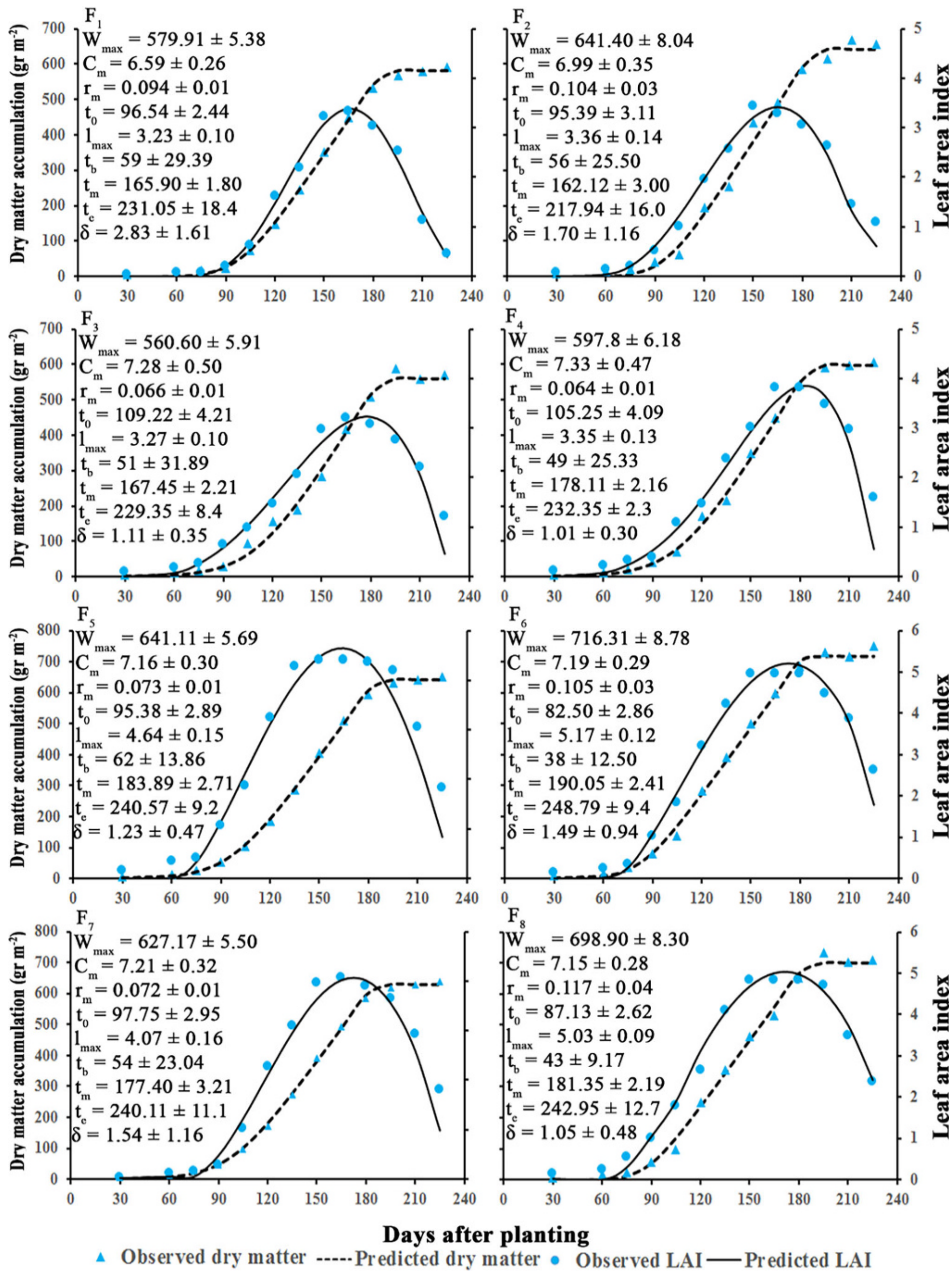

Fig. 3 Parameter estimates, observed and predicted values from the truncated expolinear function and the beta function for dry matter and leaf area of wheat (*Triticum aestivum* L. c.v 'Pishtaz'), respectively

observed in the second year by the organic fertilizing treatments ($F_4 = 1.294$ mmoh cm^{-1}) while the lowest EC was observed in control ($F_9 = 0.574$ mmoh cm^{-1}). Soil EC was increased in the second year of the experiment by the organic and integrated fertilizers while in chemical fertilizer without zeolite and control soil EC was reduced (Table 7).

Our results clearly showed that azocompost and manure fertilizer application had a great positive impact on SOC and CEC. We also found that the zeolite application in chemical, organic and integrated fertilizer management significantly improved CEC. Similar results have been reported by other experiments (Bandyopadhyay et al. 2010; Gholamhoseini et al. 2012). In this study, the accumulation rate of SOC content ranged from 0.654% (in F_9 treatment) to 1.264% (in F_6 treatment), respectively, after four years continuous cropping (Table 7). These results showed that organic amendments application could accelerate the accumulation of SOC. These findings consistent with previous reports. Previous reports showed organic fertilizer alone or in combination with inorganic fertilizer has increased the overall SOC (Liang et al. 2012; Xin et al. 2016). The electrical conductivity ranged between 0.574 to 1.298 mmoh cm^{-1} in F_9 (control treatment) and F_4 (organic fertilizer), respectively (Table 7). A previous study reported that plots re-

Table 6 Analysis of variance (mean squares) for the effects of different parameters (year, crop rotation and fertilizer treatments) on the measured traits in canola [a]

Source of variance	DF	N	K	P	Mn
Year (Yr)	1	0.00145NS	297.70*	306.16*	3.06366NS
Replication × Yr	4	0.00041	25.83	32.22	0.97300
Crop rotation (CR)	1	0.00288NS	78.35NS	20.68NS	0.08613NS
Yr × CR	1	0.00040NS	0.0014NS	17.28NS	0.00204NS
Replication (Yr × CR)	4	0.00130	25.94	17.96	1.33324
Fertilizer treatments (FT)	8	0.02891**	5187.22**	4927.15**	59.91807**
CR × FT	8	0.00019NS	32.23NS	57.18NS	0.55538NS
Yr × FT	8	0.00036NS	68.26NS	70.45NS	0.56903NS
Yr × CR × FT	8	0.00010NS	9.19NS	3.94NS	0.09637NS
Error	64	0.00021	106.68	35.78	0.54004
CV (%)	–	11.42	12.52	7.19	9.03
Source of variance	DF	Zn	*SOC*	*CEC*	*EC*
Year (Yr)	1	1.14330NS	0.00087NS	53.0040**	0.02285NS
Replication × Yr	4	1.23743	0.01870	2.51570	0.17286
Crop rotation (CR)	1	0.18517NS	0.09756NS	0.36284NS	0.01412NS
Yr × CR	1	0.00202NS	0.00104NS	0.16803NS	0.00289NS
Replication (Yr × CR)	4	0.49917	0.03171	1.15170	0.16898
Fertilizer treatments (FT)	8	24.0686**	0.35014**	151.953**	0.41028**
CR × FT	8	0.20037NS	0.00174NS	0.37616NS	0.00236NS
Yr × FT	8	0.31821NS	0.02387*	11.2300**	0.01229*
Yr × CR × FT	8	0.02069NS	0.00111NS	0.26703NS	0.00040NS
Error	64	0.44953	0.00999	0.37268	0.00548
CV (%)	–	8.97	10.04	4.69	8.53

* Significant at the 0.05 probability levels.

** Significant at the 0.01 probability levels

NS not significant at the 0.05 or 0.01 probability levels

[a]Statistical analysis of soil nitrogen (N), soil potassium (K), soil phosphorus (P), soil manganese (Mn), soil zinc (Zn), soil organic carbon (SOC), soil cation exchange capacity (CEC) and soil electrical conductivity (EC)

Table 7 Mean comparison of interaction effects of year × fertilizer treatments

	SOC		*CEC*		*EC*	
	%		Meq 100 g^{-1}		Mmoh cm^{-1}	
Fertilizer treatments [a]	2015	2017	2015	2017	2015	2017
F_1	0.8763 e [b]	0.7315 cd	1.66 d	1.20 e	0.702 e	0.654 c
F_2	0.9378 de	0.8423 c	6.30 b	8.72 c	0.740 de	0.789 c
F_3	1.0018 cd	1.0596 b	3.18 c	3.04 d	1.18 a	1.208 a
F_4	1.0453 bc	1.1428 ab	6.42 b	9.78 b	1.255 a	1.294 a
F_5	1.0111 cd	1.0498 b	2.74 c	2.46 d	0.834 bc	0.839 b
F_6	1.1883 a	1.2641 a	7.57 a	11.63 a	0.914 b	0.926 b
F_7	0.9976 cd	1.0383 b	2.52 c	2.51 d	0.827 bcd	0.831 b
F_8	1.1370 ab	1.2048 a	7.28 a	10.97 a	0.869 b	0.893 b
F_9	0.7406 f	0.6540 d	0.83 e	0.80 e	0.702 de	0.574 e

[a] 100% urea (F_1), 100% urea with 8 ton ha^{-1} zeolite (F_2), 100% composted manure (F_3), 100% composted manure with 8 ton ha^{-1} zeolite (F_4), 50% urea +50% composted manure (F_5), 50% urea +50% composted manure with 8 ton ha^{-1} zeolite (F_6), 50% urea +50% azocompost (F_7), 50% urea +50% azocompost with 8 ton ha^{-1} zeolite (F_8) and without any fertilizer and zeolite (F_9)

[b] Means within each column of each section followed by the same letter are not significantly different ($p \leq 0.05$)

Table 8 Mean comparison of fertilizer treatments main effect

	SN	SK	SP	SMn	SZn
Fertilizer treatments	%		ppm		
F_1	0.0912 e [a]	155.898 f	20.71 f	5.0308 g	5.6713 e
F_2	0.1112 d	176.593 de	40.78 d	5.7317 f	7.1155 d
F_3	0.1222 d	181.731 cd	89.09 c	9.8892 b	8.7577 b
F_4	0.1575 b	209.933 a	71.93 a	12.3575 a	10.0747 a
F_5	0.1425 c	174.617 de	36.14 de	7.9483 d	7.3161 d
F_6	0.1915 a	200.059 b	63.41 b	9.0150 c	7.9550 c
F_7	0.1396 c	168.629 e	34.20 e	8.0033 d	7.2485 d
F_8	0.1680 b	185.158 c	51.51 c	8.6767 c	7.6357 cd
F_9	0.0243 f	141.900 g	6.23 g	6.5517 e	5.4933 e

[a] Means within each column of each section followed by the same letter are not significantly different ($p \leq 0.05$)

ceived manure increased soil EC. Similarly, Eghball (2002) reported that increasing the manure rate also increased soil EC compared with chemical treatments. The positive effect of zeolite application was greater at organic treatments in cation exchange capacity. Zeolite increased the soil CEC, which resulted in more available P, K, Mn and Zn in the soil. Our results showed that zeolite in chemical treatments enhanced soil CEC (Table 7). Studies have shown that the nutrient supplying capacity of azocompost and manure applied singly or in combination with zeolite are higher than compost alone (Gholamhoseini et al. 2012).

Soil Chemical Prosperities

The main effects of fertilizer treatments were significant on all soil elements ($p \leq 0.01$) (Table 6). The maximum soil N (0.1915%) was observed in the F_6 fertilizer treatment. On an average, the F_6 treatment significantly increased soil nitrogen content by 72, 22 and 14% compared to F_2, F_4 and F_8 fertilizer treatments. Integrated fertilizer treatments combined with zeolite (F_6 and F_8) had higher soil nitrogen content than the chemical and organic fertilizer treatments (F_1, F_2, F_3 and F_4) (Table 8). The maximum soil K (209.93 ppm), P (71.93 ppm), Zn (10.07 ppm) and Mn (12.35 ppm) were observed in organic treatment incorporated with zeolite (F_4). Organic and integrated fertilizer treatments (F_3, F_4, F_5, F_6, F_7 and F_8) resulted in an increase in N, P, K, Mn and Zn content while application of chemical fertilizers (F_1 and F_2) and control (F_9) led to lowering N, P, K, Mn and Zn content of the soil. Application of zeolite considerably increased soil nitrogen, phosphorus, potassium, manganese and zinc in all of the chemicals, organic and integrated fertilizer treatments (F_2, F_4, F_6 and F_8). Our results revealed that organic amendments have the potential to increase soil nutrients. Zeolite application as a mixed form with organic amendments had a more positive effect on soil elements than direct consumption. A previous study reported that organic amendments application can enhance soil available elements (Hartl et al. 2003). The higher nitrogen contents in integrated plots combined with zeolite could be due in part to the nutrient supply with the composts and especially by the decrease of nutrient leaching by zeolite during growth season (Evanylo et al. 2008). The application of composted manure and azocompost with a more phosphorus and potassium content increased the availability of these nutrients to the crops (Bulluck et al. 2002; Laboski and Lamb 2003). It has been reported that higher microbial activity in organic soil compared with chemical soils significantly increased soil micronutrient contents.

Conclusion

This study revealed that the maximum dry matter and leaf area index were estimated in integrated nutrient management. Zeolite application in fertilizer treatments led to increases in soil CEC and more available cautions such as P, K, Mn and Zn. The organic treatment showed a significantly higher increase in soil macro and micronutrients. The application of azocompost and manure increased soil EC, however, inorganic fertilizer decreased the soil decreased the soil EC as compared to organic and control treatments. Integrated nutrient management increased the SOC as compared to inorganic fertilizer and control treatments. Our study found that application of organic amendments such as azocompost and manure composts incorporated with chemical fertilizer and zeolite can be recommended to improve soil fertility and growth properties of wheat and canola crops. Also, based on the results, complete or partial (half) replacement of chemical N source with composted manure combined with application of zeolite is recommendable in the region (sandy soil) to achieve both economic and environmental advantages.

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Conflict of interest H. Akbari, S.A.M. Modarres-Sanavy and A. Heidarzadeh declare that they have no competing interests.

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