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ORIGINAL PAPER

Changes in yield, protein, minerals, and fatty acid profile of wheat (*Triticum aestivum* L.) under fertilizer management involving application of nitrogen, humic acid, and seaweed extract

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Abstract

Purpose Synthetic and organic management practices may improve crop productivity. The objective of this project was to determine the optimum level of chemical and organic fertilizer needed to improve yield and physio-chemical attributes of wheat.

Methods The 2-year field experiment was conducted to assess the yield, protein and gluten contents, minerals, and fatty acid profile of wheat (*Triticum aestivum* L.) in a semiarid condition under different treatments of nitrogen (0, 75, 150, and 225 kg N ha^{-1}) and organic fertilizers (control; foliar-applied seaweed extract, 4 L ha^{-1}; foliar-applied humic acid, 2 kg ha^{-1}; and seaweed extract and humic acid).

Results Improved biological, spike, and grain yield of wheat were observed under 150 kg N ha^{-1} in the combination of humic and seaweed extract. The highest grain protein and zinc (Zn) was found in plants treated with 225 kg N ha^{-1} and the combination of humic acid and seaweed extract. The effect of nitrogen was stronger than organic fertilizers on gluten content and Zeleny sedimentation. The treatment with 150 kg N ha^{-1} combined humic acid and seaweed extract led to highest grain potassium (K) and phosphorous (P) contents. The main fatty acids composition was linolenic acid (C18:3, 30.9–45.6%). The N fertilizer led to decreased polyunsaturated fatty acids (PUFAs) and increased saturated fatty acid (SFAs).

Conclusions The foliar application of 2 kg ha^{-1} humic acid and 4 L ha^{-1} seaweed extract along with soil application of 150 kg N ha^{-1} to reach the optimum productivity of wheat (cv. SHS 022) in semiarid climates.

Keywords Fatty acid composition · Fertilizer management · Grain yield · Organic inputs · Synthetic fertilizer

1 Introduction

Wheat (*Triticum aestivum* L.) is extensively cultivated around the world because of its high demand and cultivars that are adapted to different environmental conditions (Ghasemi-Mobtaker et al. 2020). Wheat is the most important crop used in human food and animal feed in Iran (Houshyar et al. 2018; Azadi et al. 2019). Therefore, the cereal is an important source of protein and energy in the Iranian diet. The agricultural lands cultivated with wheat in Iran are 5,438,000 ha, which produced 12.5 million tons in 2019 (Ghasemi-Mobtaker et al. 2020).

Nitrogen (N) is frequently a limiting factor in increasing both crop yields and quality (Zhu et al. 2016). Hence, nitrogen fertilizer is commonly used in large quantities to improve crop production throughout the world (Bakhtiari et al. 2020). However, application of nitrogen fertilizer beyond the crops' demand induces the adverse effects on the environment. Excessive nitrogen application contaminates soil, water, and air locally; accelerates global climate change; and affects human health (Sainju et al. 2019).

Humic acid, as an organic fertilizer, is a naturally occurring polymeric-heterocyclic organic compound that contains carboxylic ($COOH^{-}$), phenolic (OH^{-}), alcoholic, and carbonyl fractions (Khan et al. 2018). It has been reported that humic acid increase transport and availability of nutrients (Olk et al.

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2018; Yildiztekin et al. 2018). Humic compounds, due to their effective compounds, can change the biochemical processes in plants resulting in improved photosynthesis and respiration rates and increased production of hormones and protein (Olk et al. 2018). In general, the positive role of humic acid on plant physiology is described with regard to enhancement of root growth and nutrient uptake (Dinçsoy and Sönmez 2019). Furthermore, seaweed concentrates are known to cause many beneficial effects on plants as they contain growth promoting hormones, trace elements, vitamins, and amino acids (Mahmoud et al. 2019). The successfully spraying application of seaweeds extracts has improved crop yield in spinach (Rouphael et al. 2018), red radish (Mahmoud et al. 2019), bean (Di Filippo-Herrera et al. 2019), and rice (Itroutwar et al. 2020). Besides providing NPK, seaweed supplies trace elements, such as zinc and selenium, to plants (Rouphael et al. 2018).

Recently some farmers have turned to organic fertilizers as a replacement to inorganic fertilizers and the main mechanism to improve wheat productivity. Integrated use of inorganic and inorganic fertilizers may play an important role in sustained soil fertility and crop productivity (Bakhtiari et al. 2020). Hammad et al. (2020) observed the improvement in soil fertility and protein contents of wheat grains following application of organic fertilizers. However, they also reported that synthetic fertilizer resulted in the highest grain yield. Improved plant productivity, due to the combination of chemical and organic fertilizers, were reported on rice (Mi et al. 2018; Moe et al. 2019), finger millet (Abebe and Deressa 2017), Wheat (Arif et al. 2017), and maize (Azeem and Ullah 2016). Hence, we hypothesize that wheat plants have different responses in their yield, minerals, and fatty acid profile to different treatments of organic and synthetic fertilizers. In addition, we hypothesize that integrated fertilizer practices will have an applied effect on wheat yield and chemical components when compared to application of only one type of fertilizer. The main goal of this study was to assess the effect of organic fertilizer (humic acid and seaweed extract) and synthetic fertilizer (nitrogen fertilizer) on biological and grain yield, grain protein and gluten, minerals, and fatty acid profile of wheat (cv. SHS 022).

2 Material and methods

2.1 Experimental site

The field experiment was carried out in Alborz Research Station, Research institute of Forests and Rangelands, Karaj (1312 masl, 35° 48′ 45″ N, 51° 01′ 30″ E), Iran. The soils had a pH of 7.84 and were classified as a clay loam (Table 1). During the study period, mean maximum temperature was 25.3 °C for first year and 23.2 °C for second year, whereas mean minimum temperature was 9.3 °C for first year and 7.7

Table 1 Soil characteristics at the Alborz Research Station, Research institute of Forests and Rangelands, Karaj, Iran

Depth (cm)	pH	EC (ds m^{-1})	Na (meq l^{-1})	P (mg kg^{-1})	Organic carbon (%)	K (mg kg^{-1})	NO_3 (mg kg^{-1})	Clay (%)	Silt (%)	Sand (%)	Soil texture
0–15	7.84	1.03	6.36	10.46	1.03	598.8	14.63	31	49	20	Clay loam
15–30	7.82	1.11	6.75	9.57	0.97	603.5	14.57	30	49	21	

°C for second year. The total annual precipitation was 243 mm in the first year and 265 mm in the second year.

2.2 Experimental design

We established a split-plot experiment in a randomized complete block design (RCBD) with four replications. The split-plot design was meant to evaluate the effect of humic acid and seaweed extract along with different amounts of synthetic nitrogen fertilizer on wheat (cv. SHS 022) during 2015–2016 and 2016–2017 growing seasons. Synthetic nitrogen fertilizer was considered main plot and sub-plot was organic fertilizers. The experiment consisted of four levels of nitrogen (0, 75, 150, and 225 kg N ha^{-1}) and four levels of fertilizer including control (no fertilizer application), humic acid (foliar application of 2 kg h^{-1}), seaweed extract (foliar application of 4 L h^{-1}), and humic acid + seaweed extract.

2.3 Experimental details

Nitrogen fertilizer was obtained from urea source (45% pure N) and soil applied in two stages: 50% before planting and another 50% before spike emergence. Foliar application of humic acid and seaweed extract were applied at three stages: 1, tillering; 2, stem elongation; and 3, spike emergence. The 2 Kg humic acid was used in three stages; therefore, 0.66 Kg humic acid dissolved in 1000 l of water and sprayed on plants in each stage. The plant density was 400 seeds per square meter. Each replication had 16 plots, and each plot had 6 rows with 4-m length and 2-m width, and the distance between main plots was 3 m. The distance between sub plots was 1 m. All seeds were planted in the depth of 3–4 cm at the end of October in both years. Irrigation water was applied using a flexible gated polyethylene pipe (hydro flume). The first irrigation was done immediately after sowing. Other irrigations were done on the basis of plant requirement. Hand weeding was done to control weeds.

2.4 Biological yield, grain yield, and spike number

The biological and grain yield were measured at physiological maturity stage of plants. For biological yield, the wheat plants in each plot was harvested and weighted by digital scale. The grain was threshed by threshing machine (Shameh Company, Iran) and then weighted. The biological, spike, and grain yield were determined as kg per ha. Spike number was determined by measuring the spikes in a square meter.

2.5 Total protein

The Bradford method was used to extract the protein by bovine serum albumin as a standard. Grain samples (2 g) were ground using a mortar with a phosphate buffer (5 ml with pH 7.6) and then centrifuged at 8000 rpm for 20 min. The supernatant of different samples was made equal by adding the phosphate buffer solution. After extraction, 30 µl of samples were mixed with 70 µl of distilled water. In all samples, 2.9 ml of Coosmassic Brilliant Blue solution was added and mixed thoroughly. The samples were incubated for 5 min at room temperature and absorbance at 600 nm was recorded against the reagent blank. The amount (micrograms) of protein was plot against absorbance (600 nm) and a standard curve was calculated (Bradford 1976).

2.6 Gluten content and Zeleny sedimentation

The gluten content of wheat grains was measured according to International Association for Cereal Chemistry (ICC) standard method 137-1 (Anonymous 2000) using the Glutomatic 2200 system (Perten, Huddinge, Sweden). The Zeleny sedimentation content of wheat grains was determined according to American Association of Cereal Chemists (AACC) method 56-81 (Anonymous 1983).

2.7 Mineral ions

The dry ash method was applied to assay the minerals in wheat grain. The samples were ground and then dried in an oven at 70 °C. To obtain the white ash, 1 g dried sample was transferred into ceramic vessels and slowly subjected to 500 °C in the oven. The obtained ash was cooled to room temperature and then mixed 20 mL 1N HCl. After mixing, the samples were put in the sand bath for 30 min. The samples were elutriated in a 100-mL volumetric balloon. Potassium (K) was measure by flame photometer (Model 410, Corning, Halstead, UK) in the volumetric balloons (Williams and Twine 1960). Phosphorous (P) was measured by yellow method with vanadate-molybdate (Tandon et al. 1968). P content was determined at 430 nm using the spectrophotometer (Shimadzu, UV3100). Zinc (Zn) was analyzed by atomic absorption spectrophotometer, model-2380 (Jones and Case 1990).

2.8 Fatty acid composition

The fatty acid methyl esters (FAMEs) contents of wheat grains were measured by gas chromatography (model Agilent 6890) coupled with mass spectrometer (model Agilent 5973N). Separation was done on a capillary column DB-5MS (30 m × 0.25 mm, 0.25 µm of film thickness). Carrier gas was helium with flow rate of 1 ml min^{-1}. The column temperature was programmed from

70 to 290 °C at the rate of 10 °C min^{-1}. A sample volume was injected using a split mode using a split ratio of 1:20. The mass spectrometer was set to scan in the range of m/z 70–700 with electron impact (EI) mode of ionization at 70 eV.

2.9 Statistical analysis

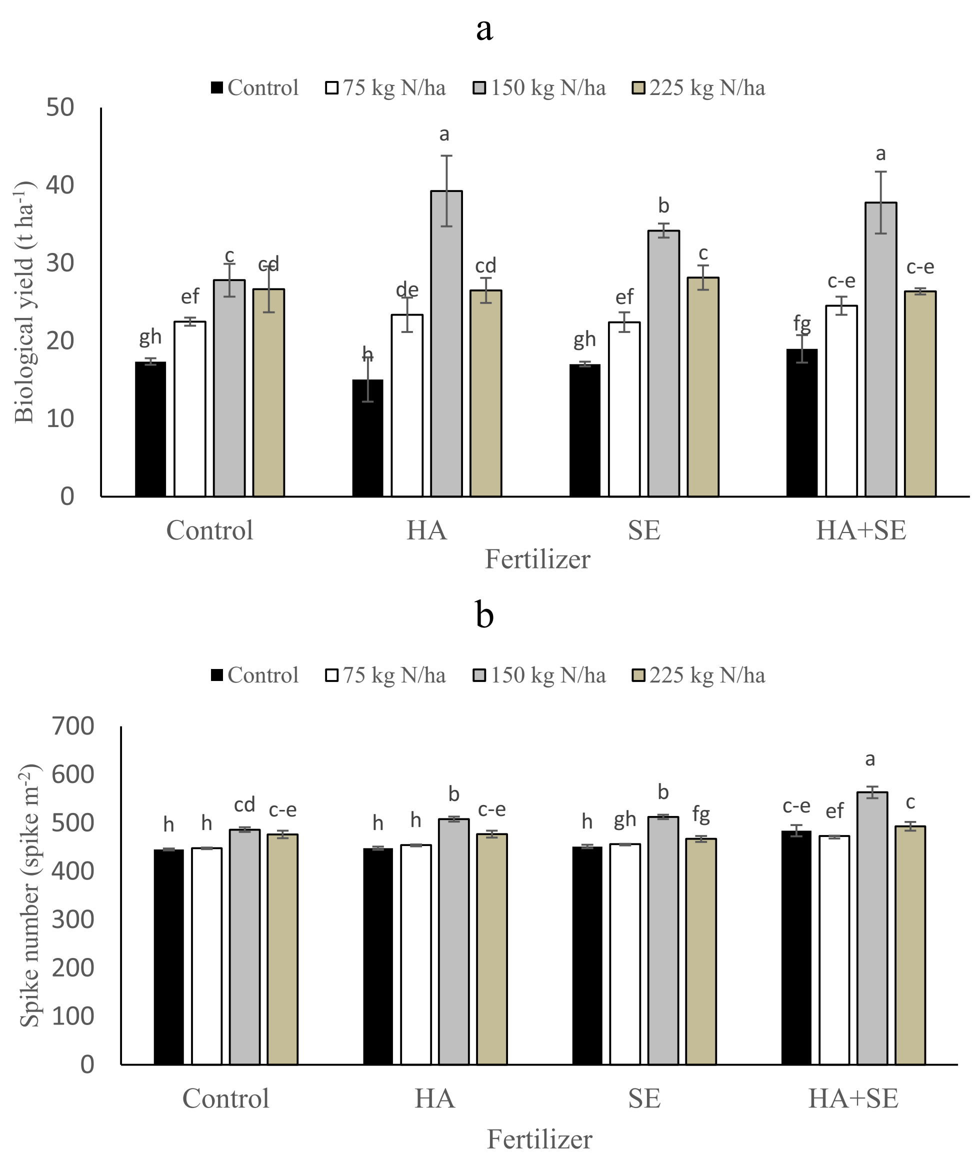
The data (n = 4) were analyzed using SAS software package for Windows (SAS, version 9.3, SAS Institute, Cary, NC). The comparison of mean values was shown by Duncan's multiple range test. The difference between treatments was significant at 5% probability level.

3 Results

3.1 Biological yield and spike number

Biological yield significantly increased with organic fertilizer. In 150 kg N ha^{-1}, humic acid and mixed humic and seaweed extract increased biological yield by 41 and 35%, respectively, compared to control (Fig. 1a). The 150 kg N ha^{-1} was more effective in biological yield and spike number. In plants treated with humic acid, we observed 1.6-fold increase of biological yield compared to non-organic fertilizer treatment. The highest spike number was observed in plants experiencing 150 kg N ha^{-1} with humic acid and seaweed to be 563.5 spikes m^{-2} (Fig. 1b). Compared to control, the 150 kg N ha^{-1} along with humic acid, seaweed, and

Fig. 1 The effect of nitrogen and organic fertilizer (humic acid and seaweed extract) on biological yield (**a**) and spike number (**b**) of wheat. Values are means ± standard deviation (SD) of four replications (n = 4). Different letters show statistically significant differences among treatments at $P \leq 0.05$. HA, humic acid; SE, seaweed extract



their interaction increased spike number by 14, 15, and 26%, respectively (Fig. 1b).

3.2 Grain yield and protein

The use of nitrogen fertilizer significantly improved grain yield, with the150 kg N ha^{-1} having the greatest increase. The highest grain yield (17.5 t ha^{-1}) was recorded at 150 kg N ha^{-1} with humic acid and seaweed extract. In plants treated with the both humic acid and seaweed extract, 1.1, 2.1, and 0.75-fold increases of grain yield was observed with 75, 150, and 225 kg N ha^{-1}, respectively, compared to control (Fig. 2a). Grain protein significantly increased with enhancing N concentration, with its highest amount found in plants treated with 225 kg N ha^{-1} and the humic acid and seaweed extract (Fig. 2b). In plants experiencing no organic fertilizer, the 75, 150, and 225 kg N ha^{-1} significantly increased grain protein by 12, 33, and 36% compared to control (Fig. 2b).

3.3 Gluten content and Zeleny sedimentation

Gluten was significantly improved relative to the control with nitrogen and organic fertilizers (humic acid and seaweed extract), with the synthetic fertilizers having a significantly greater effect than the organic fertilizers. In plants treated with the combined humic acid and seaweed extract, gluten content increased by 8, 10, and 5%, respectively, in comparison with control (Fig. 3a). Zeleny sedimentation also was enhanced with nitrogen and organic fertilizers. It ranged from 30.1 mm in control plants to 39.9 mm in plants treated with 225 kg N ha^{-1} and the humic acid and seaweed

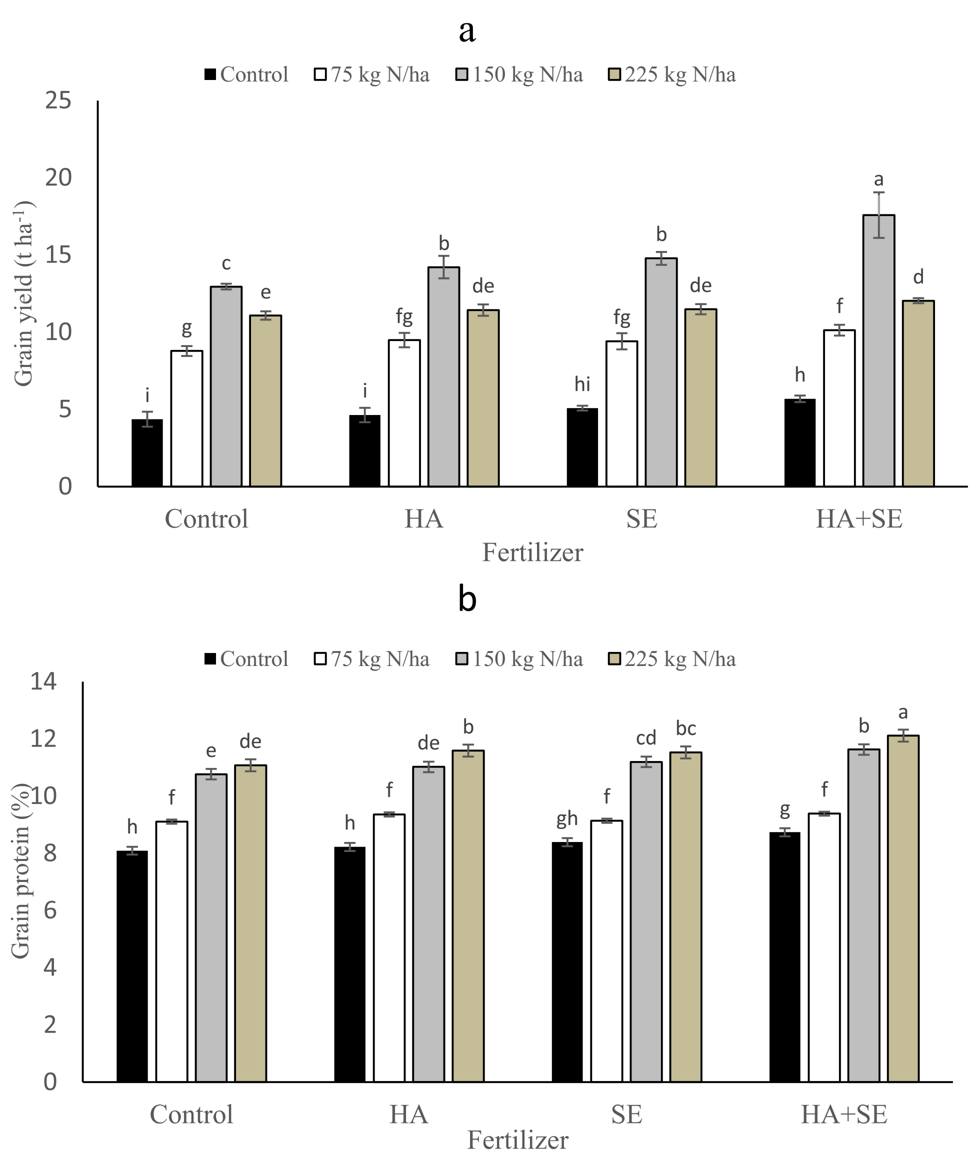


Fig. 2 The effect of nitrogen and organic fertilizer (humic acid and seaweed extract) on grain yield (**a**) and grain protein (**b**) of wheat. Values are means ± standard deviation (SD) of three replications (n = 4). Different letters show statistically significant differences among treatments at $P \leq 0.05$. HA, humic acid; SE, seaweed extract

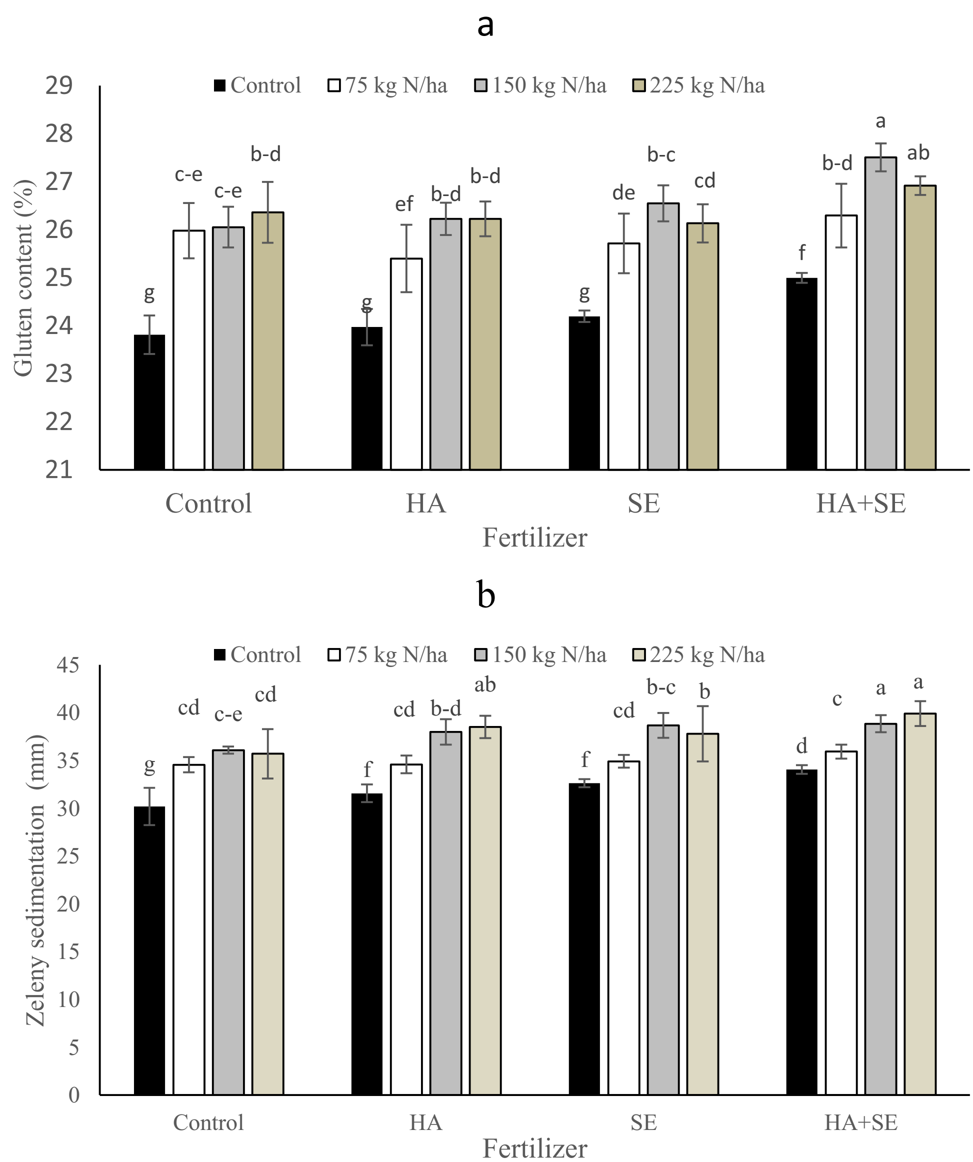


Fig. 3 The effect of nitrogen and organic fertilizer (humic acid and seaweed extract) on gluten (**a**) and Zeleny sedimentation (**b**) of wheat. Values are means ± standard deviation (SD) of three replications (n = 4). Different letters show statistically significant differences among treatments at $P \leq 0.05$. HA, humic acid; SE, seaweed extract

extract (Fig. 3b). Relative to control plants, 150 and 225 kg N ha^{-1} enhanced the Zeleny sedimentation by 26 and 32%, respectively.

3.4 Grain minerals

Grain K content significantly improved with nitrogen and organic fertilizer, where the highest amount was observed in plants exposed to 150 kg N ha^{-1} and the humic acid and seaweed extract to be 42.5 mg g^{-1} (Table 2). P content remained unchanged between control and 75 kg N h^{-1}, but significant increased when applications reached 150 kg N ha^{-1} (Table 2). The highest P content (2.86 mg g^{-1}) was found in plants in the 150 kg N ha^{-1} and humic acid and seaweed extract treatment (Table 2). Zn ranged from 26.1 in control to 44.5 mg g^{-1} in 225 kg N ha^{-1} and the humic acid and seaweed extract treatment (Table 2).

3.5 Fatty acid profile

Table 3 shows fatty acid profile of wheat under nitrogen and organic fertilizers. Palmitic acid ranged from 6.30% in 75 kg N ha^{-1} and humic acid-treated plants to 12.83% in 225 kg N ha^{-1} and the combined humic acid and seaweed extract. Although there was no significant change of stearic acid among the treatments, oleic acid content in 225 kg N ha^{-1} and combined humic acid and seaweed extract was greatest (Table 3). Linoleic acid remained unchanged under nitrogen and organic fertilizers. Linolenic acid was detected in a range of 32–43.8% (Table 3).

Table 2 The effect of nitrogen and organic fertilizer (humic acid and seaweed extract) on the minerals found in wheat grains

Nitrogen	Organic fertilizer	K (mg g^{-1})	P (mg g^{-1})	Zn (mg g^{-1})
Control	Control	33.2 ± 12.4hi	1.64 ± 0.13g	26.1 ± 1.47f
	HA	32.6 ± 0.77i	1.71 ± 013g	28.5 ± 1.75ef
	SE	34.2 ± 1.09gi	1.76 ± 0.01g	27.6 ± 0.82ef
	HA+SE	35.3 ± 0.25g	1.87 ± 0.02fg	25.8 ± 0.65f
75 kg N ha^{-1}	Control	37.4 ± 0.67de	1.74 ± 0.31g	30.2 ± 5.21de
	HA	38.6 ± 1.09cd	1.68 ± 0.07g	34.8 ± 3.13bc
	SE	37.4 ± 0.43de	1.73 ± 0.12g	33.8 ± 2.54c
	HA+SE	40.2 ± 1.23bc	1.81 ± 0.20fg	37.1 ± 4.21b
150 kg N ha^{-1}	Control	38.6 ± 1.56cd	2.18 ± 0.07de	32.5 ± 1.04c
	HA	41.7 ± 2.08ab	2.58 ± 0.11b	35.3 ± 1.05bc
	SE	40.0 ± 3.38bc	2.44 ± 0.11b–d	33.5 ± 1.63c
	HA+SE	42.5 ± 2.08a	2.86 ± 0.03a	37.6 ± 3.77b
225 kg N ha^{-1}	Control	34.9 ± 0.98gh	2.02 ± 0.21ef	42.8 ± 0.49a
	HA	35.7 ± 0.78e–g	2.21 ± 0.2de	42.5 ± 1.55a
	SE	35.5 ±0.32e–g	2.32 ± 0.24cd	44.3 ± 0.89a
	HA+SE	37.0 ± 1.09d–f	2.37 ± 0.06b–d	44.5 ±0.87a

Values in each column are means ± standard deviation (SD) of four replications (n = 4). Different letters show statistically significant differences among treatments at $P \leq 0.05$; *HA* humic acid, *SE* seaweed extract

Table 3 The effect of nitrogen and organic fertilizer (humic acid and seaweed extract) on fatty acid profile of wheat grains

Nitrogen	Organic fertilizer	Palmitic acid (%)	Stearic acid (%)	Oleic acid (%)	Linoleic acid (%)	Linolenic acid (%)
Control	Control	7.13 ± 0.42d	8.75 ± 0.57a	3.12 ± 0.53e	37.3 ± 1.10a	42.7 ± 1.09bc
	HA	7.13 ± 0.42d	8.74 ± 0.56a	3.12 ± 0.58e	37.3 ± 1.11a	42.7 ± 1.09bc
	SE	8.93 ± 0.28c	8.33 ± 0.93a	3.12 ± 0.53e	37.0 ± 0.89a	42.2 ± 0.73c
	HA+SE	7.13 ± 0.43d	8.74 ± 0.65a	3.07 ± 0.59e	36.5 ± 1.01a	43.2 ± 1.54ab
75 kg N ha^{-1}	Control	7.13 ± 0.42d	8.75 ± 0.57a	3.12 ± 0.58e	37.3 ± 1.12a	42.7 ± 1.08bc
	HA	6.30 ± 0.74e	8.75 ± 0.57a	3.17 ± 0.55e	37.2 ± 1.11a	42.7 ± 1.09bc
	SE	6.83 ± 0.41d	8.57 ± 0.84a	3.72 ± 0.54bc	37.2 ± 0.95a	42.9 ± 1.14bc
	HA+SE	6.90 ± 0.36d	8.42 ± 0.83a	3.44 ± 0.32cd	36.3 ± 0.95a	43.8 ± 1.54a
150 kg N ha^{-1}	Control	10.08 ± 0.95b	8.75 ± 0.57a	3.12 ± 0.53e	37.3 ± 1.10a	32.8 ± 1.11d
	HA	10.05 ± 1.01b	8.75 ± 0.57a	3.12 ± 0.58e	37.3 ± 1.10a	32.8 ± .93d
	SE	9.80 ± 1.04b	8.55 ± 0.85a	3.12 ± 0.54e	37.2 ± 0.95a	32.9 ± 1.01d
	HA+SE	12.83 ± 0.39a	8.72 ± 0.84a	3.32 ± 0.54de	36.5 ± 1.01a	32.0 ± .98e
225 kg N ha^{-1}	Control	10.08 ± 0.95b	8.75 ± 0.57a	3.12 ± 0.53e	37.3 ± 1.11a	32.8 ± 1.11d
	HA	10.20 ± 0.89b	7.65 ± 0.56b	3.58 ± 0.54cd	37.3 ± 1.12a	32.8 ± 0.95d
	SE	9.88 ± 01.09b	8.57 ± 0.84a	4.02 ± 0.53ab	37.2 ± 0.96a	32.9 ± 1.01d
	HA+SE	12.83 ± 0.38a	8.73 ± 0.64a	4.30 ± 0.46a	36.5 ± 1.01a	32.0 ± .97e

Values in each column are means ± standard deviation (SD) of four replications (n = 4). Different letters show statistically significant differences among treatments at $P \leq 0.05$; *HA* humic acid, *SE* seaweed extract

4 Discussion

Combining humic acid and seaweed with nitrogen fertilizers had the greatest effect on wheat yield. The biological and grain yield of wheat significantly increased with increasing nitrogen fertilizer up to 150 kg N ha^{-1} and the addition of the humic and seaweed extract. These results are consistent with previous studies by Liu et al. (2019a), who found that higher grain yields in winter wheat when nitrogen fertilizer was used in the appropriate concentration. Delfine et al. (2005) showed the improved winter wheat yield under the combination of foliar-applied humic acid and nitrogen fertilizer. Humic acid affects plant nutrition thereby improving the yield of wheat (Dinçsoy and Sönmez 2019) and fenugreek (Mafakheri and Asghari

2018). Humic substances alter plant nutrition by increasing the uptake of N, P, mg, and Ca thereby influencing grain yield (Shaaban et al. 2009). In addition, humic acid enhances Fe and Zn uptake. These two minerals are involved in the synthesis of an important plant growth hormone, i.e., indole acetic acid (IAA) (Manaf et al. 2019). Therefore, humic acid may improve plant yield (Shaaban et al. 2009).

Combining humic acid with seaweed extract was more effective at increasing wheat yield when applied with nitrogen fertilizer. The humic aid, seaweed extract, and nitrogen fertilizer create a sink for nutrients by promoting the formation of new tissue in wheat plants and enhancing photosynthesis and protein synthesis (Canellas and Olivares 2014). Manea and Abbas (2018) showed the best response in plant growth and increased head yield and quality of cabbage with 6 mL L^{-1} seaweed extract and rice residuals. Yildiztekin et al. (2018) showed seaweed and humic acid can enhance salt stress tolerance and leads to conservation of pepper plant against oxidative stress. The application of organic and inorganic fertilizers can improve the plant yield more effectively than their separate application (Mahmood et al. 2017). It can be due to the role of theses fertilizes in improving soil properties and also promoting the rhizosphere for nutrients uptake. The use of N along with organic fertilizers improves the C/N ratio thereby increasing plant growth through the improved nutrition (Mahmood et al. 2017).

Nitrogen and organic fertilizers significantly improved grain minerals of wheat. For economic and ecological reasons, understanding the appropriate nitrogen inputs to cropping systems is critical (Rathke et al. 2006). During the past few decades, researchers have determined the plant demand for nitrogen under different conditions (Bouchet et al. 2016). Thus, the amount of nitrogen fertilization can be adapted to the nitrogen demand of the crop by understanding availability of N-pool in the soil. In the case of our study, 150 kg N ha was the best concentration of nitrogen to obtain the maximum yield.

The addition of nitrogen fertilizer, humic acid, and seaweed extract is correlated with increases in mineral content of the plant. We found the highest K content in wheat plants when 150 kg N ha^{-1} was applied with humic acid and the seaweed extract, indicating that this agricultural practice can enhance the P and K absorption of wheat grain by increasing the total N, available P, and exchangeable K concentrations. Liu et al. (2019b) showed a significantly positive relationship between soil total N, available P, exchangeable K concentration and N, P, and K absorption in maize. Nitrogen fertilizer expands the root distribution in the soil, especially closer to the soil surface (Postma et al. 2014). This increase in root area alone has been found to increase P uptake 5- to 10-fold (Pasley et al. 2019). The observation suggests that humic acid and seaweed extract helps maintain the nutritional balances of wheat by increasing soil nutrient availability, which further leads to improved shoot development. Similar to our results, El-Bassiouny et al. (2014) reported an increase in minerals when humic acid was sprayed on wheat plants. Merwad (2018) showed humic acid increased NPK uptake in wheat plants under salinity stress. Moreover, Pasley et al. (2019) found nitrogen fertilizer significantly increased Zn concentration in wheat. Zn is an essential mineral nutrient for plant and human growth, and dietary Zn deficiency is a worldwide nutritional problem (Wang et al. 2012). Zn plays a significant role as a metal component of enzymes and as a functional, structural, or regulatory cofactor of a large number of enzymes (Caldelas and Weiss 2017). Similar to Pasley et al (2019), we found that nitrogen fertilizer significantly improved Zn content in wheat grains. The increase in nutrient concentration and uptake in response to humic acid and seaweed extract may be due to the fact that these organic substances may stimulate microbiological activity and enhances nutrient uptake (Daur 2014).

We determined that linolenic and linoleic acids were the main fatty acids found in the wheat. Similarly, previous studies showed that linolenic and linoleic fatty acids were the main components of wheat oil (Ian et al. 1975; Narducci et al. 2019). Difference in the fatty acid profile reported in the various studies is due to the genetic variability of cultivars (Fard et al. 2018; Feizabadi et al. 2020). Organic fertilizers can change the oil content and composition because they alter nutrient availability to the plant (Merwad 2018). In our study, saturated fatty acids (SFA) and unsaturated fatty acids (UFA, monounsaturated and polyunsaturated fatty acids) were 17.5% and 78.2%, respectively. Polyunsaturated fatty acid (PUFA) was the most common fatty acid in the wheat oil. Agricultural fertilizer management changes biochemical pathway of secondary metabolites in plants, which can influence the fatty acid profile (Faiazadi et al. 2020). Nitrogen fertilizers increase SFA but decrease UFA (Table 3). Since UFA is important for human health, the application of organic fertilizers, like humic acid and seaweed extract may be preferable over N fertilizers. Linoleic and linoleic acids are omega-6 and omega-3 fatty acids, respectively, and are considered essential FAs because they cannot be synthesized by humans. Both omega-6 and omega-3 FAs are important structural components of cell membranes, serve as precursors to bioactive lipid mediators, and provide a source of energy. Long-chain omega-3 PUFA in particular exert anti-inflammatory effects and may lower cholesterol levels (Igiehon 2020). Addition of organic fertilizers may facilitate the uptake of nutrients and subsequently affect the enzymes and genes involved in biosynthesis of particular fatty acid like long-chain omega-3 PUFA (He et al. 2020).

5 Conclusions

There is increasing interest in applying organic substrates to mitigate the chemical fertilizers in agriculture. In this work, nitrogen fertilizer, as it is the most common chemical fertilizer, was used in conjunction with organic fertilizers (humic acid and seaweed extract). The results showed 150 kg N ha^{-1} along with humic acid and seaweed extract have the greatest effect on wheat yield. The high amount of N increased palmitic acid but decreased linolenic acid. Based on our results, we recommended foliar application of 2 kg ha^{-1} humic acid and 4 L ha^{-1} seaweed extract along with soil application of 150 kg N ha^{-1} to reach the optimum productivity of wheat (cv. SHS 022) in semiarid climates with similar soils.

Author contributions All authors contributed equally to this article.

Declarations

Conflict of interest The authors declare no competing interests.

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