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Interaction between Fusarium Head Blight and Crown Rot Disease Incidence and Environmental Factors and Soil Physiochemical Analysis on Wheat in the South of Iraq, Basra Province

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Interaction between Fusarium Head Blight and Crown Rot Disease Incidence and Environmental Factors and Soil Physiochemical Analysis on Wheat in the South of Iraq, Basra Province

Abstract

This study was conducted to evaluate the interaction between disease incidence of both *Fusarium* head blight (FHB) and crown rot (FCR) and physiochemical parameters for soil samples and environmental factors in 14 selected wheat fields in the North of Basra province. The results showed that both diseases were occurred in all surveyed fields. The level of FCR incidence was higher than FHB. The incidence of both diseases was increased with favourable weather conditions (high humidity and temperature ˃15 °C), reaching the highest levels in crucial periods before and during the ripening stage. The percentage of disease incidence ranged between 6 to 71% and 3 to 54% for FCR and FHB, respectively. Nine physiochemical parameters of soil were examined in this study, but only soil organic carbon (SOC) (P< 0.0000), soil organic matter (SOM) (P< 0.0000) and Cation exchange capacity (CEC) (P< 0.0008) and (P< 0.0002) had highly significant differences among the selected wheat fields in the occurrence of disease incidence for FHB and FCR respectively. The values were ranged between 0.33-1.27% for SOC, 0.66-2.54% for SOM and 10.08-20.59 mg/100g for CEC. Favourable weather conditions and poor soils with SOM, SOC and CEC contents were found to be great factors for encouraging both diseases during this study.

Keywords

humidity, precipitation, temperature, soil texture, wheat, weather conditions

Cover Page Footnote

None

1. Introduction

Wheat (*Triticum aestivum* L. em. Thell) origin has been tracked down to the Middle East area, in particular region now portion of Iraq [1]. Among the majority of cereal crops cultivated in Iraq, wheat is the main and more favored cereal type used up by humans. In 2017, the wheat area harvested in Iraq was 1,047,531 ha and the production was 2,974,136 MT [2].

Two extremely damaging and economically significant wheat diseases, *Fusarium* head blight (FHB), also called scab, which caused predominantly by *Fusarium graminearum* Schwabe (teleomorph: *Gibberella zeae* (Schwabe) Petch) [3] and *Fusarium* crown rot (FCR), which produced frequently by *Fusarium pseudograminearum* teleomorph: *Gibberella coronicola* [4,5], have been detected in many countries around the world [6−8]. Worldwide, many other *Fusarium* species have been also identified to less extant causing FHB, up to 16 species [9], and FCR, up to 11 species [10], diseases, respectively on wheat. These two diseases are the most widespread cereal diseases that have presented in most regions of the world. Also, they are the most detrimental diseases that have infected wheat cropping systems and other cereal crops resulting in considerable yield losses every year [6−8]. Along with the annually yield losses, these causal agents of both diseases are known to produce different mycotoxins, as the key challenging concern in food safety, in harvest grains and other plant matters, which have dangerous effects on human and animal health [11].

The majority of *Fusarium* fungi are soil-borne and might develop as facultative saprophytes on living plant matter over and above on dead organic material [12]. Therefore, residues of the preceding cereal harvests provide inoculums in the type of ascospores and conidia. While the main factors of airborne ascospores are rainfall and humidity [13,14].

The causal agents of FCR, such as *Fusarium culmorum,* usually overwinter in the soil by means of sturdy chlamydospores or/and in the residues of crops as mycelia. These surviving material infect recently sown seedlings, ultimately inhabiting their crown and stem bases of wheat crops as they develop, resulting in dwarfing, reduced tillering, unfilled heads and early death of the entire crops in the case of serious disease incidence [15,16]. The distinguished symptoms of FCR on wheat plants encompass necrosis of stem internodes, crown tissues, lower leaf sheath and the root rotting that usually initiate a distinctive tan-brown colour [17,18]. While, FHB influences flowering ears causing bleached appearance of the heads. Residues of wheat and other cereal crops have been identified as the principle sources of infection, nevertheless still diminutive is understood about the manner of the infection development [16].

Cromey et al. [19], have postulated the fact that host debris for species of the genus *Fusarium* depends on agricultural methods, crop rotation and herbicide practice. Other researches performed in Poland have reported that the occurrence of necrosis symptoms on stem bases of wheat depends predominantly on the weather conditions and to less extent on the cropping system and weed invasion [20−22].

Any growth stage of cereal plants can be subjected by *Fusarium* spp., leading to FHB, FCR, seedling blight, and leaf necrosis in wheat and other cereals (Champeil et al. [23,24]). Reduction of the occurrence of FHB and FCR diseases is tremendously difficult, because of the massive share of cereals cultivation globally. Correspondingly, weather conditions are another factors effecting the presence of those diseases that influence both growth of plants and the infection occurrence [22,25].

High intensity of *Fusarium* species is present in warm and rainy years, with an abundance precipitation. The reason is that they spread by means of macroconidia and to less extant perithecia structures, which are transferred to the aboveground plant parts in raindrops. After the rains, these structures dispose of ascospores, which are moved directly to the spikes by the wind. Likewise, symptoms of grain and head infection presents once the temperature for the period of the flowering go above 20 °C and the humidity is exceeding 85−90% for at least 1−2 days [23].

This study was conducted to understand the relationship between disease incidence of both FHB and FCR and physiochemical analysis for soil samples that promote causal agents to cause these diseases and environmental factors that could decrease and/or increase symptoms on wheat by calculating infected plant parts (root, crown, stem and head) at symptom occurrence.

2. Material and methods

2.1. Disease incidence estimation

In 2017/2018, the assessment of occurrence for FHB and FCR diseases was achieved in all examined

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wheat fields as described in (Table 1). The FHB occurrence was estimated based on noticeable partly or completely infected heads, whereas the FCR occurrence was evaluated based on visible infected stems. Infected plants with observable infections were picked up at premature and ripening stages within 2—3 weeks before harvest. Disease occurrence was measured by gaining random square meters of entire plants. With the intention of collecting typical samples, the collection process was based on visible infections of wheat plants, consistent with measures styled by Yonghao [26]. The application of following formula [disease incidence percentage **(%DI)** = total number of symptomatic plants **(*TN. of* SP)**/total number of inspected plants **(*TN of* IP) x 100]** was used to calculate the incidence percentage for both diseases.

2.2. Statistical analysis

Analysis of Variance within the statistical program (SPSS® ver. 21) software [27] was used to determine: the statistical differences of interactions between the examined 9 physiochemical parameters of soil and the occurrence of both disease incidences (FHB and FCR).

2.3. Environmental factors

The association of environmental conditions and occurrence of FHB and FCR in all selected wheat fields were detailed, because the causal pathogens (*Fusarium* species) of these diseases supposed to be more common in highly humid and rainy areas. Rainfall data, maximum temperature, average temperature, maximum humidity, minimum humidity, average humidity were collected throughout the regions of the fourteen selected fields. Data were downloaded from the Iraqi Agro meteorological network http://www.agromet.gov.iq/daily.

2.4. Soil sample collection

Soil samples of the 14 selected wheat fields were taken from a depth of (10—20) cm, air-dried at room temperature (for 3—4 days) and then mixed well to get a representative sample (≈125 gm) to be analyzed in the present study. Tests for physiochemical properties were conducted include pH, EC, CEC, SOC, SOM, soil texture, and total nitrogen, concentration of calcium, potassium and Phosphorous.

2.5. Physiochemical analysis for soil samples

The physical and chemical analysis were performed by Analytical chemistry laboratory at Iraq Marine Science Centre, Basra University.

2.5.1. Soil reaction (pH)

pH was measured in each soil sample suspension 1:1 (water: soil) according to Thomas method as described in Sparks et al. [28] by using pH-meter (Hanna—HI—9812).

Table 1
The sampling sites and percentages of disease incidence of wheat in the 14 selected fields of the current study.

No.	Region and (field name)	Coordinates	D.IN. %	
			Stem/FCR	Head/FHB
1	Qurna/Mzeara'a (QM)	34º38′66.5″N, 73º27′40″E	38	34
2	Qurna/Research station (QRS)	34º36′51.8″N, 73º54′41″E	6	11
3	Thagar/Al-Izz1 (TI1)	34º50′40.5″N, 73º03′68″E	41	38
4	Thagar/Al-Izz2 (TI2)	34º54′92.1″N, 72º84′09″E	36	33
5	Thagar/Al-Izz3 (TI3)	34º54′43.6″N, 72º87′72″E	40	32
6	Thagar/Karakor (TK)	34º51′91.1″N, 73º28′64″E	7	3
7	Dair (D)	34º09′05.2″N, 74º48′90″E	71	54
8	Nashwa (N)	34º15′46.5″N, 74º98′04″E	27	32
9	Al-Modienh/Salih River (MSR)	34º24′99.1″N, 70º76′14″E	33	28
10	Al-Modienh/Salt Project (MSP)	34º22′68.9″N, 70º89′05″E	9	4
11	Talha/Marsh Land 1 (ML1)	34º15′00.7″N, 71º49′14″E	32	29
12	Talha/Marsh land 2 (ML2)	34º16′63.8″N, 71º55′44″E	17	26
13	Al-Hammar Marsh (HM)	34º07′68.9″N, 71º52′68″E	52	41
14	Huwair (H)	34º36′08.9″N, 71º58′79″E	25	16
	Mean		**31**	**27.2**

2.5.2. Electrical conductivity (EC)

EC was measured in saturated dough extract prepared according to Rhoaeles method described as in Sparks et al. [28] by using EC-meter (cc-411 –water).

2.5.3. Cation Exchange Capacity (CEC)

CEC was measured in soil samples according to the suggested method by Amrhein & Suarez as described in Sparks et al. [28].

2.5.4. Soil organic matter (SOM)

Soil organic carbon (SOC) was first measured for each soil sample according to Walkley-Black method as described in Sparks et al. [28] and then SOM was measured throughout the content of the soil organic carbon according to Pribyl [29] via the following equation ***[%SOM = % SOC x 2]***.

2.5.5. Soil texture

A pipette method was used to determine volume distribution for soil components according to the described method in Black et al. [30].

2.6. Measurement of chemical elements in soil

2.6.1. Calcium (Ca)

Calcium ions were measured by using titration method with Na_2-EDTA as described in Sparks et al. [28].

2.6.2. Total nitrogen (TN)

Determination of TN in soil samples was performed by using the common method Kjeldahl digestions (Total Kjeldahl Nitrogen – TKN) as described in Bowman and Delfino [31].

2.6.3. Phosphorous (P)

Determination of P was performed in leachate by using visible spectrophotometry method as described in Olsen and Sommers [32].

2.6.4. Potassium (K^+)

K^+ was extracted from leachate by 1 M NH4Cl and measured by using a PerkinElmer A Analyst 200 atomic absorption spectrometer as described in Peech et al. [33].

3. Results and discussion

The evaluation of disease incidence for both FHB and FCR conducted by using the certain formula (mentioned above) revealed that there were evident differences of the levels of disease incidence among the 14 selected wheat fields. The lowest percentage of FHB disease incidence (3%) was occurred in the TK wheat field, while, the highest percentage of FHB disease incidence (54%) found in the D field (Table 1). In terms of FCR, the lowest percentage of disease incidence (6%) was occurred in the QRS wheat field, while, the highest percentage of disease incidence (71%) was also found in the D field (Table 1). The mean average of FHB and FCR was (27.2%) and (31%), respectively. This displays that, very nearly 1/3rd of wheat crop planted in those 14 fields were infected by both diseases but not very severely, except in two fields (D and HM), which were devastating (54, 71%) and (41, 52%) for FHB and FCR respectively (Table 1).

It is obviously revealed that the highest disease incidence percentage for both diseases was observed in the D and HM wheat fields while lowest has been verified in the QRS, TK and MSP wheat fields.

Based on the acquired results of the recent study, it is obviously can be indicated that there were evident differences of the percentages of disease incidence among the 14 selected fields. Therefore, interaction between the presence of disease incidence and many other parameters should be investigated. These parameters include environmental factors (rainfall data, maximum temperature, average temperature, maximum humidity and average humidity) and soil physical and chemical analysis (pH, EC, CEC, SOM, soil texture, and total nitrogen, concentration of calcium, potassium and phosphorous).

3.1. Interaction between disease incidence and environmental factors

This research has for the first time conducted to investigate the interaction between important environmental conditions and disease incidence of both FHB and FCR of wheat in Iraq. During the growing season in 2017/2018, disease incidence for both FCR and FHB increased with favorable weather conditions, reaching the highest levels in crucial periods before and during the ripening stage. The percentage of disease incidence ranged from 6 to 71% and 3–54% for FCR and FHB, respectively. The crucial period for FCR was occurred from 23rd of February to 1st of March when the temperature was between 17 and 18 °C and the relative humidity between 96 and 100%, associated with total precipitation 29 mm (Fig. 1). Whereas, the favorable weather conditions for FHB were exactly during the soft dough stage (from the 2nd - 13th of April), when

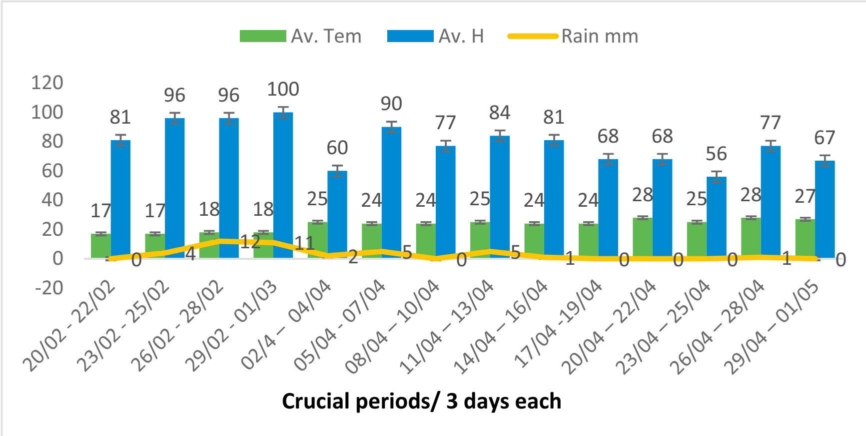

Fig. 1. Weather conditions of the research fields observed in the growing season (average humidity [%], average temperatures [°C] and total rainfall amount [mm] for each crucial three days of the two months before and during maturity (20th February −1st May 2018)).

the temperature was ranged from 24 to 25 °C and the relative humidity between 84 and 90%.

The total precipitation during the first two weeks of April (the crucial days leading up to flowering) was 12 mm (Fig. 1). Prior to and during the maturity time, the temperature was raised between 24 and 28 °C, the relative humidity ranged from 56 to 81% associated with low total rainfall amount 2 mm (Fig. 1). The growing season had the highest rainfall amount in February 23rd to March 1st and in April. This precipitation was considerably higher than documented in the cultivated region for the long-term data (according

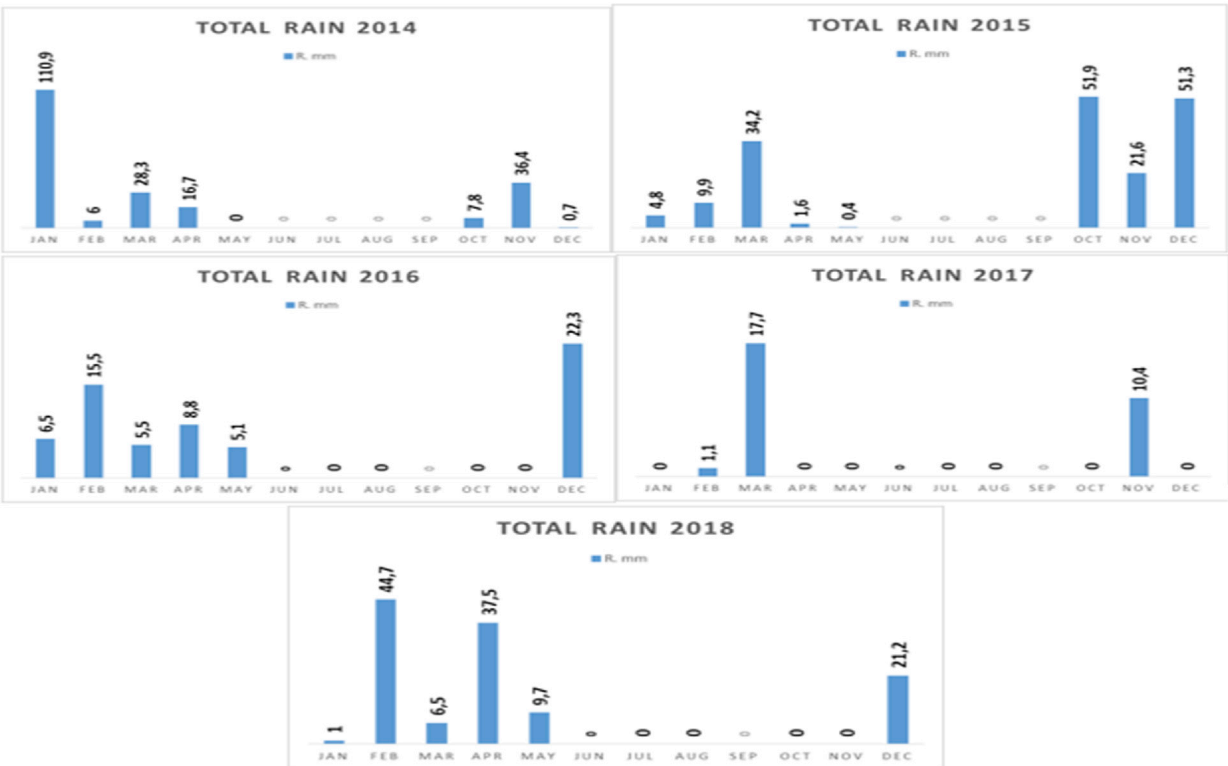

Fig. 2. shows the total rain (precipitation) of the recent study recorded in the growing season (2018) was considerably higher than documented in the cultivated region for the long-term data from (2014–2018), particularly during February and April.

to http://www.agromet.gov.iq/), particularly during February and April (Fig. 2).

The results showed that both diseases (FHB and FCR) were occurred together in all surveyed fields. However, disease incidence of FCR was higher than FHB. In Australia, there was an obvious linkage between FCR and FHB disease occurrence that used to be indicated CR-FHB continuum. This association is restricted to the epidemiology, etiology and biology of pathogens for FCR and FHB diseases. Such linkage is occurred under appropriate weather conditions when plant residues from FCR infected field colonized by macroconidia that become inoculum of FHB disease [34]. Weather conditions are important factors that considerably affect the occurrence of FHB and FCR diseases in wheat crops, as they influence both disease incidences and development of plants [22,25]. According to Champeil et al. [35], high intensity of *Fusarium* species is occurred in warm and humid days, specifically with excessive rainfall, due to their ability to spread their macroconidia that are moved to the plant heads by precipitation. In addition to, species of the genus *Fusarium* can produce another important structures called perithecia, which usually release ascospores after raining that reach the heads directly by wind. Along with Shaner [36], these ascospores have the ability to germinate quite efficiently in just about 3 h when the temperature is reached at 28 °C. At flowering stage, when the temperature is raised above 15 °C [9] associated with above 85% of moisture for no less than one to two days, the development of head infection is occurred more destructively.

Our results strongly agree with all the literatures above, as the weather conditions were more than favorable and encouraging for both diseases during the growing season (temperature was ranged from 17 to 28 °C before and during anthesis and maturity stages, and the relative humidity was between 84 and 100% in the same crucial periods, associated with moderate level of total precipitation 41 mm). The observable occurrence of FCR and FHB diseases in all studied areas during this study might be attributed to the unexpected change of weather conditions in Iraq during the last decade. Khudhair et al. [37], also proposed the same explanations when FCR disease in wheat and barley fields was first studied in the middle of Iraq. Furthermore, based on the questionnaire conducted earlier in this study, no one of the wheat farmers had eliminated the wheat stubble from previous season. This is in accordance with Khudhair et al. [38], who reported that ignoring wheat debris in the fields lead to increase the opportunity of these diseases.

Dill-Macky and Jones [39], Edwards [40], Willyerd, et al. [41] and McMullen et al. [42] have reported that several integration approaches (crop rotation, resistant cultivars, recommended seed rate and other agricultural practices) have been mostly used for managing FHB. However, when the weather conditions are highly favorable (rainy and moist weather before and at the flowering time and initial grain fill) for the disease development, there is no single approach be responsible for sufficient FHB reduction.

Table 2
Shows Physiochemical parameters of soil samples and disease incidence of the 14 selected fields in this study.

Field	SOC %	SOM %	Ca ppm	T.N %	K ppm	P ppm	EC (ds/m)	pH	CEC mg/100 g	D.IN. %	
										Stem	Head
QM	0.73	1.46	352	0.05	3,51	37,00	4,56	6,78	11.65	38	34
QRS	1.27	2.54	640	0.13	7,03	45,50	5,08	6,70	20.23	6	11
TI1	0.85	1.7	672	0.08	6,32	76,25	5,63	7,03	13.77	41	38
TI2	0.71	1.42	480	0.04	6,32	57,75	5.63	6,95	11.31	36	33
TI3	0.91	1.82	721	0.10	9.12	40.90	4.67	7.01	14.44	40	32
TK	1.26	2.52	448	0.12	4,22	39,50	4,34	7,05	20.59	7	3
D	0.33	0.66	528	0.02	12,65	53,25	4,35	6,35	10.01	71	54
N	0.90	1.8	520	0.10	8.21	36.28	4.51	6.75	14.85	27	32
MSR	0.81	1.62	496	0.07	7,03	44,00	4,87	7,06	12.18	33	28
MSP	1.23	2.46	480	0.11	6,32	31,25	4,13	7,10	20.55	9	4
ML1	0.75	1.5	720	0.08	21,08	68,50	4,41	6,75	12.70	32	29
ML2	0.72	1.44	560	0.04	8,43	45,50	4,03	6,67	11.57	17	26
HM	0.51	1.02	608	0.03	14,76	45,25	5,35	6,98	10.08	52	41
H	0.88	1.76	576	0.08	18,97	67,00	5,09	6,06	12.74	25	16

%SOM = 2 * %SOC.

Table 3
Displays statistical analysis for interaction between soil parameters and disease incidence (FCR) of the 14 selected fields in this study.

Variable	Sig.
SOM	0.0000
SOC	0.0000
CEC	0.0002
EC	0.3815
pH	0.6047
K	0.4662
Ca	0.6013
P	0.2964

3.2. Interaction between disease incidence and soil physiochemical analysis

Soil properties like SOM, EC, CEC and pH etc., influence the density and variety of soil mycoflora, and consequently affect the percentage of disease incidence caused by pathogenic fungi. Therefore, it is significant to investigate the relation between physicochemical properties of soil and the FHB and FCR disease incidence percentages obtained in this study. Table 2 shows the physiochemical parameters of soil samples and the percentage of both disease incidence on wheat crop in all selected fields.

All nine physiochemical parameters of soil were involved in the initial major component analysis, but only SOC ($P < 0.0000$), SOM ($P < 0.0000$) and CEC ($P < 0.0008$) and ($P < 0.0002$) had highly significant differences among the selected wheat fields in the occurrence of disease incidence for both FHB and FCR respectively during this study (Tables 3 and 4). The result classified different levels of physiochemical properties in the surveyed wheat fields, including the SOC value that ranged from (0.33−1.27%), SOM (0.66−2.54%) and CEC value (10.08−20.59)mg/100 g.

Our results characterized that the soil samples of the 14 surveyed wheat fields were displayed heterogeneity in some physical and chemical properties. Except the soil texture of all surveyed fields that were classified as silt loam soils, with almost correspondence in pH (6.35−7.1) and EC (4.13−5.63 ds/m) values (Table 2).

Many studies such as Del Moral et al. [43], Labuschagne, et al. [44], Royo, et al. [45] and Royo et al. [46] have reported that in general, wheat cultivars possess valuable features to withstand extreme environmental pressures, like low temperatures and drought as well as a great ability of disease and pest resistance. A number of soil physical and chemical factors, like soil SOC, SOM, EC, pH, etc. content, as well as different cations have been frequently connected to disease severity, incidence and suppression [47]. Numerous studies have assayed to figure out the function of the physical and chemical soil parameters in uncountable certain experimental system. For instance, a high value of soil pH has positive consequences in reducing *Fusarium* wilt in tomato crop [48]. On the other hand, Bonanomi, et al. [49] stated that, generally there was no statistical correlation between alteration of pH and suppression of diseases, with the exception of *Fusarium* spp.

The statistical analysis in the present study shows that there is no relation between disease incidence and pH, EC values and soil texture. The results of these three parameters are acceptable, because the disease incidence percentage of both FHB and FCR was greatly varied among the 14 selected wheat fields, while the values of the three parameters were almost identical with slight fluctuations. This means that variation in the percentage occurrence of disease incidence should be affected by other parameters, which their values were differed at all examined sites.

Combining the results of the statistical analysis of soil organic carbon and material percentages in the 14 wheat fields in one part is convenience, because their values are greatly linked together. Thus, the demonstration in this study performs only about soil organic material. The result of SOM showed significant ($p < 0.05$) differences among the studied locations Fig. 3. Where the QRS, TK and MSP wheat fields revealed higher content of organic materials (2.54, 2.52 and 2.46%) respectively. The two field D and HM reflected the lowest organic material content (0.66 and 1.02) % respectively.

Along with Horneck et al. [50], soil OM is a replacement for SOC and is calculated as a mirror image of general soil health. In natural ecosystems, SOM is substantial to a different assortment of soil biophysiochemical properties. Where SOM increases, many other soil properties increase too, such as CEC,

Table 4
Displays statistical analysis for interaction between soil parameters and disease incidence (FHB) of the 14 selected fields in this study.

Variable	Sig.
SOM	0.0000
SOC	0.0000
CEC	0.0008
EC	0.3722
pH	0.5378
K	0.3027
Ca	0.6850
P	0.2945

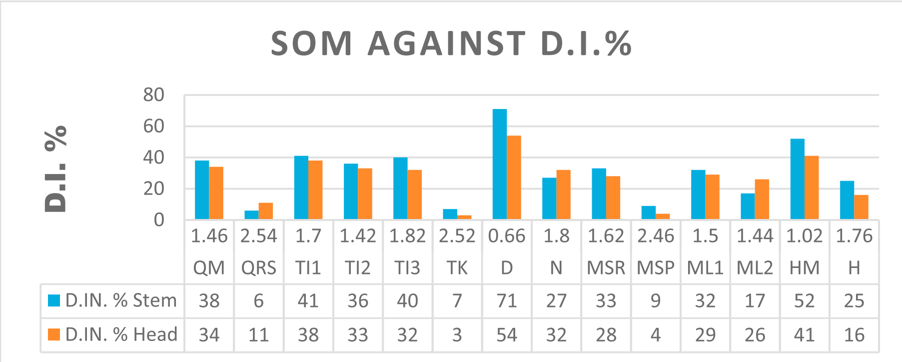

Fig. 3. shows the effect of soil organic matter on disease incidence in plant head and stem in the 14 selected wheat fields in the south of Iraq/Basra province.

activity of microbiology and capacity of holding water. Many previous studies, such as Coventry et al. [51], Tilston, et al. [52], Lazarovits, et al. [53] and Szczech [54] reported that SOM, specifically organic amendments have the capability to suppress plant diseases brought about by soil-borne pathogens.

Inappropriately, the controlling of plant diseases by amendments of organic materials is predominatingly inconsistent: for example Mazzola et al. [55], pointed out that OM amendments can increase disease incidence of some plant pathogen. While Termorshuizen et al. [56], made a broad survey on previous studies involved in the OM effects, they revealed that 45% of all studies were established disease suppression, 42.7% were proven no significant suppression, and 3.3% confirmed disease development.

The present study found that disease incidence percentage of both FHB and FCR in wheat fields with high content of organic material (QRS, TK and MSP) was suppressed significantly. Whereas, disease incidence percentage in the D and HM fields, which had less content of SOM (0.66 and 1.02%) respectively, was devastating (54, 71%) and (41, 52%) for FHB and FCR diseases respectively. The rest of selected wheat fields under investigation shown moderate percentage of disease incidence (ranged from 16-41% and 17−41% for FHB and FCR respectively) that can be attributed to their average contents of SOM. This result support the findings of previous studies mentioned above that indicated SOM can suppress plant diseases brought about by soil-borne pathogens, in specific those caused by *Fusarium* species.

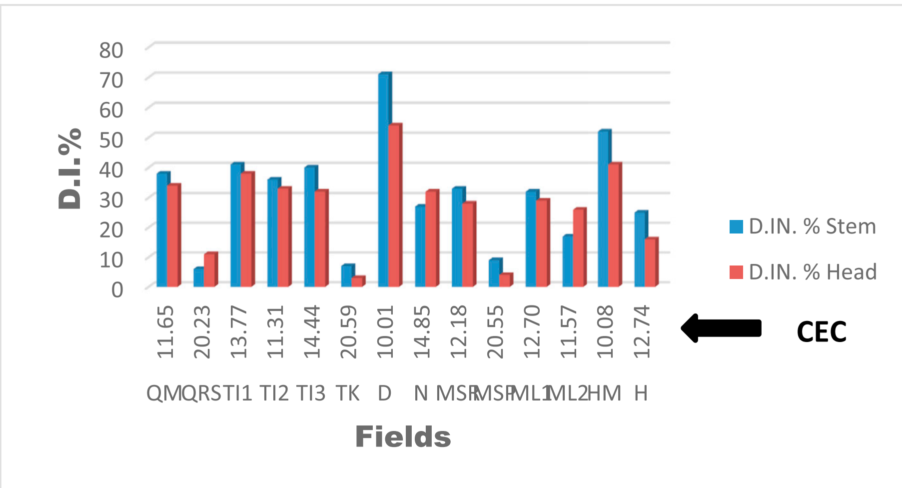

Fig. 4. shows the effect of Cation Exchange Capacity (CEC in mg/100 g) on the Disease Incidence (D.IN%) in wheat fields in the south of Iraq/Basra province according to the selected 14 sites.

In terms of other soil variables, the results of data analysis also showed that there is no relationship between disease occurrence and total nitrogen, concentration of calcium, potassium and phosphorous in all examined wheat fields. In contrast, interaction between the CEC value and disease incidence was highly significance ($p < 0.0002$) and ($p < 0.0008$) for both diseases (FHB and FCR respectively), as shows in Fig. 4.

Rohilla and Salar [47], have stated that CEC is a capacity standardization of soil to hold and release particular chemical elements such as potassium, magnesium, sodium and calcium. High content of SOM is often associated with high CEC value. Abiotic soil properties, such as OM, pH, calcium levels and CEC etc. are directly correlated to activity of soil mycoflora and other microbes [57]. Hence, as stated by Michael [58], Chen, et al. [59] physiochemical variables of soils may have indirect effects on biodiversity [60] and biological disturbance of plant pathogens, because the microbial effectiveness is greatly connected to deactivation of soil borne plant pathogens. Accordingly, this statement is in accordance with the result of present study (Table 2), as the observed increase of CEC content in the examined soils led to wheat fields with low disease incidence (QRS, TK and MSP), which had significantly higher levels of CEC (20.23, 20.59 and 20.55) mg/100 g respectively than those with higher levels of disease incidence.

Even though there were many studies, such as [61–67] have reported the allergenicity of most environmental fungi, the causal agents of both diseases (FHB and FCR) were not mentioned as allergenic to farmers, unless they consume the products of cereal grains to be affected by mycotoxins. In terms of mycotpxins produced by the causal agents of both diseases, the authors of this study have covered this issue in another research [68], which has been accepted but not published yet.

4. Conclusion

FHB and FCR are tremendously destructive and economically important wheat diseases, which have been reported globally in many countries. The results of this study showed that weather conditions were a great factor for encouraging both diseases during the growing season. No association were found between disease incidence and pH, EC values, soil texture, total nitrogen, concentration of calcium, potassium and phosphorous in all examined wheat fields. Soils with high contents of SOM, SOC and CEC were confirmed reducing the occurrence of both diseases on wheat. Further studies are needed to examine barley and corn crops in the studied areas as another hosts of FHB and FCR diseases.

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