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Response of Bread Wheat (T. aestivum L.) to Nitrogen Fertilization and Foliar Application of trace elements Zinc and Iron and Thermal Capacity of Two Different Agro Climatic Zones

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ABSTRACT

To investigate the growth and yield of two bread wheat varieties Alaa and Hasad in two different agro-climatic zones (ACZ), two different field experiments were carried out in Sulaimani and Halabja agro-climatic zones(SAZ and HAZ) during the 2019-2020 season. The wheat varieties were treated with three levels of nitrogen fertilization (80, 120, and 160) Kg ha-1 as N1, N2, and N3 and foliar application of trace elements Zn as (ZNSO4) and Fe (FeSO4.7H2O) 0.5 g/ 750ml, during the reproductive stage with 15 days difference among them. Differences in the thermal capacity as accumulated Growing Degree Days (GDD) between both agro-climatic zones resulted in significant variation in the growth performance of both varieties. The accumulation of dry matter was evaluated along the growing season through seven sampling dates with two weeks interval. There were differences in the relative growth rate(RGR) of both varieties in both ACZs, and the RGR of Alaa variety in SAZ was (0.131 to 0.190) g g-1 d-1, while it recordes at Halabja agroclimatic zone between (0.172 – 0.221)g g-1 d-1. However, the RGR of Hasad was between (0.135-0.207) g g-1d-1 at SAZ and (0.185-0.253)g g-1d-1 at HAZ. The higher results of GDD, the total grain yield, biological yield, and harvest index at HAZ can be explained by favorite conditions provided at HAZ than that obtained at SAZ. That exhibited in optimum mebolization of applied fertilization and higher heat use efficiency at HAZ(2.219 and 3.327kg grain ha-1 deg days-1 for Alaa variety with V1N2F0 and V1N3F0 respectively, and Hasad variety showed 2.045 and 2.818 kg grain ha-1 deg days-1 with V2N1F0 and V2N3F0 respectively. Differences in thermal capacity of different locations can be used for classification of agricultural zones in future studies.

INTRODUCTION

Wheat crop (Triticum aestivum L.) is considered as a widely adapted crop, it is grown in different environments with various abiotic factors (Hyles et al ., 2020). The wheat growth and development will result from temporal and spatial integration of the physiological processes during the crop life cycle. The physiological processes can be accelerated or slowed by the availability of nutrition and environmental conditions especially temperature, every phase of development requires a minimum accumulation of temperature as a crop heat unit before that stage can be complete and the plant can attain the new stage of growth (Tomar et al ., 2016, Prajapat and Saxena,2018). Nitrogen fertilization is one of the most limiting nutrients for wheat production that affects growth and development and promotes grain yield, and that it will increase in the plant height, yield

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component, grain yield, and NUE with increasing N fertilization levels(Mandic et al . , 2015). The accumulated growing degree days in all wheat varieties increased with an increase in nitrogen levels from 120 to 180 kg N ha-1(Sidhu and Raj, 2018). Accumulated dry matter varies according to the environmental factors during the growth stages along the crop life-cycle through the effect on the energy balance between photosynthesis and respiration (Mohammed and Jaza, 2015, Mahdi and Topal, 2018). The high variability in N efficiency indicates to variability in yield potential in most agro-climatic zones,(Aycicek and Yildirim, 2006, Mandic et al ., 2015). Micronutrients are playing a central role in the yield improvement as quality and quantity, the low wheat production in some agroclimatic zones is due to insufficient use of micronutrient fertilizers (Hadi et al ., 2020). The rate of dry matter accumulation is considered as a prominent parameter for crop growth and development which varies according to the environmental components especially chilling and heat, the quantification of crop heat units is useful for the evaluation of crop yield potential in different agro-climatic zones (Prajapat and Saxena, 2018, Bisht et al., 2019). The crop phenological modification and parameters used for the description of growth and development has been evaluated by thermal heat tolerance and thermal parameters such as growing degree days GDD, crop heat units CHU, heat use efficiency HUE, Phenothermal index (PTI) (Kuar et al., 2010, Paliwal et al ., 2012, Gutierrez et al., 2013). The concepts of heat GDD are based on the concept that real-time to accomplish phenological stage is linearly related to optimum temperature (Kumar and Kumar, 2014). Heat use efficiency (HUE) quantification is necessary for evaluation yield potential of crops in different environmental conditions (Pal and Murty, 2010). Chilling temperature during vegetative growth and high temperature at physiological maturity are typical requirements for wheat (Kalra et al ., 2008). Recent studies indicated to variation in heat use efficiency among cultivars might be the cultivar's inherent characteristics, as well differences in accumulated GDD caused a deleterious effect on dry matter accumulation and grain yield (Saiyed et al., 2008, Gill et al ., 2014, Prasad et al.,2017).

Although the same agricultural processes and nutrient applications were made, but differences in environmental factors, especially temperature, results accurate variation in the growth and production processes of wheat in different agrclimatic zones, these differences may display different crop responses to environmental factors.(Tomar etal ., 2016, Liu et al ., 2020).The aims to investigate the influence of different agroclimatic zones on the performance of bread wheat varieties under non-high levels of nitrogen fertilizer and foliar application of trace elements Zn, and Fe include growth and yield and Heat use efficiency.

MATERIALS AND METHODS

Two different field experiments were carried out during the winter season of 2019 -2020 in two different agroclimatic zones in Sulaimani and Halabja to study the growth and yield and also the thermal requirements of two varieties of bread wheat (Hasad and Alaa) through determining the GDD. Besiedes to variation in climatic factors of both locations, the two wheat varieties were treated with three different levels of nitrogen fertilization 80, 120, and 160 kg ha^{-1} which applied as Urea 46% in two different doses first with the seeding and second at tillering stage as well as foliar application of trace elements Zn as (ZnSO4) and Fe (FeSO4.7H2O) 0.5 g / 750ml, during the reproductive stage with 15 days difference between them. The experiments were conducted with R.C.B.D accompanied by three replications. The experiment of SAZ was carried out in Qlyasan Agricultural research center of University of Sulaimani situated at (Lat. 35o 34' 307"; N, Long 45o 21' 992"; E, 765 masl), while the agricultural research center of Halabja was located at (Lat. 35o 17' 11"; N, Long 45o 98' 992"; E, 755 masl). All agricultural processes have achieved as required in both locations. The sowing dates were Nov.17 and Nov.18 at both ACZs respectively. The total amount of phosphate fertilizer (Triple super phosphate) was applied during final land preparation before sowing, the wheat seeds of both varieties were sown manually in rows 20 centimeter (cm) apart. Besides determining the rate of dry matter accumulation across the growing season through seven sampling dates from Feb.18, 2020 in SAZ and Feb.16,2020 in HAZ with 2 weeks interval, in which destructive sampling of entire plants of the two wheat varieties were taken from inner rows of experimental units each 2 weeks, Fresh weight was taken for both plants and oven dried at $70^{o}C$

till complete dryness then they were waited. Some of the vegetative and reproductive criteria were also studied like the length of growth stages include number of days from seeding to 50% flowering, No. of days from 50% flowering to 50% physiological maturity(filling period), and number of days from seeding to 50% physiological maturity, flag leaf area estimated according to the equation (Flag leaf area = $L_{max.}$ x $W_{max.}$ x index factor (0.905) (cm^2), and biological yield Kg ha^{-1}, Grain Yield Kg ha^{-1}, and harvest index determined at harvesting. GDD was calculated by using the base temperature of 5 ˚C from the daily mean temperature according to the equation (GDD = [Tmax + Tmin] / 2 - T_{base}). Heat use efficiency (HUE) for grain yield was obtained from the equation, HUE = Grain Yield Kg ha^{-1} / accumulated heat units ˚C day^{-1} (Tomar et al ., 2016). To evaluation the rate of dry matter accumulation, the Relative Growth Rate (RGR) was determined according to the equation, RGR g g^{-1} d^{-1}=ln W_2 – lnW_1/ t_2 –t_1 (Mohammed, 2018), where: lnW_2 is the natural logarithm of the plant weight at a later date, lnW_1 is the natural logarithm of the plant weight at a previous date, t_2 is the time 2 or later date, and t_1 is the previous date. The meteorological data of both locations are shown in the following table:

Table (1) Some meteorological data of Sulaimani and Halabja agroclimatic zones

Months	Locations	Air temperature ˚C			Precipitation mm	Relative Humidity %
		T max	T min	T mean		
Nov	Sulaimani	21.8	4.2	13	16.4	48.6
	Halabja	20.8	3.9	12.35	9.1	35.6
Dec	Sulaimani	18.7	2.8	10.75	144.5	69.9
	Halabja	18.4	1.8	10.1	106.1	51.06
Jan	Sulaimani	15	-0.9	7.05	104.1	73
	Halabja	14.5	-0.4	7.05	91.4	50.64
Feb	Sulaimani	18.6	-7.5	5.55	136.5	70
	Halabja	20	-5.5	7.25	67.9	50.86
Mar	Sulaimani	23.5	3.5	13.5	188	62.9
	Halabja	24.1	4.1	14.1	124.5	46.74
Apr	Sulaimani	27.8	7.8	17.8	71.2	59.7
	Halabja	31	8.8	19.9	83.6	45.8
May	Sulaimani	38	11.5	24.75	13.4	41.4
	Halabja	40	13	26.5	10	34.55

The obtained data were analyzed statistically by using analysis of variance techniques with (XLSTAT). Differences between parameter means were assessed using Duncan's Multiple Range Test at $P \leq 0.05$ level.

RESULTS AND DISCUSSIONS

There were differences in thermal capacity of both agroclimatic zones Sulaimani and Halabja, which expressed as the accumulated growing degree days (GDD) along the life cycles of both varieties were organized in table 2. The HAZ provide a higher accumulation of GDD than SAZ, the total GDD accumulated by V1 of the growing season at HAZ was much higher (1535.783) than its behavior at SAZ (1451.550) While V2 accumulated (1544.383) GDD at HAZ that exceeded its achievement at SAZ (1467.850)GDD. The results demonstrate the higher thermal requirements of both varieties due to the higher performance of those two varieties in HAZ resulted in higher means of daily temperature as well as higher accumulation of GDD along the growing seasons, our results agree with (McMaster et al ., 2003, Kumudini et al., 2014, and Ram et al ., 2016)

Table (2) Thermal requirements as GDD of different stages of the growing seasons at SAZ and HAZ.

Wheat Varieties	GDD Sulaimani			GDD Halabja		
	Days to 50% Flowering	Days from seeding to physiologica l maturity	Filling period days	Days to 50% Flowering	Days from seeding to physiological maturity	Filling period days
V1	788.075	1451.550	676.600	762.192	1535.783	800.042

V2	783.700	1467.850	702.258	769.650	1544.383	809.108

The performance of both varieties was similar and did not show significant differences at SAZ, while their behaviors were significantly varied at HAZ during the end of vegetative and the end of reproductive growth stages in which V1 exceeded V2 at vegetative growth stage but the superiority was to V2 during two different stages of the reproductive period at Halabja as shown in Table 3. There were a lower accumulation of dry matter and a smaller relative growth rate along the life cycle of both varieties at the SAZ. However, the results of the rate of dry-matter accumulation were higher in Halabja with 1540.05 GDD than that obtained by the two wheat varieties in Sulaimani. When an accumulation of GDD was not exceeded 1455.75 in that growing season, differences in varieties behavior in different growing conditions may emphasize differences in provided growth requirements in different growth habitats, (Hou et al., 2014, Ram et al ., 2016).

Table (3) Rate of Dry matter accumulation of both varieties Alaa and Hasad in both ACZs

ACZ	Varieties	1	2	3	4	5	6	7
Halabja	V1	1.124 a	2.343 a	4.956 a	8.606 b	10.472 a	13.889 b	16.833 a
	V2	1.106 a	2.212 a	4.651 b	9.178 a	10.556 a	15.056 a	16.611 a
Sulaimani	V1	0.726 a	1.365 a	4.283 a	7.111 a	9.089 a	11.556 a	12.722 a
	V2	0.704 a	1.348 a	4.365 a	7.250 a	9.333 a	11.444 a	13.389 a

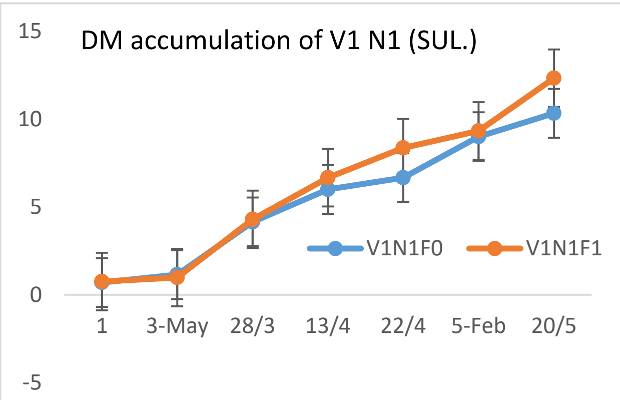
Table 4, indicates the significant effect of nitrogen fertilization applied through three different levels and foliar application of Zn and Fe on the rate of dry matter accumulation, the nitrogen level 160 Kg ha-1(N3) exceeded significantly in all sampling dates at Sulaimani, while the superiority of N2 level was illustrated during the beginning of the vegetative stage and N3 level exceeded at most other growth stages at Halabja. The influence of the foliar application of Zn and Fe was significantly shown in the latest growth stage of both varieties at Sulaimani, but the exceeding of F1 at Halabja was demonstrated during the reproductive stages. Differences in the nitrogen fertilization levels directly influenced performance of wheat varieties and the rate of dry matter accumulation, because nitrogen comprises 7% of plant total biomass and elemental cell components such as nucleic acids, amino acids,enzymes, and photosynthetic pigments (Atia and Ragab, 2013). The maximum accumulated dry weight and the higher RGR were obtained mostly with higher levels of nitrogen N2 and N3 and foliar application of Zn and Iron. The effect of temperature may influence the shortening and extention of the growing periods, the interval between the two stages of development is shortest under optimal conditions for development and may be normalized for the maximum rate due to influence at the rate of biochemical processes. This also may act as a trigger at the start of a stage of development in which the high degree of the linear relationship between total dry matter production and GDD demonstrating that dry matter partitioning varies substantially with among temperature regimes and phases of development, and between genotypes, (Girijesh et al., 2011, Mohammed and Jaza, 2015, Mandic et al., 2015 and Rai et al., 2018).

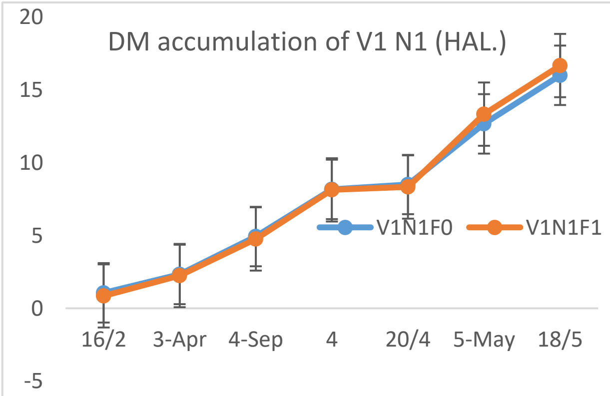
Table (4) Effect of nitrogen levels and foliar application of Zn and Fe on the rate of dry matter accumulation of both varieties at both ACZs

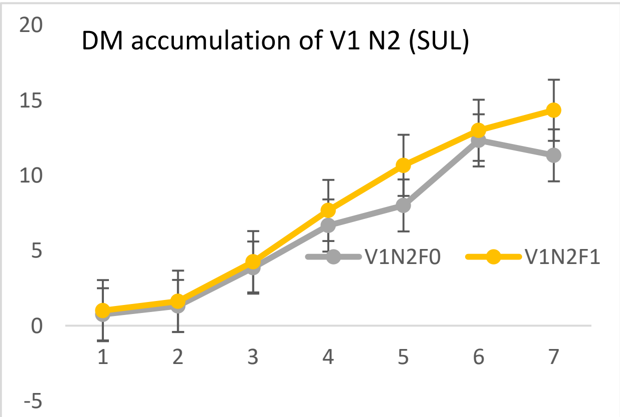
ACZ	N. levels	1	2	3	4	5	6	7
Sulaimani	N1	0.692 b	1.097 b	4.138 a	6.500 b	8.008 c	9.500 b	11.000 b
	N2	0.839 a	1.466 a	4.279 b	7.250 a	9.250 b	12.417 a	13.25 a
	N3	1.614 b	1.513 a	4.553 b	7.792 a	10.375 a	12.583 a	14.912 a
	F0	0.693 a	1.307 a	4.248 a	7.000 a	8.472 b	11.278 a	12.333 b
	F1	0.737 a	1.406 a	4.401 a	7.361 a	9.950 a	11.722 a	13.738 a
Halabja	N1	1.071 b	2.268 ab	4.733 a	8.508 b	9.208 b	13.417 b	16.333 b
	N2	1.258 a	2.397 a	4.732 a	8.875 ab	10.750 a	14.250 b	15.917 b
	N3	1.017 b	2.178 b	4.292 a	9.292 a	11.583 a	15.750 a	17.750 a

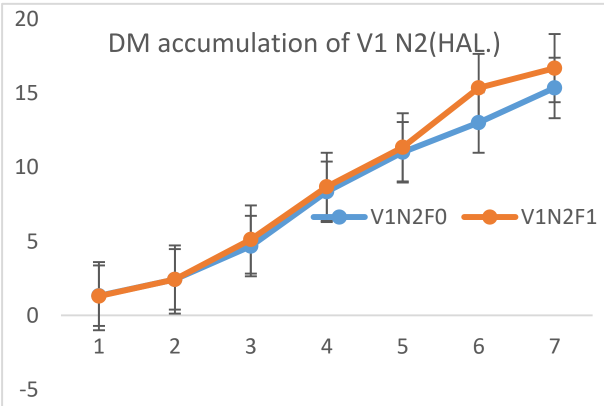
	F0	1.046 a	2.255 a	4.712 a	8.917 a	10.083 b	13.833 b	16.056 b
	F1	1.184 a	2.320 a	4.894 a	8.867 a	10.944 a	15.111 a	17.278 a

Fig.1 and 2 illustrate the significant variation in the rate of dry matter accumulation of Alaa and Hasad varieties in both ACZs under the effect of three nitrogen levels and foliar application of Zn and Fe. In SAZ, there was a slight increase in the rate of dry matter accumulation with increasing the level of nitrogen fertilization from (N_1) 80 kg ha^{-1} to (N_2)120 kg ha^{-1} and to (N_3) 160 Kg ha^{-1} and also foliar application (F1) of trace elements Zn and Fe for both varieties. While an acceleration in the rate of dry matter accumulation of both varieties in HAZ was significantly exhibited, variation in the effect of nitrogen levels and trace elements application between both ACZs might be differences in thermal capacities of both ACZs, because elevated temperature alters uptake and allocation of N, which affect the efficiency of nitrogen using and leading to proper biomass formation of vegetative parts especially the tillers and leaf area of the wheat plant as well hastening of physiological processes especially the photosynthesis enzyme activities led to increasing in the photosynthetic rate. The results are in harmony with previous studies by (Mc Master et al., 2003, Rahman et al ., 2014, Mandic et al ., 2015, Ram et al ., 2016, and Hama and Mohammed, 2019).









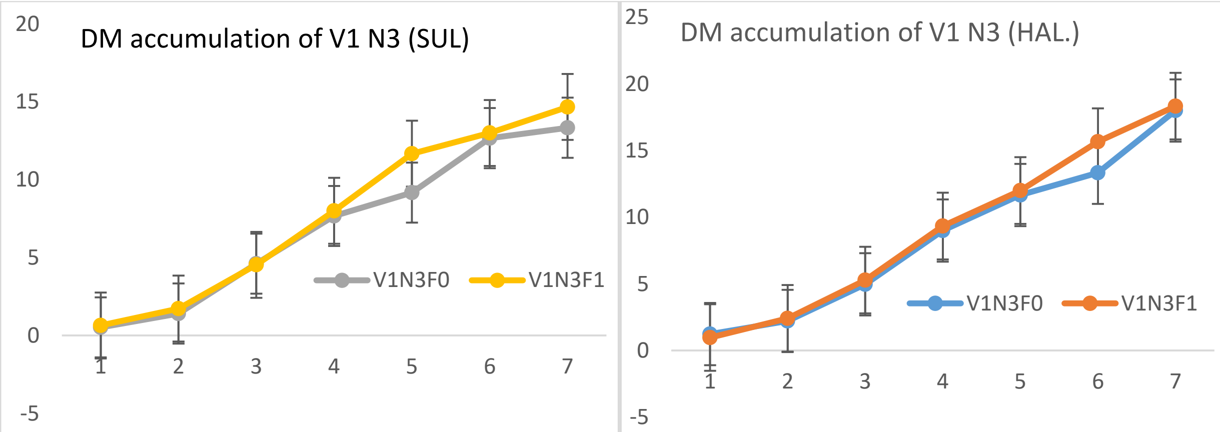


Fig.1, Rate of Dry Matter accumulation of Alaa and Hasad varieties at Sulaimani Agroclimatic zone

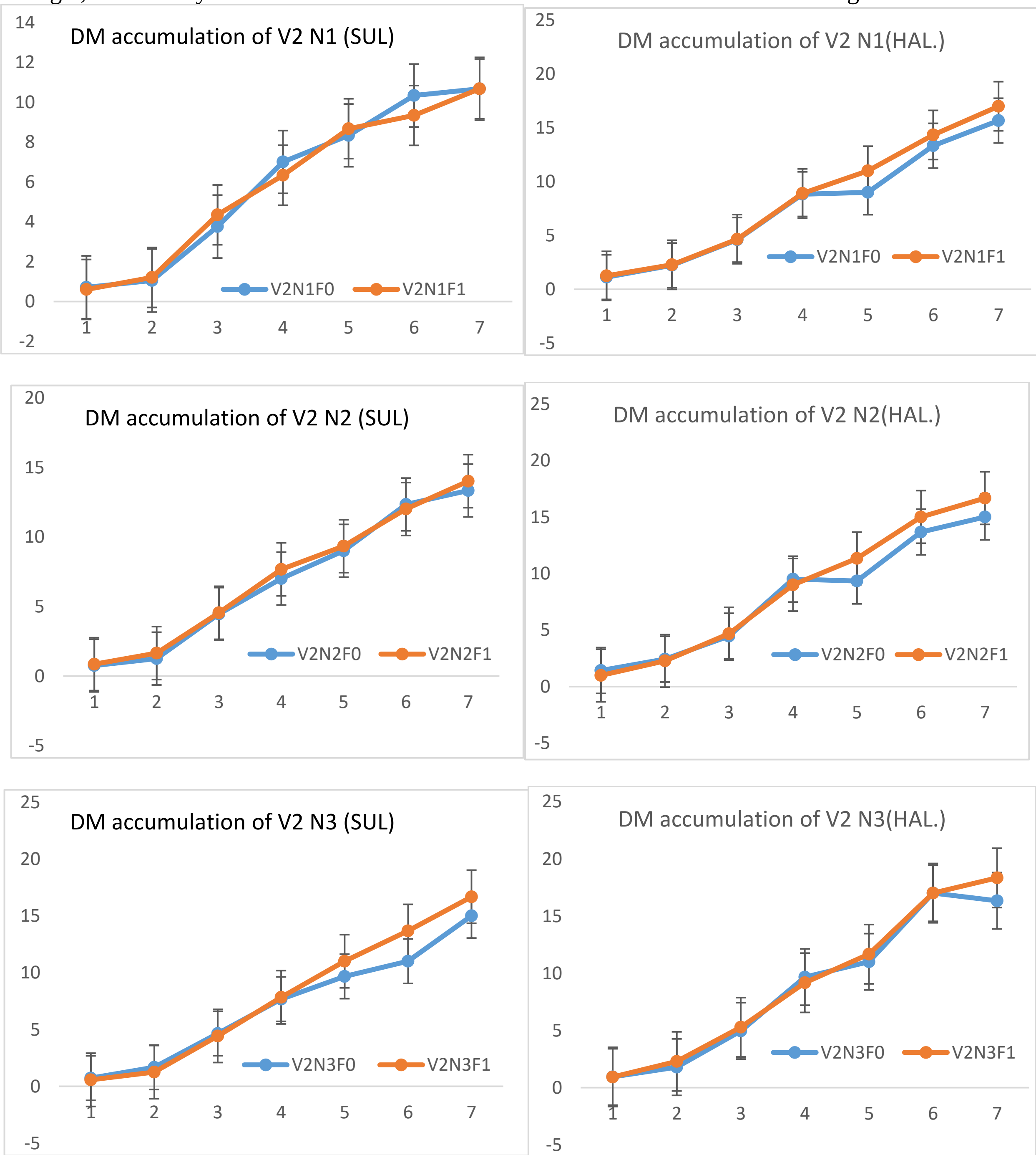


Fig.2, Rate of Dry Matter accumulation of Alaa and Hasad varieties at Halabja Agroclimatic zone.

Fig.3, demonstrate significant differences in the Relative Growth Rate (RGR) of both varieties, the RGR of Alaa variety at Sulaimani was between (0.131 to 0.190) g g-1 d-1 exhibited by (V1N1F0 and V1N2F1) respectively. While the results of Alaa variety at second agroclimatic zone were between (0.172 – 0.221)g g-1 d-1, whilst the RGR of Hasad was between (0.135-0.207) g g-1d-1 at SAZ and (0.185-0.253)g g-1d-1 at HAZ (Fig.3). Differences in RGR of both varieties may reveal variation in their genetic composition that controls their response to the abiotic factors especially temperature which provides a more accurate physiological estimate than counting calendar days (Gutierrez et al., 2013), as well quantitative and qualitative changes from seedling to maturity is related to the accumulation of heat or temperature units above a base temperature, results agree with (Kumudini et al., 2014, Ram et al ., 2016, Sidhu and Raj, 2018, and Tolenaar et al ., 2018).

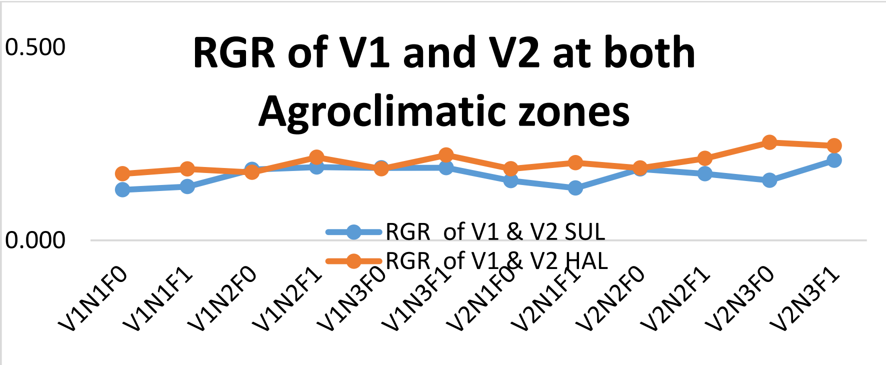


Fig3, Relative Growth Rate of Alaa and Hasad varieties at both ACZs

Table 5, reveal the significant variation among reproductive criteria at both ACZ s, the highest weight of 1000 grain, Grain yield, biological yield, and harvest index at SAZ were (46.293g, 3050 kg ha-1, 9200 kg ha-1, and 33.824) resulted by V1N1F1, V2N1F1, and V1N3F1) respectively, while at Halabja agroclimatic zone were higher (48.157g, 5123.33 Kg ha-1, 14673.3 Kg ha-1, and 39.223) obtained by (V2N1F1, V1N3F0, and V1N2F1) respectively.

Table (5) The yield and yield component parameter of both varieties at both ACZs

Treatments	Sulaimani				Halabja			
	1000 grain Wt. g	Yield	Biological Yield	H.I	1000 grain Wt	Yield	Biological Yield	H.I
V1N1F0	45.57 ab	2166.67 d	7800bc	27.774 a	42.373e	3473.33 ef	9666.67 efg	35.931 a
V1N1F1	46.207 a	2223.33 cd	7150c	31.341 a	45.093d	3473.33 ef	10073.3 def	34.480 ab
V1N2F0	45.54 ab	2500 bcd	7273.33 c	35.852 a	46.42abcd	3416.67 ef	11316.7 bcd	30.191 b
V1N2F1	46.293 a	2683.33bcd	8483.33 bc	31.847 a	47.15abc	4373.33 b	11150cd	39.223 a
V1N3F0	44.563 bcd	2600 bcd	8310bc	31.604 a	46.07bcd	5123.33 a	14673.3 a	34.916 ab
V1N3F1	46.153 a	2916.67abcd	8616.67 bc	33.824 a	46.193bcd	4516.67 b	12506.7 b	36.114 a
V2N1F0	42.18 d	2700 bcd	8160bc	33.312 a	46.317bcd	3150f	8473.33 g	37.175 a
V2N1F1	44.143 bc	3050 ab	9200b	33.703 a	48.157a	3550e	9423.33fg	37.672 a

V2N2F0	43.863 bc	2783.33 abcd	8950b	31.097 a	45.913bc d	3910d	10300de f	37.961 a
V2N2F1	45.45 bc	3223.33 ab	11250a	28.669 a	47.61ab	4010cd	10896.7 cde	36.800 a
V2N3F0	42.59 cd	3023.33 abc	9323.33 b	33.199 a	45.563cd	4340bc	11260bc d	38.544 a
V2N3F1	42.353 cd	3533.33 a	11150a	31.68a	47.51ab	4310bc	11800bc bc	36.525 a

In addition, the grain yield and biological yield of all treatments at Halabja were greater than that resulted at the Sulaimani agroclimatic zone (Fig. 3 and 4). The greater yield and yield components of both varieties Alaa and Hasad at HAZ than that resulted from SAZ created a progress indicator to the additional effect of such a factor than different fertilization applications, this indicated to the role of nitrogen that plays a vital role in grain growth and wheat crop development in favorate conditions, so the environmental and climatic factors influenced the responses of two varieties at both ACZs which has an important role in the modification of the production process especially that related to accumulated GDD. The higher means of 1000 grain weight, and greater yield and biological yield, as well as harvest index in HAZ in compare to SAZ of both varieties, may reveal advantages that indicate to better growth and development of both varieties at HAZ due to favorite thermal capacity of HAZ which was at lower means during the beginning of the growing season and higher means at the reproductive stage, results were agree with the results of (Saiyed et al ., 2009, Kumudini et al., 2014).

HEAT USE EFFICIENCY

The higher means of temperature at HAZ was accelerated growth and development of both varieties at HAZ than that at SAZ, Fig.4, illustrate the HUE of both varieties demonstrating that the Alaa variety at SAZ was between 1.488 to 2.004 kg grain ha-1 deg days-1 recorded with V1N1F0 and V1N3F1, while the Hasad variety showed higher efficiency in using heat at the same SAZ which was 1.855 and 2.427kg grain ha-1 deg days-1 with V2N1F0 and V2N3F1. The higher HUE was exhibited by V1 and V2 at HAZ which were 2.219 kg grain ha-1 deg days-1 and 3.327kg grain ha-1 deg days-1 for Alaa variety with V1N2F0 and V1N3F0 respectively, as well as the V2 variety showed 2.045 and 2.818 with V2N1F0 and V2N3F0, differences in HUE of both varieties in different growing conditions are similar with results of other researchers (Pal and Murty, 2010, Kingra and Kaur, 2012). Higher HUE in HAZ might be due to favorite weather conditions coincides with developing stages that utilize more heat units for organizing the proper relationship between source and sink that led to the net assimilation rate for grain yield increasing. The results are supported by the findings of (Pragyan et al., 2009, Girijesh et al., 2011, Kumar and Kumar, 2014 and Tomar et al ., 2016).

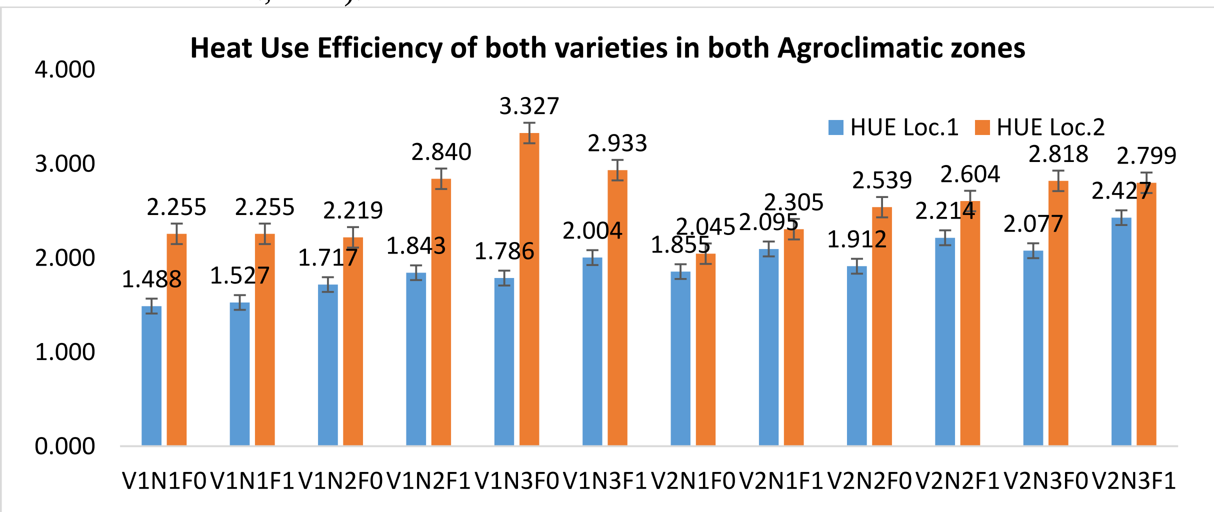


Fig4, Heat Use Efficiency of both varieties Alaa and Hasad at both ACZs

CONCLUSIONS

Differences in the thermal capacity between both agroclimatic zones created significant variation in the performance of both varieties Alaa and Hasad in Sulaimani and Halabja. The lower means of temperature at the beginning of the growing season and higher means at the later stages at HAZ provided the better performance of both varieties at that agro-climatic zone. The higher accumulation of GDD by both varieties at HAZ resulted in higher heat use efficiency of both of them at that Agro Climate Zone, as well as acceleration in the influence of nitrogen levels and foliar application of trace elements Zn and Fe which were more effective at HAZ. The reproductive criteria of both varieties Alaa and Hasad were significantly higher at HAZ, include 1000 grain weight, total Grain Yield Kg ha-1, Biological Yield Kg ha-1, and also harvest index.

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استجابة قمح الخبز (*T. aestivum L.*) للتسميد النيتروجيني والرش الورقي للعناصر النادرة الزنك والحديد والقدرة الحرارية لمناطق مناخية زراعية مختلفة

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الخلاصة

من اجل دراسة النمو والإنتاجية لصنفين من القمح الطري (آلاء وحصاد) في منطقتين مناخيتين زراعيتين مختلفتين ، أجريت تجربتان حقليتان مختلفتان في منطقتي السليمانية وحلبجة المناخية الزراعية خلال موسم 2019-2020. تمت معاملة أصناف القمح بثلاثة مستويات من السماد النيتروجيني (80 ، 120 ، 160) كجم / هكتار (N1 و N2 و N3) والرش الورقي للعناصر النادرة الزنك و الحديد باستعمال (Zn (ZNSO4و 0.5)FeSO4.7H2O)جم لكل750 مل) خلال مرحلة النموالتكاثري بفارق 15 يوم بينهم. أدت الاختلافات في السعة الحرارية مثل درجات النمو اليومية المتراكمة (GDD)بين كلا المنطقتين المناخية الزراعية إلى تباين كبير في أداء النمو لكلا الصنفين. تم تقييم تراكم المادة الجافة على طول موسم النمو من خلال سبعة تواريخ لأخذ العينات بفاصل أسبوعين. كانت هناك فروق في معدل النمو النسبي لكلا الصنفين في كل من منطقة السليمانية و الحلبجة ، وكان معدل النمو النسبي لصنف الاء في السليمانية (0.131 إلى 0.190) جم جم -1 يوم-1 بينما سجل في منطقة حلبجة الزراعية المناخية بين (0.172 - 0.221) جم جم -1 يوم-1. ومع ذلك ، كان معدل RGR لصنف الحصاد بين (0.207-0.135) جم جم -1 يوم-1 في (منطقة السليمانية الزراعية المناخية) و (0.185-0.253) جم جم -1 يوم-1 في (منطقة حلبجة الزراعية المناخية). يمكن تفسير النتائج العالية لـ GDD وإجمالي محصول الحبوب والمحصول البيولوجي ومؤشر الحصاد في (منطقة حلبجة الزراعية المناخية) من خلال الظروف المفضلة المتوفرة في تلك المنطقة عن تلك التي تم الحصول عليها في (منطقة السليمانية الزراعية المناخية) مما ادى الى التحويل الامثل للاسمدة المضافة و أظهر ذلك كفاءة عالية في استخدام الكفؤ للحرارة في حلبجة 2.219و 3.327 كجم من الحبوب هكتار-1 / درجة الحرارة في اليوم لصنف الاء مع V1N2F0 و V1N3F0 على التوالي ، وأظهر صنف حصاد 2.045 و 2.818 كجم من الحبوب هكتار-1 / درجة الحرارة في اليوم مع V2N1F0 و V2N3F0 على التوالي. يمكن الاستفادة من الاختلافات في السعات الحرارية للمناطق المختلفة في تصنيف المناطق الزراعية في الدراسات المستقبلية.

الكلمات المفتاحية: القمح ، التسميد النيتروجيني ، معدل النمو النسبي RGR، المنطقة المناخية الزراعية ، درجات النمو اليومية GDD