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Research Paper

Relation between Agro-Meteorological Indices, Heading Date and Biological/Grain Yield of Durum Wheat Genotypes

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ABSTRACT:- *A field experiment was conducted during 2014/2015 cropping season in Boulifa-Kef in order to investigate the relation between agro-meteorological indices (growing degree days (GDD), photothermal index (PTI) and heat use efficiency (HUE) at heading date) and biological/grain yield for eight durum wheat varieties. Results showed differences in number of days required to reach heading for durum wheat genotypes. The earliest heading date was observed for Magherbi and Ben Bechir genotypes with an average accumulation of GDD about 1128.85°C and 1146.65°C respectively, while heading was delayed for Mahmoudi followed by Chili variety with a GDD requirement of 1382.80 °C and 1356.90 °C respectively. Differential behavior of durum wheat genotypes for heat use efficiency was also noted. Ben Bechir and Salim genotypes recorded highest heat use efficiency (2.96 and 2.87 kg/ha/°C) and grain yield respectively (3486.67 and 3507 kg/ha). The highest PTI (11.33 and 11.03) and lowest grain yield were noted in Mahmoudi and Chili respectively (1696.67 and 2196.67 kg/ha). Correlation analysis indicated that grain yield were highly significant and negatively correlated with growing degree days (r = -0.90**) and heat use efficiency (r = - 0.88**). In semi arid region, it is recommended to use genotypes with early maturity (precocious) and a moderate time to reach heading stage as Salim variety.*

KEYWORDS: *Grain yield, growing degree day, stage, temperature.*

I. INTRODUCTION

Durum wheat is the most important grown crop in Tunisia in terms of area cultivated and production. It presents about 60% of production and area occupied compared to other cereals. However, durum wheat development is affected by many factors such as nutriments, water, photoperiod, and temperature. Research concerning the relationship between weather parameters and wheat yields is growing rapidly, inter alia the role of temperature data to determine yields (White and Reynolds. 2003; Tacka et al., 2015). Temperature is among main environmental factors affecting the growth and development of durum wheat. It influences the phenological stages, and biological and grain yield of plants (Bishnoi et al., 1995). Plants have a definite temperature requirement to accomplish phenological stages. Because of the very close relation between temperature and plant development, growing degree-days (GDD) are frequently used as an indicator for crop development evaluation. Therefore, it's currently important to have exact information of the phonological stages duration and their related effect on grain yield. Several authors used degree-days to describe this connection between temperature and crop development (Kingra and Kaur, 2012; Salazar-Gutierrez et al., 2013). The accumulated temperature is considered as the principal factor affecting year-to-year variation in phenology. In general, increasing temperatures accelerate phenological development by reducing growth period (Asseng et al., 2011). GDD also changes with growing stage and permits to estimate the exact time of occurring growth stage in particular location (Mc Master et al., 2012). Research has shown that the growing degree days for achievement of the phenological stages differ from genotype to another (Porter and Gawith, 1999; Trudgill et al., 2005). Several models proposed for describing the effect of temperature on phenological development (Yang et al., 1995). One of the most common used method, independently of environment or year, is the accumulation

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of daily mean temperature (degree days) above a base temperature (Tb) (Ritchie and Ne Smith, 1991). A basic requirement for this approach is the determination of the temperature under which phenological development stops, according to the base temperature (Tb) (Steinmaus et al., 2000). For more quantifying the thermal relation of crops, thermal units' method is also extensively used (Ramteke et al., 1996) and has been further modified to include photothermal units (Rao et al., 1999). The photothermal unit concept provides a reliable index for the progress of the crop that can be used to predict the yield of any crop (Pal et al., 2013). Heat use efficiency index could be also used in order to predict phenological phases (Sikder, 2009; Girijesh et al., 2011). Few studies reported the requirement in term of temperature (degree days) for each variety. Therefore, the objective of this study is to evaluate the correlation between agro-meteorological indices at heading stage and biological/grain yields on eight durum wheat genotypes.

II. MATERIAL AND METHODS

2.1 Vegetal material

Eight durum wheat genotypes namely Maali, Karim, Maghrbi, Chili, Ben Béchir, Mahmoudi, Razzak and Salim were evaluated for their degree days requirement to reach heading stage and its correlation with their performance. The origins and the characteristics of the eight varieties are resumed in Table 1.

Table 1: Different durum wheat genotypes used in this study, their origin and agronomical characteristics (Boeuf, 1932; Deghaïs et al., 2007)

Cultivars	Origin	Characteristics
Chili	Selected by pedigree and registered in 1953	Spike: whitish , sometimes mottled brown Terminal spikelet: almost identical hulls, both end tip Straw: hollow
Mahmoudi	Tunisian north and trays, registered in 1953	Spike: Medium density, white glumes and black beards Kernel: Gross, hunchback, amber or red Straw: Large, medium height
Maghrbi	CIMMYT introduced in 1968/1969. It's selection and experimentation were made by INRAT	Spike: whitish to reddish brown, narrow to slightly pyramidal and short. Terminal spikelet: similar glume, in both end points Straw: variable but most often hollow and very rarely full.
Ben bechir	Introduced by INRA in 1972, officially registered in 1982	Spike: whitish yellow, elongate, narrow and parallel edges. Terminal spikelet: almost identical hulls, both end tip Straw: hollow
Karim	Selected by the "INRAT the CM9799 cross made at CIMMYT / Mexico introduced in Tunisia in 1973	Spike: yellowish white Terminal Spikelet: glumes yellowish white dissimilar Straw: hollow section thick enough wall
Rezzak	Selected by the karim x Dmx69-331 cross made at INRAT, registered in 1987	Spike: whitish, narrow and parallel edges. Terminal spikelet: almost identical hulls, both end tip Straw: hollow
Maali	New variety after crossing: D92-27 made in 1992, proposed to inscription in 2003	Spike: white elongated with parallel edges. Terminal spikelet: unlike white glumes. Straw: thin-walled hollow section over the entire length.
Salim	New variety proposed to inscription in 2007 by INRAT	Spike: square barbed blackish Tillering: strong and moderately resistant to lodging

2.2 Trial design

A field experiment was conducted during 2014/2015 cropping season at Higher Agriculture School of Boulifa-Kef, located in the North Ouest of Tunisia (Altitude of 780 m). The soil of experimental site was a clay-loam with EC = 2.1 dsm-1 and having pH= 7.91. The trail was laid out in completely randomized design with 4 replications. Seeds were sown using drill in plots (6.5 m²) with 0.20 m row spaced on 24 December with a seeding rates of 160 kg/ha. The experiment field received 100 kg ha-1 of Di-Ammonium Phosphate at sowing and fertilized with ammonitrate respectively at early tillering (100 kg/ha) and stem elongation (100 kg/ha). An herbicide Puma evolution (Fénoxaprop-P-Ethyl + Iodosulfuron-methyl Sodium +Méfenpyr-diéthyl) was applied at the dose of 1 l/ha as treatment for weed control.

Meteorological data, maximum, minimum and average temperature (°C) during vegetative and reproductive stage were recorded (Table 2). Temperatures data shows that durum wheat crop had exposed to various thermal regimes during vegetative and reproductive phase of the crop.

Table 2: Meteorological data, maximum, minimum and average temperature (°C) for 2014/2015 cropping season in Boulifa/kef Site

Months	T Maximum (°C)	T Minimum (°C)	Average T (°C)
December	**20.80**	**72.70**	**46.75**
January	**94.50**	**389.40**	**241.95**
February	**109.10**	**333.60**	**221.35**
March	**175.40**	**517.00**	**346.20**
Avril	**177.80**	**626.00**	**401.90**
May	**370.30**	**897.60**	**633.95**
June	**474.60**	**933.20**	**703.90**
Total	**1422.50**	**3769.50**	**2596.00**
Mean	**203.21**	**538.50**	**370.85**

2.3 Parameters measured

The Agro-meteorological indices growing degree days (GDD), photothermal index (PTI), heat use efficiency (HUE) was calculated on the basis of following formula:

GDD (ºC) = (($Temp_{max}$ + $Temp_{min}$)/2) – Threshold temperature

$Temp_{max}$: maximum temperature

$Temp_{min}$: minimum temperature

Threshold temperature of 5°C was considered for wheat crop (Nuttonson, 1955).

HUE_{GY} (Kg/ha/°C day) = (Grain yield (kg/ha)/ Accumulated GDD (°C day))

HUE_{BY} (Kg/ha/°C day) = (Biological yield (kg/ha)/ Accumulated GDD (°C day))

PTI = degree days consumed between two phonological stages/ number of days between two phonological stages

Heading days data were recorded during the growth period, when approximately 50% of spikes had completely emerged from the boot. Grain yield is recorded for all genotypes.

2.4 Statistic analysis

Tukey test ($p<0.05$) was used to note the significance difference between means. The correlation between agro-meteorological indices and grain yield were analyzed by SPSS 16.0 version.

III. RESULTS

Data pertaining to grain yield, biological yield, GDD, PTI and HUE at heading stage of all genotypes tested are presented in Table 3. GDD was used to explain the relationship between heading duration and temperature. This concept assumes a direct and linear relationship between growth and temperature. In this study, differences in the heading dates for the durum wheat genotypes were noted. Durum wheat genotypes required an average of 1240.91°C to reach heading from the planting day. In general, the time required to attain heading from planting varied from 123 to 133 days with an average of 127 days for all genotypes. The earliest heading date was observed for the genotypes Magherbi and Ben Bechir with accumulated average of GDD 1128.85 °C and 1146.65 °C respectively, while heading was delayed Mahmoudi followed by the Chili with a GDD requirement of 1350.8 °C. In this study, asignificant increase in temperature occurred at the beginning of spring (March) until the end of the growing season (end of April) (Table 2). March and April were the months where the highest temperatures were reported and when the earliest heading occurred.

Table 3: Biological/Gain yield and different agro-meteorological indices (Growing Degree Days (GDD), Photothermal index (PTI) and Heat Use Efficiency (HUE)) calculated for used genotypes

Genotypes	Grain yield (Kg/ha) *	Biological yield (Kg/ha)	GDD (°C day) from planting to heading	HUE (grain yield)	HUE (Biological yield)	Photothermal index (PTI)
Mahmoudi	1696.67c	6258.33a	1382.80	1.23	4.54	11.33
Chili	2196.67b	7550.00a	1356.90	1.62	5.58	11.03
Maghrbi	3216.67a	3837.50	1160.85	2.77	3.32	9.28
Ben bechir	3486.67a	5575.00b	1178.65	2.96	4.75	9.42
Razzek	3406.67 a	4920.83b	1208.10	2.82	4.09	9.66

Karim	3100.10a	4412.50c	1208.10	2.57	3.67	9.58
Maali	2776.67b	4262.50c	1208.10	2.30	3.54	9.15
Salim	3507.00a	4662.50c	1223.85	2.87	3.83	9.20
Average	2923.38 b	5184.90b	1240.91	2.39	4.17	9.83

*Means followed by different letters within for biological and grain yield have significant differences at the level of P<0.05 for Tukey test

Among durum wheat genotypes tested, Ben Bechir and Salim genotypes recorded highest grain yield (3486.67 and 3507 kg/ha, respectively) and highest heat use efficiency for grain (2.96 and 2.87 kg/ha/°C). While, Mahmoudi and Chili genotypes showed and HUE for grain yield (1.23 and 1.62 kg/ha/°C, respectively) and lowest grain yield (1696.67 and 2196.67 kg/ha). For HUE related to biological yield Ben Bechir (4.75 kg/ha/°C) and Mahmoudi (4.54 kg/ha/°C) recorded the highest values. It's also noted that the highest grain yield of salim variety is accompanied with a moderate GDD (1223.85 °C). The PTI, expressed as degree-days per growth day, for each variety and is presented in Table 3. Highest PTI value was observed in Mahmoudi (11.33) and Chili (11.03). The genotype Maali (9.15) showed the lowest one.

The results obtained from the correlation analysis indicated that grain yield were highly significant and negatively correlated with growing degree days at heading stage (r = -0.90**) and heat use efficiency (r = -0.88**) (Table 4). A positive correlation was noted in the case of biological yield (r = 0.72*) and (r = 0.88**) respectively for the two indices. This result indicated that late genotypes given less yield grain than earliest ones. While, long heading stage provides for plant more biomass. Mahmoudi took longer time to attain the heading phase with growing degree days about 1382.80 °C. This variety showed the lowest grain yield (1696.67 kg/ha).

Table 4: Pearson correlation coefficients of biological and grain yield with agro-meteorological indices (growing degree days (GDD), photo thermal index (PTI) and heat use efficiency (HUE)) at heading.

	Grain yield (kg/ha)	Biological yield (kg/ha)	GDD	HUE (biological yield)	HUE (grain yield)	PTI
Grain yield (kg/ha)	1	-0.55	-0.90**	-0.47	- 0.88**	0.99**
Biological yield (kg/ha)		1	0.72*	0.88**	0.71*	-0.59
GDD			1	0.67	-0.95**	-0.93**
HUE (biological yield)				1	0.72*	-0.51
HUE (grain yield)					1	-0.90**
PTI						1

*: Correlation is significant at the 0.05 level; **: Correlation is significant at the 0.01 level

IV. DISCUSSION

The date heading is among the important traits related to the adaptation of wheat genotypes under field conditions and research by durum wheat breeders. In this study, differences in GDD to attain heading were noted for used genotypes. According to our results, the heading date could be successfully predicted using GDD accumulated. This approach of GDD accumulation has also been reported by others studies in wheat (Anjum et al., 2014) and other crops (Snyder et al., 1999; Ruml et al., 2010). According Salazar-Gutierrez et al. (2013), differential response of genotypes for winter wheat were reported and the average GDD requirement from planting to heading was 2705°C. This study indicated that the variation of GDD accumulation was probably a selective advantage for winter wheat. It also provides the basis for adjusting the sowing date, to achieve the yield potential with different growth characteristics. According to Zhang et al. (2009), heading dates are affected by genetics and environmental conditions. A strong interaction between genetics and the temperature occurs when the crop is exposed to low temperatures during vegetative and reproductive development, which is affected by sowing date, seeding rate, fertilizer applications, irrigation and fluctuations in short term weather and long-term climate conditions (Hu et al., 2005). In fact, the heat unit system or growing degree days (GDDs) shows a direct and linear relationship among plant growth and temperature (Parthasarathi et al., 2013). These authors found that same cultivar showed similar phenology and have similar heading dates independent of the growing season. In contrast, changes in the heading date would indicate changes in temperatures, particularly during spring. Early sowing dates result on higher heat units as GDD than late sowing dates. In this study, differential behavior of durum wheat genotypes for HUE could be attributed to their genetic potential (Bhat et al., 2015; Sattar et al., 2015). Every crop needs a specific amount of GDD to start reproductive phase from vegetative phase. Similar results were observed by Amrawat et al., (2013). Pandey et al. (2010) also reported lower consumption of heat units under delayed sowing. Heat tolerant wheat cultivars had greater growing degree day (GDD) and heat use efficiency than sensitive (HUE) cultivars (Sikder, 2009). Heat use efficiency (HUE) quantification is necessary for a crop yield potential assessment in different growing conditions (Pal and Murty 2010). Kingra and Kaur (2012) reported that HUE affects dry matter accumulation and depends on genetic factors and practical application. Also, differences between durum wheat varieties for PTI were noted. In this context, Gill et al. (2014) found that the phenothermal index (PTI) is affected by the growing environment and cultivars. Same authors reported also that temperature increases physiological activities which results a higher grain yield. According to these results, genotypes with low value of PTI and high value of HUE showed more important yield, which strengthened the previous deduction of Pal and Murty (2010). Correlation values were observed between yield and meteorological indices reinforcing the previous observed relationship found by Ganajaxi et al. (2001) and Shamim et al. (2013). However, Al-Karaki (2012) showed that grain yield was positively correlated with GDD to heading. In this context, Amrawat et al. (2013) reported that long growth duration provides for plant an opportunity to accumulate maximum of biomass. In Tunisian semi arid regions, earliest genotypes with a high HEU and moderate GDD to attain heading showed highest yield and more adaptability.

V. CONCLUSION

In this study, the agro-meteorological indices provide the effect of temperature on phenological behavior, it showed significant differences in heading duration stage among wheat genotypes. More research is required to estimate duration for others phenological stages and further evaluation is required under a wider range of genotypes and environment.

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