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Harvest moisture content affecting yield and quality of wheat grains in Brazil

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The wheat quality and yield may be limited or compromised by several factors in the field, being the climatic main factor at the end of the crop cycle. The aim of the study was to determine whether different harvest times affect crop yield and wheat grain quality; four experiments were conducted, differing by cultivars type and sowing time, at Ponta Grossa city, PR, Brazil. The experimental design used for both cultivars (BRS-Pardela and Quartzo) were randomized complete block with five grain moisture content at harvest time (30, 25, 20, 15 and 13%) being 4 replications. For the first sowing time, the different harvesting times had no effect in yield, falling number (FN) or hectoliter weight (HW) for both cultivars. In the second sowing time, the yield components and yield for both cultivars were not affected by the different harvest times. A linear and quadratic decrease on the pH with the delaying of harvest time was noticed for BRS-Pardela and Quartzo, respectively, for the FN only the BRS-Pardela showed quadratic reduction delaying the harvest time.

Key words: *Triticum aestivum*, no-tillage, harvest time, industrial quality.

INTRODUCTION

Wheat crop (*Triticum aestivum* L.) is important cereal crop because it is increasing the demand of the population for these cereal products, making it important to the economies (Seghezzo and Cuniberti, 2010; USDA, 2011). As a result, there are research institutions in various regions with breeding programs and management aiming higher yield. In addition to yield, wheat grain must also possess desired technological quality by the industry, thus avoiding the use of additives for reasons of cost and food security (Franceschi, 2009).

Yield and quality of wheat grains can be defined as a result of interaction between what the culture suffers in the field, the effect of ground conditions, the management of culture, cultivate, harvest and weather conditions (Edwards, 2004; Shewry et al., 2003). The weather has a profound impact on production and helps explain why different parts of the world produce wheat with better quality (Bozzini, 1988). In Southern Brazil, the main pr oblems are the high moisture content of the air in September and October, the high temperatures in the grain filling stage, the possibility of hail and frosts in silking and rains at harvest (Franceschi, 2009; Noda et

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al., 1994).

The high rainfall after wheat physiological maturity influences negatively the hectolitre weight, thousand grain weight, number of fall, the P/L and grain yield due to increased severity of disease and enzyme activity (Guarienti et al., 2003, 2005).

The grain moisture content at harvest is directly related to the resistance of grain to mechanical damage and the humidity range from 13 to 15% is considered ideal for the harvest, depending on the cultivar. The late harvest, after physiological maturity contributes to undesirable changes in the technological quality of wheat (Carneiro et al., 2005). One option to improve grain quality is an early harvest. To this end, the producer must take into account the need and availability of drying, the risk of deterioration and energy spent on drying (Carneiro et al., 2005; Embrapa, 2010; Quick and Buchele, 1978).

The early harvesting process after physiological maturation can be an alternative to obtain a product with appropriate industrial quality, when there are high levels of starch, protein and water, preventing the grain to be exposed longer to diseases such as fungi producing mycotoxin (Carneiro et al., 2005).

The early harvesting can affect the number of fall (Falling Number) and hectolitre weight, among other characteristics of wheat grain, being necessary to assess whether the moisture content at harvest interfere in these characteristics of grain.

MATERIALS AND METHODS

Four experiments were conducted in the city of Ponta Grossa – PR, Brazil. The experimental design used in the four experiments, which differ by sowing date and cultivar was randomized blocks, with 5 moisture content at harvest (30, 25, 20, 15 and 13%) and 4 repetitions. In all experiments, the plots showed 8.0 m long and 6.0 m wide and useful production area of 6.0 × 4.0 m. The moisture content at harvest was obtained within the range of physiological maturity (30%) and the moisture content for wheat storage (13%). The cultivars used were Quartzo and BRS-Pardela.

The harvest dates for each treatment, for both varieties are shown in Table 1. Wheat was grown at no tillage system with soybean as the previous crop. The first sowing was done on June 11th 2013 and the second was done on July 3th of the same year. As fertilization, 300 kg ha^{-1} of 14-34-00 was carried out at the sowing time. At the beginning of the tilling stage, 40.5 kg ha^{-1} of nitrogen and 60 kg ha^{-1} of K_2O was applied as coverage fertilization. The seeding rate used in two seasons and in both cultivars was 75 viable seeds per meter, 0.17 m spacing between rows and average depth of seeding 0.04 m.

When the grains have reached the mature stage (Table 1), hand sickles were used to harvest the plants, and one meter of plant row was sampled for the assessment of yield components. The meter of plant row per plot was evaluated on the number of ears; the number of spikelets per spike, grain per spikelet and also the weight of a thousand grains. The yield was determined by the useful production area of each plot and its moisture was corrected to 13% being the value converted into kilograms per hectare.

Of harvested wheat, grain was also evaluated with industrial quality: hectolitre weight (HW) and falling number (FN). The HW was measured in the Laboratory of Plant Science at the State University of Ponta Grossa through the DALLEMOLLE balances and the FN in CONAB company by the apparatus of brand Perten model FN 1700.

Data were subjected to analysis of variance by F test and the differences among the averages of the different moisture contents were analyzed by polynomial regression.

Correlation analysis was performed to verify a possible relationship between the meteorological variables and industrial quality variables. For this, they were calculated in average maximum and minimum temperature and precipitation for harvest period, the sum of rainfall, the amount of days of rainfall and days when the plant was in the field after physiological maturity. For the interpretation of correlation coefficients (r), the table proposed by Shikamura (2014) was used.

RESULTS AND DISCUSSION

The moisture content at harvest did not affect the weight of a thousand grains (WTG) and yield of both cultivars in the two sowing dates (Table 1), as the harvest seasons were very close, with no weather changes (rainfall and temperature) substantially between treatments (Figure 1). This indicated that probably are needed sharp changes in temperature and rainfall to affect WTG.

Guarienti et al. (2003) observed reduced WTG and yield due to high temperature (above 35 °C) in the grain filling period. They also indicated that the grain fillers stage there is influence of temperature, precipitation and solar radiation in WTG and grain yield, but the harvest time in this work were carried out after physiological maturity, that is, low temperature variation between treatments in the grain filling period and thus the WTG and yield were not affected.

The hectolitre weight (HW) was not influenced by harvest times in both cultivars in the first sowing time and the second sowing time the cultivars showed different results for HW (Table 1). To BRS-Pardela the answer was negative linear, with lower HW with the delayed harvest, i.e. for crops with lower moisture contents. To Quartzo response was quadratic, with maximum point in humidity of 22% where the HW was 78.1 and then decrease as the crop was more time in the field, confirming the downward trend HW with delayed harvest.

According to Hirano (1976), there is a deterioration mechanism of wheat industrial quality due to rainfall which occurred over periods of more than 20 days before harvest. Who also argued that due to the rain the grains start to get chochos and the HW decreases. Guarienti et al. (2003), also showed the negative influence of rainfall on the HW when precipitation occurs in periods of more than twenty days prior to harvest.

Comparing the results of the second sowing with wheat quality table (IAPAR, 2013), BRS-Pardela in harvest times with 30%, 25% and 20% humidity would be classified as wheat type 2, HW value between 75-78 and crops with 15% and 13% moisture content wheat classified as type 3, HW value between 70-75. To cultivate Quartz the time of 30% wheat crop had type 2, the harvest with 25% and 20% had type 1 wheat and the harvest with 15% and 13% moisture content wheat was

Table 1. Thousand Grain Weight (TGW), Yield, Hectoliter Weight (HW) and Falling Number (FN) to the wheat cultivars BRS-Pardela and Quartzo in two sowing dates at different levels of moisture harvest (Ponta Grossa, PR, 2013).

Moisture harvest	First time sowing		Second time sowing	
	BRS-Pardela	Quartzo	BRS-Pardela	Quartzo
		Thousand grain weight (g)		
13	37.84	37.38	40.5	39.4
15	36.46	39.09	40.4	40.6
20	36.52	38.62	39.9	38.9
25	35.93	40.00	38.5	38.4
30	34.53	37.74	38.8	39.3
Regression	NS	NS	NS	NS
		Yield (kg/ha)		
13	2.022	2.752	1.549	2.194
15	1.948	2.822	1.699	2.016
20	1.936	2.677	1.647	2.107
25	2.355	2.800	1.152	2.002
30	2.284	2.934	1.413	2.104
Regression	NS	NS	NS	NS
		Hectolitre weight		
13	77.04	76.91	77.62	77.06
15	78.79	78.51	77.63	78.47
20	77.39	76.57	75.98	78.80
25	79.53	77.46	74.01	76.16
30	75.95	77.23	73.86	75.27
Regression	NS	NS	L	Q
		Falling number		
13	313.3	337.2	269.5	367.2
15	296.5	318.6	232.0	369.0
20	290.0	346.7	288.0	355.2
25	294.5	348.5	325.5	367.0
30	322.7	373.5	187.0	308.2
Regression	NS	NS	Q	NS

NS = Not significant; Q = Quadratic; L = Linear; Hectolitre weight: BRS-Pardela: $Y= 71.37 + 0.223x$ (R^2= 90.83); Quartzo: $Y= 67.23 + 0,98x – 0.022x^2$ (R^2=84.12); Falling Number: BRS-Pardela: $Y= -330.44 + 53.27x -1.103x^2$ (R^2= 95.79).

type 3, with the clear advantage the anticipated harvest to prevent the reduction of HW in both cultivars.

The correlation between HW and days which precipitation occurred was performed where the correlation was very weak, but negative, confirming that rainfall before harvesting reduce the HW of wheat. However, as in this work the weather conditions were little rain before the harvest, the HW was not affected by harvest time.

According Guarienti et al. (2003, 2005), precipitation, relative humidity and the water surplus negatively influence the HW, the WTG, the Falling Number (FN) and the grain yield. The decrease in HW can be attributed to the successive changes in grain moisture due to rainfall (Mellado et al.,1985), suggesting that it is more damaging to the quality of wheat when there are several days of rain during the crop maturation period than just a rainy day with a high volume of water.

Finney and Yamazaki (1967) observed that the intermittent wetting and drying the wheat grains reduce the WH, as a result of decreasing grain density. The wheat grain density may decrease because the grain have started the twinning process, may cause decreased yield, WTG and HW due to the high rate of respiration, which consumes the accumulated carbohydrates in grains (Bhat et al., 1981; Fleurat-Lessard, 2002; Bhattacharya and Raha, 2002).

These theories can explain the results of this study, in

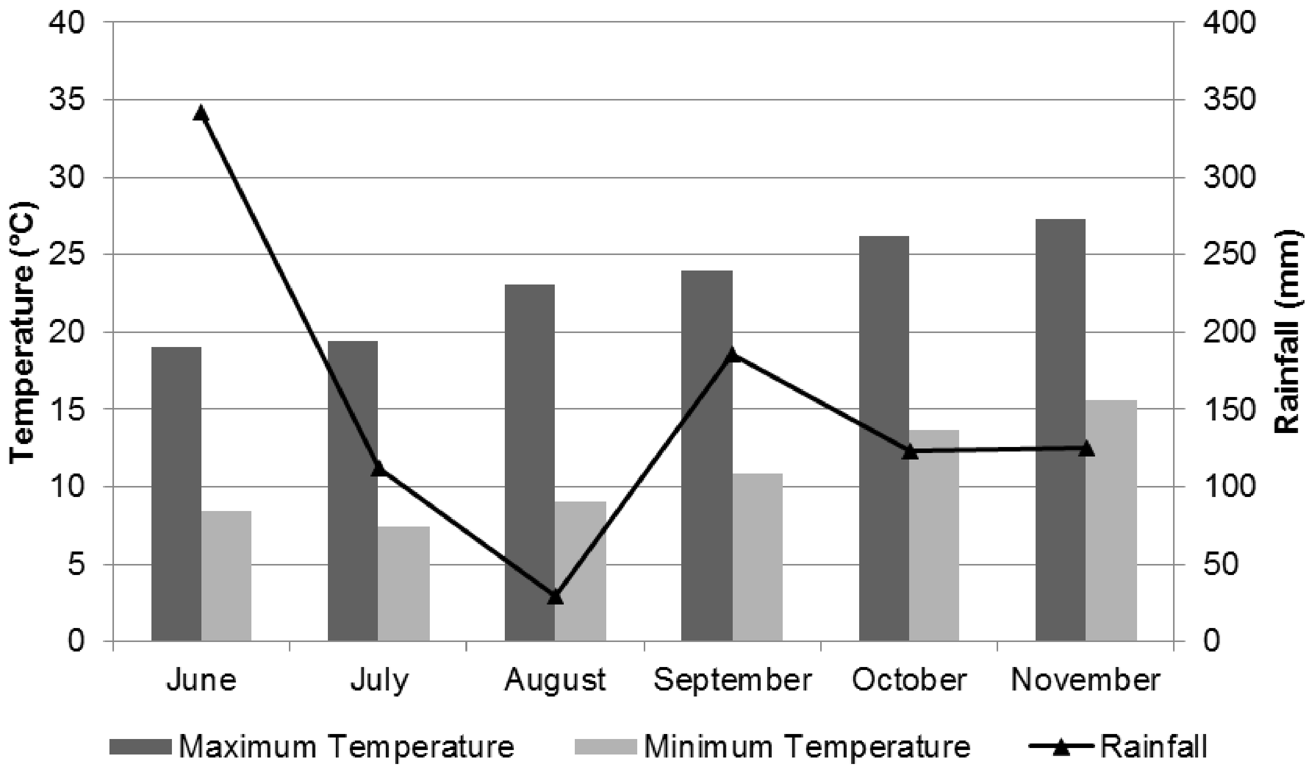

Figure 1. Temperature Analysis, maximum and minimum, and rainfall in the municipality of Ponta Grossa, PR. Brazil, 2013 (Source: IAPAR).

which the HW values showed strong negative correlations on BRS-Pardela and moderate negative to Quartzo, with the sum of rainfall, the number of days the sum they occurred and precipitation summation days when plants were in the field. These results demonstrated that the longer the crop is in the field after physiological maturity, may be prone to adverse weather conditions, reducing the industrial quality of wheat grain. To minimize these losses quality is recommended anticipate the harvest.

The different moisture content at harvest did not affect the FN of both cultivars in the first sowing. In the second sowing date there were no significant differences between the moisture content at harvest to cultivate Quartz and for BRS-Pardela the response was quadratic with maximum point with 24% grain moisture (Table 1). This difference between the cultivars may be related to susceptibility to germination in the ear. The cultivar Quartz is moderately resistant to germination in the ear (Sementes, 2014) and despite the BRS-Pardela be moderately susceptible (Embrapa, 2014), both cultivars showed high FN, an answer that may be related to climate, without precipitation excesses before the point of harvest, which comprises the harvest times that composed the treatments.

Barnard and Smith (2012) conducted a study with eleven cultivars to determine the influence of climate on FN and observed that the rains during the latter stages of the filling stage and grain maturity showed negative effect on the FN in seven of the eleven cultivars, while that high temperatures in these periods were positively correlated with the FN in eight of the eleven cultivars, suggesting that higher maximum temperatures after physiological maturity can lead to higher values of FN.

To BRS-Pardela in the first sowing the correlation between the FN and minimum temperatures was weak but negative and the total days the plants were in the field was moderate negative, indicating that there is a downward trend when FN culture is for longer exposed to climate variations. Correlations were moderate negative to the precipitation, for the amount of days that occurred rainfall and the days when the treatments were in the field, i.e. the longer the culture is exposed to bad weather, are more damaging to the FN. In the second sowing time for BRS-Pardela, the minimum temperature, the sum of rainfall and rainy days summation may have affected the FN because there was a negative correlation of these factors with the FN. To Quartzo that was not observed.

These results showed that the FN decreases due to rainfall after their physiological maturity and the longer the period in which the crop in the field is, the lower the NF. Barnard and Smith (2012) observed similar results regarding correlations where frequent rainfall immediately after physiological maturity were more important in determining FN values lower than a large amount of rain in a single period.

According Guarienti et al. (2004) in field germination before the harvest is induced when grains absorb water at low temperature and also the soaking water at low temperature promotes dormancy breaking and germination results in pre-harvest, reducing the FN due activation of the synthesis of alpha-amylase enzyme (Indrani and Rao, 2007).

The results of this study showed that the harvest season exerted very marked influence on the quality of wheat grain, but the correlations with climate variables indicate that weather conditions affect the industrial quality but are necessary temperature variations and frequent rainfall to decrease values TGW, HW and FN. THG, HW and FN are negatively influenced by high temperatures that occur during the grain filling stage, but higher temperatures favor physiological maturity after these characteristics due to rapid drying of the grains.

Frequent rainfall, or several days after the rains with physiological maturity are more detrimental to the TGW, the HW and the FN to high rainfall in fewer days, as a result of intermittent wetting and drying reduces the density of grains and activate the enzyme alpha-amylase, which reduces NF. To minimize these effects, the anticipation of the harvest becomes an interesting option because it reduces the time that culture is exposed to bad weather, but it is necessary to evaluate its feasibility due to the need for drying grain, or even the use of desiccants.

Both wheat sowing dates were within the recommended by climatic zoning for the region, but noted that for the sowing of the second season yield was lower (27% on the average of treatments), and this can be attributed to tillering phase, where for the first time, the average temperature was lower compared with the second time, resulting in increased number of tillers and larger number of ears per meter, which may have resulted in greater yield.

In the second, sowing the FN was lower (14.2% on average) compared to the first time to BRS-Pardela, which can be attributed to more frequent rainy days during the harvest second season. To Quartzo the difference was a little, so to the FN, the cultivars show a difference response, due to BRS-Pardela have greater susceptibility to germination in Quartzo spike and cultivating be moderately resistant to resistant to this characteristic.

Conclusions

Frequent rainfall after their physiological maturity is more detrimental to the THG, the HW and the FN to high rainfall in fewer days. The larger is the period that the culture is in the field exposed to climate variations, is more damaging to industrial grain quality and to minimize these effects, the anticipation of the harvest becomes an interesting option, it does not affect yield since is performed after physiological maturity.

CONFLICTS OF INTERESTS

The authors have not declared any conflict of interests.

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