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YELLOW BERRY, PROTEIN AND AGRONOMIC CHARACTERISTICS IN BREAD WHEAT UNDER DIFFERENT CONDITIONS OF NITROGEN AND IRRIGATION IN NORTHWEST MEXICO

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Abstract

The aim of this research was to determine the effect of the amount of nitrogen fertilizer and number of irrigations on the YB disorder of wheat cultivar *Tarachi,* as well as its relationship with protein content, and the agronomic characteristics. The experiment was conducted in northwestern Mexico, during the fall-winter season, 2009-2010. Three levels of nitrogen (75, 150 or 250 kg ha^{-1}) and three levels of irrigation (3, 4 or 5 irrigations) were studied. Increasing the nitrogen rate decreased the YB content, the thousand kernel weight and hectoliter weight; and increased the protein content and the number of grains per spike. The number of irrigations did not affect the number of grains per spike. However, increasing the number of irrigations increased the YB content, the thousand kernel weight and hectoliter weight; on the other hand, the protein content decreased. A negative correlation between protein content and percentage of YB was presented. It was concluded that the presence of the disorder YB in bread wheat, *Tarachi*, is due to a low nitrogen rate in the soil and an increase in number of irrigations.

Introduction

The state of Sonora is the largest producer of wheat in Mexico. The producers of wheat in this state, and in the rest of the country, are concerned about the presence of a physiological disorder called "yellow berry" (YB) in the grains of bread wheat (*Triticum aestivum* L.). This disorder is characterized by high starch content and a low content of protein, which affects the quality of baking, causing penalties to farmers.

Wheat (*Triticum aestivum* L.) is a staple crop useful for human nutrition. Currently, wheat is the largest crop in number of acres in the world, due primarily to its adaptability to all types of terrain and different climates (Seadh *et al*., 2009). This basic grain provides proteins, carbohydrates (high-energy) and minerals. Therefore, it is considered important for the development of the humanity (Shi *et al*., 2010). On the other hand, wheat flour is used in the preparation of food products such as bread, noodles and biscuits (Gao *et al*., 2010).

Nitrogen fertilization is often the most limiting factor for plant growth, development and yield of wheat (Jan *et al*., 2010; Jan *et al*., 2011). It also, temperature and water are important factors for better production of wheat especially during the grain filling period (Khan *et al*., 2010; Din *et al*., 2010). Soil moisture availability at planting time of wheat is critical and can delay sowing if moisture is insufficient in a typical rainfed area. Shortening of vegetative growth (post-emergence to pre-flowering) by delay sowing can cause yield losses (Akmal *et al*., 2011). Nitrogen deficiency in soils of northwestern Mexico is wide and the low number of chilling hours and the drought are factors that reduce wheat yields.

In Mexico, the cultivation of wheat is concentrated geographically. The northwestern region provides 82% of wheat production, and the state of Sonora contributes with 50% of the national production. However, currently wheat farmers in Sonora and the rest of the country are concerned by the presence in the grains of a physiological defect called "yellow berry" (YB). This defect is described as a poor development of the endosperm, which causes yellowing grains, due to low protein content (Sharma *et al*., 1983). Globally, the phenomenon YB is considered a serious disorder in the grain of durum wheat, bread wheat and triticale. YB significantly affects the grain protein concentration, resulting in poor quality in bakery products and pasta elaboration (Ammiraju *et al*., 2002). This problem, mainly in durum wheat, has been the subject of worldwide research. A deficiency of nitrogen in the soil is considered the most critical factor in the expression of YB in durum wheat grain (Anderson, 1985). Bnejdi & Gazzah (2008) found that the expression of the YB phenomenon also depends on genetic factors; existing cultivars more susceptible to this phenomenon.

In the Bajio region of Mexico (central part), was found that the factors favoring the YB presence in the grain of durum wheat (*Triticum turgidum* L. var. *Durum*) are: low nitrogen fertilization and the use of susceptible varieties, in addition, a greater number of irrigations (Solis & Diaz, 2001). However, in the region of Sonora and the rest of Mexico, the causes of this problem are not yet clear in bread wheat. Therefore, the purpose of this research was to study the effect of the nitrogen fertilization and number of irrigations on the content of YB in bread wheat cultivar *Tarachi*, as well as the effect of these factors on protein content, number of grains per spike, thousand kernel weight and hectoliter weight.

Materials and Methods

The experiment was conducted on arable farmland in the valley of Empalme, Sonora, Mexico (27º 58' N, 110º 49' W; 10 m.a.s.l.), during the fall-winter period 2009-2010. The area is characterized by loam-clayey soil, and a semi-arid climate with an annual rainfall of about 400 mm. To determine the soil characteristics, 5 samples from a 30 cm depth were collected and analyzed by a soil testing laboratory. Table 1 shows the basic physical and chemical properties of the soil. The cultivar of bread wheat, *Tarachi*, was selected on the basis of its relative variability in the YB content in the kernels of mature wheat, and this cultivar is grown by local farmers.

Table 1. Physical and chemical properties of soil from experimental plots.

Variable	Value
pH	7.88
Organic matter (%)	1.67
$N\text{-}NO_3^-$ (ppm)	18.50
$P\text{-}PO_4^-$ (ppm)	27.60
K (ppm)	199
Ca (ppm)	12900
Mg (ppm)	430
S (ppm)	39
Fe (ppm)	3.9
Cu (ppm)	2.6
Zn (ppm)	0.7
Mn (ppm)	1.6
Na (ppm)	563

The preparation of the soil, for the test plot, consisted of bare fallow and harrowing. The seed bed was 30 cm deep, with a 90 cm separation between beds. After pre-planting irrigation, using an irrigation lamina of 24 cm, the wet soil was seeded in double rows, using a density of 80 kg ha^{-1}. Fifteen days after planting irrigation was applied, with a lamina of irrigation of 14 cm, in order to help the sprouting of the wheat. Subsequently, the number of auxiliary irrigations was varied, using an irrigation lamina of 14 cm. The factors studied were: total nitrogen rate and number of irrigations. Taking into account the initial concentration of nitrogen in the soil (Table 1), three levels of nitrogen rate were studied: 75, 150 or 250 kg ha^{-1}. Urea (46% N) was used as a nitrogen source, and the fertilization was carried out at the tilling stage. The number of irrigations consists of three levels (3, 4 or 5 irrigations), including the irrigation at pre-planting and the irrigation at the time of sprouting. The mature wheat grain was harvested manually, and was characterized by determination of YB content, protein content, number of grains per spike, thousand kernel weight and hectoliter weight.

The content of YB was determined according to the following methodology: 100 grams of mature wheat were weighed and were separated manually. Then, grains that presented a spots white-yellowish in more than 25% of its surface, according to the Mexican norm NMX-FF-055-1984 (Anon., 1984), were considered as wheat grains with YB. The grains separate were weighed, using a balance (OHAUS, model AR2140, China) and reported as percent in weight of YB. To evaluate the total protein content, firstly, moisture content of wheat grain was determined, using the method 44-20 of the Anon., (2000). The evaluation of protein content was carried out by the combustion method of Dumas, in a nitrogen determinator (LECO, model FP528, USA) and the method 46-13 of the Anon., (2000). The value obtained from nitrogen was multiplied by the conversion factor 5.7, and the moisture values obtained were captured in the software, for conversion to total protein on a dry basis. For determination of number of grains per spike, 10 spikes from each treatment were taken, were threshed and grains per spike were counted. For thousand kernel weight data, thousand grains were counted manually in triplicate for each treatment, and subsequently were weighed using a balance (OHAUS, model AR2140, China). In determination of hectoliter weight, was used a balance for hectoliter weight (Seedburo brand, model 8850, USA).

The experiment was designed in randomized complete block design with split plot arrangement and three replications. The main plot was number of total irrigations (3, 4 or 5 irrigations); and the subplot was total nitrogen rate (75, 150 or 250 kg ha^{-1}). The experimental unit was of 4 furrows of 6 m in length by 0.90 m of separation, using the two middle furrows as a useful plot, eliminating 1 m at the beginning and the end of the furrow. With the data obtained, an analysis of variance (ANOVA) was made with a level of reliability of 95%. Tukey test ($p \leq 0.05$) was used to analyze differences among specific treatment means. In addition, a test of simple correlations was performed among all the results obtained. The statistical analysis was performed using SAS program (Anon., 2002).

Results and Discussion

Regarding to YB content in the grain of wheat cultivar *Tarachi* as affected by nitrogen rate and number of irrigations is presented in Fig. 1. The YB content was affected by both the nitrogen rate and the number of irrigations. An average content of YB - up to 68% - was obtained for the treatment of 5 irrigations and nitrogen rate of 75 kg ha^{-1}, and a value of 0.54% for the treatment of 4 irrigations and nitrogen rate of 250 kg ha^{-1}. For the number of irrigations, the Tukey test showed differences between groups for each treatment, and for the nitrogen rate factor, no difference existed between treatments of 150 and 250 kg ha^{-1} were observed. In general, increasing the nitrogen rate decreases the YB content, and increasing the number of irrigations increases this phenomenon. The effect of nitrogen rate differed to a greater proportion on average in the expression of the character of YB. These results are in agreement with those reported by Solis and Diaz (2001) for durum wheat grain (*Triticum turgidum* L. var. *Durum*), who reported an average percentage of YB at 70% for a treatment without nitrogen, and only 7% of YB for the nitrogen treatment of 240 kg ha^{-1}. In this research, using a nitrogen rate of 150 kg ha^{-1}, it was obtained only an YB average percentage of 1.13%, showing that the bread wheat is less susceptible to this phenomenon.

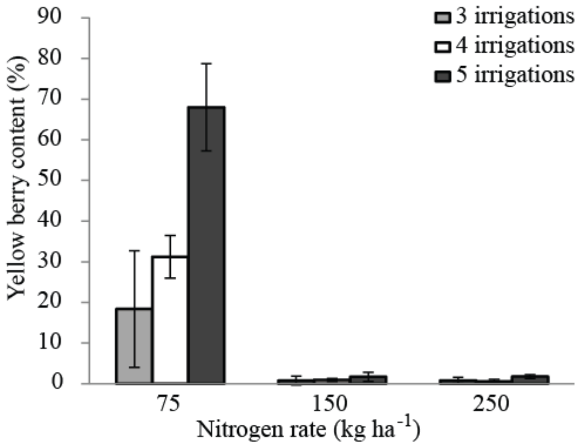

Fig. 1. Effect of nitrogen rate and number of irrigations on the content of "yellow berry" in grain of bread wheat, cultivar *Tarachi*. Error bars denote standard errors of the means.

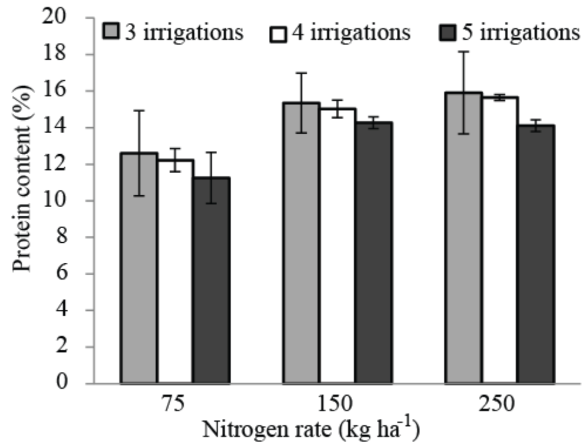

Fig. 2. Effect of nitrogen rate and number of irrigations on the protein content in grain of bread wheat, cultivar *Tarachi*. Error bars denote standard errors of the means.

Another factor affecting the content of YB was the number of irrigations. As the number of irrigations increases, the YB also was increased (Fig. 1). This behavior was also reported in durum wheat grain (Solis & Diaz, 2001). It has also been reported that the wheat cultivar is another factor that requires consideration for the presence of YB. Anderson *et al*., (1986) studied five cultivars of bread wheat under the same seeding conditions, and reported the YB content in the range of 25.2-84.6%, making it clear that some cultivars are more sensitive to this phenomenon.

The total protein content was reported for each treatment. The statistical analysis revealed that significant differences existed for the nitrogen rate and number of irrigations. In addition, the interaction between these two factors was also significant. Fig. 2 shows that as the nitrogen rates increased, total protein content increased. This may be explained by the greater availability of nitrogen for amino acid synthesis and for the way of protein synthesis. Ejaz *et al*., (2002) observed a linear increase in the percentage of protein in bread wheat with the increase of nitrogen rate, and reported protein content up to 14.18% for treatment with nitrogen of 180 kg ha^{-1}. These researchers applied 1/3 of the fertilizer at planting, 1/3 in the first auxiliary irrigation, and finally 1/3 in the third auxiliary irrigation.

This research obtained a 14.28% protein content with the treatment of 5 irrigations (3 auxiliary irrigations) and applying 150 kg ha^{-1} of total nitrogen. The difference with Ejaz *et al*., (2002) is that the application of nitrogen was performed in a single event in the tillering stage, indicating that this practice is more efficient. It was found that as the number of irrigations increases, the protein content tends to decrease. This behavior is attributed to that the water is leaching the nitrogen to the subsoil, thus avoids the availability of the nitrogen for use by the plant for protein synthesis. Peña *et al*., (2001) studied the nitrogen cycle and its agronomic and ecological implications, using isotopic techniques (N^{15}). They encountered nitrogen losses up to 90%, emphasizing that the greatest losses occur by leaching and is closely linked to water management. In this sense, farmers make fertilizer practice, and then they saturate with water the ground, causing the washing of fertilizer. From the agricultural point of view, over irrigating results in a low protein content of the grain and increases the presence of YB. From the ecological point of view, this causes serious problems of environmental pollution, by contamination of water of subsoil.

Moreover, Entz and Fowler (1989) associated the deficit of water in the pre-anthesis stage with higher protein content in Canadian winter wheat, and they also reported that to maintain grain with 17% protein, increased water availability in anthesis must be accompanied by an increase in available nitrogen. The quality of the wheat grain is determined by the protein content, and the interest of producing bread wheat high in protein lies in the effect that shows on the bread volume. It has been reported that the higher the protein content is obtained breads with higher volume (Stewart, 2003).

A negative correlation at $p=0.01$ ($p<0.01$) between protein content and percentage of YB ($r= -0.879^{**}$) was presented; lower protein content is accompanied with a higher percentage of YB. These results agree with those reported by Behera *et al*., (2007) in bread wheat. The YB phenomenon is attributed to a decrease and abnormal synthesis of protein, which becomes more pronounced under conditions of nitrogen deficiency. It was also observed that increasing the number of irrigations increased the content of YB (Fig. 1), which is in agreement with a decrease in protein content (Fig. 2).

The number of grains per spike was only affected by the nitrogen rate. Fig. 3 shows those higher nitrogen rates, increases the number of grains per spike in a range from 39.38 to 49.24 grains, for treatments with nitrogen rates of 75 and 250 kg ha^{-1}, respectively. Bahrani *et al*., (2009) studied the response to nitrogen rate and water deficit in bread wheat, reporting similar behavior. They found that with a difference of nitrogen of 80 kg ha^{-1}, the number of grains per spike increased by 10%. These results indicate that production of the grains is not dependent on number of irrigations but on the available nitrogen in soil.

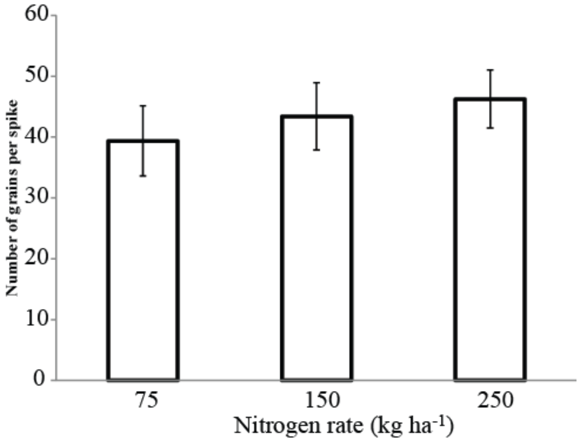

Fig. 3. Effect of nitrogen rate on the number of grains per spike in bread wheat, cultivar *Tarachi*. Error bars denote standard errors of the means. For each treatment, different letters denote significant differences among treatments according to Tukey test (p≤0.05).

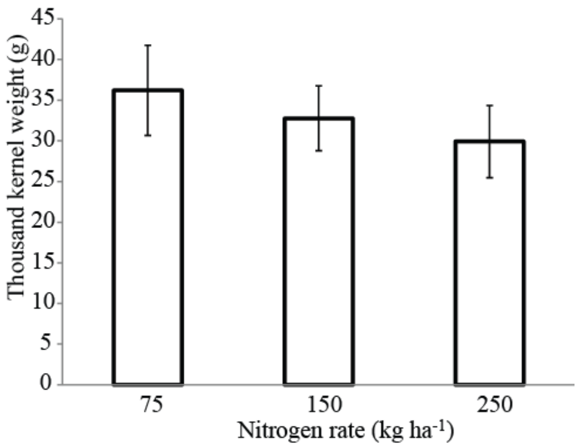

Fig. 4. Effect of nitrogen rate on thousand grain weight in bread wheat, cultivar *Tarachi*. Error bars denote standard errors of the means. For each treatment, different letters denote significant differences among treatments according to Tukey test (p≤0.05).

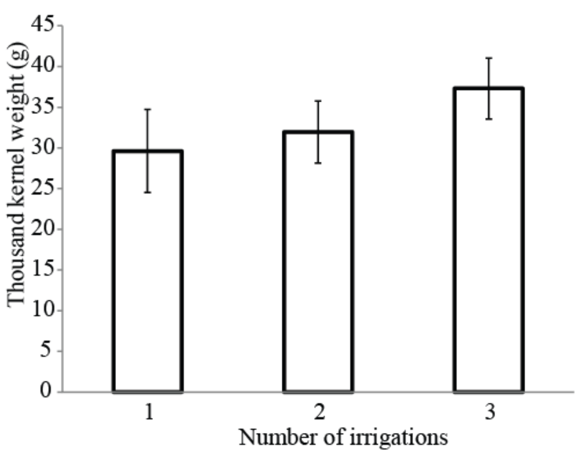

Fig. 5. Effect of number of irrigations on thousand grain weight in wheat, cultivar *Tarachi.* Error bars denote standard errors of the means. For each treatment, different letters denote significant differences among treatments according to Tukey test (p≤0.05).

The thousand kernel weight was significantly affected by the nitrogen rate and the number of irrigations. Fig. 4 shows that the thousand kernel weight is reduced as the nitrogen rate increased. Fig. 5 shows that increasing the number of irrigations, the thousand kernel weight is increased. The result showed a positive correlation at p=0.05 ($p<0.05$) with the percentage of YB (r= 0.715*), and a positive correlation at p=0.01 ($p<0.01$) with the hectoliter weight (r= 0.788**). The thousand kernel weight present a negative correlation at p=0.01 ($p<0.01$) with protein content (r= -0.840** for thousand kernel weight and r= -0.919** for hectoliter weight). Results obtained in this determination suggest an inverse relationship between grain quality of wheat (protein content) and grain yield. Eck (1988) reported that any agricultural practice to increase grain yield of wheat can reduce grain protein content, due to dilution of protein with carbohydrates (starch). Thousand grain weight increased proportionately by the available nitrogen in the soil. The omission of fertilizer in the post-anthesis stage increases the accumulation of starch in the grains, reducing the accumulation of protein (Altenbach *et al*., 2003). On the other hand, Lopez-Ahumada *et al*., (2010) reported that grains with YB have higher starch content than normal grains, and this difference in starch content can be attributed to lower protein content of grains with YB. This indicates that the increase in grain weight of wheat is due to increase in the proportion of starch in the endosperm of the wheat kernel. In relation to the number of irrigations, Spiertz *et al*., (2006) reported that wheat crops that experiencing water deficit during grain filling, limits the yield of the same. Tahmasebi *et al*., (2003) also found that rapid ripening of wheat grain, due to dehydration of the grain by water deficit leads to reduce the size and weight of grain. Furthermore, we found that decreasing the number of irrigations (water deficit) decreases the yellow berry content.

The hectoliter weight is a characteristic that presents the weight of wheat grain contained in a volume of 100 liters, providing the density of the wheat grain. Hectoliter weight was affected significantly by the nitrogen rate and the number of irrigations. Fig. 6 and Fig. 7 show the effect of nitrogen rate and number of irrigations on hectoliter weight, respectively. A similar behavior to the thousand kernel weight was presented. At higher nitrogen rates, the hectoliter weight is decreased; this behavior is attributed to an increase in the proportion of protein. This is explained due that at higher number of irrigations, the hectoliter weight was increased, accompanied by a decreased in protein content, attributed to a leaching of nitrogen available in soil because of the irrigation water.

Hectoliter weight showed a positive correlation at p=0.05 ($p<0.05$) with the percentage of YB (r= 0.724*), and a positive correlation at p=0.01($p<0.01$) with the thousand kernel weight (r= 0.788**). Also shows a negative correlation at p=0.01($p<0.01$) with the protein content (r= -0.919**), indicating that at higher quality of wheat, grain is decreases the yield.

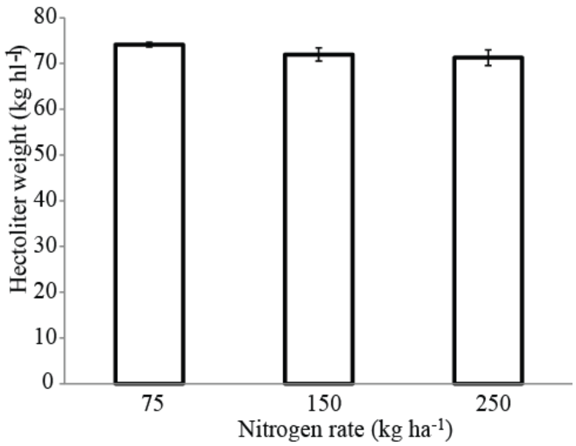

Fig. 6. Effect of nitrogen rate on the hectoliter weight in bread wheat, cultivar *Tarachi*. Error bars denote standard errors of the means. For each treatment, different letters denote significant differences among treatments according to Tukey test (p≤0.05).

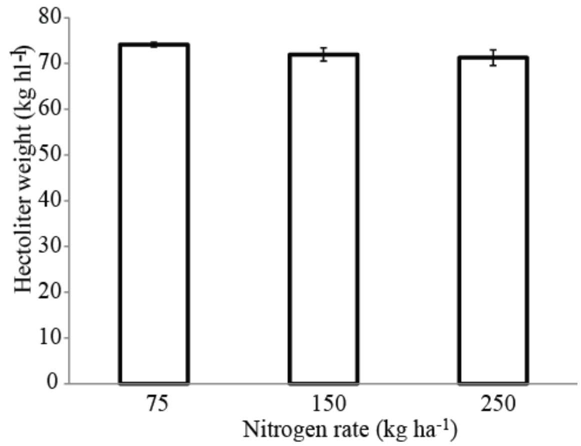

Fig. 7. Effect of number of irrigations on the hectoliter weight in bread wheat, cultivar *Tarachi*. Error bars denote standard errors of the means. For each treatment, different letters denote significant differences among treatments according to Tukey test (p≤0.05).

Conclusions

The presence of the disorder YB in bread wheat, *Tarachi*, was due to a low nitrogen rate in the soil and an increase in number of irrigations. The protein content was positively affected by increasing the nitrogen rate and negatively by increasing the number of irrigations. The nitrogen rate was the only factor affecting the number of grains per spike, a higher nitrogen rate increases the number of grains per spike; however, reduces the thousand kernel weight and hectoliter weight. The number of irrigations increases the thousand kernel weight and hectoliter weight, showing an inverse relationship with protein content.

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