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Durum wheat cultivation and use in the USA with special reference to California

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Abstract. Durum wheat (*Triticum durum* Desf.), one of the first crops to be domesticated, originally came to us from the Levant Region of the Near East and the Ethiopian Highlands about 10,000 years ago. Man has depended upon the wheat plant for himself and his beasts of burden for thousands of years. It is now cultivated and traded worldwide. A global wheat failure would be a disaster that few nations could survive. Wheat cultivation was introduced into Mexico in 1521 by early colonizers, but it did not appear in the territory that would later become Canada and the United States until 1602 with the arrival of the first explorers, settlers, and adventurers. After introduction, the main wheat production today comes from Montana, North Dakota, and Kansas among others in the U.S. and mainly the provinces of Manitoba and Saskatchewan in Canada. In the state of California, the San Joaquin Valley and the Imperial Valley are the two growing areas. According to FAO (2010), world production of both durum and bread wheat was 651 million tons, making it the third most-produced cereal after maize (844 million tons) and rice (672 million tons). U.S. durum wheat production in 2012 was 1.5 million tons, but due to demand and upward moving prices the 2012-2013 projected yields is expected to be 2.5 million tons. However, since the U.S. also exports half of durum wheat production and because pizzas and pasta are very popular, significant imports of durum wheat is also needed to fulfill the total demand. Durum wheat in general commands higher prices in the world market than bread wheat. There are many other uses of durum wheat besides pasta and pizzas. For example durum wheat is extensively used in biscuit-making. However, it is the yellow endosperm of durum wheat that gives pasta its familiar color. The ground endosperm of durum wheat is called semolina. There are several major pasta-makers both domestic and foreign. Italian pasta-makers like Barilla and De Cecco are famous in the U.S. due to their aggressive advertising campaigns. A world without pasta seems inconceivable.

Keywords. California – Climate change – Desert durum® – Durum wheat history – Pasta products – United States – “Wheat Kings”.

Culture et utilisation du blé dur aux Etats-Unis et plus particulièrement en Californie

Résumé. *Le blé dur (Triticum durum Desf.), une des premières cultures domestiquées, nous est parvenu initialement de la région du Levant, au Proche-Orient, et des hauts plateaux éthiopiens, il ya environ 10 000 ans. Pendant des milliers d’années, l’homme a été dépendant des plantes de blé pour ses propres besoins et ceux des bêtes de somme. Le blé est aujourd’hui cultivé et commercialisé dans le monde entier. Un déficit important de blé à l’échelle mondiale serait un désastre auquel peu de nations pourraient survivre. La culture du blé a été introduite au Mexique en 1521 par les premiers colonisateurs, mais elle n’a fait son apparition sur les territoires qui deviendront plus tard le Canada et les États-Unis qu’en 1602, avec l’arrivée des premiers explorateurs, colons et aventuriers. Depuis son introduction, la production de blé est assurée principalement par le Montana, le Dakota du Nord, et le Kansas, entre autres, aux États-Unis, et par les provinces du Manitoba et de la Saskatchewan au Canada. Dans l’État de Californie, la vallée de San Joaquin et la Vallée Impériale sont les deux zones de culture. Selon la FAO (2010), la production mondiale de blé dur et de blé tendre était de 651 millions de tonnes, ce qui en fait la troisième céréale la plus produite après le maïs (844 millions de tonnes) et le riz (672 millions de tonnes). La production de blé dur des États-Unis en 2012 était de 1,5 millions de tonnes, mais en raison de la demande et de la tendance à la hausse des prix, le rendement prévu pour 2012-2013 devrait s’élever à 2,5 millions de tonnes. Cependant, comme les États-Unis exportent aussi la moitié de leur production de blé dur et les pizzas et les pâtes sont très populaires, des importations importantes de blé dur sont également nécessaires pour satisfaire la demande totale. En général, le blé dur obtient des prix plus élevés sur le marché mondial que le blé tendre. A part les pâtes et les pizzas, on peut faire du blé une utilisation variée. Par exemple, le blé dur est largement utilisé dans la biscuiterie. Toutefois, c’est l’endosperme jaune du blé dur qui donne aux pâtes leur couleur connue. L’endosperme broyé de blé dur est appelé semoule. Il y a plusieurs grands fabricants de pâtes nationaux et étrangers. Les producteurs*

de pâtes italiens comme Barilla et De Cecco sont célèbres aux Etats-Unis en raison de leurs campagnes publicitaires agressives. Un monde sans pâtes semble inconcevable.

Mots-clés. *Californie – Changement climatique – Blé dur des zones désertiques (durum wheat®) – Histoire du blé dur – Pâtes alimentaires – Etats-Unis – « Rois du blé ».*

I – Introduction

Through the archeological evidence left by nomadic humans in west Asia, researchers have learned that humans adapted from hunting animals to also gathering seeds for food. Periods of glaciers no doubt inspired this move by reducing available game. The early gatherers were also the first millers and selected grains that could be most easily released from their glumes or husks and prepared. People parched, simmered, and ground these grains and prepared flat cakes. Thus, using grains as food changed the way early ancestors lived their daily lives, in addition to providing basic sustenance. The evolution of agriculture and cultivating seeds for harvest (which occurred about 9,000 to 10,000 years ago) changed not only the available food supply but how people moved about. Human beings' ability to process (mill), store, cultivate, and trade grain marked the beginnings of civilization.

Durum wheat (*Triticum durum* Desf.), is a type of wheat that is high in protein, gluten, and generally very firm and strong. Its kernels are usually large and amber colored. This wheat is most commonly used for making pasta rather than for baking because of its denseness and cooking quality. Pasta made from this type of wheat is typically yellow in color because of the wheat's yellow endosperm. The endosperm of wheat is found in the kernel and is usually full of niacin, iron, starch, and protein. De Vita (2009) lists over 300 shapes, sizes, and types of pasta. In fact, the earliest cookbook from the Middle-East, and the first to mention pasta, was written in the 10th century AD during the reign of the Abbasids whose capital was Baghdad (Verde and Verde Barr, 2013).

Durum wheat or 'macaroni wheat', as it is commonly called, is the only tetraploid species of wheat of commercial importance that is widely cultivated today. It was developed by artificial selection of the domesticated emmer wheat strains formerly grown in Central Europe and the Near East around 7000 B.C.E., which developed a naked, free-threshing form. Durum in Latin means "hard", and the species is the hardest of all wheats. Its high protein content, as well as its strength, make durum good for special uses, the most well-known being pasta which in Italy is exclusively made from the flour of durum wheat. Durum wheat is also used extensively in flat-bread making. However, it is unusual in that, despite very high protein content, it is low in desirable gluten needed to form a glutinous web necessary for loaf bread to rise. As a result, although 100 % durum wheat breads do exist, such as pagnotte di Enna from Sicily, as well as others, in most instances bread doughs contain only a portion of durum wheat and are supplemented substantially with commercial white flours, oftentimes those higher in gluten necessary to offset the poor gluten contribution of durum flour. When durum flour is used as the sole flour in bread (such as focaccia bread), substantial additions of isolated wheat gluten are necessary to effect rising. Without it, 100 % durum wheat breads are often heavy, with very close grain, and will split easily when risen for baking. When we were at the CNR's Istituto del Germoplasma, we used to often partake of the famous focaccia Pugliese.

Milling durum wheat turns it into ground semolina, which is made into many types of pasta. Semolina is a grainy substance that may be off-white or yellowish in colour. The next step after grinding the wheat is usually mixing it with water to form dough. Semolina dough is often very stiff, which generally makes it easier to use for melding into various pasta shapes. Dies and metal discs are commonly used for creating the many different shapes.

II – Historical background

Even in Europe the daily bread (as is now in the countries of the Near-East), a prerequisite to stability and satisfaction of the less privileged class. Poor harvests, dearth and famine put the social order and peace in peril. Ultimately the King was responsible. In fact, in 1898 bread riots broke out in Milan, Italy, and were so violent that it cost the lives of 24 of the protestors and ultimately the King Umberto I, who was assassinated in 1900. The *Battaglia del Grano*, unleashed by Mussolini (Il Duce) from 1923 to 1932 successfully doubled wheat production and cemented his popularity and support among the Italians. It was not until very recently (in 2006) that the price control on bread was abolished in Italy (Bjornstad, 2012).

Wheat cultivation was introduced into Mexico in 1521, but it did not appear in the territory that would become Canada and the United States until 1602. Wheat was introduced to North America by explorers, traders, settlers, and soldiers in the sixteenth and seventeenth centuries. Kansas is the biggest wheat producing state in the U.S. Large-scale mechanized farming and continued planting of wheat without regard to crop rotation exhausted the soil of large areas. High-yield wheat, one of the grains resulting from the Green Revolution, requires optimal growth conditions, e.g., adequate irrigation and high concentrations of fertilizer.

Discovering wheats suitable for new areas was a reoccurring struggle. In the more temperate 'Middle Colonies', the cultivars transplanted from Western Europe fared better. However, the challenges were particularly acute when pioneers moved wheat cultivation westward onto the northern Prairies, Great Plains, and Pacific Coast. All these regions eventually became major wheat suppliers, but only after farmers learned to overcome climatic conditions far different from those prevailing to the East and in Western Europe. The initial attempts to grow traditional wheat cultivars imported from Europe frequently failed.

The California Gold Rush (1848-1855) resulted in rapid expansion of the urban population. Wheat was a natural crop that was adapted to California conditions which included very fertile and flat valleys that required little clearing to become extremely good arable land. Wheat exports were used to procure other foods for the fast growing population. Exports to Britain and Europe increased because of the California wheat varieties' excellent milling quality, high gluten content, and ability to absorb large quantities of water and produce a large and heavy loaf of bread. San Francisco became the hub of flour milling in California. Before the advent of the railroads, wheat for export was moved through such ports as Oakland and Stockton. The grain fleet sailing through San Francisco Bay constituted a major part of commerce in the region from 1870 to 1900 with over 300 vessels departing each year. This circa 1900 photo shows wheat harvesting activity on the Wiseman family ranch, located within the Sacramento Valley. In 1899, Yolo (2.5 million), Sacramento (1.1 million), Colusa (3.2 million), Sutter (1.2 million) and San Joaquin (4.1 million) counties produced some 12 million bushels of wheat. Combine harvesters pulled by 27 mules and horses were put to work the vast fields of bread and durum wheats in California. One such animal-drawn combine harvester is stored in a barn near the city of Woodland in Yolo county (Fig. 1).

III – American "Wheat Kings"

Not even the shrewdest grain trader from the East (New York), including "Wheat King" Arthur W. Cutten on the cover of TIME magazine (TIME, 1928) (Fig. 2), could have foreseen the tremendous increase in wheat production in California, especially from the Sonoma and Napa Valleys. In fact Santa Clara county alone could produce enough wheat to meet the requirement of the entire state of California (Rothstein, 1987). However, after 1928 the prices of wheat declined in the global market and at the same time farmers were turning to orchards and growing plums, almonds, pistachios, and rice in the delta regions (Drynan, 1986). The arrival of refrigeration in the 1920s

further led to the decline of wheat production in California, and led to the bankruptcy of many a "wheat king", including Cutten, considered to be one of the great bulls of Wall Street, who lost $60 million almost overnight due to speculation of wheat prices and thereafter died of a heart attack. The Sonoma and Napa Valleys began to plant wine grapes and the flat Jan Joaquin and Imperial Valleys began to plant fruits and nuts. The urbanization of California after WWI created a significant local demand for perishable farm products. The latter coupled with demand for alfalfa cattle-feed for the fast growing dairy industry and the use of bees for pollination on a grand scale meant that California had literally, a 'land of milk and honey' (Rothstein, 1987)

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Figure 1. A combine harvester pulled by 27 horses in the great plains in U.S.

Figure 2. "Wheat King" Arthur W. Cutten (1870-1936) on cover of TIME magazine. The Bull and the Bull's Uncle.

In the United States (U.S.) today, North Dakota is the state where the majority of durum wheat is produced. Roughly 73% of durum that is used in the U.S. comes from this state, although Montana, Minnesota, and South Dakota also produce durum wheat. Countries outside the U.S. States normally import durum wheat grown in these areas because it is typically very strong. However, in recent years California grown durums have also gained popularity abroad. The majority of the wheat planted in the U.S. is fall-seeded winter wheat, and only about 6% is durum.

In 2013 an estimated 690,000 acres were planted to wheat out of which only 10% were durum (J. Cooper, pers comm.). A downward shift in durum was observed due to lower prices and problem of water in the Imperial Valley. The top varieties in Southern California were Desert King, Orita,

and Havasu, whereas Volante, Westmore, and Platinum were the top three durum varieties in the San Joaquin Valley. Worldwide nearly 90% of wheat planted is bread wheat and only 10% is planted to other wheats including durum wheat. However, 80% of the worldwide 10% of durum wheat is planted in the West Asia and North Africa region. Pasta is increasingly becoming very popular globally and especially in the U.S. which means that acreage devoted to durum wheat plantings will increase (Fig. 3).

Figure 3. A hoarding along a highway promoting pasta product near Los Angeles.

The pedigree and development of the well-known bread wheat, Marquis, by David Fife and later by C.E. Saunders in Ontario, Canada is a well-known fact and I will not go in to it here. However, the first introductions of durum wheat were made by a certain group of Mennonites who emigrated to the U.S. from southern Russia and settled in the middle Great Plains which included Kansas. They brought with them wheat selections from Turkmenistan which were found to be well-adapted to the fields in the vicinities of towns of Newton and Halstead. At the time the new durum variety attracted only some local attention, but it was not until a USDA cerealist named M.A. Carleton who picked it up because of its tolerance to drought and good yields under adverse climatic and soil conditions. In fact, he even went to Russia and brought back several varieties like Turkey, Kharkof, Crimean, Beloglina, etc. which he introduced to the U.S. The work of USDA through Carleton was instrumental in establishing wheat industry. Up to this time durum wheat was also planted by several farmers in the U.S., but had failed to achieve commercial success. Once again it was the Russians settled in North Dakota who brought with them Arnautka and began to market it commercially in 1898. Two years later, in 1900, Carleton introduced the durum variety Kubanka in the middle Great Plains and also brought in some seeds of Arnautka. However, after decades of cultivation Kubanka is still considered as the most widely adapted durum wheat in the U.S. In fact, Kubanka is the standard durum variety against which new durum varieties are judged for over 100 years.

Other wheat breeders, such as H.L. Bolley and N.E. Hansen of the North and South Dakota Experimental Stations, were responsible for further introductions of durum wheat. Bolley introduced Pentad and Monad material, both rust resistant durums, from which a variety Kota was selected. Pentad, a red durum, was the first variety to be widely grown in the U.S. Its popularity increased rapidly and by 1911 its acreage had increased to a wide area. This commercial success was no so much for semolina or macaroni manufacture since the grain quality was not up to par, but it was a great success in the feed grain business.

After the re-discovery of Mendel's work by de Vries, Correns, and Tschermak in Europe and Spillman in the U.S., new methods of breeding wheat were developed. Selection work at the Minnesota Agricultural Experiment Station resulted in a variety called Minnesota Durum (shortened to "Mindum"). It had become very popular in the mid to late 1930s. It was well received by the wheat traders and was as popular as Marquis at that time. Mindum's positive traits were high yields, high straw production, and a bright amber color that was unanimously accepted by the pasta makers.

IV – Pasta products

Commercially produced dry pasta, or *pasta secca*, is made almost exclusively from durum semolina. Certain home made fresh pastas (*pasta fresca*), such as orecchiette, cavatelli, and malloreddus, also utilize durum wheat, while others, such as *tagliatelle*, utilize only soft wheat, often "00," or a combination of soft and hard wheats. The availability of commercially prepared pasta is relatively recent. Before that, all pasta used to be made at home and each Italian housewife had her own secret recipe which she proudly guarded (Fig. 4).

Husked but unground, or coarsely ground, it is used for *semoules* in the couscous of North Africa, and other parts of the Arab world. It is also used for Levantine dishes such as *tabbula*, *kishk*, *kibba*, *bitfun* and the *bulghur* for pilafs. In Arab cuisine, it forms the basis of many soups, gruels, stuffings, puddings and pastries. When ground as fine as flour, it is used all over the Middle East, for baking flat round breads, and in Europe and elsewhere, it can be used for pizza, *torte*, etc. It is not, however, good for cakes, which are made from soft wheat to prevent toughness. The use of wheat to produce pasta was described as early as the 10th century by Ibn Wahshīya of Cairo. The Arabs called the product *itrīya*, from which Italian sources derived the term *tria* (or *aletria* in the case of Spanish sources) during the 15th century. Another type of pasta, *al-fidawsh* (called "dry pasta"), was popular in al-Andalus. From there it was transmitted to Christian Spain, and it frequently appears in Hispano-Muslim cookbooks. From *al-fidawsh* was derived the Spanish word for noodles, *fideos*, and the Italian *capellini*.

In the American Great Plains, durum wheat is used almost exclusively for making pasta products such as spaghetti and macaroni. Most of the durum grown today is amber durum, the grains of which are amber-colored and larger than those of other types of wheat. Durum has a yellow endosperm, which gives pasta its color. When durum is milled, the endosperm is ground into a granular product called semolina. Semolina made from durum is used for premium pastas and breads. There is also a red durum, used mostly for livestock feed. The cultivation of durum generates greater yield than other wheats in areas of low precipitation (300–500 mm). Good yields can be obtained by irrigation, but this is rarely done. In the first half of the 20th century, the crop was widely grown in Russia. Durum is one of the most important food crops in West Asia. Although the variety of the wheat there is diverse, it is not extensively grown there, and thus must be imported. West amber durum produced in Canada is used mostly as semolina/pasta, but some is also exported to Italy for bread production. In the Middle East and North Africa, local bread-making accounts for half the consumption of durum. Some flour is even imported. On the other hand, many countries in Europe produce durum in commercially significant quantities.

Figure 4. Italian women making pasta in the home kitchen in the 19th Century.

Pasta fresca, as its name implies, is fresh home-made pasta. Soft and pliable, *pasta fresca* is meant to be cooked promptly. While, strictly speaking, it can be made with durum wheat flour, sometimes the flour is enriched with eggs and becomes easier to work, especially by hand. *Pasta secca*, on the other hand, is the kind of pasta commonly found on grocery-store shelves. This form of pasta can be made only with durum flour, because durum's unique properties permit its nearly indefinite preservation. Writing in the 14th century, the Mamluk civil servant Al-Umari cited a government report that claimed that the durum wheat of North Africa "could be stored for 80 years in silos," and, in the 11th century, Andalusian geographer Al-Bakri boasted that one of the characteristics of Toledo is that "its wheat never changes or goes bad over the years."

Table 1. Durum Wheat Area (x 1000 ha) and Production (x 1000 tons) in different continents.

Region	Area	Production
Western Europe	2,490	5,730
North America	2,960	5,756
South America	102	196
Middle East	4,462	6,950
North Africa	3,290	3,214
Others	3,756	3,540
World	17,060	25,360

V – Desert Durum®

Desert Durum" is a collection of wheat varieties that were developed by and under the ownership of the Arizona Grain Research & Promotion Council and the California Wheat Commission. These wheats are produced in the deserts and dry lowlands of both states under irrigation. These are regions of high temperature (above 32C in May and June) and low rainfall (annual precipitation of less than 200 mm). The wheat is typically planted from November through February, and harvested in May or June. This gives Desert Durum an advantage because they enter the international and domestic market from 1 to 3 months before the spring durum crops from other parts of North America. The Desert Durum varieties are "Desert King", "Duraking", "Havasu", "Kronos", "Maestrale", "Ocotillo", "Orita", "RSI 59", "Saragolla", "Sky", "WB-Mead", and "Westmore". These wheats have been thoroughly evaluated for various agronomic and quality characters: Protein and Moisture Content, 100-KW, Kernel Size, Milling and Semolina characteristics, and Pasta-Making quality including color and firmness. A detailed chart of all this data is available.

There is considerable export demand surfacing for U.S. durum in the last 2-3 years and domestic demand is still fairly sluggish. But there are encouraging signs that domestic pasta makers will buy more Desert Durums in the future. In fact some of these varieties have already started to move to the elevators.

Looking to USDA report the planting estimate for the U.S. desert durum region in 2012 was 90,000 acres in Arizona – up 13 percent from last year, and California was up 17 percent at 140,000 acres for a combined planting of 230,000 desert durum acres. Estimating yield at about 100 bushels/acre, the potential yield is around 23 million bushels – up from the area's more traditional level of 16-18 million in recent years, but lower than the all-time high of more than 30 million bushels.

VI – The future of durum production and climate change

I don't think there's any question" that climate change is already affecting durum wheat production in North Dakota, says Roger Johnson, a former durum farmer who was the state's agriculture commissioner from 1996 to 2009. Johnson points out that Dakota Growers Pasta Co., one of the nation's leading pasta producers, built a combined durum mill and pasta-making plant in Carrington, a town in eastern North Dakota, in 1993. At the time, the decision made economic sense. But as the durum zone has shifted west, transport costs have increased, putting the Carrington plant at a competitive disadvantage. "Looking at the cost of logistics, it has certainly had a negative impact," says Ed Irion, the plant's general manager.

Extreme and volatile weather patterns are especially threatening to durum, which is more finicky than conventional wheat varieties. If too much rain falls at the wrong time, durum's quality can be ruined. Too little rain is not good either. Because durum is trickier to grow, farmers require a price premium over what conventional wheat earns. Already, farmers complain, grain companies have been shrinking these premiums to boost their own profit margins. As climate change intensifies

and durum gets even harder to grow, how high will the price premium have to rise to entice farmers to take the risk? Opland, a durum farmer, wonders whether he will plant durum at all next year.

Moving west also puts durum in direct competition with the richest business enterprise in human history, an industry that has very different plans for the prairies of North Dakota.

The local water supply and its quality are also threatened. Fracking pumps millions of gallons of fresh water underground at high pressure to force oil and gas deposits to the surface. This water is extracted from an aquifer beneath North Dakota, “and we have no right to do that to future generations who’ll need that water,” say the natives. Then the contaminated water is brought back to the surface and disposed of in huge storage ponds, risking spills that can pollute creeks and soil for generations to come.

Perhaps most worrisome for the future of pasta, is ecological fall out of the Bakken oil boom in North Dakota that is gobbling up prime farmland. By an accident of geology, the Bakken oil deposits lie beneath the very area to which climate change has shifted durum production, an area that in recent years also has accounted for most of the durum exports. The U.S. and Canada, are the two leading exporters of durum, with most of their production coming from western North Dakota, eastern Montana, and the southern half of Saskatchewan province. Lay a map of the durum production zone onto a map of the Bakken oil deposits, and the two line-up almost exactly.

Driving west from Minot (a city in North Dakota) one afternoon, Opland passed a new housing development and a freshly completed La Quinta Inn—one of 18 hotels recently built to accommodate oil-boom workers. “That housing development covers 160 acres, and the hotels even more,” Opland laments. “That land won’t come back to farming, not in our lifetimes.” The Bakken oil reserves are large enough to last at least 100 years at full production capacity.

The end of pasta production will not come overnight. If it comes, and it can still be avoided, if humans act swiftly enough. It will come in fits and starts, as harvests falter one year but not the next, and it will be expressed more in shockingly high prices for pasta than in an absolute disappearance of spaghetti and macaroni from grocery-store shelves (Hertsgaard, 2012).

But this need not happen if the U.S. finally gets serious about climate change. That means, among other things, shifting to climate-smart agriculture. If we want to continue enjoying pasta and many other foods we currently take for granted, we need more farmers to emulate the sustainable practices of Glen Bauer and Fred Kirschemann. We also need, desperately, to limit global warming, because even the most skillful adaptation measures cannot cope with 7˚F of global temperature rise. That means the federal government must stop ignoring the mounting climate crisis and take swift aggressive action to slash greenhouse gas emissions.

The televised horrors of Hurricane Sandy may help break the climate silence that still afflicts many Americans. “Mother Nature is better at bringing people to Jesus than any politician is,” notes Jay Fuhrer, the extension agent. But a fear of offending friends and neighbors still inhibits many. “The first thing we always talk about here is the weather, because it affects our lives so much,” says Donny Nelson. “But global warming, people just don’t get into it.”

VII –Conclusion

Traditionally durum wheat has received much less attention of the breeders then bread wheat. But since around the mid-1970s all that has changed and in recent years the prices of durums has always been a little higher than bread wheat, thus giving a good incentive for farmers to grow more durums. The future for durum wheat in the U.S. is excellent, both in consumption as well as production. In fact, California has even begun exporting durum wheat to Italy. But climate change

and oil drilling in the lands that are best for durum production threaten to take over and thereby putting the U.S. durum wheat exports in to jeopardy.

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