Specialty Maize Production:
Management Guidelines for Optimizing Yield and Grain Quality

P. R. Thomison[1]

Abstract

In recent years, end users and processors have become more interested in the quality characteristics of grain and how it affects their business. Through conventional breeding and biotechnology, the chemical composition of maize has been modified to better meet the needs of livestock feeders, the food industry, and industrial users of maize. Grains that meet a specific end user's needs are characterized as "value enhanced" , "value added" or identity preserved (IP) grains. A diverse group of IP grains are currently being produced from maize. Some of these IP grains are grown using specialty maize developed for altered grain quality traits (waxy, high oil, high lysine, high extractable starch), whereas others are grown using cultural practices to ensure that they are organically produced and "GMO" free. The objective of this paper is to identify and review management practices required for successful specialty maize production. Such information is needed to help growers determine whether potential yield reductions associated with specialty maize used in IP grain production offset premiums and the enhanced feed value of these crops. Characteristics of specialty maize types that affect their performance and response to production practices and environmental conditions will also be considered.

Introduction

Traditionally most of the maize produced in the U.S. has been treated, handled, and marketed as a bulk commodity. In recent years, end users and processors have become more interested in the quality characteristics of grain and how it affects their business (U.S. Grains Council, 2001). Through conventional breeding and biotechnology, the nutritional composition of maize has been modified to better meet the needs of the livestock feeders, the food industry, and industrial users of maize. Grains that meet a specific end user=s needs are characterized as "value enhanced" , "value added" or identity preserved (IP) grains.

As commodity grain prices have decreased to record low levels in recent years, IP grains have received more attention as potentially profitable alternatives to commodity grains due to premiums offered by

[1] Department Horticulture and Crop Science, The Ohio State University, Columbus, OH 43210-1086; Salaries and research support provided in part by State and Federal funds appropriated to the Ohio Agricultural Research and Development Center, The Ohio State University, thomison.1@osu.edu.

end-users. Although the rapid adoption of certain genetically engineered crops ("transgenic" or "GMOs") has led to interest in producing special crops with unique traits, it has also resulted in a strong interest in non-GMO grains due to public concern about the safety of GMOs.

Although a number of crops can be grown in Ohio for IP grain markets, specialty maize can be grown for IP grain production with same the equipment and similar cultural practices used in commodity grain production. Moreover, since maize along with soybean, account for the greatest acreage of the field crops used in grain production, these are the crops from which most IP grains are being generated. They also appear to be the crops most often targeted by biotechnology and seed companies for future genetic modifications involving value added traits.

A number of different IP grains are currently being produced from maize (Table 1). Some IP grains are grown using specialty maizes developed with altered grain quality traits. These are often genetic modifications of maize hybrids normally grown for commodity grain. Figure 1 shows the acreage of some of the most popular "value-enhanced" maize types according to a recent estimate by the U.S. Grains Council (2001). Other IP grains are produced with conventional maize hybrids using "organic" cultural practices and/or isolation methods to ensure that they are GMO free. Organically produced and non-GMO grain probably represent the fastest growing segment of the IP grain market (L. Clarkson, personal communication, 2000).

The objective of this paper is to identify and review management practices required for successful specialty maize production. Such information is needed to help growers determine whether potential yield reductions associated with specialty maize used in IP grain production offset premiums and the enhanced feed value of these crops. Characteristics of specialty maize types that affect their performance and response to production practices and environmental conditions will also be considered.

Yield Potential of Specialty Grain vs. Commodity Grain Crops

The yield potential of specialty maize hybrids used in IP grain production has often been lower than that of conventional hybrids. This "yield drag" or "lag" as it has been called by growers is a major obstacle limiting production of certain specialty maize hybrids used in IP grain production. Several factors contribute to lower yields of specialty maize.

The conversion of a normal maize hybrid to a specialty type requires numerous cycles of backcrossing (crossing a first generation hybrid with its parent). The time required to complete the backcross process results in the introduction of the specialty hybrid lagging a few years behind that of its normal counterpart. Sometimes this results in an automatic yield disadvantage when specialty hybrids are compared to newer, elite conventional hybrids. Moreover, the conversion of normal hybrids to specialty types is not always "clean." Sometimes undesirable agronomic characteristics are strongly linked to the gene that confers a specialty trait and this "linkage" decreases hybrid performance. The transferred gene may affect yield *per se* by inhibiting plant growth and development. Conversion of a normal hybrid to a specialty type may also divert metabolic energy from grain production, and thereby lower yield. In the future, new seed technologies such as **TopCross7** grain production and genetic engineering, may limit losses associated with specialty crops. New gene transfer techniques associated with biotechnology may eliminate some of the problems encountered in traditional breeding described above involving "linkages" that have contributed to lower yield potential of specialty grains.

Recent Ohio Evaluations of Specialty Maize

Selecting high yielding, adapted specialty maize is complicated by a lack of performance data. However, such information is needed to determine if the premiums offered for these specialty crops compensate for the possibly lower yields (i.e. yield lag or drag) and the special handling required for the specialty grain.

Aside from seed company data, there is limited university information comparing the performance of specialty maizes with high yielding maize grown for commodity grain. Evaluating specialty maize, especially **TC-Blends7** (used in TopCross high oil maize production), is difficult due to isolation requirements. If pollen from normal yellow dent maize hybrids pollinates certain specialty maize, then the compositional trait of value associated with the specialty maize will not be expressed.

Evaluations have been conducted by The Ohio State University (OSU) Horticulture and Crop Science Department to compare the agronomic performance of specialty maize hybrids with popular high yielding conventional hybrids to determine what, if any, yield losses are associated with IP grain production.

White Maize: Since 1996, OSU has participated in an international white food grade maize testing program involving 10 U.S. states and the Canadian province of Ontario , which is coordinated by Dr. Larry Darrah, USDA-ARS at the University of Missouri. Table 2 compares the average and range of yields for white maize entries in the 1996-2000 Early White Food Maize Hybrid Performance Trials to those of yellow (normal) check hybrids (Darrah et al., 2000). White maize hybrids averaged yields 4 to 7% lower than the yellow maize checks, but top white maize hybrids each year produced yields comparable to yellow maize checks.

High Oil Maize (HOM): Field trials have been conducted at two Ohio from 1997 to 2000, to evaluate the yield potential of HO-TC Blends. Although HOM TC Blends averaged yields 6% less than the normal maize over this four year period (Figure 2), top performing TC Blends generally produced yields that were comparable to some of the conventional maize hybrids each year (Thomison et al., 2002; Thomison and Geyer, 1999).

Waxy Maize hybrids adapted to Ohio were compared with conventional maize hybrids at four Ohio locations in 1996-1997 (Figure 3). Some of the waxy maize hybrids produced grain yields similar to their non-waxy conventional counterparts, whereas other waxy hybrids yielded consistently less than the conventional maize hybrids at each site (Thomison, unpublished data, 1997, 2001).

Nutritionally Enhanced Maize including Supercede and Nutridense maize hybrids developed by Dow AgroSciences and ExSeed Genetics, respectively, were evaluated at Hoytville and Wooster in 1999 and 2000 (Thomison and Geyer, 2000). In 1999, the nutritionally enhanced hybrids produced grain yields comparable to conventional hybrid checks at both locations, whereas in 2000, the nutritionally enhanced maize yields were 22% less than the conventional checks (Table 3). Greater stalk lodging in the nutritionally enhanced maize was a major factor contributing to reduced yields in 2000.

Low Phytate or Highly Available Phosphorus Maize: In 2000, a commercially developed low phytate maize hybrid was evaluated at five locations of the Ohio Maize Performance Test. Averaged across sites, the low phytate hybrid yielded 35% less than the conventional hybrid entries (Thomison, unpublished data, 2000).

Food Grade Open Pollinated (OP) Maize: Blue and red food grade OP cultivars and blue maize hybrids were evaluated at four locations of the Ohio Maize Performance Test in 2000. Average OP maize yields ranged from 1.2 to 4.9 Mg/ha across locations whereas hybrid entry yields ranged from 7.8 to 10.8 Mg/ha. Lodging (stalk breakage below the ear) was much greater in the red and blue OP maize culitvars and blue maize hybrids compared to the conventional hybrids (Thomison, unpublished data, 2000).

Management Considerations

The major difference between specialty and commodity grain production is the need to follow management practices that will 1) preserve the purity and identity of the specialty grain from planting through storage, and 2) reduce risk from environmental stress and pest problems. The latter is an important consideration since some specialty maize hybrids may be more vulnerable to environmental stress and pests than conventional hybrids.

The "best" management practices recommended for use in normal crop production become especially important in specialty crop production. In commodity grain production, not following recommended practices may result in lower grain yield, but in specialty grain production it may jeopardize grain quality and premiums, in addition to yield. Growers should follow recommended agronomic practices, including the maintenance of good soil fertility and good control of weeds and other pests, to minimize stress and maximize yield potential.

The following are key management steps to consider when producing value-added grains with specialty maizes.

1. **Select field sites with high yield potential**. Plant specialty crops on the most fertile, well drained soils to reduce stress and maximize yield potential and grain quality. Avoid droughty soils as well as poorly drained soil conditions. Under stress conditions, the yield differential between specialty and normal types may widen.

2. **Use crop rotations**. Plant specialty maize hybrids or HO-TC Blends after soybeans or forage legumes. Grain yields of maize grown in rotation with soybean will typically be about 10% higher than continuous maize (monoculture). The yield advantage of growing maize in rotation with soybean is often much more pronounced when drought occurs during the growing season (OSUE, 1995). The benefits of growing maize in rotation with a legume vs. continuous corn cropping also include less injury from diseases and insects.

In 1997, problems with poor pollination and reduced kernel set in TopCross HOM fields in west central Ohio were associated with significant grain yield losses. Silk clipping and root lodging caused by western maize rootworm were much greater in TopCross fields following maize than in those following soybeans or wheat (Thomison et al.,1997).

Using a crop rotation will also minimize volunteer maize which can be a problem in continuous maize. This may be of greater concern in TopCross HOM production than with other specialty maize types because of the limited number of fertile pollinator plants in HO-TC Blends. In a TopCross HOM production field following maize, volunteer maize could fertilize the sterile TC Blend grain parent instead of the TC Blend pollinator, and thereby reduce oil content of the grain and jeopardize premiums.

3) **Isolate specialty maizes from normal yellow dent maize**. Fields planted to certain specialty maizes need to be isolated to minimize cross pollination with normal maize and thereby prevent a reduction or change in the value-added grain characteristic. Growers producing non-GMO maize in the proximity of various GMO (transgenic) maizes such as Bt, Liberty-Link, and Roundup Ready will also have to develop isolation strategies. Several methods or combinations of methods can be used to obtain isolation, including planting at a different time, planting "upwind" of the prevailing wind direction, or providing barriers and border rows. All these methods will help reduce isolation distances. In seed maize production fields, distances of 201 m from yellow dent maize are recommended to minimize pollen contamination and ensure seed purity. Limited pollen contamination of specialty maize grain production fields is tolerable if it does not affect the grain quality (e.g. oil level) and jeopardize the premiums. Therefore, isolation distances recommended between yellow dent maize and specialty maize may be as little as 15.2 m, if growers plant upwind of normal field maize, and use four or more border rows. In TopCross HOM production, the minimum isolation distances (between TopCross high oil maize and normal maize fields) recommended by seed companies range from 18.2 to 61 m. Some companies indicate that if isolation is not possible, then the first 30 to 40 rows (i.e. 23 to 30.4 m if planting with 0.76-m row planter) of TC Blend maize bordering normal yellow dent maize may be affected by foreign pollen. Although foreign pollen from conventional corn will lower the oil content of TopCross grain, Ohio State University research (Figure 4) suggests that the first 10 rows (i.e. 7.6 m if planting with 0.76- m row planter) of HO-TC Blend maize bordering normal maize are affected the most by foreign pollen (Thomison, 2000). Effects on TopCross grain 30 and 40 rows away (i.e. 23 to 30.4 m if planting with 0.76-m row planter) will be much less pronounced. In non-GMO maize, similar isolation distances will be required because end-users have specified a zero (in some cases, no more than 1%) tolerance for GMO maize contamination. Use of a independent agent to monitor and certify that isolation strategies were followed may help in establishing credibility with the contractor and end-user.

4) **Select the specialty crops best adapted to your growing conditions**. Choose the specialty maize best suited to your operation based on maturity, drydown, stalk quality, disease resistance, and yield potential and stability. Since premiums and relative feed value are based on the oil content of HO TopCross grain, growers need to plant TC Blends with high yield potential and grain oil content to maximize profits. Since some specialty hybrids may be less tolerant of herbicides than the conventional hybrids used in commodity maize production, check for pesticide restrictions.

5) **Prepare a seedbed that will promote uniform seed emergence and crop development**. Soil crusting or cool weather could have different effects on emergence and stand establishment of the two seed components in HO-TC Blends. Seedbed conditions that result in good seed to soil contact and seed furrow closure will help minimize variability in performance between the two seed types contained in a TC Blend.

6) **Follow recommended seeding rates**. According to company recommendations, HO- TC Blend seed maize should be planted with a plateless planter at a density of 5,000 kernels per hectare greater than the typical density with a maximum planting rate of 75,000 kernels per hectare. Above 75,000 kernels per hectare, TC Blend seed should be planted with a plateless planter at the same rate as a normal hybrid seed. The higher seeding rate is recommended to help compensate for the lower grain yields of the pollinator plants. White maize end users often specify plant populations of less than 62,500 plants per hectare to help provide conditions for increasing kernel size.

7) **Plant early to optimize grain yields**. Planting early will help extend the grain filling period and reduce the likelihood of stress during pollination. However, avoid wet, cold soils which may cause emergence problems. In maize, adjust seeding rates 10 to 15% higher than the suggestion in (6) to compensate for higher seedling mortality that often occurs in early plantings especially with reduced tillage.

8) **Scout fields for potential pest problems throughout the growing season**. Weed pressure should be monitored. Early season weed control is essential to minimize stress caused by weed competition for sunlight, soil nutrients and water. Early season insect problems like cutworms or slugs which reduce stand or injure young plants could be particularly serious in HO-TC Blends if the number of functioning pollinator plants is reduced below the level needed for successful pollination. Similarly, excessive pollen feeding and silk clipping by insects such as rootworm beetles and Japanese beetles could pose a greater threat to TC Blends than to normal maize because of the limited number of pollinators (Strachan and Kaplan, 2001).

9) **Adjust combine cylinder speed and clearance** during the harvest operation as necessary to reduce grain breakage and maintain quality.

10) **Follow practices that will minimize IP crop contamination by normal seed or grain.** Clean all seed out of the planter before planting. Clean the combine, augers, trucks, dryers, bins, legs and pits prior to beginning harvest of specialty crops. Store specialty grain in separate bins to prevent mixing with normal maize grain.

11) **Use recommended grain drying procedures**. Avoid artificial drying of IP grain, or use low heat (<49 degrees C) to prevent stress crack damage.

12) **Keep detailed records of the management practices and inputs.** Document what crops are being grown in the proximity of IP maize so proper isolation methods can be used to prevent cross pollination. When growing non-GMO maize for a specialty market, it will be especially important to establish if any transgenic maize is planted in nearby fields. Retain samples of specialty grains produced to corroborate end user grain quality analyzes, and to meet requests for purity guarantees.

If public concerns regarding the potential safety and environmental risks of GMO crops persist, greater production IP grains in the future is likely, as organic and non-GMO crop acreage increases. Specialty crops such as low phytate maize may be adopted in major livestock feeding areas as a means of managing phosphorous pollution. Specialty grains with nutrient compositional changes that are healthier for human consumption may increase specialty crop acreage. Some IP crops (such as non-GMO) do not require any major changes in management beyond careful isolation and segregation. However others may warrant additional adjustments of the production system, if genetic modifications affect a specialty crop's agronomic performance and response to production practices and environmental conditions. The agronomic performance of specialty maize will improve as specialty traits are incorporated into adapted, elite genetics. Data on the yield potential of specialty maize relative to elite commodity grain hybrids will be of critical importance to growers. Such information will help growers determine if the premiums and contracts offered for IP grain production are profitable alternatives to commodity grain production.

TopCross7 and **TC-Blend7** are registered trademarks of DuPont Specialty Grains. **SupercedeJ** and **NutriDenseJ** are trademarks of Dow AgroSciences and ExSeed. Genetics, respectively.

References

Darrah, L.L.,D.R.West, R.L. Lundquist, B.E. Hibbard, A. Schaafsma, E.A. Lee, S. Mbuvi, C.G. Poneleit, F.J. Betran, W. Xu, J.K. Pataky, L.D. Maddux, B. Gordon, R.W. Elmore, D.E. Stenburg, Z.W. Wicks, P. Beauzay, P.R. Thomison, D.M. Jordan, K.E. Ziegler, R. Henry, J.A. Deutsch, J.F. Strissel, and D.B. Fisher. 2000. White Food Corn - 2000 Performance Tests. Special Report 528.

Ohio State University Extension. 1995. Ohio Agronomy Guide, 13th ed., Bulletin 472, OSUE, Columbus, OH.

Strachan, S.D., and S.L. Kaplan. 2001. Responses of high-oil corn to rootworm beetles during pollination. Agron. J. 93: 1043-1048.

Thomison, P.R. 2000. Specialty grain production: agronomic performance and management considerations. Ohio=s Challenge 12:22-27.

Thomison, P.R., and A.B. Geyer. 1999. Evaluation of TC-Blend**7** used in high oil maize production. Plant Varieties and Seeds. 12: 99-112.

Thomison, P.R. and A.B. Geyer. 2000. Nutritionally Enhanced Corn Hybrids-1999 Evaluation. OSU-Extension AGF-144-00

Thomison, P.R., A.B. Geyer, L.D. Lotz, H.J. Siegrist, and T.M. Dobbels. 2002. TopCross high oil corn production: agronomic performance. Agron. J. 94:290-299.

Thomison, P., A. Geyer, L. Lotz, and H. Siegrist. 1997. Using TC Blends7 in high oil corn production. p.283-298 *In* R.J. Falasca (ed.) Proc. of Fifty-Second Annu. Corn and Sorghum Indus. Res. Conf., Chicago. 10-11 Dec. Am. Seed Trade Assoc., Washington, D.C.

U.S. Grains Council. 2001.2000-2001 value-enhanced grains quality report. U.S. Grains Council, Washington, D.C.

Table 1. Different types of maize produced for IP grain or specialty markets.

- Waxy
- High Amylose
- High Oil
- High Lysine
- Nutritionally Dense (e.g. high protein)
- Popcorn
- Low Phytate
- White and Yellow Food Grade
- Open Pollinated
- Sweetcorn
- Non-GMO
- Organic
- High extractable starch

Table 2. Yields of white food grade hybrids, Early White Food Maize Performance Trials, averaged across all locations, 1997-2000.

	Yield (Mg/ha)			
Type	1997	1998	1999	2000
White-Avg	8.5	10.9	9.8	9.2
Range	7.3 – 10.0	8.5 – 12.6	8.5 – 11.0	8.0 – 10.3
Yellow-Avg	9.0	11.4	9.2	8.4
Range	8.0-10.1	11.2 – 11.7	9.1 – 9.3	8.3 – 8.5

Table 3. OSU evaluations of nutritionally dense maize, averaged across locations, 1999-2000.

	Yield (Mg/ha)	
Type	1999	2000
Nutritionally Dense – Avg	9.7	5.9
Range	7.5 – 12.0	4.1 – 8.3
Conventional Check – Avg	9.7	7.5
Range	7.3 – 12.0	6.3 – 8.2

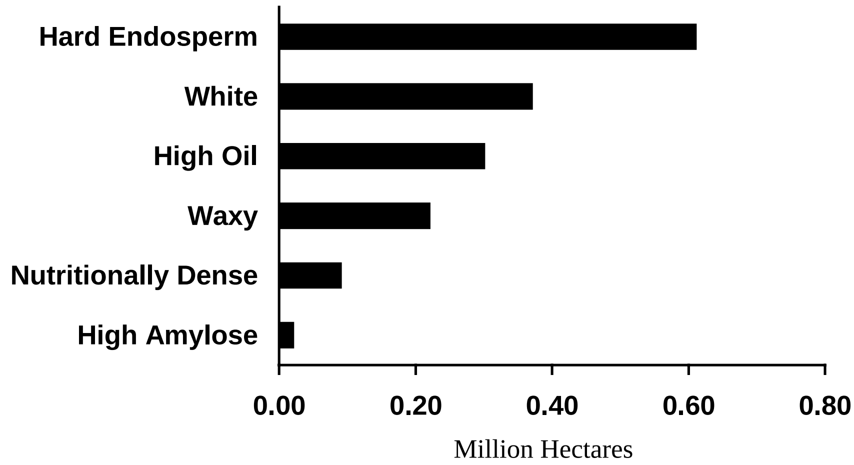

Figure 1. Hectares of specialty maize in the U.S.; 2000 estimates
Source: US Grains Council, 2001.

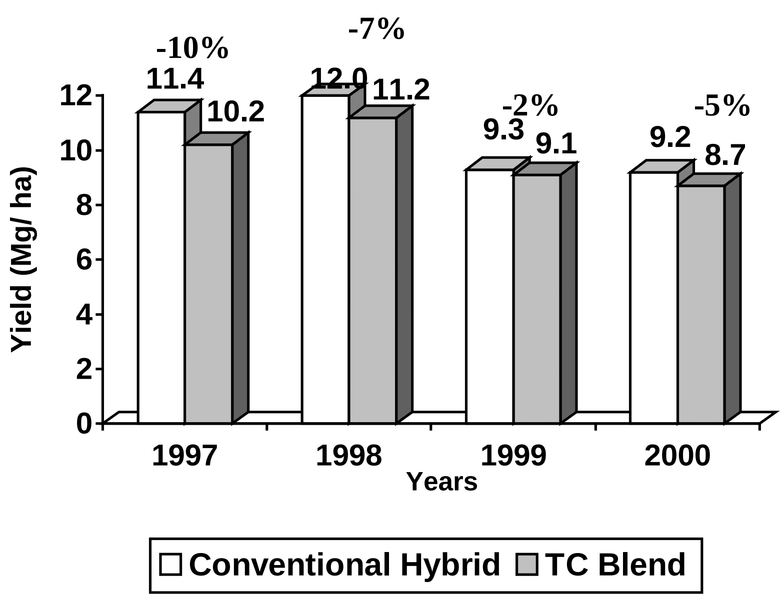

Figure 2. Comparison of TC Blends and conventional maize yields, High Oil (HO) TC Blend Evaluations, 1997-2000

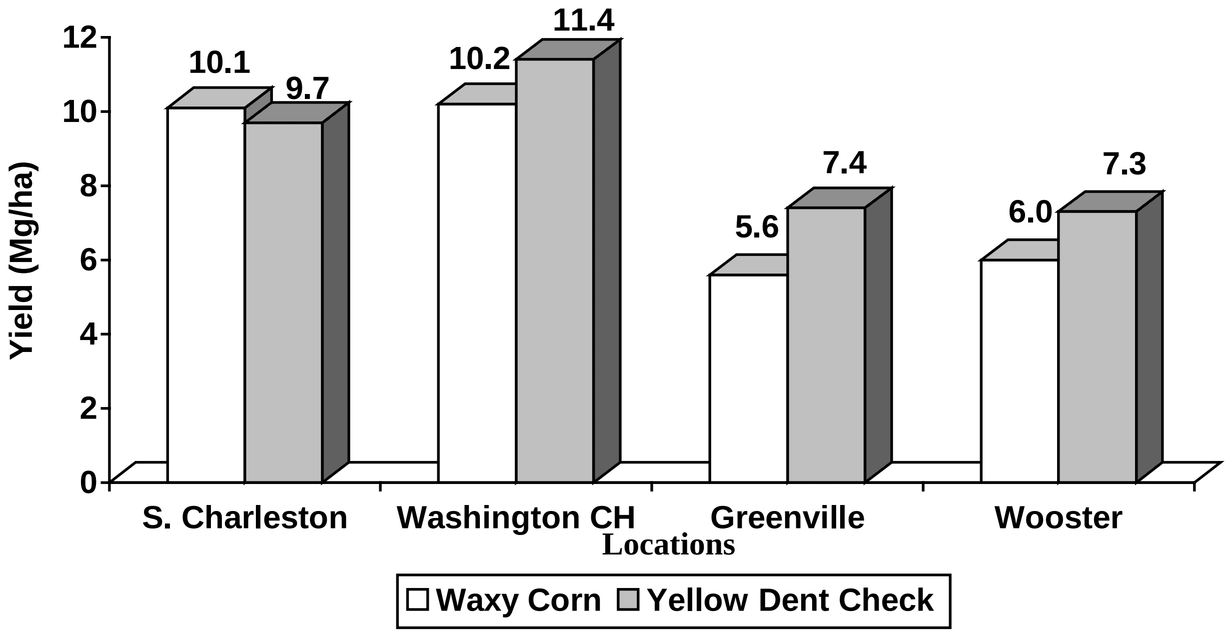

Figure 3. Waxy maize grain yields, four Ohio locations, 1996-1997.

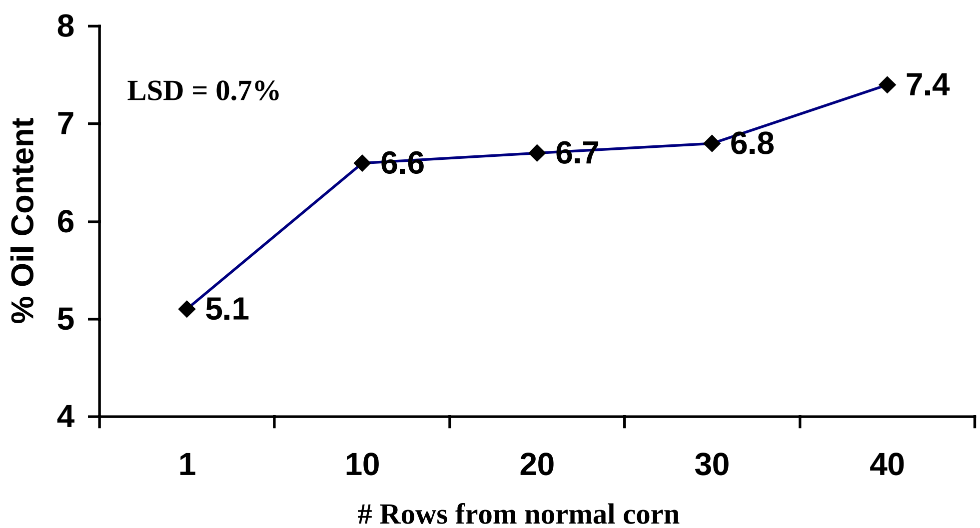

Figure 4. Effects of adjacent normal maize on oil content of TopCross grain.