Boron for cotton

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Boron

for Cotton
On the cover: Individual plants from plots fertilized and not fertilized with boron. Note sparse fruiting and compact bushy appearance of the top of the plant from the no boron plot.
Boron Now Recommended For Cotton

By J. D. LANCASTER, B. C. MURPHY, R. E. COATS, R. C. ALBRITTON, B. C. HURT, JR., B. L. ARNOLD, AND LOUIE WALTON

On the basis of recent experimental results along with the observation of severe boron deficiency in many farm fields, it is recommended that cotton in the Hill Section of Mississippi be fertilized with boron. Fertilization of soils in the Delta-Foothills with boron may also be beneficial particularly following the application of lime.

Cotton may be fertilized with boron (1) by applying a borated fertilizer, (2) by foliar application perhaps with insecticide solution at regular intervals during the fruiting period, and (3) by the direct application of borate fertilizers to the soils. To obtain uniform distribution with direct application, it is recommended that a borate solution be sprayed on the soil either before, after, or during seed bed preparation.

Sixteen chemical elements are known to be essential for the normal growth and reproduction of crop plants, as well as many other plants. Of these elements, seven are required in very small amounts, and, accordingly are often referred to as "trace" or "minor" elements. More appropriate terminology which is now gaining in usage, refers to them as micronutrients, micro meaning a small amount. The micronutrients are: iron, copper, manganese, zinc, boron, molybdenum, and chlorine.

In an illustration of the small amounts of some of these nutrients that are actually required, a mature crop of cotton yielding two bales per acre may contain as little as 0.1 pound of boron in the above-ground portion, while the amount of molybdenum may be no more than 0.005 pounds per acre. An apt expression in this connection is that "a little switch starts a big motor."

Just as with nitrogen, phosphate, or potash, a deficiency of any of the micronutrients will result in a reduction in yield and possibly in quality as well. Sometimes, too much of one of the micronutrients may be present causing toxicity and reduced yields. Therefore, there may be a problem not of too little, but of too much. Both problems have been encountered in Mississippi: Namely, manganese toxicity (crinkle leaf) and boron deficiency. In a report on manganese toxicity in Mississippi Farm Research, December, 1953 it was pointed out that the toxic condition occurs on rather acid soils and is easily corrected by liming.

Evidence and Symptoms Of Boron Deficiency

The first evidence in Mississippi of boron deficiency in cotton was obtained at the North Mississippi Branch Station, Holly Springs (1941-43) by Dr. Russell Coleman. Yield increases attributed to boron ranged from around 50 to 200 pounds of seed cotton per acre and apparently were associated with an increase both in the number and size of the bolls. Yield increases were obtained on both limed and unlimed soil, but were greater on limed soil. Study of soils collected from the resource areas of the state indicated that soils of the Delta Area contained much higher levels of available boron than did those of the Hill Section, especially the sandy loam and silt loam soils of the Hill Section. However, fertilization of cotton with boron was not recommended at that time and no further work was done for several years.

In 1954, research work in cotton fert-

1 Appreciation is extended to W. Y. Parker, County Agent, Yalobusha County, for his interest in and assistance with experiments conducted there.
Figure 1. On the left is a nearly normal crop. On the right, an adjacent area of the same field is extremely deficient in boron and the cotton is sparsely fruited, stunted and vegetative.

Ilitzation was greatly expanded. One of the treatments included in many of the experiments was the addition of the fertilizer of a micro-nutrient mixture, or of boron. One of a micro-nutrient mixtures employed was Fritted Trace Elements (FTE N-502) a product supplied by the Ferro Corporation, Cleveland, Ohio. The FTE contained 3.9% iron, 9.7% manganese, 2.0% copper, 4.0% zinc, 2.8% boron, and 0.13% molybdenum and was applied at the rate of 50 pounds per acre. The other micro-nutrient mixture, EsMinEl, was obtained from the Tennessee Corporation, Atlanta, Georgia. One ton of the EsMinEl contained approximately 835 pounds of manganese sulfate, 300 pounds ferric sulfate, 200 pounds of zinc sulfate, 300 pounds of copper sulfate, 300 pounds of magnesium sulfate and 30 pounds of Borax. Ninety pounds of EsMinEl was mixed with 10 pounds of either colemanite or borax and 50 pounds of the mixture applied per acre.

Where boron was the only micronutrient added, the source was either borax or colemanite and the rate either 0.5 or 1.0 pound per acre. A few other experiments were conducted (Black Belt, Pontotoc and North Mississippi Stations) in which certain of the micronutrients were applied separately and in combination. Molybdenum was applied either as a foliar spray or as a soil-foliar combination. Soil application of the other nutrients with the NPK fertilizer was made.

Results of these tests are summarized in Table 1. As summarized, these data provide no convincing evidence that micronutrients are needed in the fertilizer for cotton. The largest increase was for mixtures of micronutrients containing boron, or for boron alone. Among these trials, a statistically significant increase (odds 9:1) was obtained for boron at the Pontotoc Station, one year; at the North Mississippi Station for a micro-nutrient mixture, three years; and on farm fields with a micro-nutrient mixture, one year. In a little more than 60% of the trials, a higher yield was obtained with either a micronutrient mixture or boron than where neither was applied. In view of the lack of response to either zinc, copper or molybdenum and in terms of subsequent findings, practically all, if not all of the increase in yield associated with the micronutrient mixtures is attributed to boron.
In 1958, at the Pontotoc Station a serious production problem was encountered with cotton on an acid soil which had been limed to around pH 6.4. The problem had been recognized before the soil was limed, but it became somewhat more acute afterwards. In some areas, the cotton completely failed to produce mature bolls, although the plants appeared to be normal in other respects. There were no obvious vegetative abnormalities such as severe stunting or leaf-chlorosis. Throughout the fruiting period, the cotton put on squares and bloomed in what then appeared to be a normal manner, but the bolls were shed usually long before they were half-grown.

Based on fertilization practices and a limited chemical analysis of leaves from the affected plants it was concluded that a micronutrient deficiency was involved. In subsequent field experiments, it was established that the trouble was due to boron deficiency.

During a drought in the summer of 1960, there were several reports of unusually severe shedding by cotton, not only of squares, but of bolls as well, sometimes nearly grown bolls. In some of the fields, there were small areas where the cotton was moderately to severely stunted and excessively branched giving the cotton a distinctly bushy appearance. One such area is shown in Figure 1. Close examination revealed that the extremities of the main stem and branches were extremely rosetted (dwarfed). In some instances, the terminal bud had died. Such plants failed to develop mature bolls even though some squares, blooms and small bolls were produced. Cotton, so affected, remained vegetative and retained its leaves until frost.

In other parts of the field, the only obvious abnormality was severe shedding. In some instances, plants that were not particularly stunted failed to produce mature bolls; in others, small often imperfectly shaped bolls were produced. Such bolls opened slowly and never fully, and the cotton generally was not fluffy (hardlocked); there was a reduction both in the number and size of locks which shows that boron deficiency interferes with reproductive processes in cotton. Bolls on boron-deficit cotton seemed to be more susceptible to rot, both before and after opening. A range of the boll characteristics at the Moore Farm in Yalobusha County, 1961, is shown in Figure 2. Severely boron-deficient cotton is difficult to pick by hand and almost impossible to pick efficiently by machine.

In many cases, the nectaries at the base of squares and sometimes bolls had ruptured giving rise to an exudate which formed a ribbon-like protrusion upon drying. It was also noted that leaf petioles were often encircled by very dark green bands at irregular intervals giving an

<table>
<thead>
<tr>
<th>Micronutrient Treatment</th>
<th>Location Years</th>
<th>Combination 1</th>
<th>Without Micro-Nutrient</th>
<th>With Micro-Nutrient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combination 1</td>
<td>72</td>
<td>1864</td>
<td>1893</td>
<td></td>
</tr>
<tr>
<td>And/or Boron</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td>7</td>
<td>1643</td>
<td>1574</td>
<td></td>
</tr>
<tr>
<td>As copper sulphate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zinc</td>
<td>10</td>
<td>1687</td>
<td>1688</td>
<td></td>
</tr>
<tr>
<td>As zinc sulphate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Molybdenum, As molybdate</td>
<td>4</td>
<td>1720</td>
<td>1731</td>
<td></td>
</tr>
</tbody>
</table>

1 The combination was supplied either by Fritted Trace Elements (a slag containing iron, manganese, zinc, copper, boron, and molybdenum) or by EsMinEl (a mixture of soluble salts of iron, manganese, zinc, copper and boron). Boron was applied either as colemanite or Agricultural Borax.
appearance that has been termed “banded petioles.” When such petioles were sliced open, it was noted that the pith directly beneath the dark bands was almost always necrotic (dead).

One area of moderately stunted cotton on the Rufus Purdy Farm in Yalobusha County was sprayed with 0.25 pound of boron per acre as boric acid in 40 gallons of water on July 26. In view of the tremendous increase in yield which resulted, it was tentatively concluded that boron deficiency was responsible both for the severe shedding and the abnormal vegetative characteristics.

That severe boron deficiency was involved was verified in a greenhouse experiment and in field experiments in 1961. Cotton grown in the greenhouse on a boron deficient soil was stunted, excessively branched, and many of the leaves were distorted. (Figure 3). In earlier stages of growth, severe boron deficiency could be mistaken for thrips injury.

Besides the abnormalities already described, there are other vegetative symptoms which seem to result from boron deficiency. With moderate to severe deficiency, the leaf petioles, in addition to being “banded” may be somewhat enlarged and otherwise distorted, that is, twisted and crooked. On stunted plants, some of the older leaves were thickened and very much larger than normal resulting in a condition that might be described as “leathery leaf” because of the leather-like texture of the leaf as indicated by feel. Such leaves are apt to be very dark green in color. Another symptom of boron deficiency often noted was the deterioration (darkening) of tissue at the base of the boll just above the juncture of the boll with its stem. This may be noted by slicing the boll either in cross-section or longisection which reveals an area of darkened, water soaked tissue.

**Relation of Boron Deficiency to Liming**

Liming acid soils increases the need for boron. Consequently, severe boron deficiency is more likely to occur and has been observed much more frequently on limed than on unlimed soils. However, liming even up to pH 7.0 is not likely to produce a severe deficiency except where a moderately severe deficiency exists already. Liming intensified boron deficiency apparently for two reasons; (1) As the soil pH is raised by liming the availability of the soil boron is reduced and (2) with an increase in the calcium content of the plant as a result of liming the boron requirement of the plant may be increased. Farmers should not hesitate to use lime for fear of boron deficiency; rather, it should be recognized that both lime and boron may be needed for maximum yields. The use of boron should not be restricted to limed soils.

**Drought and Boron Deficiency**

Boron is not translocated readily from old to new tissue in plants. Therefore, if the cotton plant fails to absorb boron, even for relatively short periods, certain parts of the plant may become deficient. In
periods of drought, continuous absorption of boron from the soil may be interrupted or greatly curtailed because (1) plants do not absorb boron efficiency, if at all, from soils depleted of plant-available water and (2) much of the available boron is found in the surface 6-inches where the available water is depleted first because of plant-use and evaporation. If the sub soil does not contain adequate boron, then a deficiency may develop after the surface soil is depleted of available water. During the fruiting period, the first visual evidence of drought-induced boron deficiency is very likely to be excessive shedding of squares, young bolls, and in some cases relatively large bolls. Other symptoms such as leaf-petiole necrosis and ruptured nectaries of squares may also be evident.

Annual fertilization of cotton with boron could reduce markedly the incidence of drought-induced boron deficiency. Should this not be the case, however, then foliar application may be necessary. Additional research is needed in this area before a definite conclusion can be drawn.

Field Trials With Boron in 1961

As a result of the experiences in the summer of 1960, the research program with boron on cotton was greatly expanded. One series of field experiments had the following objectives: (1) To provide confirmation of boron deficiency in certain cotton fields that were severely affected in 1960; (2) to obtain information as to rate and method of application to soils for most effective results; and (3) to determine if foliar application in addition to soil application of boron is necessary to obtain maximum response to boron.

Experiments were located at the Walter Moore and Rufus Purdy farms in Yalobusha County, at the North Mississippi Pontotoc Ridge-Flatwoods and Brown Loam Branch Stations and at the Central Station, State College. Soils not already heavily limed were heavily limed prior to putting out the boron treatments. Where lime was applied, the rate was twice that indicated by a lime requirement determination. All test sites were fertilized adequately and uniformly with nitrogen, phosphate and potash.

The boron treatments imposed are shown in Table 2. Solubor, a highly water-soluble borate fertilizer, was the source of boron. Before being applied, the Solubor was dissolved in water. Broadcast application was made by spraying the Solubor solution on the soil surface just prior to seed bed preparation. Drill application was made by dribbling the solution in the water furrow with the NPK fertilizer. Foliar application was made by spraying the foliage with a Solubor solution using a compressed-air garden-type sprayer.

Yield results are given in Table 2. A very large increase was obtained for boron both at the Moore farm and the Pontotoc Station, a moderately large increase at the Purdy Farm, a fair increase at both the Central Station and the Brown Loam Station, but only a slight increase at the North Mississippi Station.

Both broadcast and drill applications of boron were highly effective. A drill application of 0.5 pound was adequate, or more than, even under conditions of severe boron deficiency. On the average, soil plus foliar application gave slightly larger yields than soil application alone, but the evidence is by no means conclusive that foliar application is or is not needed where a soil application is made. Actually, there was little opportunity to measure the need for additional boron as a foliar application in 1961 because soil moisture was adequate, or more than, throughout most of the fruiting period.

Though large increases in yield were obtained in some cases, there was no visual evidence of boron deficiency until late in the growing period. At no time was shedding so severe as it was during the drought periods of 1960. No squares with ruptured nectaries were observed and only under the most severe conditions
of deficiency were the petioles "banded". However, a darkened, water-soaked area at the base of the bolls was commonly observed. The appearance of boron deficiency in cotton late in the season on the Moore farm was marked by sparse fruiting, upright condition, and the compact, bushy appearance of the boron-deficient cotton, especially in the upper part of the plant.

In another series of experiments, foliar applications of boron to cotton which had not been fertilized with boron were made during the fruiting period using tractor-mounted spray equipment. Five to six applications of 0.1 pound of boron each as Solubor were made. Results are presented in Table 3. On the average there was an increase in yield for the boron-spray treatment which again suggests that boron is needed for cotton and that foliar spraying is an effective method of application.

In many nitrogen-rates experiments in the Hill Sections relatively high rates of nitrogen have reduced the yield below that obtained with a lower rate particularly, or shallow soils during dry summers. Accordingly, another series of experiments was initiated to determine if the reductions in yields with high rates of nitrogen were caused by boron deficiency. The treatments and the resulting yields are shown in Table 4. These results are inconclusive, but there is a hint that boron deficiency may have been involved in yield reductions with high rates of nitrogen. However, the true relationship must be shown in future experiments.

It has been shown by many investigators that toxicity may result when relatively low rates of water-soluble boron are applied to some crops. Toxicity is more apt to occur when the borate fertilizer is drilled in close proximity to the seed. In view of this possibility, an experiment was conducted to determine how much water soluble borate fertilizer could be applied to cotton without toxic effects, particularly in the seedling stage. The
tests was carried out at State College on Verona fine sandy loam. There were three rates of boron; 0.5, 1.0, and 2.0 pounds per acre plus a no-boron check. Placement of borate fertilizer was 2 inches to the side and 2 inches below the seed and in the water-furrow three inches below the seed. Yield data were not taken because of a severe wilt infestation. However, there were no observable toxic effects. Even so, it is recommended that no more than 0.5 pound of water-soluble boron be banded close to the seed.

### Extent of Boron Deficiency

Severe boron deficiency is known to have occurred in 10 counties of the Hill Section, possibly in five others, and in one Delta Foot-Hills County. As a general rule, relatively small, irregularly shaped areas within a field are affected very severely by it, but there may be exceptions particularly during drought periods. Data on the relative available boron status of Mississippi soils are shown in Table 5. Clay soils of the Delta Area contain the largest amounts of available boron and are given a relative rank of 100. Soils of the Hill sections contain considerably less available boron than soils of the Delta Area. It appears that boron deficiency is much less likely to occur in the Delta Area than in the Hill Section.

Because of the possible involvement of drought-induced boron deficiency in the "dry-weather" shedding of cotton, it is difficult to anticipate the degree and extent of boron deficiency in cotton in the Hill Section. It is recognized that cotton sheds for many reasons, and in periods of drought if it does not shed because of boron deficiency it will eventually shed for some other reason.

### Boron Recommended for Cotton in Hill Section

Based on the experimental data available and observations of boron deficiency in farm fields of cotton, it now appears that cotton in the Hill Sections and possibly in the Delta Foot-Hills (especially limed silt and sandy loam soils) should be fertilized annually with boron. This may be done (1) by applying a borated fertilizer, (2) by foliar application perhaps

#### Table 3.—Response of cotton to boron applied as a foliar spray during the fruiting period.

<table>
<thead>
<tr>
<th>Location</th>
<th>Soil type</th>
<th>Pounds of seed cotton per acre</th>
<th>No Boron spray</th>
<th>Boron spray¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>McFarland Farm</td>
<td>Unclassified silt loam</td>
<td></td>
<td>2400</td>
<td>2435</td>
</tr>
<tr>
<td>Shapley Farm</td>
<td>Unclassified silt loam</td>
<td></td>
<td>1947</td>
<td>2036</td>
</tr>
<tr>
<td>Black Belt Station</td>
<td>Hunt clay</td>
<td></td>
<td>1718</td>
<td>1726</td>
</tr>
<tr>
<td>Central Station</td>
<td>Verona sandy loam</td>
<td></td>
<td>1493</td>
<td>1448</td>
</tr>
<tr>
<td>Northeast Miss. Station</td>
<td>Iuka sandy loam</td>
<td></td>
<td>1418</td>
<td>1628</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td></td>
<td></td>
<td>1795</td>
<td>1855</td>
</tr>
</tbody>
</table>

¹Five to six applications of 0.1 pound of boron each at approximately weekly intervals. Solubor was the source of boron.

#### Table 4.—Response of cotton to boron as affected by amount of nitrogen applied.

<table>
<thead>
<tr>
<th>Location and Soil Type</th>
<th>Lbs./A, pounds of seed cotton per acre</th>
<th>Boron¹</th>
<th>No Boron</th>
</tr>
</thead>
<tbody>
<tr>
<td>north Miss. Station</td>
<td>80</td>
<td>160</td>
<td>80</td>
</tr>
<tr>
<td>Grenada silt loam</td>
<td>1802</td>
<td>1772</td>
<td>1806</td>
</tr>
<tr>
<td>Pontotoc Station</td>
<td>2292</td>
<td>2221</td>
<td>1481</td>
</tr>
</tbody>
</table>

¹An application of 0.5 pound of boron as Solubor in drill with NPK Fertilizer prior to planting plus 5 or 6 foliar applications of 0.1 pound each as Solubor at weekly intervals during the fruiting period.
with the insecticide solution at regular intervals during the fruiting period, and (3) by direct application of borate fertilizers to the soil. The use of borated fertilizers provides a very convenient and perhaps the least expensive procedure. For this purpose borated fertilizers having P₂O₅ to K₂O ratios of 1:1 and 2:1, as typified by 6-8-8 and 5-10-5, respectively, should contain enough boron to give a per acre application of 0.3 pound of boron when applied at the rate of 48 pounds of P₂O₅ per acre, which is the amount of P₂O₅ generally recommended for cotton in the Hill Section.

Fertilizers containing this amount of boron would have a P₂O₅ to boron ratio of 160:1. Farmers who use as little as 32 pounds of P₂O₅ per acre still would apply 0.2 pound of boron per acre which would very probably be adequate except in case of severe deficiency. Farmers who use as much as 60 pounds of P₂O₅ would add 0.4 pound of boron per acre. The extra amount of boron would not often be expected to be beneficial, neither would it be expected to be toxic with proper placement of fertilizer. Where fertilizers are banded as recommended with respect to the seed, the rate of water-soluble boron added with the fertilizer should not exceed 0.5 pounds per acre. Larger amounts from slowly-soluble sources may be applied without danger of toxicity. If the borated fertilizer is applied broadcast, as much as 2 pounds of boron per acre may be added without danger of toxicity. Both water-soluble and slowly-soluble (borated slag) sources of boron should be satisfactory for formulation with fertilizers.

Solubor is recommended for foliar spray and for direct application to the soil as a spray. Except possibly in cases of moderate to severe deficiency, 0.5 pound of boron sprayed on the soil should be adequate but up to 2 pounds may be applied without appreciable danger of toxicity. It is probable that the boron can be applied satisfactorily with the premerge herbicide, but this has not been verified. Should this method be employed, the boron-rate should not exceed 0.5 pound per acre in a 12 to 14-inch band.

From 5 to 7 foliar applications of approximately 0.1 pound of boron per acre each at weekly intervals during the fruiting period would be expected to give satisfactory results. Solubor is found to be compatible with all insecticides for cotton, then, a convenient and inexpensive way to make foliar applications would be to dissolve Solubor in the insecticide solution after it is prepared for application and spray them on together. Compatibility tests of Solubor with cotton insecticides have not been completed, but based on
Table 5.—Relative amounts of available boron in Mississippi soils.

<table>
<thead>
<tr>
<th>Soil area</th>
<th>Clays¹</th>
<th>Silt Loams</th>
<th>Sandy loams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delta</td>
<td>100</td>
<td>52</td>
<td>50</td>
</tr>
<tr>
<td>Blackland</td>
<td>59</td>
<td>—</td>
<td>56</td>
</tr>
<tr>
<td>Loess, Thick and Thin</td>
<td>—</td>
<td>36</td>
<td>—</td>
</tr>
<tr>
<td>Coastal Plain, Upper and Lower</td>
<td>44</td>
<td>33</td>
<td>33</td>
</tr>
</tbody>
</table>

¹Delta clays are highest in available boron and are given a relative rank of 100. Data on available boron were supplied by Dr. L. E. Nelson.

Table 6.—Amounts of Solubor to add per gallon of solution for a foliar application of 0.1 pound of boron per acre.

| Gallons of solution applied per acre | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10
|--------------------------------------|---|---|---|---|---|---|---|---|---
| Pounds of Solubor¹ needed per gallon | 0.24| 0.16| 0.12| 0.10| 0.08| 0.07| 0.06| 0.055| 0.05

¹Solubor contains 20.5% boron.

their chemical characteristics it is probable that only the organic phosphates would be affected. A schedule of the amounts of Solubor to add per gallon on spray solution is shown in Table 6.

Borate is not strongly retained by soils and like nitrate salts is easily lost by removal in water percolating through the soil. Consequently, there is little danger of an accumulation of toxic amounts of boron from annual applications of recommended rates of boron.

Solutions of Solubor and other borate compounds are non-corrosive to farm equipment used in the application of herbicides and insecticides. These solutions are non-toxic to the skin and are very safe to handle.

Just because a little boron used properly may be highly beneficial farmers should not assume that much more would be even better. To the contrary, toxicity and reduced yields may easily result. This is especially true where water-soluble sources are banded with the fertilizer near the seed.

Fertilizers containing the amount of boron suggested for cotton (0.3 pound of B for each 48 pounds of P₂O₅) may be used on other row crops such as corn and grain sorghum without danger of appreciable toxicity but little if any benefit would be expected from the boron. It is recommended that such fertilizers not be applied to small grain particularly if the fertilizer is drilled in contact with or very close to the seed.

Economics of Boron Fertilization

Large increases in the yield of cotton have been obtained with boron on extremely deficient soils. Fortunately very little of the cotton acreage is severely deficient in boron and a more reasonable expectation would be for yield increases ranging up to 100 pounds per acre. An increase in the yield of less than 5 pounds of seed cotton per acre would be required to pay for the boron. Therefore, an average increase of only 50 pounds of seed cotton would be quite profitable. For so little cost, it would seem that farmers might want to eliminate the risk of boron deficiency in cotton in the Hill Section.
Figure 4. A contrast of boron vs. no boron at the Moore farm, 1961.

Figure 5. In the foreground is a no-boron check plot at Moore farm, 1961. Note the upright, compact, and sparsely-fruited conditions as opposed cotton in the background pulled over into the middle with bolls.