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EC129

Evaluating Hail Damage to Grain Sorghum

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A hailstorm can cause damage ranging from slight to total in a sorghum crop. To accurately predict the effects of this damage on sorghum yield, research has been conducted. The results are used by hail insurance companies to assess yield losses and determine adjustments paid to clients. This publication describes procedures used to assess sorghum hail damage and may be useful in estimating crop yields wherever stand loss or defoliation occurs.

Yield loss predictions are based on two factors:

1. stage of growth at the time of damage, and
2. the degree of plant damage.

Plant damage is classified as either direct or defoliation. Direct damage is divided into three categories: stand reduction, stalk damage, and head damage. Defoliation is the loss of leaf area which may lead to later yield losses. Each step of the adjustment process will be discussed. A worksheet is provided to illustrate these adjustment procedures.

Determining Sorghum Growth Stages

Accurate determination of growth stage is necessary to determine yield loss due to hail. *Table 1* lists and describes sorghum growth stages and indicates the number of growing degree days and the number of days until the next growth stage for a typical 115-day grain sorghum hybrid. The Growing Degree Days (GDD) method of measuring heat units was developed to estimate the rate of grain sorghum growth. In calculating GDD, daily average temperatures (Farenheit) are accumulated for the growing season by applying the following formula to each day's maximum and minimum temperatures.

$$GDD = \frac{(\text{Max } ^{o}F + \text{Min } ^{o}F) - 50}{2}$$

Maximum temperatures higher than 100°F are entered as 100 and temperatures below 50°F are entered as 50 in the formula.

Table 1. Description of sorghum growth for mid season hybrid

Stage (One-half of the actual leaf is exposed)	*Average Time Interval*	*Growing Degree Days*	*Collar of this Leaf is Visible*	*Tip of this Leaf is Visible*	*Percent of Total Leaf Area Exposed*
Emergence to 10th Leaf	32 days	680			
11th Leaf	4 days	770	9th	13th	12
12th Leaf	4 days	850	10th	14th	20
13th Leaf	3 days	920	11th	15th	28
14th Leaf	3 days	980	12th	16th	39
15th Leaf	3 days	1050	13th	17th	50
16th Leaf	3 days	1110	14th	18th	62
17th Leaf	3 days	1170	15th	19th	72
18th Leaf	2 days	1220	16th	20th (flag leaf)	79
19th Leaf	2 days	1260	17th	Part of 20th (flag leaf) is visible	85
20th Leaf	3 days	1320			92
Full Leaf Development (Early Boot)	3 days	1390	All leaves are fully extended and exposed. Head has started to swell and is extended to just below the flag leaf.		100
Boot	2 days	1430	Head is almost full size and has started to emerge from the sheath of the flag leaf.		
Just Headed	2 days	1470	More than 50 percent of the heads have emerged from the boot—no blossoms showing.		
Bloom	5 days	1580	All heads have emerged from the boot and more than 50 percent of the heads show yellow pollen tubes on more than 50 percent of each head.		
Blister	4 days	1665	Grain is in a watery form and only partially formed—no color to liquid.		
Early Milk	5 days	1770	Grain is fully formed. Substance is a clear to slightly white, milky liquid. Removal of fluid from grain would leave only the hull.		
Milk	6 days	1880	Substance is thick milky liquid, no solids.		
Late Milk	6 days	2010	Grain has reached a semi-solid form.		
Soft Dough	5 days	2110	When grain is crushed, a white substance emerges in a semi-solid form.		
Dough	5 days	2220	When grain is crushed, a white substance emerges in an almost solid form.		
Hard Dough	6 days	2350	Grain is firm and nothing emerges when crushed.		
Mature	Physiological maturity has been reached; moisture content is less than 40 percent. A thin black layer has developed on bottom tip of grain.				

Stages of Growth for Grain Sorghum

1. Actual leaf count is used to determine the stage of growth until all the leaves are exposed.
    a. Start with the rounded tip leaf and count all leaves developed up to, and including the stage indicator leaf. The stage indicator is the leaf which is at least 50 percent exposed. It is usually the uppermost leaf tip that is pointing below a horizontal line.
    b. The node identification system will be used if the rounded tip leaf can not be determined.
        (1) Pull up the entire plant and carefully split the stalk to expose stalk nodes and root whorls.
        (2) The seventh leaf attaches to the top of the first noticeable elongation between the nodes (an internode) (*Figure 1)*.
        (3) After the seventh leaf node is identified, count the leaf nodes upward on the stalk to the stage indicator leaf.
        (4) In the early stages of the plant's development, the nodes are compact and difficult to distinguish; by stage nine or ten, the internode elongation should be easily found.
2. Head development determines the stage of growth after the boot stage.

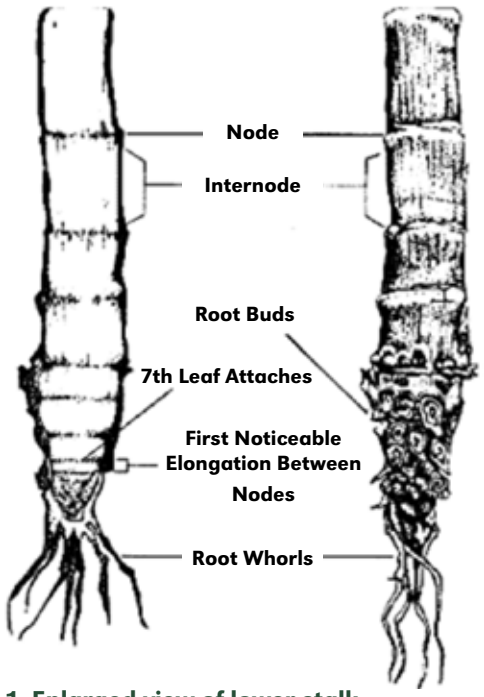

Figure 1. Enlarged view of lower stalk.

To use the accompanying tables and loss procedures properly, the total number of leaves produced by the plant must be determined. This can be accomplished by unrolling the unemerged leaves from the whorl. If this cannot be done, wait until later in the season to determine ultimate leaf number. Typical ultimate leaf numbers for Nebraska range from 15 in the high plains of western Nebraska to 19 in the southeast.

Appraisal Methods

Instructions are provided for the following appraisal methods:

- **Stand Reduction Method —** For planted acreage with no emergence, and from emergence to the milk stage
- **Hail Damage Method —** For the 1st leaf stage until the sorghum reaches the milk stage
- **Headed Weight Method —** For all grain appraisals from milk stage through maturity

Stand Reduction Method

This method is used for all appraisals from emergence to the milk stage. (Beginning with the 10th leaf stage, the *Hail Damage Method* is used.) This method is based on the number of surviving plants in a designated sample row length.

If the reduction in stand is solely because of non-emerged seed due to insufficient soil moisture, do not complete appraisals prior to the time specified in the Loss Adjustment Manual (LAM) published by USDA's Federal Crop Insurance Corporation. Refer to the paragraph in the LAM regarding deferred appraisals and non-emerged seed.

1. The stand reduction method is based on the number of surviving plants in a designated sample row length.
2. Surviving plant counts are converted to bushels per acre by multiplying the percent of potential remaining production by the base yield per acre.
3. Up to and including the 19th leaf stage, the *Hail Stand Reduction Loss Factors* in *Table 3* are used to determine the percent of potential remaining production.
4. After the 19th leaf stage to the milk stage, the yield and stand reductions are on a one-to-one ratio; for example, 80 percent stand equals 80 percent yield potential.

5. Samples consist of 1/100 acre, unless the crop is broadcast. Use a sample area 6.6 feet by 6.6 feet (1/1000 acre) for broadcast grain sorghum. Refer to *Row Width* and *Row Length* in *Table 2* for other sample sizes.

Hail Damage Method

Use the *Hail Damage Appraisal Worksheet* for hail-damaged grain sorghum appraisals beginning with the 10th leaf stage and until the grain sorghum reaches the milk stage. This method is based on the calculation of direct and indirect damage from hail to determine the percent of potential remaining production, converted to a bushel per acre appraisal. For damage due to hail, inspections for immature grain sorghum must be delayed at least 7 to 10 days after the damage for a more accurate damage assessment.

Determination of direct damage includes stand reduction and damage to the stalk and the head.

Stand Reduction

- Hail damage from defoliation prior to the 10th leaf stage is considered recoverable since the plant growing point is largely protected at this stage and regrowth will usually show no adverse effect in grain yield.
- In the 10th leaf through the 19th leaf stage, the *Hail Stand Reduction Loss Factors* in *Table 3* are used to determine percent of damage due to stand reduction.
- After the 19th leaf stage to the milk stage, the yield and stand reductions are on a one-to-one ratio; for example, an 80 percent stand reduction equals an 80 percent loss of potential

Head Damage

The gross percent of damage to grain sorghum heads caused by hail damage is determined by dividing the average number of destroyed kernels per head by the average total number of kernels per head in a sample of four "average" heads.

To determine the gross percent of head damage:

1. Determine the average total number of kernels and the number of kernels destroyed by hail on four "average" heads by calculating the average number of kernels per spikelet (using four spikelets — one from near the bottom of the head, one from a quarter of the way up, one from half way up, and one from three-fourths of the way up). After determining the total number of kernels per spikelet, count the number of kernels that are destroyed (missing, cracked, bruised) by hail. Multiply both counts by the number of spikelets on the head. (Count the four or five small spikelets in the very top of the head as one average spikelet.)

2. Total the number of all kernels (destroyed and not destroyed). Then total the number of destroyed kernels. Divide each result by the total number of heads sampled. The results will be the average total number of kernels per head and the average number of kernels destroyed per head.

3. Divide the average number of kernels destroyed per head by the average total number of kernels per head to determine the gross percent of head damage.

Example 1. Sample data collection to determine the gross percent of head damage

	Head 1		*Head 2*		*Head 3*		*Head 4*	
Spikelets	***Total Kernels***	***Destroyed Kernels***	***Total Kernels***	***Destroyed Kernels***	***Total Kernels***	***Destroyed Kernels***	***Total Kernels***	***Destroyed Kernels***
1	47	31	51	23	38	12	45	13
2	86	52	82	35	77	29	79	21
3	95	47	90	40	84	40	88	30
4	77	46	65	28	62	29	71	25
Total	305	176	288	126	261	110	283	89
Avg. Per Spikelet	76.3	44	72	31.5	65.3	27.5	70.8	22.3
Number of Spikelets Per Head	70	70	73	73	59	59	62	62
Avg. Kernels Per Head	5,341	3,080	5,256	2,300	3,853	1,623	4,390	1,383

The following equations can be used to calculate the gross percent of head damage and include sample calculations using data from *Example 1.*

Total average kernels per head (from 4 heads) ÷ Number of heads = Average kernels per head

18,840 kernels ÷ 4 heads = 4,710 average kernels per head

Total average number of destroyed kernels per head (from 4 heads) ÷ Number of heads = Average number of destroyed kernels per head

8,386 kernels ÷ 4 heads = 2,097 average destroyed kernels per head

Average number of destroyed kernels per head ÷ Average kernels per head = Gross percent of head damage

2,097 destroyed kernels ÷ 4,710 kernels/head = 0.445 = 45% gross head damage (when 44.5% is rounded to the nearest 5%)

For this example use 20% for the percent damage from stand reduction.

Apply *Gross Percent of Head Damage* and *Percent Damage from Stand Reduction* from *Table 4* to arrive at 36% net percent head damage.

Stalk Damage

Plants with bruises on the stalk should not be counted as destroyed until they actually fall over and become unharvestable. Young bruised plants usually will produce a normal or near normal head even though stalk damage is present. When considerable bruising is evident, defer adjustment until actual loss can be determined.

Indirect Damage

Indirect damage is caused by defoliation (the loss of leaf area) due to hail. To determine the amount of defoliation and subsequent yield loss:

1. Select representative plants.
2. Remove the leaves which were exposed at the time of hail damage.
3. Determine the percent of leaf area destroyed (missing or brown areas) on each removed leaf.
4. Total the leaf-area-loss percentages.
5. Divide the total percentage by the total number of leaves (rounded to the nearest 5 percent) to determine the average percent defoliation. Apply the average percent to the *Leaf Loss Chart* in *Table 5*.

If the damage occurred prior to boot stage, use the top portion of the chart. Determine the ultimate number of leaves by all of the leaves. After the stage indicator leaf has been identified, dissect the plant and count the nodes or leaves not yet emerged to determine the ultimate number. If the actual number of leaves to be produced cannot be determined, defer the appraisal until the actual number of leaves can be determined. At the time of deferral, accurately determine the percent of defoliation as of the date of hail loss. No further determination of defoliation should be made unless further damage occurs.

If the damage occurred during the boot through early milk stages, apply the average percent defoliation (determined above) to the lower portion of *Table 5*.

Headed Weight Method

Use this method for all grain appraisals from milk stage through maturity. This method is based on weighing the grain heads in a fraction of an acre, then converting this production to bushels per acre.

1. Select representative samples of:
   - 1/100 acre if the potential yield appears to be 20 bushels per acre or less.
   - 1/1000 acre if the potential yield appears to be more than 20 bushels per acre.
   - If the grain sorghum has been broadcast planted, use a sample size of 20.87 feet by 20.87 feet for 1/100 acre or a sample of 6.6 feet by 6.6 feet for 1/1000 acre.
   - Use *Table 2* for row-planted grain sorghum.
2. Harvest all grain heads in the sample by cutting heads from the stalks as close as possible to the lowest head branch. Weigh each sample. Calculate the average sample weight by totaling the sample weights and dividing the total by the number of samples.
3. Multiply average sample weight by:
   - 1.34 if the sample size was 1/100 acre
   - 13.4 if the sample size was 1/1000 acre

   The result will be the bushels per acre of potential production.
4. If the grain is light and chaffy or heads are poorly filled, determine threshing percentage in accordance with *Table 6* and adjust yield by threshing percentage.
5. Determine the average moisture percentage of all samples. Multiply the appropriate number from *Table 7* to adjust yield for moisture.

Table 2. Row width and length for various sample sizes

Row Width	*Row Length For 1/100 Acre*	*Row Length For 1/1000 Acre*	*Row Length For 1/2000 Acre*
42 inches	124.5 feet	12.4 feet	6.2 feet
40 inches	130.7 feet	13.1 feet	6.5 feet
38 inches	137.6 feet	13.8 feet	6.9 feet
36 inches	145.2 feet	14.5 feet	7.3 feet
34 inches	153.7 feet	15.4 feet	7.7 feet
32 inches	163.4 feet	16.3 feet	8.2 feet
30 inches	174.2 feet	17.4 feet	8.7 feet
28 inches	186.7 feet	18.7 feet	9.3 feet
26 inches	201.0 feet	20.1 feet	10.1 feet
24 inches	217.8 feet	21.8 feet	10.9 feet
22 inches	237.6 feet	23.8 feet	11.9 feet
20 inches	261.4 feet	26.1 feet	13.1 feet
18 inches	290.4 feet	29.0 feet	14.5 feet
16 inches	326.7 feet	32.7 feet	16.3 feet
14 inches	373.4 feet	37.3 feet	18.7 feet

Table 3. Hail stand reduction loss factors

	Percent of Stand Remaining (Rounded Percent of Stand to The Nearest 5 Percent)									
	100	***90***	***80***	***70***	***60***	***50***	***40***	***30***	***20***	***10***
Percent of Potential Production Remaining Through the 19th Leaf Stage	100	96	91	85	79	72	63	50	35	17
Percent of Potential Production Remaining After the 19th Leaf Stage	100	90	80	70	60	50	40	30	20	10

	Percent Of Stand Remaining (Rounded Percent Of Stand To The Nearest 5 Percent)									
	100	***90***	***80***	***70***	***60***	***50***	***40***	***30***	***20***	***10***
Percent Damage Beginning With 10th Leaf Stage Through the 19th Leaf Stage	0	4	9	15	21	28	37	50	65	83
Percent of Damage After the 19th Leaf Stage	0	10	20	30	40	50	60	70	80	90

Table 4. Net percentage of head damage

Gross Percent of Head Damage	*Percent of Damage From Stand Reduction*								
	10	***20***	***30***	***40***	***50***	***60***	***70***	***80***	***90***
10	9	8	7	6	5	4	3	2	1
20	18	16	14	12	10	8	6	4	2
30	26	24	21	18	15	12	9	6	3
40	36	32	28	24	20	16	12	8	4
50	45	40	35	30	25	20	15	10	5
60	54	48	42	36	30	24	18	12	6
70	63	56	49	42	35	28	21	14	7
80	72	64	56	48	40	32	24	16	8
90	81	72	63	54	45	36	27	18	9
100	90	80	70	60	50	40	30	20	10
Round gross damage figures to the nearest 5 percent.									

Table 5. Leaf loss factors

Ultimate Number of Leaves on Plants									*Percent Defoliation (Round Percentage of Leaf Area Destroyed To Nearest 5%)*									
15	16	17	18	19	20	21	22	23	10	20	30	40	50	60	70	80	90	100
* Stages Of Growth									Percent Of Damage									
					11	11	11	12	0	0	1	1	1	1	2	2	3	3
		11	11	12	12	13	13	14	0	1	1	1	2	2	3	4	4	5
	11	12	12	13	13	14	15	15	1	1	2	2	3	4	5	6	7	8
11	12	13	13	14	14	15	16	16	1	2	3	4	5	7	9	12	14	16
11	12	13	14	14	15	16	17	17	2	3	5	7	8	11	14	17	21	24
12	13	14	14	15	16	17	17	18	3	4	7	9	11	15	19	24	28	33
12	13	14	15	16	17	18	18	19	3	5	9	11	14	19	24	30	35	41
13	14	15	16	17	18	19	19	20	4	7	10	14	17	23	30	36	43	50
14	15	16	17	18	19	20	20	21	4	7	11	16	20	26	34	41	49	57
15	16	17	18	19	20	21	22	23	5	8	13	18	22	30	38	47	56	65
Full Leaf Development									6	10	15	21	26	36	45	55	66	77

*As determined from *Table 1* where the stage of growth is repeated in the same column, use the upper line for early and the second line for later in the stage. If the correct *Stage of Growth* is not shown in the column for *Ultimate Number of Leaves*, use the Stage of Growth from the next *higher Ultimate Number of Leaves* column.

Stages Of Growth	*Percent Of Defoliation (Percent of Leaf Area Destroyed Rounded to Nearest 5%)*									
	10	***20***	***30***	***40***	***50***	***60***	***70***	***80***	***90***	***100***
Boot	4	10	18	25	31	42	53	65	78	90
Just Headed	4	12	20	27	34	45	58	71	85	98
Bloom	4	11	19	26	33	44	57	69	83	96
Blister	3	9	17	23	30	40	51	62	74	86
Early Milk	3	8	15	21	26	36	45	55	66	77

Table 6. Threshing factors (from five-pound sample of heads)

Weight of Grain In Whole Pounds	*Tenths Of Pounds*									
	0.0	***0.1***	***0.2***	***0.3***	***0.4***	***0.5***	***0.6***	***0.7***	***0.8***	***0.9***
	Sorghum Threshing Factors									
0	.00	.03	.05	.08	.11	.13	.16	.19	.21	.24
1	.27	.29	.32	.35	.37	.40	.43	.45	.48	.51
2	.53	.56	.59	.61	.64	.67	.69	.72	.75	.77
3	.80	.83	.85	.88	.91	.93	.96	.99	—	—

For example:

Threshed grain from a 5 lb sample of heads weighed 2.8 lb. A threshing factor of .75 would be applied to the *per-acre* yield.

Calculating Actual Loss Due to Hail

A worksheet is provided to estimate percent yield loss due to hail damage. Two examples are shown.

- Example 1 is for a hailstorm occurring at a vegetative stage.
- Example 2 is for a hailstorm occurring at a reproductive stage.

The procedure first determines the amount of direct damage to the crop (stand reduction and head loss). Secondly, yield loss due to defoliation is determined based on the percent crop remaining (100% — direct damage). The actual yield loss due to hail is the sum of the direct and defoliation yield loss.

These instructions are intended as a general guideline for assessing sorghum yield loss due to hail damage. Occasionally, it is difficult to determine actual loss on the first inspection. Insurance companies may defer final yield loss determination until later in the season. Although early season defoliation appears quite devastating, research and experience has shown that sorghum plants can recover under favorable growing conditions. Since regrowth is typical in sorghum plants, use these charts with caution when deciding whether to replant. Precise yield loss estimates should be left to trained hail adjusters.

Sorghum Yield Loss Worksheet

	Examples		*Your Figures*
A. Background information	**#1**	**#2**	
1. Date of loss (storm)	7/15	8/28	
2. Inspection date	7/21	9/7	
B. Growth stage			
1. Stage at loss	13	Early Milk	
2. Stage at inspection	15	Late Milk	
3. Ultimate number of leaves	17	—	
C. Determining losses			
1. Stand reduction			
a. Destroyed plants in 100 ft of row	90	30	
b. Original plants in 100 ft of row	150	120	
c. Percent SR (1a/1b)	60%	25%	
d. Stand reduction yield loss			
If growth stage is less than 10, no loss	—	—	
If growth stage is between 11 and full leaf development, use *Percent Gross Damage* (C1c) and *Table 3*.	37%	—	
If GS is reproductive, *use Percent Gross Damage (C1c)*	—	25%	
2. Stalk Damage Usually deferred; if totally damaged add like stand reduction	0	0	
3. Head Loss			
a. Average number of spikelets per head	—	45	
b. Average number of kernels per spikelet	—	30	
c. Average number of kernels per head (3a × 3b)	—	1350	
d. Average number of kernels destroyed per head	—	351	
e. Average gross percent head loss (3d/3c)	—	26%	
4. Defoliation			
a. Percent defoliation	50%	30%	
b. Use *Table 5* to determine percent yield loss	6%	15%	
5. Calculate Actual Yield Loss Due to Hail			
a. Reduced stand (C1d + 2)	37%	25%	
b. Percent remaining crop (100% - C5a)	63%	75%	
c. Head damage yield loss (C5b/100 × C3e)	0	19.5%	
d. Total direct loss (C5a + C5c)	37%	44.5%	
e. Percent remaining (100 – C5d)	63%	55.5%	
f. Defoliation yield loss (C4b/100 × C5e)	3.8%	8.3%	
6. Actual loss (C5d + C5f)	40.8%	52.8%	

Table 7. Moisture adjustment factor

Whole Percent Moisture	*Tenths Of Percent Moisture*									
	.0	*.1*	*.2*	*.3*	*.4*	*.5*	*.6*	*.7*	*.8*	*.9*
14	1.00	.9988	.9976	.9964	.9952	.9940	.9928	.9916	.9904	.9892
15	.9880	.9868	.9856	.9844	.9832	.9820	.9808	.9796	.9784	.9772
16	.9760	.9748	.9736	.9724	.9712	.9700	.9688	.9676	.9664	.9652
17	.9640	.9628	.9616	.9604	.9592	.9580	.9568	.9556	.9544	.9532
18	.9520	.9508	.9496	.9484	.9472	.9460	.9448	.9436	.9424	.9412
19	.9400	.9388	.9376	.9364	.9352	.9340	.9328	.9316	.9304	.9292
20	.9280	.9268	.9256	.9244	.9232	.9220	.9208	.9196	.9184	.9172
21	.9160	.9148	.9136	.9124	.9112	.9100	.9088	.9076	.9064	.9052
22	.9040	.9028	.9016	.9004	.8992	.8980	.8968	.8956	.8944	.8932
23	.8920	.8908	.8896	.8884	.8872	.8860	.8848	.8836	.8824	.8812
24	.8800	.8788	.8776	.8764	.8752	.8740	.8728	.8716	.8704	.8692
25	.8680	.8668	.8656	.8644	.8632	.8620	.8608	.8596	.8584	.8572
26	.8560	.8548	.8536	.8524	.8512	.8500	.8488	.8476	.8464	.8452
27	.8440	.8428	.8416	.8404	.8392	.8380	.8368	.8356	.8344	.8332
28	.8320	.8308	.8296	.8284	.8272	.8260	.8248	.8236	.8224	.8212
29	.8200	.8188	.8176	.8164	.8152	.8140	.8128	.8116	.8104	.8092
30	.8080	.8068	.8056	.8044	.8032	.8020	.8008	.7996	.7984	.7972
31	.7960	.7948	.7936	.7924	.7912	.7900	.7888	.7876	.7264	.7252
32	.7840	.7828	.7816	.7804	.7792	.7780	.7768	.7756	.7744	.7732
33	.7720	.7708	.7696	.7684	.7672	.7660	.7648	.7636	.7624	.7612
34	.7600	.7588	.7576	.7564	.7552	.7540	.7528	.7516	.7504	.7492
35	.7480	.7468	.7456	.7444	.7432	.7420	.7408	.7396	.7384	.7372
36	.7360	.7348	.7336	.7324	.7312	.7300	.7288	.7276	.7264	.7252
37	.7240	.7228	.7216	.7204	.7192	.7180	.7168	.7156	.7144	.7132
38	.7120	.7108	.7096	.7084	.7072	.7060	.7048	.7036	.7024	.7012
39	.7000	.6988	.6976	.6964	.6952	.6940	.6928	.6916	.6904	.6892
40	.6880	.6868	.6856	.6844	.6832	.6820	.6808	.6796	.6784	.6772