NUTRITIONAL EVALUATION OF SOME VARIETIES OF SORGHUMS *(sorghum bicolor)*

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SUMMARY

Significant differences were observed in the dry matter, crude protein, indigestible residue, ether extract, ash, tannins, starch and free sugar contents of number of varieties of sorghum grown in 1980 and 1981. The differences were of varietal as well as seasonal in origin.

Significantly different values were obtained for the polyphenolic (tannins) content of the different varieties, and the absolute values depended upon the method of determination.

Tribolium assay as well as Chicken assay were in agreement in differentiating between the best and the worse varieties, but not the intermediate quality sorghum.

The growth of chickens was not correlated to either AME or ANR of the diets. A high tannin sorghum had a high AME and ANR value, but depressed the growth of chickens.

INTRODUCTION

Grain sorghum belong to the genus *Sorghum bicolor* (L.) Moench of the tribe Andropogoneae, a member of the Gramineae family. It ranks 4th among the major cereal of the world, and is widely used for human consumption in many countries of Asia and Africa. However, it is mainly fed to animals in U.S.A. Sorghum is also called milo maize, gyp corn, grain, kafir corn in U.S.A., jowar, juar, cholam in India, Guinea corn in West Africa, kafir corn in South Africa, durra in Sudan, mtama in East Africa, millets in England (Rooney 1973) and mapila in Zambia and Malawi.

Sorghum, mainly a tropical or subtropical plant, can also be cultivated in temperate climates, and plant geneticists are continuously producing new varieties to improve yields and pest resistance. In general, sorghum may be classified as follows according to their color: yellow, white, brown (high tannin content or bird-resistant) and mixed.

Different varieties of sorghum differ in their chemical composition (Neucere and Sumrell, 1980), protein content (Miller et al. 1964), nutritive value (Breuer and Dohm 1972), and amino acid profiles (Waggle et al. 1967; Breuer and Dohm 1972; Sikka and Johari 1979; Briley et al. 1979). The protein content and amino acids are influenced by the agronomic factors.

The nutritional value of sorghums has been evaluated using chickens (Waggle et al. 1967; Armstrong et al. 1974; Luis et al. 1982a), poults (Luis et al. 1982b), rats (Axtell et al. 1981) and preschool children (Maclean et al. 1981).

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A lot of information on sorghums has been compiled in a recent book (Hulse et al. 1980).

The present study attempts to evaluate the nutritional value of different varieties of sorghums using *Tribolium castaneum* larvae and chickens as the test organism.

MATERIALS AND METHODS

Based on an earlier study, ten varieties were selected that were the best, intennediate and the worse in supporting the growth of tribolium larvae. The selected varieties identified as in parenthesis were DeKalb , DD 50T (DD 50T), O'Gold EXP 9520 (EXP 9520), Northrup King NK 1580 (NK 1580), Northrup King NK 129 (NK 129), P.A.G. 4432 (PAG 4432), Pioneer 8790 (P. 8790), Asgrow Corral (Corral), DeKalb A 28+ (A 28+), P. Oil POI652G (I652G), and O'SG M 0505 (M 0505). These were grown at Davis, Ca. Three high-tannin varieties NK 300, Savanna 5, and Savanna 5 X 3174 were donated by Northrup King Co., Minneapolis, Minnesota.

Dry matter (DM), crude protein (% CP = % Kjeldahl N x 6.25), ether extract and ash were determined according to the AOAC (1970) procedures.

The method developed by Hellendoorn et al. (1975) was used for the estimation of indigestible residue. Starch was determined by the method of Southgate (1969) and free sugars were determined as glucose by the glucose oxidase method using Sigma reagents.

Tannins or polyphenols were measured by the vanillin-HCl methods of Price et al. (1978), Earp et al. (1981); spectrophotometric method of Price and Butler (1977), and Folin-Denis method as used by Burns (1971). The first three methods use catechin as a standard, and the last method uses tannic acid.

The procedure followed for the bioassay using *Tribolium castaneum* was the same as described by Vohra et al. (1981). The test samples were ground finely and fed in diets at a level of 90% along with 10% brewers yeast.' The larval weights were determined on the 14th day.

Day-old broiler chicks obtained from A.M. hatchery, Santa Rosa, Ca were weighed, wing-banded and distributed randomly, eight birds per cage in a Petersime battery. A replicate of the experiment was set up on each side of the battery with test diets (Table 10) assigned to each cage in such a way that the same diet was not on the same level or side of the battery. The usual system of husbandry was followed. Food and water were provided ad libitum. The chicks were weighed individually twice a week. Two 24-hour total collection of excreta were made during the 3rd week of the experiment. The corresponding food intake was also measured. The excreta were dried in a forced-air oven at 60°C.

From the gross energy data of food and excreta, apparent metabolizable energy (AME) of the diets was calculated. Also, from the Kjeldahl nitrogen content of a diet and the corresponding nitrogen excretion, apparent nitrogen retention (ANR) of a diet was calculated.

The data were subjected to analysis of variance and Duncan's (1955) new multiple range test or some other suitable statistical treatment (Steel and Torrie 1960).

RESULTS AND DISCUSSION

The results of the proximate composition and the tannin content of the sorghum varieties grown in 1980 and 1981 seasons are presented in Tables 1 and 2, and of available carbohydrates in tables 3 and 4, respectively, Significant ($p<0.01$) varietal differences were observed for all the measured parameters.

Table 1. Proximate composition on a dry matter basis of ten sorghum varieties grown in the 1980 season

Variety	Dry matter %	Crude protein %	Indigest. residue %	Ether extract %	Ash %	Tannin* %
DD 50T	88.1 a	12.2 d	9.7 a	2.8 b	1.7 c	0.28 e
EXP 9520	92.8 f	11.3 c	12.6 f	3.1 c	1.5 a	0.27 e
NK 1580	90.9 d	10.8 a	12.3 d	3.5 d	1.7 c	0.24 cd
NK 129	92.3 e	11.2 b	15.4 j	4.8 f	1.7 c	0.23 c
PAG 4432	89.6 c	12.3 e	12.2 c	2.7 b	1.7 c	0.32 f
P. 8790	93.4 g	11.3 bc	12.9 g	2.6 a	1.8 d	0.26 c
Corral	88.8 b	13.9 h	14.9 i	3.1 c	1.6 b	0.13 a
A 28+	92.2 e	12.1 d	11.7 b	5.7 g	1.9 e	0.26 de
PO I652G	88.5 ab	13.0 g	13.1 h	3.0 c	1.9 e	0.13 a
M 0505	90.7 d	12.5 f	12.5 e	4.2 e	1.9 f	e.18 b
Mean	90.7	12.3	12.5	3.5	1.9	0.23

Different letters in a column indicate significant differences ($p<0.01$).

* As catechin equivalent (Price _et al_. 1978).

Table 2. Proximate composition of ten varieties of sorghums grown locally in 1981 and one special high tannin variety on a dry matter basis

Variety	Dry matter %	Crude protein %	Indigest. residue %	Ether extract %	Ash %	Tannin* %
DD 50T	92.2 g	10.3 d	9.9 bc	5.0 g	1.9 d	0.35 e
EXP 9520	91.0 e	10.1 c	9.8 b	4.1 e	2.1 f	0.27 b
NK 1580	90.1 d	10.9 g	8.8 a	4.6 f	1.8 b	0.30 d
NK 129	91.5 f	11.2 h	10.1 bc	3.0 b	2.0 e	0.35 e
PAG 4432	90.5 d	10.9 g	10.0 bc	3.6 c	2.1 f	0.35 e
P. 8790	88.9 c	9.8 b	8.9 a	4.6 f	1.7 a	0.26 b
Corral	87.9 b	10.7 f	11.8 e	4.0 d	1.9 c	0.36 e
A 28+	90.4 d	9.3 a	15.3 g	2.9 a	2.8 g	0.36 e
PO I652G	86.6 a	10.5 e	10.1 c	5.3 h	1.8 b	0.25 a
M 0505	88.5 c	10.8 g	10.9 d	5.5 f	2.0 e	0.28 c
NK 300**	91.2 ef	11.6 i	12.7 f	3.6 c	1.8 b	1.15 f
Mean	89.9	10.5	10.6	4.3	2.0	0.39

Different letters in a column indicate statistically significant differences ($p<0.01$).

* As catechin equivalent.

** High tannin variety obtained from Northrup King Co.

The dry matter content of the different varieties was not significantly (p<0.01) different and the mean values were 90.7% (range, 88.1-93.4%) during 1980, and 89.9% (range, 88.5-92.2%) during 1981.

The crude protein content showed significant varietal differences and the mean value was 12.3% (range, 10.8-13.9) for 1980 sorghum and 10.5% (range 9.3-11.2%) for 1981.

Indigestible residue averaged at 12.5% (range, 9.7-15.4%) for 1980 and 10.6% (range, 8.8-15.3%) for 1981.

Mean values for ether extract, ash and tannin content were 3.5% (range, 2.6-5.7%), 1.9% (range, 1.5-1.9%), and 0.23% (range, 0.13-0.32%), respectively for 1980. The respective values for 1981 were 4.3% (range, 2.9-5.5%), 2.0% (1.7-2.8%), and 0.31% (range, 0.25-0.36%) neglecting the high tannin variety not grown at Davis.

The available carbohydrate constituents, starch and glucose also were significantly different in different varieties during both the seasons. The mean value for starch was 67.4% (range 61.1-72.6%) and for free sugars 1.63% (range, 1.01-2.62%) for the 1980 samples, and the respective values for the 1981 samples were 73.6% (range, 69.0-80.7%) and 1.05% (range, 0.76-1.26%) which also included the high tannin variety.

Table 3. The available carbohydrate content on a dry matter basis of ten varieties of sorghums grown in the 1980 season

Variety	Starch A, %	Free sugar as glucose B, %	Total available carbohydrates A + B, %
DeKalb DD 50T	72.6 h	1.33 b	73.9 g
O'Gold EXP 9520	66.4 d	1.01 a	67.4 d
N. King NK 1580	69.1 f	2.62 g	71.7 f
N. King NK 129	61.1 a	2.04 f	63.1 a
P.A.G. 4432	65.0 c	1.47 c	66.4 c
Pioneer 8790	70.4 g	1.81 e	72.2 f
Asgrow Corral	70.9 g	1.34 b	72.2 f
DeKalb A 28+	63.0 b	1.45 c	64.4 b
P.OIL PO I652G	68.3 e	1.58 d	69.9 e
O'SG M 0505	66.8 d	1.60 d	68.4 e
Mean	67.4	1.63	68.8

Different letters in a column indicate significant differences (p<0.01).

Available carbohydrate values have been rounded to 1 decimal place.

Significant differences were observed in the same parameters for the 1980 and 1981 samples as determined by t-test (Table 5). The grains were slightly smaller in 1980, had a significantly higher crude protein, indigestible residue and free sugars than the 1981 samples which were larger in size. The latter had a significantly higher ether extract, ash, starch and tannin contents. It is probable that the 1980 crop encountered some adverse agronomic factors which reduced the plumpiness of the grain, reduced their yield, starch content, but increased the protein level.

Table 4. The available carbohydrate content of ten varieties of locally grown sorghums in 1981 season and of the high tannin variety

Variety	Starch A, %	Free sugar as glucose B, %	Total available carbohydrates A + B, %
DeKalb DD 50%	69.0 a	1.17 g	70.2 a
O'Gold EXP 9520	71.1 b	1.14 f	72.2 b
N.King NK 1580	71.2 b	1.13 f	72.3 b
N.King NK 129	72.2 c	1.05 d	73.2 c
P.A.G. 4432	72.0 bc	0.99 c	72.9 c
Pioneer 8790	75.5 e	0.89 b	76.4 e
Asgrow Corral	77.1 f	0.76 a	77.9 f
DeKalb A 28+	73.4 d	1.12 f	74.5 d
P.OIL PO 1652G	80.7 g	1.20 g	81.9 g
O'SG M 0505	73.4 d	1.08 e	74.5 d
N.King NK 300	72.3 c	1.26 h	73.6 cd
Mean	73.6	1.05	74.5

* Footnote as in Table 3.

Table 5. The effect of growing season on the composition of ten varieties of sorghum grown in 1980 and 1981

Constituent % ± S.D.	Growing season 1980	1981	Mean
Dry matter	90.7 ± 1.9	89.7 ± 1.1	90.2 ± 1.3
Crude protein	12.3 ± 0.3**	10.4 ± 0.3	11.3 ± 0.3
Indigest. residue	12.5 ± 0.3**	10.4 ± 0.7	11.4 ± 0.5
Ether extract	3.5 ± 0.2	4.3 ± 0.1**	4.0 ± 0.2
Ash	1.7 ± 0.1	2.0 ± 0.3*	1.9 ± 0.1
Tannins	0.23 ± 0.03	0.32± 0.03	0.28± 0.03
Starch	67.4 ± 4.0	73.7 ± 3.1**	70.6 ± 2.1
Free sugars	1.6 ± 0.2**	1.1 ± 0.14	1.3 ± 0.1

** Significantly different ($p<0.01$) by t-test; * $p<0.05$

The total protein content of cereals is controlled by the genetic potential of the plant, nitrogen fertilization and other agronomic conditions. The main increase in protein level is due to an increase in kafirin (prolamines) like storage proteins (Seckinger and Wolf, 1973) and not in the structural proteins such as glutelins which form matrices for the starch granules. Unless the granules get plumped with starch, the protein content of the grain is relatively high. The storage proteins are deposited along with the carbohydrate deposition (Rooney 1973).

The data on the varietal and seasonal differences in the composition of sorghum grain is in agreement with the values compiled by Hulse et al. (1980).

Table 6. A comparison of values determined by 4 methods of polyphenol (tannins) determination for 14 varieties of sorghums grown in 1981 season on a dry matter basis

Variety	Methods				Mean
	Vanillin-HCl		Prussian blue	Folin-Denis	
	(1)	(2)	(3)	(4)	
DD 50 T	0.35	0.41	0.123	0.71	0.39
EXP 9520	0.27	0.37	0.101	0.79	0.83
NK 1580	0.31	0.33	0.115	0.56	0.33
NK 129	0.35	0.48	0.111	0.74	0.42
PAG 4432	0.35	0.41	0.115	0.83	0.43
P. 8790	0.27	0.29	0.108	0.63	0.32
Corral	0.36	0.49	0.133	1.06	0.51
A 28+	0.36	0.80	0.121	0.03	0.36
PO 1652G	0.25	0.35	0.115	0.07	0.20
M 0505	0.29	0.46	0.131	0.11	0.25
NK 300	1.15	1.96	0.380	2.45	1.49
Savanna S-91906	1.10	1.97	0.309	1.72	1.27
X-3174-63836	0.84	1.44	0.250	1.65	1.22
BR Y 936	1.04	1.82	0.238	1.79	1.27
Mean	0.52	0.83	0.167	0.94	

Anova table

Source	DF	Mean Square	F ratio
Varieties	13	2.308	851.89
Methods	3	4.996	1844.22
Interaction	39	0.314	115.88
Error	112	2.709E-03	

Tannins are polyphenolic compounds present mostly in pericarp. A high tannin content of the sorghum grains is of value against bird predation. However, we still do not have a very reliable method for the determination of tannins. The most commonly used method relies on the development of color with a vanillin solution in HCl and the color is calibrated against color produced by a known amount of catechin (Price et al. 1978). However, vanillin gives no color with tannic acid or gallic acid. Tannins were determined in 14 varieties of sorghum, 10 of which were low tannin variety of the 1981 season and 4 were of high tannin varieties. The data on the determination of tannins by four methods is given in Table 6.

The Prussian blue method of Price and Butler gave lowest values of all the methods. In general, higher values were obtained by using Folin-Denis reagent than vanillin-HCl, but the method is tedious and time consuming.

The data indicate significant varietal differences in the tannin contents, significant differences in the results obtained by different methods, and a significant interaction between the methods of determination of tannins and the varieties of sorghums. These data are in agreement with of the results of Earp et al. (1981) who also found wide differences in values depending upon the method used.

The amino. acid profiles of the 1980 varieties of sorghums are given in Table 7. The data could not be evaluated statistically because only a single sample of each variety was analyzed.

Table 7. Amino acid profiles of ten varieties of sorghums grown in the 1981 season

Amino acid, % of protein	Variety									
	1	2	3	4	5	6	7	8	9	10
Crude protein, %	10.3	10.1	10.9	11.2	10.9	9.8	10.7	9.3	10.5	10.8
Non essential										
Alanine	8.7	7.9	9.8	11.3	8.3	7.9	6.2	7.3	6.0	7.0
Aspartic	6.1	5.7	6.4	7.0	5.2	4.9	4.2	4.8	4.8	5.1
Glutamic	16.4	14.7	22.1	25.6	18.4	17.2	11.1	13.0	14.9	17.0
Glycine	3.2	3.3	3.9	3.5	3.2	4.0	2.5	3.0	2.6	2.7
Proline	7.5	7.9	10.3	8.1	7.0	6.3	5.9	5.8	5.8	6.2
Serine	2.9	2.9	3.8	3.3	2.9	2.7	2.1	2.6	2.4	2.3
Tyrosine	3.7	3.5	5.1	4.2	3.5	3.3	3.0	2.8	2.7	2.9
Ammonia	15.2	11.0	17.8	16.4	14.5	13.9	10.8	12.4	12.0	14.0
Essential										
Arginine	2.5	3.3	4.2	3.7	2.9	2.9	2.6	2.9	2.5	2.9
Cystine	0.9	1.1	1.3	1.0	0.9	0.9	0.7	0.9	0.8	0.8
Histidine	1.6	1.7	2.2	1.9	1.7	1.6	1.4	1.5	1.4	1.4
Isoleucine	2.6	2.7	3.8	3.2	2.7	2.5	2.2	2.5	2.4	2.7
Leucine	11.7	10.4	15.2	13.3	10.9	10.3	8.4	9.4	9.1	10.2
Lysine	2.2	2.2	2.6	2.4	2.1	1.9	1.5	2.0	1.7	1.8
Methionine	0.5	0.7	1.2	0.8	0.7	0.6	0.6	0.5	0.5	0.7
Phenyalanine	4.4	4.2	6.1	5.0	4.1	4.0	3.2	3.7	3.5	3.8
Threonine	5.2	5.1	6.8	5.8	4.9	4.7	3.6	4.4	4.2	4.5
Valine	3.4	3.6	5.0	4.2	3.5	3.3	2.8	3.3	3.0	3.5
Tryptophan*	0.9	0.9	0.7	0.9	0.8	0.9	0.7	0.9	0.9	1.2

* Determined by method of DeVries et al. 1980.
The values are rounded to 1 place in decimal.

The different varieties suggest differences in amino acid profiles and the results are within the range of values reported by Sikka and Johari (1979), and Badi et al. (1978).

The composition of the diets used for bioassy with tribolium larvae is given in Table 8. The samples were first assayed in 1980 and 3 times in 1981. The data on the growth response of tribolium larvae over a 14 day period is given in Table 9. The data were analyzed by a 2-way analysis of variance and the Least significance difference (LSD) for the data was calculated.

Table 8. The composition of the diet to screen the relative nutritive value of different varieties of sorghums using *Tribolium castanewn* as test organism

Ingredient	Test diet %	Control diet %
Sorghum	90	-
White wheat flour	-	90
Brewer's yeast	10	10

Table 9. The average larval weight of *Tribolium castaneum* at 14 days of age fed various varieties of sorghums of the 1980 and 1981 seasons

Variety of sorghum	Average larval weight (mg) at 14 days of age 1980 season	1981 season Test 1	Test 2	Test 3	Varietal Mean
DD 50T	3.10	3.01	2.69	3.10	2.98
EXP 9520	2.80	3.10	2.16	2.97	2.73
NK 1580	1.50	3.10	2.83	3.10	2.68
NK 129	1.80	2.93	2.53	2.68	2.48
PAG 4432	2.40	2.87	1.86	2.49	2.39
P. 8790	1.60	2.73	2.08	2.49	2.23
Corral	3.30	3.00	2.77	1.99	2.77
A 28+	0.94	2.96	2.21	2.75	2.21
PO I652G	2.70	2.89	2.92	3.10	2.89
M 0505	1.40	2.91	2.91	3.10	2.56
Control diet	3.20	3.04	3.12	3.12	3.11
Mean	2.23	2.95	2.56	2.81	

Anova table

Source	DF	Mean Square	F ratio
Varieties	10	1.039	16.99
Tests	3	3.376	55.24
Interaction	30	0.654	10.69
Error	88	0.064	

LSD $(p<0.01) = 0.27$

Significant differences were observed in the growth response of the tribolium larvae to different varieties of 1980. The varieties NK 1580, NK 129, Pioneer 8790, DeKalb A 28+ and O'SG M 0505 were significantly inferior to the other varieties. This was the basis for planting these varieties in 1981. However, these differences disappeared in the first test in December 1981 on fresh samples. The 2nd and 3rd tests were run on these stored samples during June and December 1982. Some significant differences were observed and the variety Pioneer 8790 was still the poorest and DeKalb DD 50T was still the best variety in supporting larval growth. The ranking of other varieties was different in 1981 than in 1980. Seasonal differences in weights of tribolium larvae have also been recorded by Rogel et al. (1983).

Tribolium larvae respond to amino acid balances (Vohra et al, 1978), complex carbohydrates (Vohra et al. 1979a, 1979b; Rogel and Vohra, 1981) and some other heat labile antinutrients (Shariff et al. 1981). The 1980 grains were not as large as those of 1981. The agronomic factors may have reduced the antinutrients in 1981 crop. The effect of storage on nutritional quality deserves further study. In the studies with chickens diets were fed based on sorghums and soybean meal containing 24% crude protein and supplemented with 0.45% DL-methionine (Table 10). To obtain this level of protein, neither sorghums nor soybean meal could be kept at a constant level.

Table 10. The main constituents of the chicken diets fed various varieties of sorghums (g/kg diet)

Ingred.	50T	9532	1580	129	4432	8790	Cor	A28	652G	0505	300
Sorghum	540	535	516	532	530	523	555	545	537	533	530
Soybean meal	370	375	394	378	380	387	355	365	373	377	380
Vitamins and minerals	---- 90 ----										

Corn-soybean control contained 505 g corn, 405 g soybean meal and 90 g vitamins and minerals.

The results of feeding these diets to chickens are presented in Table 11.

The data indicate significant differences in the growth of chickens fed diets containing different varieties of sorghums. The diet 1580 incorporated the highest level of soybean meal followed by diet 8790. The diets 4432 and 300 contained the same level and Corral had the lowest level. If the growth of chickens was a reflection of the incorporation of soybean meal, maximum growth should have been for birds fed the diets NK 1580, and Pioneer 8790, and poorest on Asgrow Corral. Actually, the growth on P.A.G. 4432 was not significantly different from that on NK 1580 variety which had a much higher inclusion of soybean meal. The growth of chickens was not correlated to the level of soybean meal in the diets.

The data suggest varietal differences in the nutritive value of sorghums for chickens. The adverse effedts of high tannin sorghums as reported by other workers (Armstrong et al. 1973) are also confirmed.-

Apparent metabolizable energies of diets containing different varieties of sorghums differed significantly. AME of the *diet was* not dependent upon the level of soybean inclusion. Unexpectedly, AME of the diet containing high tannin sorghum (NK 300) was significantly higher than of any other diet even when the growth of chickens was significantly depressed. No correlation was observed between the AME of the diets and the growth-of chickens.

Table 11. The effect of diets containing 24% crude protein based on different varieties of sorghums on the body weights of chicks at 3 weeks of age, and on apparent metabolizable energy (AME) and apparent nitrogen retention of the diets (16 birds/diet)

Sorghum variety	Average body at 3 weeks, g	AME Kcal/kg	ANR %
DD 50T	532 f	3352 d	63.6 c
EXP 9520	527 ef	3405 f	65.0 d
NK 1580	552 g	3433 g	60.6 b
NK 129	525 de	3241 c	63.2 c
PAG 4432	544 g	3447 h	65.8 d
P. 9790	531 f	3407 f	66.2 d
Corral	485 a	3427 g	62.7 c
A 28+	511 cd	3086 a	58.8 a
PO I652G	515 cd	3396 e	69.7 e
M 0505	510 c	3160 b	70.0 e
NK 300*	498 b	3487 i	73.1 g
Corn-soy	519 ed	3374 j	71.4 f
Mean	521	3373	65.8

Different letters in a column indicate significant differences ($p<0.01$).

Apparent nitrogen retention was also different for the diets containing different varieties of sorghums, and the highest value was observed for the high-tannin variety NK 300, contrary to our expectations. No significant correlation was observed between the growth of chickens and ANR, or between AME and ANR.

Tribolium assay on 1981 samples also suggested that NK 1580 was significantly superior than Agrow Corral. The intermediate values are harder to predict.

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