A REVIEW OF SOME RESEARCH CONTRIBUTIONS TO AGRICULTURE BY AE & CI LIMITED*

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Abstract

Over the past 45 years AE & CI has played a significant part in the development of agriculture in South Africa. The company's research activities have covered a wide field and the results of many of these investigations have borne fruit in the applied field of practical farming.

Hormone weedkillers were discovered during World War II and shortly after its end, AE & CI's scientists carried out the first experiments in South Africa to harness this new weapon to control weeds in maize. They developed the principles of pre-emergence spraying which are today used in practice all over the maize triangle.

Phosphates were thought to be the only form of fertilizer necessary for South African soils in order to produce a successful crop of maize. At Frankenwald in 1951 it was first shown that nitrogen could play a major role in increasing yields. In order to do this plant populations had to be raised from the recommended 12 000 per ha to 35 000 per hectare and to conserve moisture, lands had to be kept weed-free. This was the beginning of a new era in maize production and these principles plus the introduction of hybrid maize have increased the annual crop from 2,7 million tonnes to 10,5 million tonnes.

The fertilization of veld and pastures was first studied by an AE & CI research team in 1929. The information obtained from experimental work at the Frankenwald and Bapsfontein Research Stations in the years that followed is being applied in practice today to improve production from both veld and pastures.

Because the veld in South Africa has little nutritive value in the dry winter months, grazing animals must be fed a supplement if they are to be kept in reasonable condition. South Africa has become a world leader in the field of supplements and the feedblock so popular with farmers was conceived and first made by AE & CI's research workers at Frankenwald. Today feedblocks of all kinds are manufactured in their millions and are used all over the world.

Another 'first in the world' was the development and production of feed-grade biuret as a safe non-protein nitrogen for use in supplements and concentrated rations for ruminants.

AE & CI scientists have played leading roles in other fields. With their colleagues in Cooper's (SA) Pty Ltd they have tackled and overcome problems of ticks developing resistance to various chemicals and compounds. The arsenic-resistant blue tick was first defeated by BHC. Researches showed that within a short time a resistance to BHC was developed and so DDT was introduced into dips and thus the story continued until organo-phosphates and carbamates were formulated for current use in dips.

In the 1930's many sports were played on hard fields and there were more 'Kimberley-blue' greens than grass greens on golf courses. The establishment of the South African Turf Research Station at Frankenwald by AE & CI and the University of the Witwatersrand provided information for the establishment of grass-playing surfaces for all kinds of sports. Our present rugby, cricket, soccer and hockey fields are equal to the best in the world not to mention our golf courses and bowling greens.

Finally, the generosity of AE & CI enabled the standard work on South African grasses 'The Grasses and Pastures of South Africa' to be compiled and published. These are but a few of AE & CI's contributions to South Africa's agriculture.

Introduction

For over forty years AE & CI took an active interest in agricultural research in South Africa. The researches of the Company covered a wide field and the results of the numerous investigations have played a not inconsiderate role in the scientific development of agriculture in Africa south of the Sahara. Some of the research achievements are discussed in this paper.

Veld and pastures

Dr T D Hall, who was Agricultural Adviser to AE & CI from 1927 to 1952, was one of the pioneers who investigated the response of veld to the addition of artificial fertilizers. He initiated trials that were spread across the African continent from Kenya to the Cape Province. In general the veld showed an immediate response in growth to the addition of nitrogenous fertilizers. Some of these early results are well worth recording in the light of the work the Fertilizer Society of South Africa is doing today, ie over forty years later. See Tables 1 and 2.

More detailed experiments were carried out during this period at Umbogintwini and the work was expanded later at Frankenwald. Dr D Meredith in his thesis "Fertilizing

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Grasses in South Africa" covered the years from 1929 to 1945. The value of his work to the well-being and development of the cattle and sheep industry lies in the future. However, the foresight and tenacity of those who contributed to the carrying on of research that showed no commercial return, must be commended.

It must be remembered that in the 1930's and the 1940's farmers were not even applying nitrogenous fertilizers to their arable crops, so to expect them to become interested in the novel idea of using fertilizers on their veld was expecting too much. The results however were there for all to see which showed that beef production per hectare could be increased almost fourfold. (Table 3).

TABLE 1 Milk production per ha on natural veld: Kenya

Fertilizer treatment	1933	1934
	127 days grazed litres of milk produced	244 days grazed litres of milk produced
No fertilizer	1 279	1 620
47 kg N 28 kg P	1 579	2 939
No nitrogen 28 kg P	1 283	1 911

TABLE 2 Response of natural veld to fertilization : South Africa
Cow-days per hectare,
Year and treatment

Site	1931–32			1932–33			1933–34			1934–35		
	0	P	NP	0	P	NP	0	P	NP	0	P	NP
Klerksdorp Tvl	181	265	520	93	78	161	242	421	467	279	509	742
Koekemoer Tvl	123	127	151	–	–	–	134	182	235	315	308	504
Kliprivier Tvl	183	193	292	233	257	397	106	228	198	123	187	292
Warmbaths Tvl	54	90	78	79	117	110	161	251	389	91	134	160
Louis Trichardt Tvl	246	292	310	373	378	412	393	445	686	118	144	204
Paardekop Tvl	226	259	215	270	322	358	196	356	291	175	312	363
Holfontein OFS	93	205	271	–	–	–	278	278	555	112	168	266
Odendaalsrus OFS	223	174	195	–	–	–	170	232	317	145	203	289
Swartberg, East Griq	298	459	489	114	236	305	275	415	522	253	344	235
Thomas River C P	123	141	216	182	212	219	254	309	414	67	47	96
Trappes Valley C P	287	495	538	369	345	379	386	494	564	139	219	233
Average	184	245	361	215	243	293	236	326	421	166	233	307

Treatments 0 = no fertilizer
N = 106 kg sulphate of ammonia per hectare per annum (22 kg N)
P = 212 kg superphosphate per hectare per annum (18 kg P)

TABLE 3 Live-mass gains of beef in kg per hectare from veld: Frankenwald

Treatments	1937–38	1938–39	1939–40	1940–41	1945–46	1946–47	1947–48	1948–49	Average
No fertilizer	65	74	41	96	50	62	68	68	65
18 kg P	82	79	33	94	50	75	104	68	73
18 kg P + 58 kg N	226	241	196	225	215	188	317	198	226
Season rainfall in mm	650	725	800	900	625	600	800	750	

By fertilizing veld, milk production was doubled in an experiment at Frankenwald. (Table 4). An interesting feature was that the quality of the milk obtained from those cows on the fertilized veld was better than the milk from normal veld. (Table 5).

The practical question was whether or not the difference in quality had a biological significance. Experiments with white mice, chickens and pigs showed that the quality of the milk from the group of cows on fertilized veld was superior to that of the control group. (Tables 6, 7, 8).

TABLE 4 Milk production on fertilized and unfertilized veld : Frankenwald

Summer season	Milk yields in l/ha Treatment	
	Unfertilized veld	Fertilized veld
1948–49	1 200	1 900
1949–50	1 150	2 300
1950–51	1 240	2 920
mean	1 197	2 373

TABLE 5 Quality of milk produced from fertilized and unfertilized veld

Milk source	Average composition of milk		
	% Total solids	% Butterfat	% Total nitrogen
Fertilized veld	13,89	5,04	0,52
Unfertilized veld	12,56	4,73	0,51

TABLE 6 Biological evaluation of milk using mice

Whole milk diet; Mass gains over a period of 28 days			
Mouse No.	Fed on milk from fertilized veld	Mouse No.	Fed on milk from unfertilized veld
1	10,4 g	6	8,3 g
2	9,5 g	7	5,3 g
3	7,7 g	8	4,0 g
4	7,1 g	9	0,9 g
5	5,1 g	10	0,2 g
Average mass gain	7,96 g		3,74 g

TABLE 7 Biological evaluation of milk using chickens: Food conversion ratio

Chick strain	Milk source	Weeks 1	2	3	4	5	Mean
White Sussex X White Leghorn	Fertilized veld	3,4	2,3	3,6	3,5	3,2	3,20
	Unfertilized veld	3,4	2,5	4,9	4,5	4,9	4,04
White Sussex X New Hampshire	Fertilized veld	3,0	4,4	3,6	3,3	3,9	3,64
	Unfertilized veld	2,8	5,2	3,7	3,9	4,2	3,96
Black Australorps	Fertilized veld	2,9	2,9	2,9	2,6	2,8	2,82
	Unfertilized veld	3,3	2,7	3,0	3,1	3,0	3,02
White Leghorn X Black Australorps	Fertilized veld	3,4	2,5	2,5	2,7	3,6	2,94
	Unfertilized veld	3,6	2,3	2,7	2,9	3,9	3,14

TABLE 8 *Biological evaluation of milk using pigs Average pig mass gains and carcass analysis*

	Milk from fertilized veld	Milk from unfertilized veld
Mass gain per day	0,408 kg	0,399 kg
Days to reach 90,7 kg	184	190
Length of side	85,4 cm	83,9 cm
Fat thickness – shoulder	4,6 cm	4,8 cm
mid-back	2,3 cm	2,1 cm
loin	3,1 cm	3,1 cm
Thickness of streak	3,2 cm	3,5 cm
Area of glutens medius	11,2 sq cm	8,7 sq cm
Eye muscle length	7,9 cm	8,0 cm
Eye muscle depth	4,6 cm	4,5 cm
Fat over eye muscle	2,0 cm	2,2 cm
Fat on ribs	2,8 cm	3,0 cm
Total scores for judgement	9,8 points	9,1 points

Supplementation of veld in winter

The fact that most grassland veld types are deficient in phosphorus and nitrogen for many months of the year, particularly during the dry winter months, was borne out by the researches carried out by Du Toit and his co-workers at Onderstepoort.

The possibility of supplementing the veld in winter with a source of protein was investigated. The non-protein-nitrogen compound urea was used in numerous experiments and practical trials and was found to extend the protein content of poor winter veld. Mixtures of molasses and urea were used by farmers in many ways to improve the source of roughage fed to their cattle. Unfortunately accidental deaths occurred when animals ingested too much urea in a short time. Thought was then given to ways and means of making the feeding of urea safer. The aim was to make it impossible for the animal to consume more than a small quantity of urea at a time.

Feedblocks

After many attempts to restrict the intake of urea by mixing it with salt in molasses with chemicals to reduce the palatability of the mix, the idea of making a block containing urea was born. And so at Frankenwald the first feedblock was made. To quote from a report by P K van der Merwe of National Chemical products – "Recently the African Explosive workers, Altona and Tilley have made the remarkable observation that the free choice feeding of a salt, urea, molasses mixture to pregnant beef cows fed good quality hay, powerfully stimulated growth. The astonishing feature of the work is, however, that the free choice feeding of the urea-salt lick to lightweight steers on summer grazing powerfully stimulated growth (1,06 kg per head per day) as compared with controls (0,78 kg per head per day). The mixture was in hard block form and the success of the method is probably due to slow intake of urea by licking. If substantiated, the work of Altona and Tilley must be considered a major break-through in the economy of the extensive feeding of stock".

The block has been accepted universally as an easy and practical way of feeding supplements to cattle and millions of blocks are now fed annually all over the world. Although the block method made urea-feeding a far safer proposition, accidents still occurred and farmers lost stock, so a search was made for a safe source of non-protein-nitrogen. Biuret appeared to be a likely candicate as all published reports showed it to be a safe source of NPN for ruminants. Before proceeding with any extended trials and research work the desirability of having a safe source of NPN made available to the South African frarmer was discussed with officials of the Department of Agriculture. Even at an elevated price it was agreed that biuret with its built-in safety factor would be a boon to cattle and sheep farmers.

A combined research project was undertaken with the CSIR, Onderstepoort, Agricultural research stations and AE & CI playing their parts. The outcome of this work was the erection of the first biuret plant in the world.

Fertilized pastures

The fertilization of veld was discussed earlier in this paper without any mention of sown pastures. However, some of the earliest work done by Meredith was the fertilization of Kikuyu which showed excellent response to nitrogen fertilizers. Work on mixed pastures of Rhodes and Paspalum followed and in the 1950's extensive trials were carried out on different varieties of *Eragrostis curvula*. These early trials were the forerunner of trials carried out at many research stations where both the protein value and bulk were shown to increase by fertilizing the pasture with nitrogenous fertilizers.

The pastures were given annual fertilizer dressings of 69 kg nitrogen, 26 kg phosphorus and 21 kg potassium per hectare. Over a 3-year period the four best grasses gave the results shown in Table 9.

TABLE 9 *Average annual production of established pastures per hectare over 3 years*

	Grazing days	Dry matter (hay in kg)	Protein content %	Crude fibre %
Kikuyu	1,181	11 600	13,9	27,2
Paspalum	891	6 450	11,8	31,7
Rhodes	749	9 100	12,3	30,7
Eragrostis	656	10 400	9,6	32,5

Agronomy

The most important grain crop grown in South Africa is maize and an area of about 6 million hectares is sown to this crop annually.

Our soils are notoriously poor in phosphorus and the lack of this element was recognised by farmers as being one of the limiting factors in crop production. As long ago as 1906, over 17 000 tonnes of phosphate fertilizer was imported into South Africa. Once the phosphorus requirements of the crop were satisfied it was considered that the main limiting factor in the maize triangle was moisture. Early experimental work at Potchefstroom, Pretoria and Kroonstad research stations on rates of planting led to the 3′ x 3′ (approx 1 m x 1 m) planting pattern being adopted for all field experimental plots. This population of 10 000 plants per morgen (approx 12 000 per ha) was the standard used in fertilizer experiments at the time and farmers were advised to restrict their planting to this number to ensure that the plants did not suffer from lack of moisture during the growing season.

Based on this plant population, experimental results showed that maize did not respond to dressing of nitrogenous fertilizer. A typical example of this is illustrated by the results obtained over 9 years at the Kroonstad Agricultural Research Station. (Table 10). The acceptance by both farmer and research worker that plant population was limited in practice to 12 000 plants per hectare because of erratic rainfall and insufficient moisture restricted potential yields to about 2 000 kg per hectare.

At Frankenwald in a weedkiller experiment in 1950 a far-reaching observation was made that led to the beginning of a new era in maize production. It was noticed that weed-free, close-planted maize fared better during dry periods than did maize spaced the conventional 3′ x 3′. The shading of the close-planted crop kept the soil cooler and the top 8 cm was moister than that of the sunbaked soil of the 3′ x 3′ spaced maize. This observation led to renewed thinking on the possibility of increasing crop yields by closer planting with the addition of nitrogenous fertilizer.

TABLE 10 Response of maize to fertilization: Kroonstad: Average of 9 years (1938–1946)

Spacement 30,48 cm x 30,48 cm (11 670 plants per hectare			
Treatment per hectare			Maize yields per hectare
P	=	18 kg P (superphosphate)	1 876 kg
P	+	N_1 (11 kg N)	1 884 kg
P	+	N_2 (22 kg N)	1 926 kg
P	+	N_3 (33 kg N)	1 842 kg
P	+	N_4 (44 kg N)	1 842 kg

TABLE 12 Effect of plant population and fertilization on maize yields (kg per ha) : Pretoria

Fertilizer treatment per hectare			Spacement	
			11 670 plants	35 010 plants
P	=	53 kg P	2 646 kg	3 493 kg
P	+	N (67 kg N)	2 752 kg	4 763 kg

TABLE 11 Effect of plant population and fertilization on maize yields (kg per ha) : Frankenwald

Fertilizer treatments per hectare			Plants per hectare		
P	=	18 kg P	11 670	23 340	35 010
P	+	N (67 kg N)	1 694	2 540	2 329
			2 540	3 176	4 869

The following season the first successful nitrogen-response experiment was laid down at Frankenwald (Table 11).

These results, like pebbles dropped into a quiet pool, sent out disturbing ripples to the three corners of the maize triangle. The first reaction came from the University of Pretoria and a nitrogen x espacement experiment was laid down at the university farm (Table 12).

The stage was set and with the introduction of hybrid maize and chemical weedkillers the pattern of maize production changed and yields shot up from 3,5 million tonnes in the mid-fifties to over 10 million tonnes in 1974, an increase of 300 per cent in 20 years.

Bapsfontein research station

A research station was started in 1956 in the Bapsfontein area about 24 km west of Delmas. For 15 years, applied and fundamental research was carried out on the plant-food requirements of a wide range of crops; weed control studies; insect pests; pathogens and the nutritional requirements of animals.

The principles of balanced fertilization were established and long-term results showed that a well-fertilized crop made better use of water in a dry season than did a poorly-fertilized crop. (Table 13).

Feeding the soil rather than supplying the crop with an apparent deficient nutrient meant that in good seasons

TABLE 13 Effect of plant population and fertilization on maize yields in 'good' and 'poor' seasons (kg grain per ha)

Plant population '000 per ha	Fertilization level							
	Low	High	Low	High	Low	High	Low	High
	Good years							
	1961		1963		1964		Average	
11	3 027	3 588	2 879	3 281	2 614	2 869	2 837	3 250
23	4 001	5 091	3 123	3 948	3 197	4 276	3 440	4 435
35	3 800	5 038	2 689	4 128	3 408	5 176	3 302	4 784
47	3 514	5 282	2 773	4 668	3 440	6 044	3 271	5 335
58	2 657	5 208	2 318	5 070	2 847	6 213	2 604	5 494
	Poor years							
	1962		1965		1966		Average	
11	2 773	2 593	2 170	2 466	1 567	1 387	2 170	2 149
23	2 509	3 165	2 318	3 112	1 207	1 418	2 011	2 212
35	1 831	2 487	1 969	2 943	1 080	1 704	1 588	2 382
47	1 672	3 207	1 831	3 154	921	1 852	1 471	2 741
58	1 418	3 281	1 217	3 345	730	1 874	1 122	2 837

the plants could reach their genetical potential while in poor climatic seasons they made the best use of available soil moisture.

With an adequately balanced fertilizer programme, higher plant populations could be successfully grown over a number of varying seasons, that is to say through both dry and good years. During the latter a bumper crop would be harvested while in the former a crop as good as lower populations less adequately fed would obtain.

Zinc deficiency in maize

In the Western Transvaal in the 1960's maize crops in the early stages showed yellowing of the leaves of the young plants. The plants affected grew very slowly and never reached maturity.

The problem was tackled by AE & CI and Dr N J Viljoen was sent to the United States of America to discuss the problem with leading scientists in the United States Department of Agriculture. On his return, fundamental studies were carried out by the Company's Research Department and a follow-up of these results by field trials established that the yellowing was caused by a lack of soluble zinc in the soil.

Based on this work the Minister of Agriculture allowed zinc to be included in fertilizer products to enable farmers to combat the deficiency in maize production.

Weed control

The importance of weed control in the early stages of growth of the maize plant was established in a series of experiments at Frankenwald and later at Bapsfontein. These experimental results have become classical and are widely quoted in literature on weed control practices.

TABLE 14 Nutrient uptake by maize and weeds growing competitively. Analyses done four weeks after germination of the maize (kg per ha)

	Dry plant material	Nutrient uptake		
		N	P	K
Maize	220	6,4	2,6	4,4
Weeds	999	22,0	2,0	14,2

In the keen competition for food and moisture the quick-growing weeds with their fibrous root systems are at a considerable advantage over the slower-growing maize plants. Furthermore 'uintjies' (Cyperus spp) do not only compete with the crop plants but they exude from their underground bulbs and roots a chemical substance that actually retards the growth of those maize plants growing in the same soil.

The results of plantfoods removed by uncontrolled weed competition in the first four weeks after the emergence of the maize crop are dramatic. (Table 14).

These figures show clearly that weed control is most important when the maize plants are young.

Selective weedkillers

During World War II synthetic organic compounds called plant regulators that could be used as selective weedkillers were discovered. Applied at the right concentration they would not damage certain crops while young weeds were killed by the chemical spray.

Trial quantities of some of these selective weedkillers were sent to South Africa by ICI inventors. Some of this material was used in the first weedkiller trials in South Africa on the control of weeds in maize. The trials were put down at Frankenwald in 1948.

Work overseas had proceeded along the lines of spraying weeds when they were in the seedling stage. Little was known about pre-emergence spraying and the effect on both weeds and maize crop itself.

As the main weeds consisted of grasses and sedges, post-emergence spraying was of little use so investigations on pre-emergence spraying had to be carried out.

The principles of pre-emergence spraying that evolved from the results of this work are still used in practice today whenever weedkillers are used on maize in South Africa.

Tick control

Another area in which AE & CI has been active for many years is in the control of ticks. For almost 50 years sodium arsenite was effectively used in dips to control ticks. In 1938 it was observed in the East London area that the blue tick had become resistant to arsenic.

An AE & CI and Cooper's team of scientists headed by Dr A B M Whitnall immediately started looking for an effective chemical to replace sodium arsenite. They made a major break-through when it was found that the chlorinated hydrocarbon acaricide, benzene hexachloride or BHC was very effective against the arsenic resistant tick. After 18 months of general use of BHC dips, resistance to this compound developed and BHC-resistant blue tick populations which still retained their resistance to arsenic, became established very quickly along the eastern coastal area of South Africa.

DDT although also a hydrocarbon insecticide, but very different from BHC, was effective in controlling the arsenic-BHC-resistant blue tick. DDT remained effective for approximately five years, but resistance to it also developed eventually. A variety of organo-phosphate and carbamate insecticides replaced DDT and have been used effectively for nearly 15 years.

The grasses and pastures of South Africa

A reference book on the identification of grasses of South Africa and pasture management was long overdue and shortly after World War II a move was made to publish a volume that would be companion to the Birds of Southern Africa, the Fishes of Southern Africa and the Mammals of South Africa.

As was the case in these other publications, AE & CI sponsored the publication of "The Grasses and Pastures of South Africa". Today this book takes its place in the Africana Library alongside its companions on the birds, fishes and mammals.

Turf research

At the end of the 1920's there were very few playing fields down to grass in South Africa. Except at the coast, rugby, soccer, hockey and cricket were played on hard grounds. Most of the golf 'greens' on the highveld were surfaced with 'Kimberley Blue' gravel. It was generally accepted that our climate was not congenial to the growing of turf surfaces for sporting surfaces. It was quite evident that South Africa needed a research station where problems connected with the growing of turf could be investigated.

In 1933 this much-wanted station was started at Frankenwald as a joint venture by AE & CI Ltd and the University of the Witwatersrand. Under the vigorous direction of Dr T D Hall and Professor John Phillips the station flourished and its findings established principles that formed the basis for turf growing in all the summer rainfall areas. Once the fundamental requirements for growing turf had been laid down, problems of maintenance and improved grass strains had to be tackled. Soil fertility studies were carried out while researches into insect, fungus and weed problems became more and more important as grasses of different qualities were introduced to provide special playing surfaces for specific sports.

The high quality of sporting surfaces found all over the Republic today owes much to the sound advice and information that has emanated from the South African Turf Research Station, Frankenwald over the past forty years.

Conclusion

These are but a few of the contributions AE & CI has made to agriculture and related biological fields. Her endeavours in research and extension have played an important role in improving the lot of mankind in Southern Africa. For her unshakeable belief, through they years, in the agricultural potential of the Republic and her generosity in the funds she provided for such a wide scope of research, AE & CI has earned a 'well done' from South Africans of all walks of life.

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