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ADVANTAGES OF COMPLEX FERTILIZERS IN LOGISTICS, APPLICATION AND ENVIRONMENT

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A look at West Europe with its intensive agriculture shows, that compared to other fertilizer systems the use of complex fertilizers and other multinutrient fertilizers predominates (**Figures 1, 2**). Over the last decade their share even increased from 52.4 % to 54.9 % in 1989/90.

What are the reasons for this development?

Due to their specific chemical and physical characteristics complex fertilizers offer a number of distinct advantages over other fertilizer systems such as straight fertilizers, PK fertilizers, physically mixed fertilizers (bulk blends) as well as over the use of slurry and other organic manures.

The major characteristic of chemically produced complex fertilizers is the combination of all fertilizer nutrients, not only in one single fertilizer, but in each granule in the prescribed ratio. From this fact results that complex fertilizers have advantages with regard to:

- logistics,
- labour requirement,
- application technique,
- plant nutrition,
- ecology.

LOGISTIC ADVANTAGES

The complex fertilizers produced and marketed in West Europe have a high total nutrient concentration. Thus the fertilizer quantity to be handled, transported and stored is reduced. **Figure 3** shows the approximate volume required in a retailer's warehouse for the storage of the same amount of N, P_2O_5 and K_2O for basal fertilization (alternatively NPK complex fertilizer, straight fertilizers, PK + CAN) and for N-topdressing (CAN).

An other advantage of complex fertilizers, which is of special importance for developing countries and other regions with an insufficient infrastructure, is the fact that all fertilizer nutrients are transported to the farm together so that a supply gap for a single nutrient might not occur.

LABOUR REQUIREMENT

At the retailer level, with the reduced quantities to be handled, not only the storage capacity but also the workload is reduced with complex fertilizers. This is illustrated by **Figure 4**. As these figures show, almost 20% less weight has to be handled in the case of the NPK 14+10+20.

For the farmer a complex fertilizer makes it possible to apply 3 to 5 fertilizer nutrients with one application round. The reduced quantity to be transported to the field and to be spread, in consequence of the high nutrient concentration also benefits the farmer. Together this results in a much lesser workload with NPK complex fertilizers compared to straight fertilizers or other systems (**Figure 5**).

APPLICATION TECHNIQUE

Today more than 90% of the mineral fertilizer in West Europe is applied broadcast, using fertilizer spreaders with rotating discs (or a pendulum spout) that throw the fertilizer particles over wide distances. To obtain a good result with this type of spreader, a fertilizer needs to have a balanced and even particle size spectrum, combined with adequate hardness of the particles and resistance to abrasion. Modern complex fertilizers as manufactured in West Europe have physical characteristics which fully meet these requirements and therefore lead to an excellent fertilizer distribution in the field (**Figure 6**).

They also have the advantage that the spreader has only to be calibrated once by the farmer, whereas with straight fertilizers due to their various particle sizes, specific densities and surface characteristics, the spreader has to be set anew before each round which multiplies the risk of a calibration error. The consequence of such a wrong calibration of the spreader would be an uneven nutrient distribution in the field leading to a reduced yield.

Since all nutrients in a complex fertilizer are contained in each granule, the even fertilizer distribution (civ **Figure 6**) automatically results in the uniform distribution of its nutrients.

In contrast, a multinutrient fertilizer in the form of a bulk blend, i.e. consisting of different straight fertilizers which are physically mixed, is liable to segregation during handling, transport and application so that the nutrient distribution becomes uneven.

BULK BLENDS

Bulk blends have been introduced as a simple possibility to obtain the advantages of a multinutrient fertilizer. Their de-centralized production in small batches allows to manufacture them with specific nutrient ratios adapted to individual soil and crop requirements.

Recently they have gained ground in Europe for the reason that they are often cheaper per 100 kg fertilizer than a similar complex fertilizer formula. It can be assumed that at almost equal prices they would stand no chance against complex fertilizers, as the various characteristics of their components differ quite considerably, i.e. particle size distribution (**Figure 7**), specific density, particle form and surface characteristics (**Figure 8**).

These differences entail the following risks:

- segregation with each reloading of the fertilizer;
- heterogeneous nutrient distribution in the field;
- yield reductions in intensive arable cropping.

It is relatively easy to show the segregation of the different components of a bulk blend when the fertilizer is piled to form a cone (**Figures 9 and 10**), or when it is flowing out of the hopper of a fertilizer spreader (**Figure 11**).

Also the uneven distribution of the nutrients from a bulk blend in the field can be demonstrated in a test run with the spreader, during which the broadcast fertilizer is caught in a series of trays placed side by side and crosswise to the direction of travel of the tractor/spreader, and then analyzed (**Figure 12**).

However, to establish the actual consequences which the application of a bulk blend has on the yield of an intensively managed crop, large scale field trials in farmers' fields have to be laid out. Small scale trials under the idealized conditions of academic research invariably fail to show the true extent of the shortcomings of a bulk blend application.

Figure 13 is such a field experiment under practical conditions: With the help of plastic sheets, windows have been formed in a field of winter cereals, one for each replication of the same treatment. The tractor with the mounted fertilizer spreader travels over these windows and broadcasts the first fertilizer. After the first pass, the sheets are shifted so that the plots of the second treatment are now uncovered on which the other fertilizer is then broadcast in a second pass. The control plots - without fertilizer application - remain all the while covered.

A second possibility for which less land is needed, is shown in **Figure 14**.

The fertilizer broadcast by the spreader is collected in a series of trays, placed on the ground across the spreading path. From the samples collected in the trays, the respective fertilizer amounts and nutrient ratios are then determined. From these figures the various application rates per hectare in the strip of field represented by each tray are calculated and a series of replicated small plots fertilized accordingly (**Figure 15**).

This procedure is carried out both with a bulk blend and with a complex fertilizer of the same formula. The plot yields are than added up in each case and the respective yields per hectare are calculated for the bulk blend and for the complex fertilizer.

The result of a double trial to winter barley and winter wheat after the first pattern is shown in **Figure 16**; a trial series conducted with winter wheat and rye after the second pattern gave the results illustrated in **Figure 17**.

In both cases did the complex fertilizer clearly outyield the bulk blend. It can be seen from **Figure 17**, that as the nitrogen source in the bulk blend calcium ammonium nitrate was superior to urea.

ORGANIC MANURES (SLURRY)

Viewed from the angle of a crop, farmyard manure and slurry are "organic complex fertilizers"; i.e.: they contain NPK and other plant nutrients in (bio)chemically combined form.

Of course manures and their use have to be seen not only from the crops' point of view, but in a global context. As farmyard manure or slurry are the unavoidable by-product of animal husbandry they are already available on many farms, have to be disposed of anyway and so have to be utilized preferably as fertilizers, as has been the case for centuries. However, the exclusive application of slurry or solid manures is not sufficient - neither quantity- nor quality-wise - to meet the needs of today's intensive farming.

In the 'old' federal states of the FR Germany, the nutrient supply from organic manures is almost as high as that from mineral fertilizers in the case of N and P; it is even higher for K (**Figure 18**).

At present in the highly developed agriculture in West Europe, manure is generated mostly in liquid form as a mixture of faeces and urine (slurry), sometimes with minor inclusions of straw from bedding.

Manures are not a commercial product, but are generally utilized on the farm. Frequently this leads to problems with surplus slurry, especially on farms raising pigs or poultry at a large scale. As a reaction to regional surplus-problems and the ensuing pollution by over-application of nutrients, there are regulations coming up in various states, to limit livestock keeping and to relate it more strongly to the agricultural area available.

The nutrient ratio in organic manures is determined by its source (type of livestock, feeding practice, form and duration of storage). On average it contains:

- N: 50 - 70% as ammonium-nitrogen, the remainder incorporated in organic compounds;
- P_2O_5: 60 - 80% as inorganic phosphates, the remainder in organic form (e.g. in phytin);
- K_2O: 80 - 90% as water-soluble potassium.

Compared to mineral complex fertilizers, slurry has a number of disadvantages:

- the nutrient concentration is significantly lower (only about one-fourth);
- the nutrient contents may vary considerably;
- the nutrient efficiency (especially of N) may vary rather unpredictably, influenced by timing of application, incorporation into the soil, additional incorporation of straw/green manuring, and type of crop.

Considering the total nitrogen content of slurry, the utilization rate for N may range from about 20 to 40% (in comparison: utilization rate for N from mineral fertilizers is 60 to 80%).

- For the N-emissions into the atmosphere, NH_3 released by livestock is of major importance (**Figure 19**).

Example:

Depending on the milking performance of a cow, per animal and year 100 to 120 kg N are excreted in faeces and urine, of which only 64 to 70 kg N reach the field for application. The difference is lost as NH_3 during storage, handling and transport. Part of the N applied is further lost after application by leaching as NO_3, as a result of the long-term release of the organically bound N (also in seasons without active vegetation,when it can not be utilized by the crop).

PLANT NUTRITION

The efficiency of a fertilizer application is largely dependent on the correct timing and on the suitable chemical form of the fertilizer nutrients. Under our agroclimatic conditions the best results are obtained with ammonium nitrates (N) and fully acidulated phosphates (P_2O_5), as contained in complex fertilizers of the nitrophosphate type and in many straight fertilizers.

Commonly used straight fertilizers with different chemical composition and their disadvantages are:

- Urea: retarded fertilizer effect during cool wheather, NH_3-volatilization losses up to 20%, especially when not incorporated (grassland, top dressing of winter cereals) damage to emerging fine seeds, strongly increased soil acidity.

- Rock phosphate, Partly acidulated RP, Basic slag: do not contain water-soluble phosphate, thus P_2O_5 is not readily plant available when required by the crop.

- DAP: risk of damage to emerging fine seeds, increased soil acidity, additional complementary N application is necessary.

The above negative characteristics can be the cause of yield reductions when these fertilizers are used.

In intensive, highly developed agriculture, on soils which have received for decades substantial amounts of plant nutrients, the present practice is to substitute by fertilizer application only those nutrients which have been removed with the harvested crop. It is therefore important to apply immediately plant available nutrients the moment they are required by the crop (in spring).

This last point is illustrated in **Figure 20**. In a long-term field trial (1966 - 1990) the application of NPK in spring as complex fertilizer increased yields by an average of 5 % over the application of P and K as straight fertilizers in autumn.

When an amount of 500 kg/ha granulated mineral fertilizer is spread, this means that on average three granules fall on each 10 by 10 cm (100 cm^2) of the field. If a complex fertilizer is used, each of these granules contains all the fertilizer nutrients; in the case of highly concentrated straight fertilizers one has only nitrogen, one only phosphate and one only potash - provided the three fertilizers have been evenly distributed - if not, only one or two of the nutrients may have been applied within this area.

On the same 100 cm^2 there grow, in the case of cereals, three plants (300 plants/m^2). With a complex fertilizer each of these plants is well supplied with all fertilizer nutrients which are present in the same spot, whereas with straight fertilizers and bulk blends, though the same nutrient amounts have been applied, the individual plant may face a rather unbalanced supply situation.

ENVIRONMENT

Nutrient losses with the complex fertilizer system are less than with other types of mineral fertilizers or organic manures. **Figure 21** shows the relative losses of N and P_2O_5 from mineral fertilizers and farm manures.

In **Figure 22** a model calculation has been made with these data to establish the costs the German farming community would have to bear if - as are the regulations for the fertilizer industry - farmers had to pay effluent discharge fees for the application of mineral fertilizers and organic manures.

Since NPK complex fertilizers are applied in spring, when the nutrient uptake by the crop begins, there are no losses of fertilizer nutrients by erosion over winter as with straight P and K fertilizers or PK-fertilizers applied in autumn.

Nitrogen is contained in complex fertilizers manufactured by the nitrophosphate route in a combination of approx. 65% ammonium-N and 35% nitrate-N. In this form it is plant available both immediately and for a sustained period, and is thus efficiently utilized by the crop to which it has been applied This means it is much less prone to volatilization losses than e.g. nitrogen in urea which is present as amide.

The uniform supply of the primary nutrients to every plant in the field in the desired ratio ensures the efficient utilization of the fertilizer nutrients, thus reduces the amount of unused nutrients liable to losses by leaching or erosion.

Less strain is put on the soil structure in the tramlines - and especially on the headlands - as only one pass over the field is necessary.

In comparison to organic manures nutrients are present in the exact required ratio and are plant available when needed by the crop - not when the soil has turned fallow after harvest.

The complex fertilizer system saves energy. With the high nutrient content and the combination of all primary nutrients in one granule, less energy is required for handling, transport and application.

Share (%) of various fertilizer systems in the P_2O_5 consumption of West European agriculture

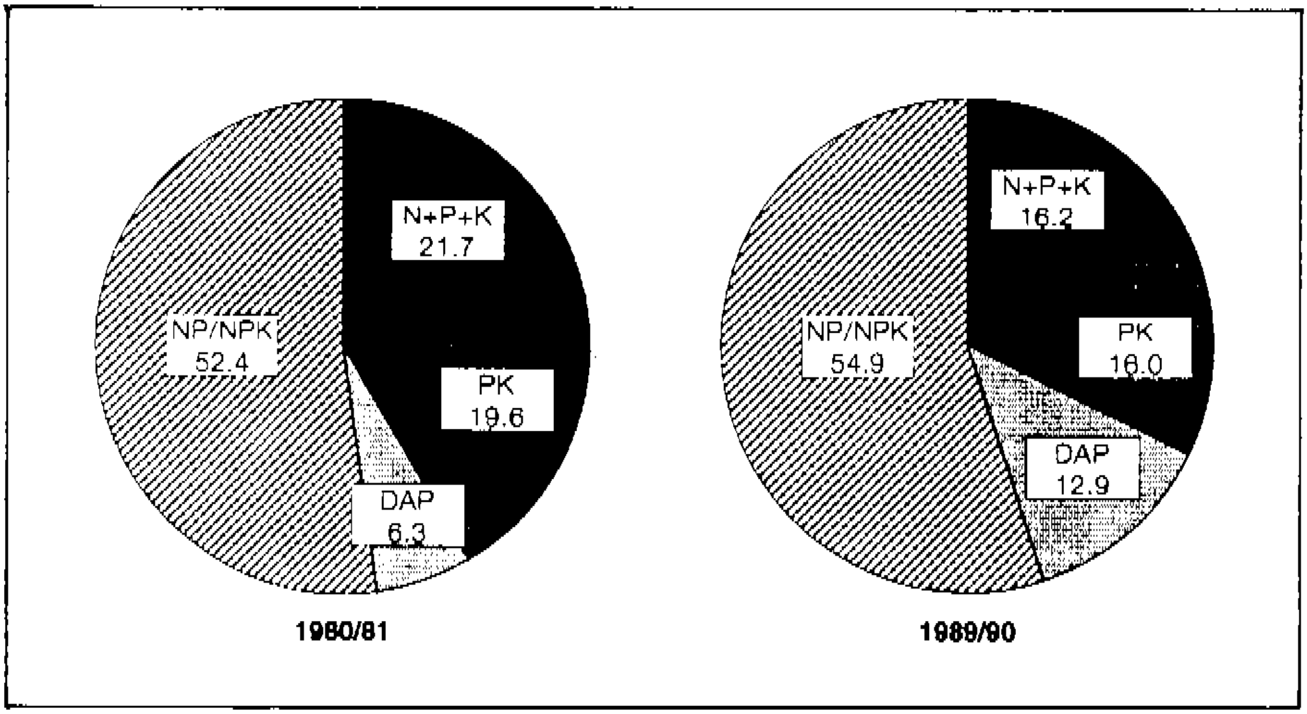


Figure 1

Share (%) of various fertilizer systems in the P_2O_5 consumption of some West European Countries

	1980/81				1989/90			
	N+P+K	PK	DAP	NP/NPK	N+P+K	PK	DAP	NP/NPK
Belgium/Luxembourg	22.5	29.4	–	48.0	10.4	32.2	1.1	56.3
Denmark	4.5	39.6	0.9	55.0	4.2	20.0	8.4	67.4
F.R. Germany	23.3	27.0	8.2	41.5	15.2	21.5	23.0	40.3
France	25.8	32.5	5.2	36.4	21.5	31.5	10.1	36.9
Italy	26.8	0.8	22.7	49.7	25.3	0.5	21.5	52.7
Netherlands	32.5	6.0	1.2	60.2	21.6	1.2	2.4	74.8
Austria	26.3	17.2	1.0	55.6	15.6	17.2	9.4	57.8
United Kingdom	11.1	6.7	0.5	81.7	9.3	-	6.5	84.2
West Europe total	**21.7**	**19.6**	**6.3**	**52.4**	**16.2**	**16.0**	**12.9**	**54.9**

N+P+K = Straight Fertilizer System
PK = PK-Fertilizer-System
DAP = Diammoniumphosphate
NP/NPK = Multinutrient Fertilizers

Average storage capacity needed by a retailer serving an area of about 3 000 hectare

Average fertilizer rate (kg/ha): 160 N, 70 P_2O_5, 140 K_2O.
Assumed utilization rate of capacity: 70 %

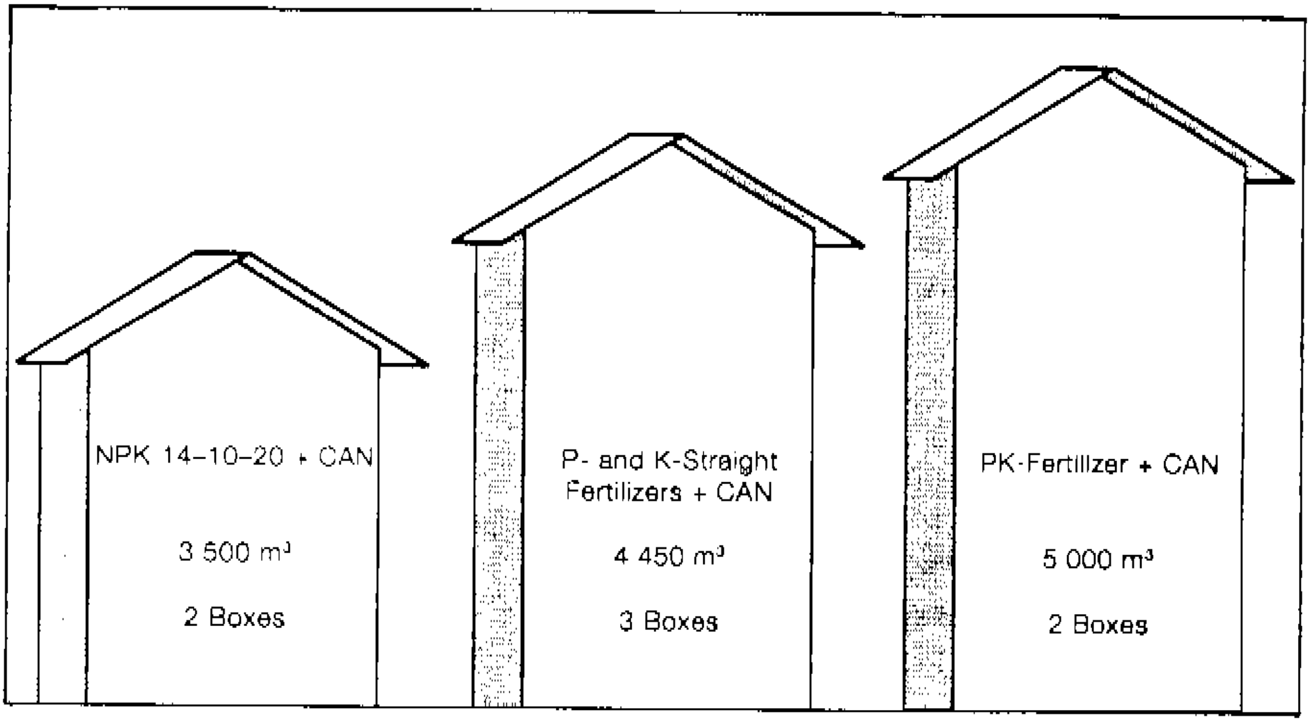


Figure 3

Comparison of fertilizer amounts to be handled

Nutrient rate (kg/ha): 84 N, 60 P_2O_5, 120 K_2O

Fertilizer	**Amount kg**
NPK 14–10–20	**600**
CAN (27%)	311
TSP (45%)	115
MOP (40%)	300
Total N+P+K	**726**

Required work (man-work-hours per ton) for different fertilizer systems at various farm sizes (ha)

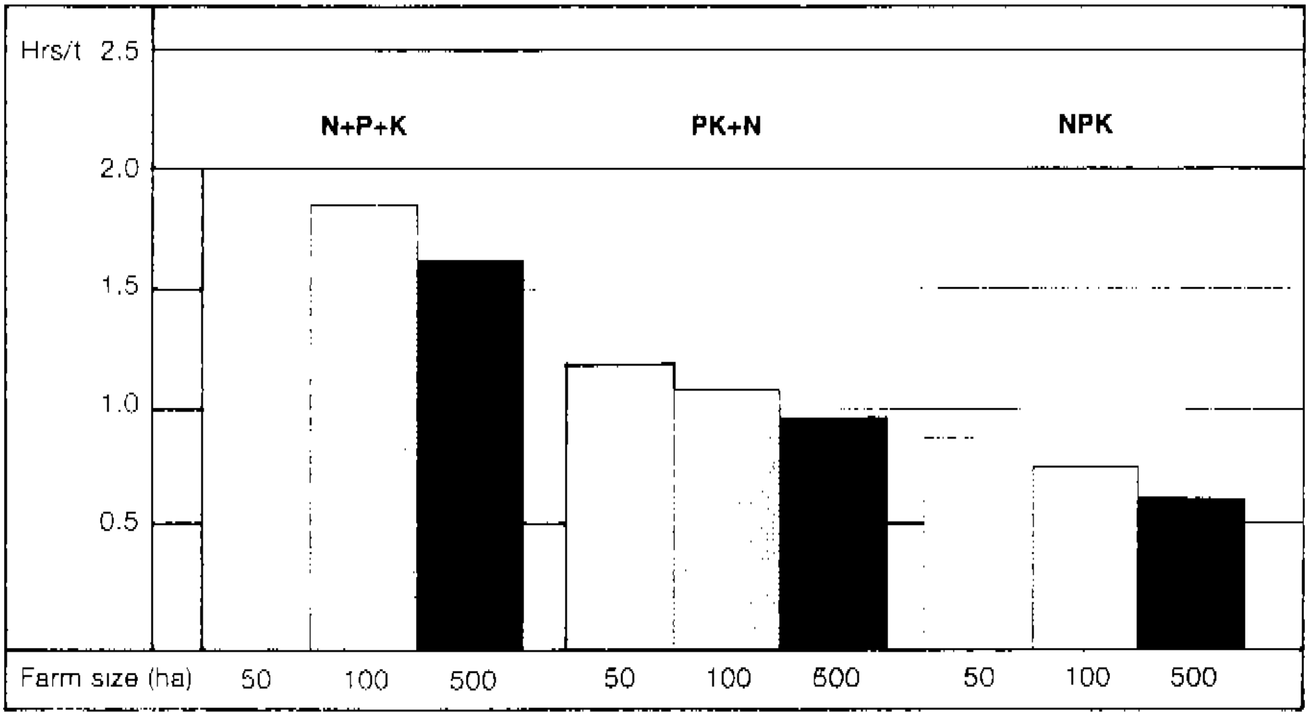
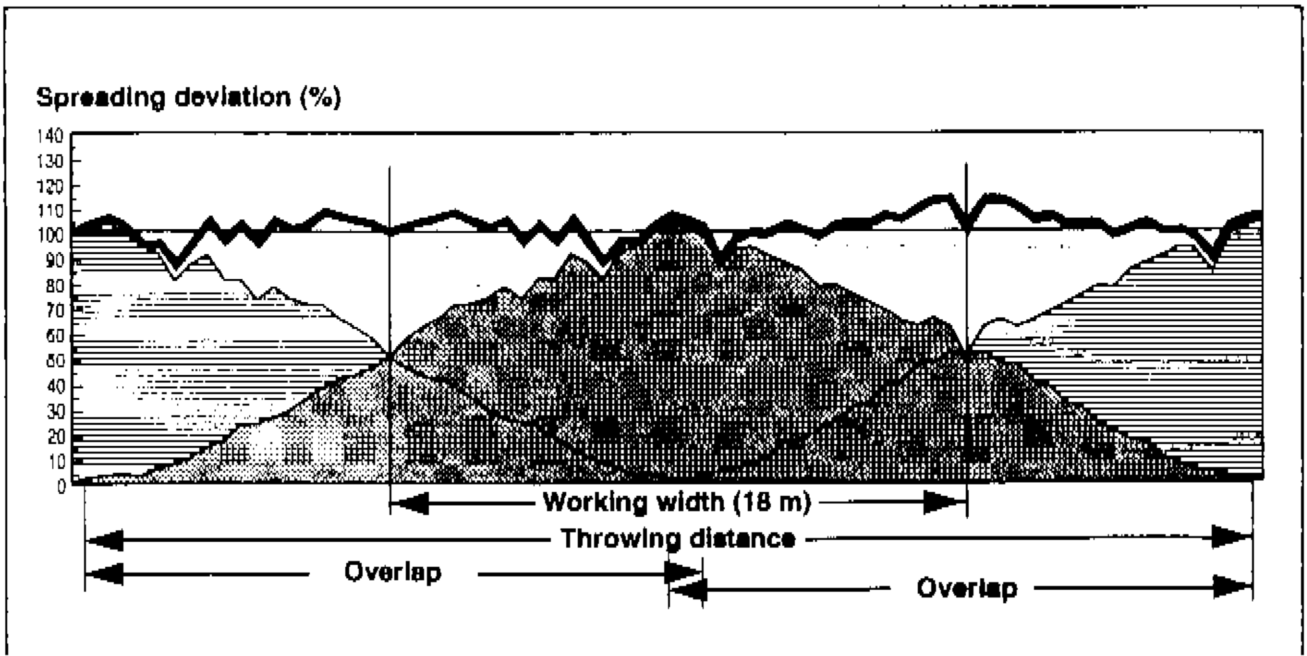


Figure 5

Lateral distribution of an NPK complex fertilizer, spread with a twin disc broadcaster

Fertilizer rate: 400 kg/ha



Screen-analysis of the individual components of a physically mixed fertilizer

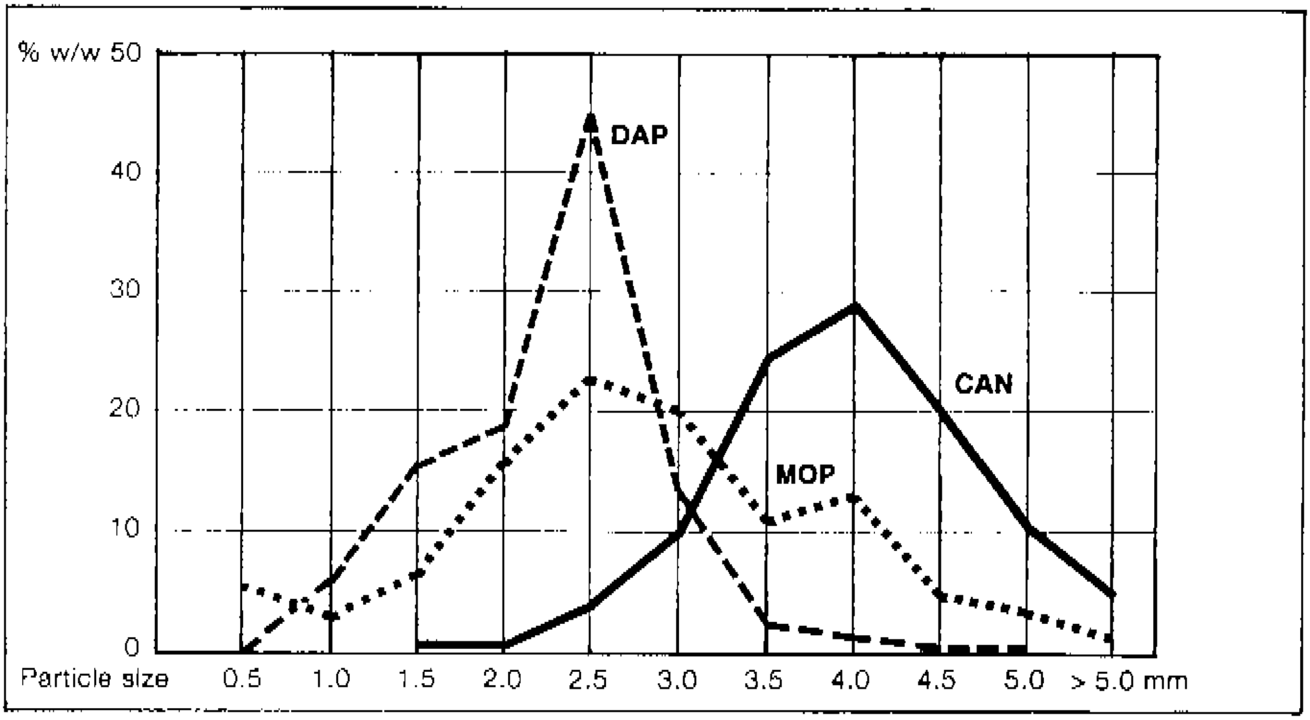
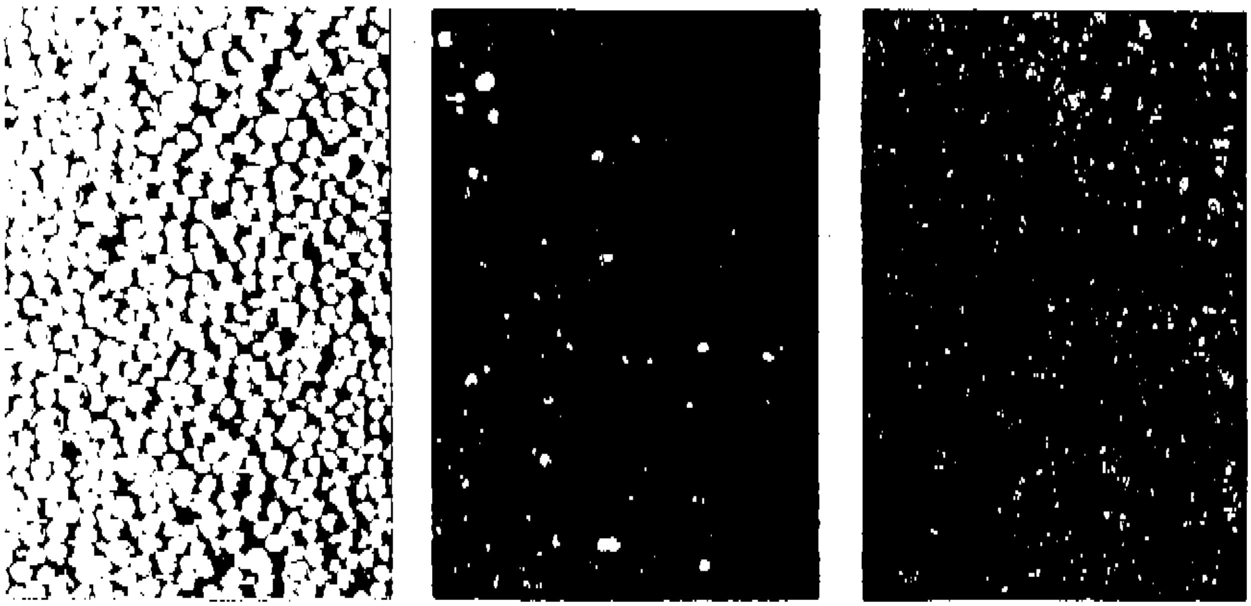


Figure 7

Visual aspect of three common N-, P_2O_5- and K_2O-sources for bulk blends



Calcium ammonium nitrate **Diammonium phosphate** **Potash**

Bulk blend 15–15–15 being discharged from the hopper of a fertilizer spreader

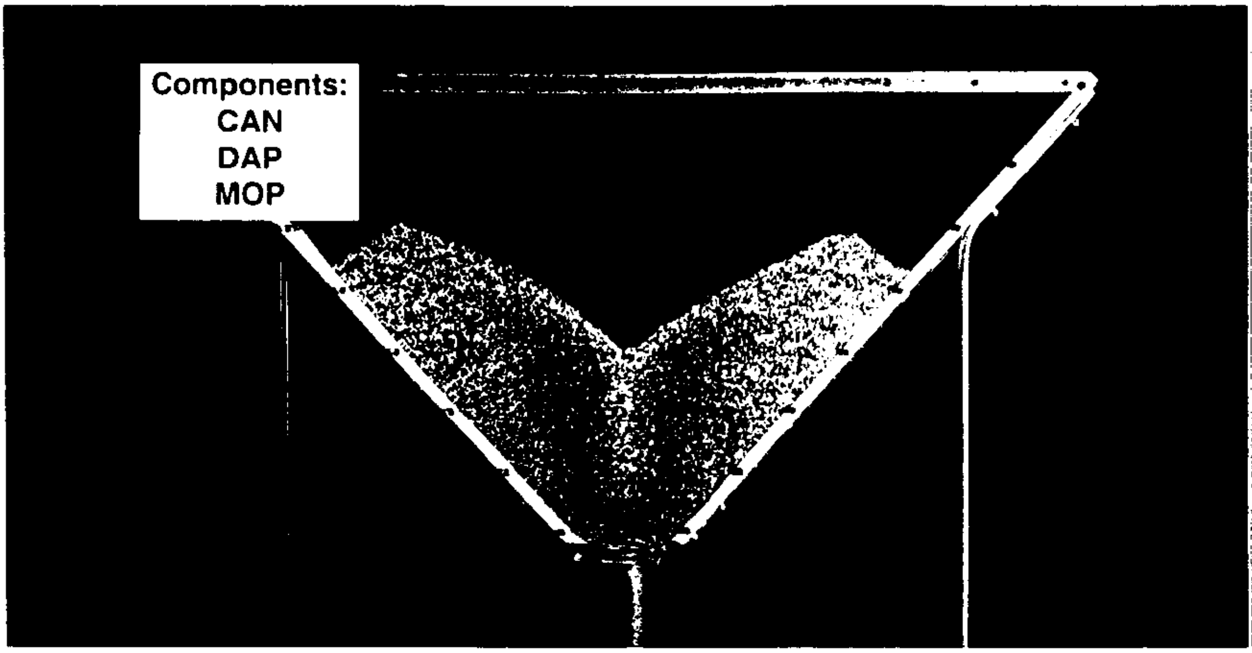


Figure 11

Lateral distribution of nutrients from a bulk blend of CAN, DAP and MOP (Target formula: 13–13–21)

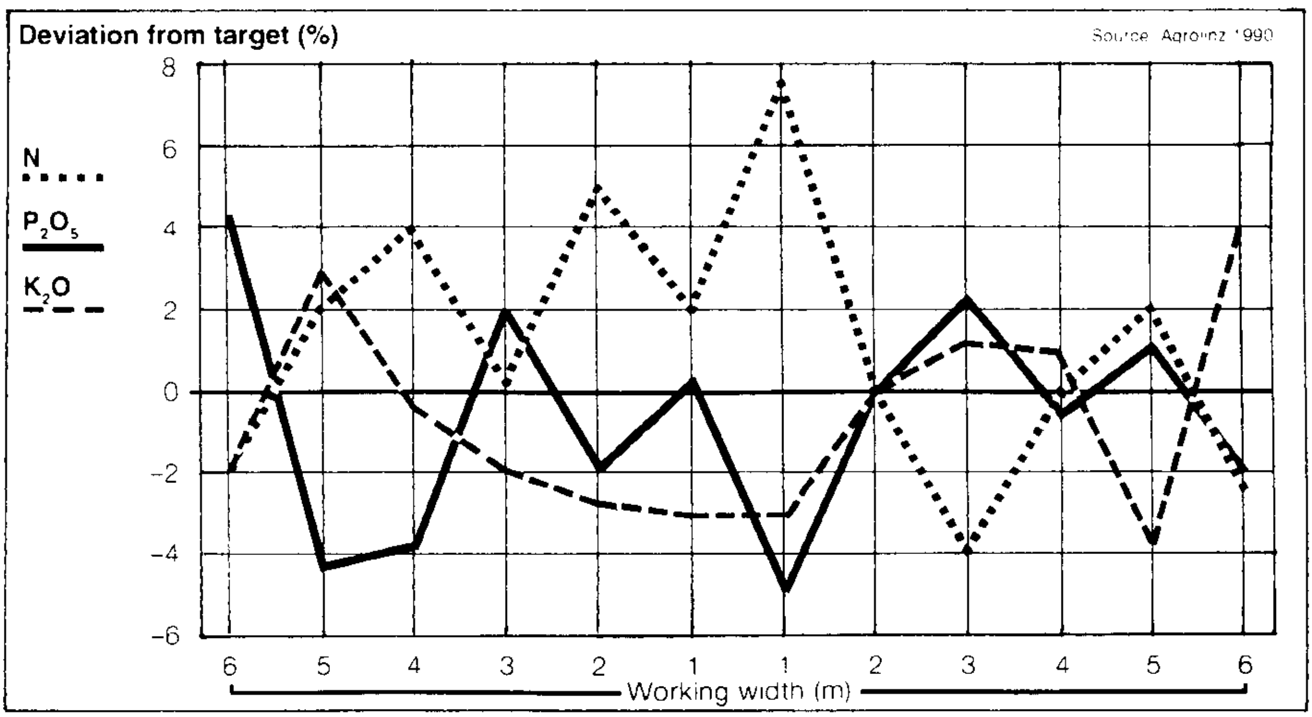


Figure 12

Cross-section of a pile of a bulk blend 15–15–15

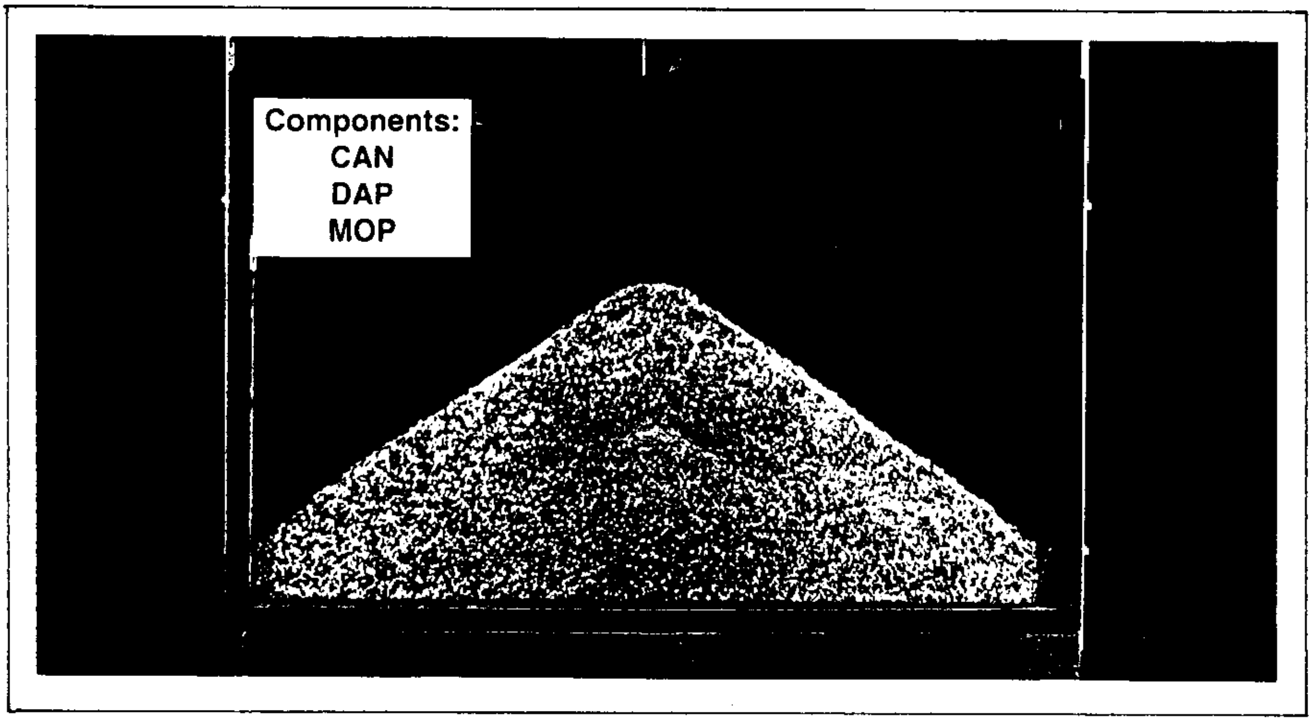


Figure 9

Nutrient distribution in a pile of a bulk blend from CAN, DAP and MOP
(Target formula: 15–15–15)

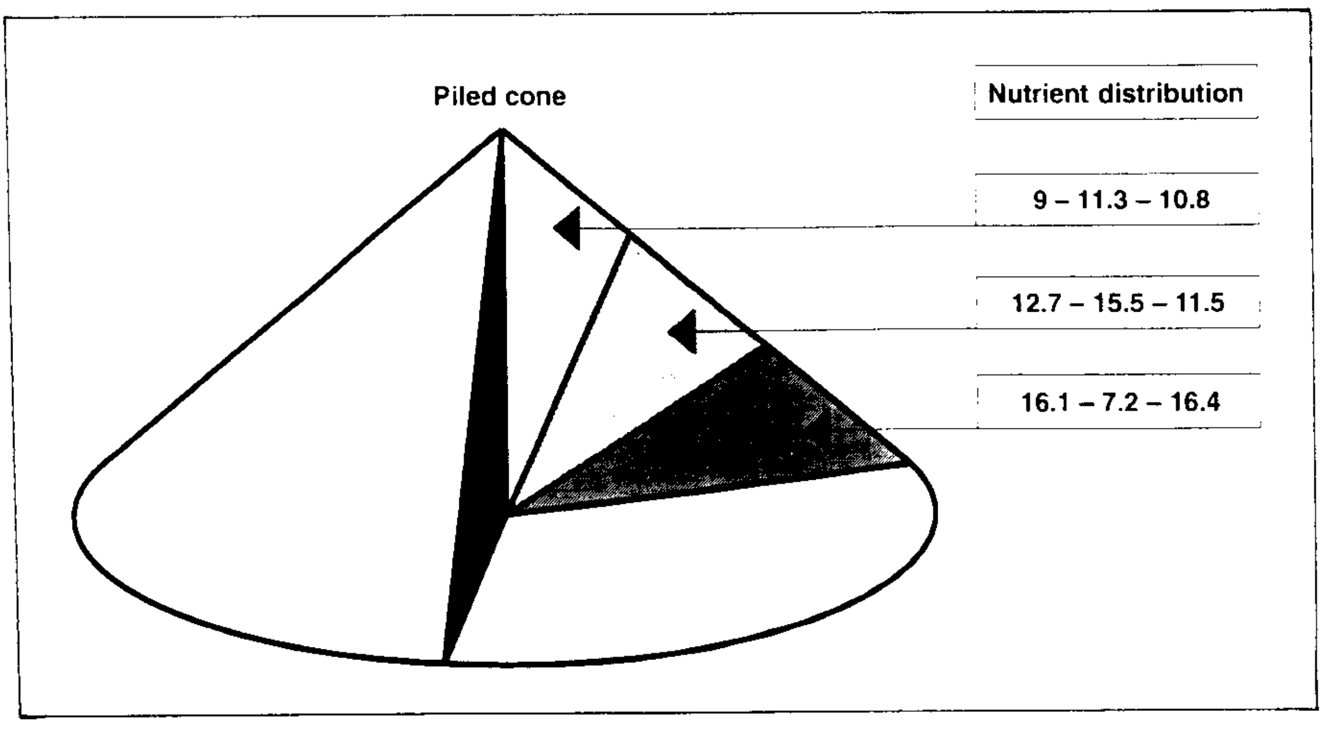


Figure 10

Laying out a field experiment to compare an NPK complex fertilizer with a bulk blend

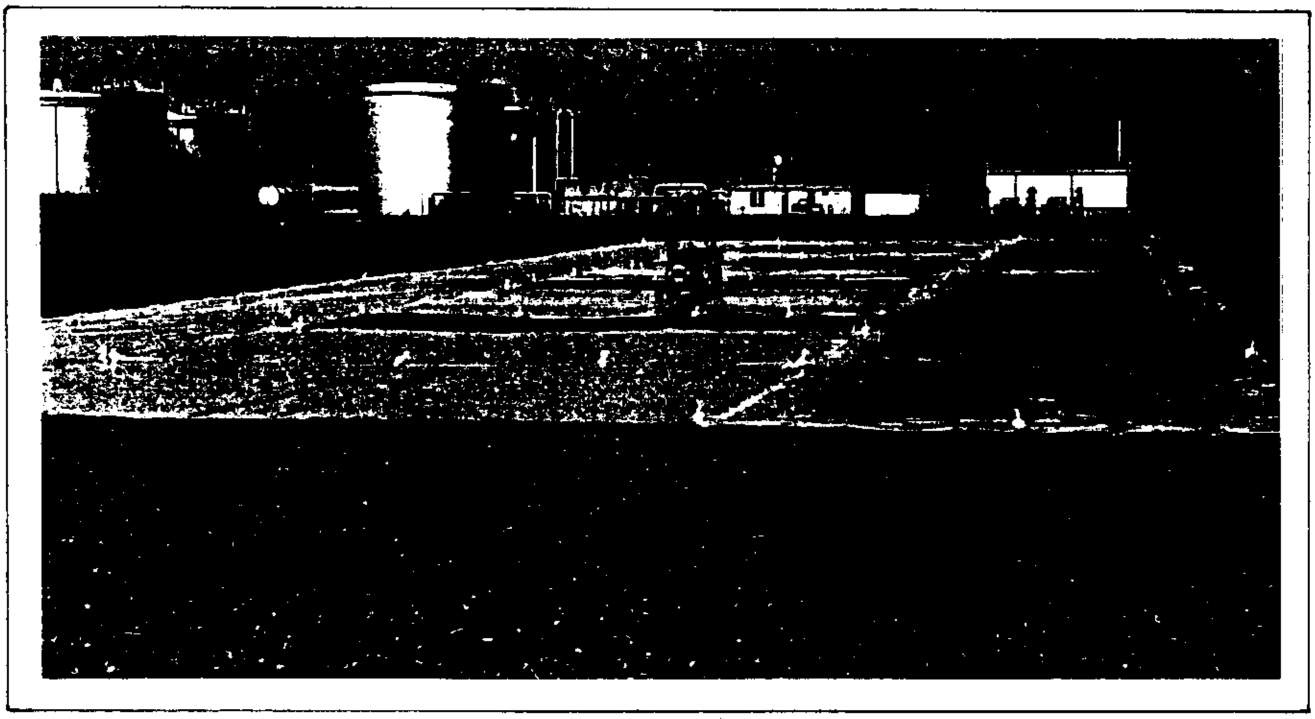


Figure 13

Alternative method to test the performance of bulk blends

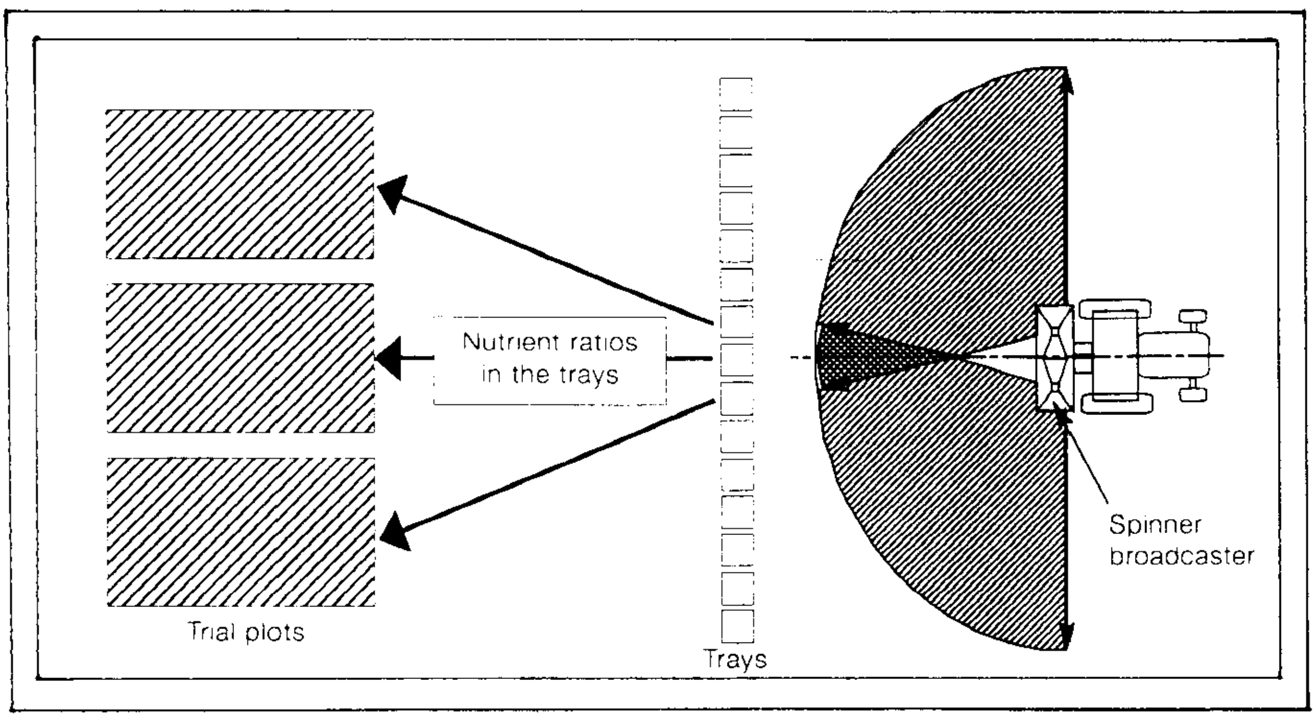


Figure 14

Plots from a field trial NPK complex fertilizer vs. bulk blend

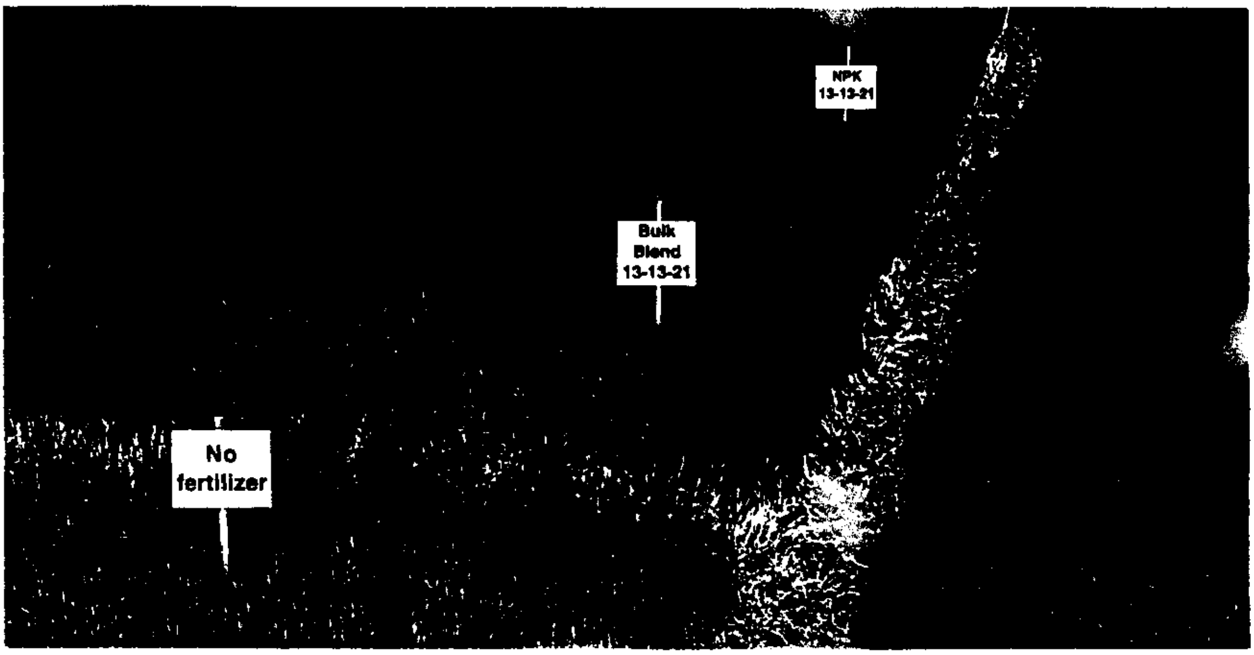


Figure 15

Effect on cereals of an NPK complex fertilizer 13–13–21 and a bulk blend of the same formula (I)

Results 1989; yields in t/ha

	Winter barley	Diff.	Winter wheat	Diff.
No Fertilizer	3.70		3.78	
NPK 13-13-21	4.57		7.58	
CAN+DAP+MOP	4.55	- 0.02	6.76	- 0.82
Urea+DAP+MOP	4.48	- 0.09	6.64	- 0.94

Figure 16

Effect on cereals of an NPK complex fertilizer 13–13–21 and a bulk blend of the same formula (II)

Results 1991; yields in t/ha				
	Winter wheat	Diff.	Winter rye	Diff.
No Fertilizer	3.12		4.01	
NPK 13–13–21	4.27	- 0.49	5.13	- 0.51
Urea+DAP+MOP	3.78		4.62	

Figure 17

Consumption of fertilizer nutrients from farm manures and mineral fertilizers 1950 – 1990/91 (Original FR Germany)

(kg/ha N + P_2O_5 + K_2O)

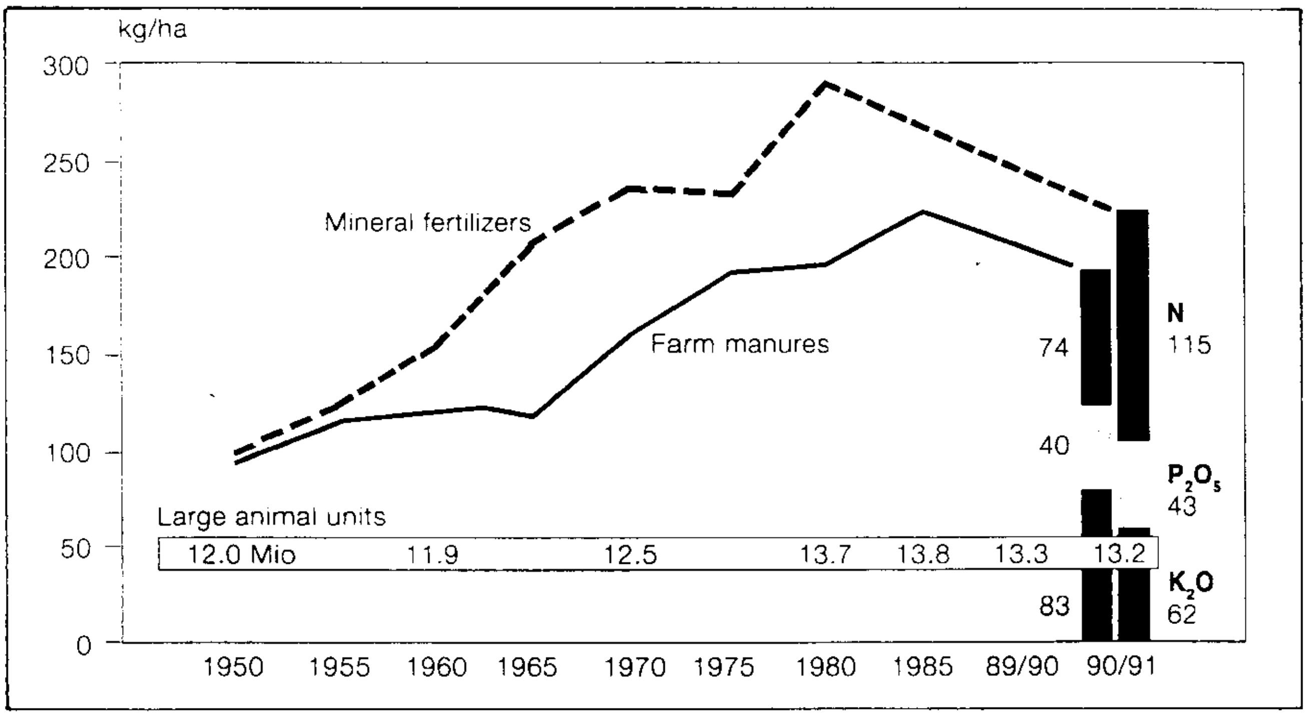


Figure 18

Balance-sheet: Nitrogen losses per large animal unit (Cattle)

■ Annual excretion with urine and faeces	100 – 120 kg N
■ Estimated amount of N from manures reaching the field	64 – 80 kg N
■ (Previously neglected NH_3 volatilization losses	36 – 40 kg N)
■ Utilization of the N actually applied (50–75%)	32 – 40 kg N
■ Total annual losses per large animal unit	68 – 60 kg N (or 68–50%)

Figure 19

Effect of different fertilizer systems on yield of arable crops in a long-term field experiment

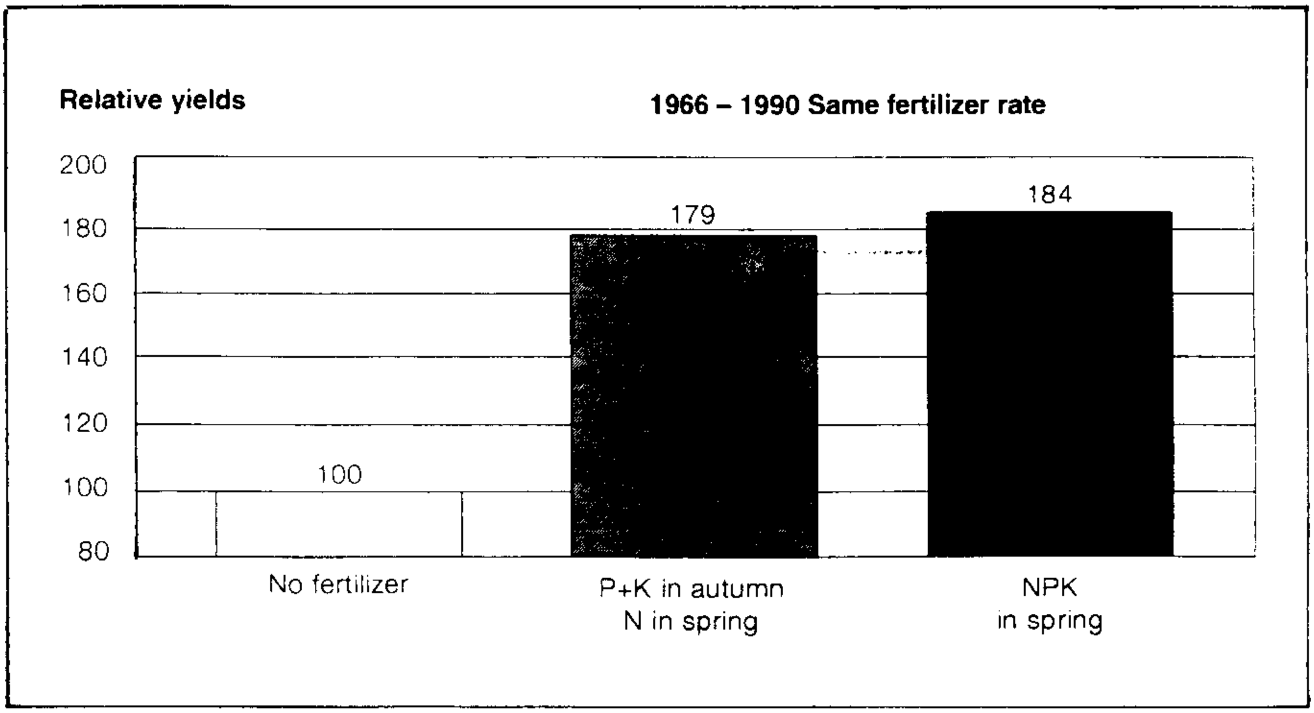


Figure 20

Utilization of mineral fertilizers and farm manures (FR Germany 1988/89)

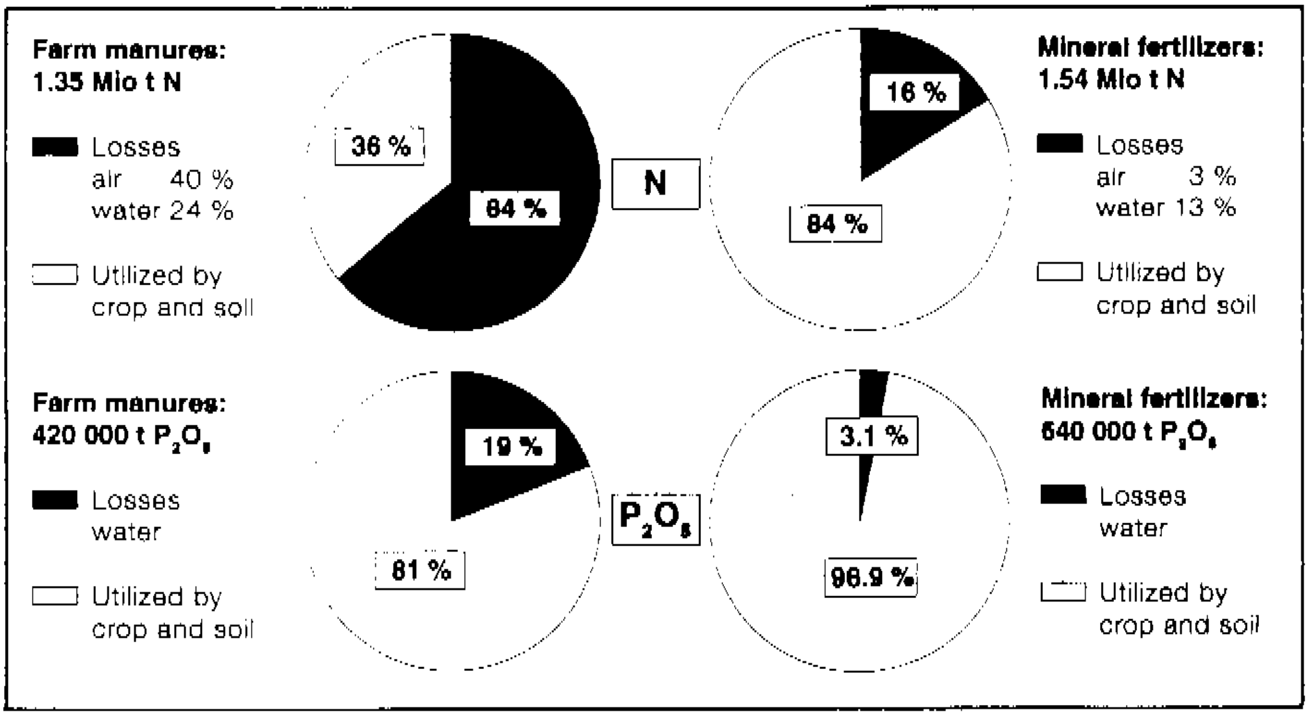


Figure 21

Effluent discharge fees for mineral fertilizer production (effective) and for agriculture (fictitious)

		Production	Agriculture	
			Mineral fertilizers	Organic manures (slurry)
Production/application	t.p.a. N t.p.a. P_2O_5	650 000 250 000	1 540 000 640 000	1 350 000 420 000
Total discharge (water)	t.p.a. N t.p.a. P_2O_5	900 70	200 000 20 000	325 000 80 000
Mio DM[1]	N P_2O_5	2.1 0.7	480 190	1 040[2] 770
Mio DM	total	2.8	670	1 810

[1] based on effluent discharge fees 1993
[2] whereof fees for emission into the air DM 260 Mio

Figure 22