

# Influence of the conditions under which the poppy is grown on the alkaloid content of the opium obtained

by T. N. Ilinskaya and M. G. Yosifova

The following two articles have been transmitted by the Representative of the U.S.S.R. on the Commission on Narcotic Drugs.

There is now a large body of published data showing that the chemical composition of plants is subject to considerable fluctuations according to the geographical area in which they grow or are cultivated. N. N. Ivanov (7, 8), M. I. Knyaginichev (10) and others have established, for example, that there is an extremely wide variation in the albumen content of wheats cultivated in different areas, as may be seen from the following figures :

Type of wheat	Where cultivated	% albumen
Lutescens 0.62	Chelyabinsk Province	24.4
"	Minsk Province	9.8
Kanred	Rostov Province	19.3
"	Ukrainian SSR	8.6

The work of S. L. Ivanov (4, 5, 6) on fatty vegetable oils is well known. He has established that oleaginous plants have a higher oil content when grown in the north than when grown in the south. Thus white mustard contained 37.4% fatty oil at Kotlas, and 18.9% at Kharkov. In addition, the oils obtained in the north have a higher degree of non-saturation, as is shown by the higher iodine counts.

For example, linseed oil from Archangel had an iodine count of 195 as against 180 for Moscow and only 154 for Tashkent.

V. V. Arasimovich (1) says that the sugar content of the ichksyl variety of melon is 6.9% in the central Volga region, and 11.7% in central Asia. Tomatoes grown in Moscow have a 2.9% sugar content, and those grown in the Crimea 5% (13, 18).

The starch content of Soviet varieties of potatoes ranges from 14% to 24% (14). Furthermore, the quality of the produce differs in different years in the same district. Thus during nine years of cultivation the sugar content of Voltman potatoes ranged from 14.4% to 22.7%.

Kok-saghyz roots grown in Leningrad Province contained 7.12% of rubber and those grown in Kazakhstan 4.63% (12).

Considerably less study has been devoted to the effect of the district in which plants are grown on their content in alkaloids, glycosides, essential oils, etc., but the available data show that the content in these substances is also subject to appreciable fluctuations.

According to A. A. Shmuk (15, 16, 17), the nicotine content of makhorka varies from 1.5% to 8% according to the district in which it is grown. The alkaloid content of the lupin ranges from 0.83% to 1.6%. In his work on the influence of geographical factors on the morphine content of the opium poppy, Annet (20) concludes that districts of high and low morphine

content may be distinguished. This is confirmed by Wisner (23), who states that the morphine content of the opium poppy in different countries fluctuates between 2% and 15%.

The alkaloid content of cinchona bark depends on the height above sea level at which the tree is grown. The amount and composition of quinine alkaloids is shown by Howard's data (see Reimers, 22) :

Height above sea level in metres	Quinine	Quinidine	Cinchonidine
500	0.47	0.30	0.05
1,800	2.06	traces	3.47

According to A. I. Yermakov (2, 3), hoary erysimum (*Erysimum canescens*) grown in Moscow Province and picked at flowering time contained 1.1% glucosides, as against 1.8% for plants picked in Poltava Province.

It is also known that there are variations not only in the amount of alkaloids but also in their composition according to the conditions under which plants grow.

S. Yunusov (19) says that Japanese chemists have found the alkaloid coclaurine in the evergreen shrub *Cocculus laurifolius*. Grown in the Batum Botanical Gardens, this plant contained no coclaurine at all but on the other hand it was found to contain two new alkaloids of an entirely different structural type.

There is a reference in Henry (21) to the effect that *Duboisia myoporoides* contains alkaloid in the basic form of scopolamine in the northern districts of Australia and hyoscyamine in the southern districts.

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The All-Union Institute for Scientific Research on Medicinal and Aromatic Plants (VILAR) has for a number of years been making geographical sowings of three varieties of the opium poppy : Tarbagatai 20, Tian-Shan 27 and China 42.

The sowings were made in a uniform manner as regards choice of plot, preparation of the soil, sowing conditions and tending.

According to the instructions, the poppy was sown in furrows directly in the soil, during the first two or three days after field work began. Sowings were made in double drills with 60 and 30 cm. between the rows, the seeds being covered to a depth of 1.5 to 2 cm.

The experimental plots were set at 100 square metres, and the experiments were repeated not less than three or four times.

Observations were made during the growing period to check the length of the individual development stages and

Table 1

CONTENT IN THE FIVE MAIN ALKALOIDS AND TOTAL ALKALOIDS CONTENT OF OPIUM FROM POPPIES GROWN IN DIFFERENT DISTRICTS — 1947

District where grown	Variety	Percentage of alkaloids content of opium					Total for all alkaloids
		Morphine	Codeine	Papaverine	Thebaine	Narcotine	
Krasnodar	Tarbagatai 20 .....	13.10	1.49	0.41	0.67	5.68	34.20
"	Tian-Shan 27 .....	13.00	1.00	0.48	1.32	3.30	36.90
"	China 42 .....	13.50	1.27	traces	0.54	12.30	34.30
Voronezh	Tarbagatai 20 .....	10.40	1.79	traces	1.30	7.50	42.30
"	Tian-Shan 27 .....	8.18	1.25	0.70	0.83	4.70	33.90
"	China 42 .....	10.20	1.62	0.40	2.30	6.10	38.70
Bitzy, Moscow Prov.	Tarbagatai 20 .....	12.00	2.30	0.17	1.10	6.00	37.50
" " "	Tian-Shan 27 .....	8.00	2.20	0.15	1.92	8.40	38.00
" " "	China 42 .....	9.48	2.10	0.10	2.10	4.50	35.00
Vologda	Tarbagatai 20 .....	10.40	2.17	none	0.81	8.40	40.70
"	Tian-Shan 27 .....	5.50	2.60	none	0.86	4.00	36.80
"	China 42 .....	6.60	2.53	none	1.50	6.30	41.60

measurements were taken of the height of the plants and the degree of foliation. In addition, specimen plants were selected from each plot, before the crop was harvested, in order to measure the increase in organic mass.

The crop was gathered in the form of opium, to obtain which the capsules were lanced with special knives. The lancing was done during the period of initial technical maturity in 15-20% of the opium-yielding capsules. They were repeated four or five times every other day. On each occasion only technically ripe capsules were lanced. The opium was collected the day after lancing, dried, pulverized by grinding in a mortar and then analysed for content in the six main alkaloids by Klyachkina's method (9), and for total alkaloid content by the method devised by the VILAR's Chemistry Department (11).

The tests results are given in Tables 1, 2 and 3. As regards the alkaloid narceine, it occurred only in traces in all the samples, and hence no figures are given for it.

The first thing to be noted is the exceptionally wide variation in the content in the main alkaloids of opium obtained from poppies grown in different geographical areas. The morphine content, for example, ranges from 5.50% to 13.50%, codeine from 0.36% to 2.60%, papaverine from zero to 2.30%, thebaine from 0.14% to 7.00%, narcotine from 4.00% to 12.30% and total alkaloids from 26.3% to 41.6%.

The districts in which the poppy was grown were, in order of latitude, Krasnodar, Voronezh, Moscow and Vologda (see Table 1).

Proceeding from Krasnodar to Vologda, the morphine

content decreases and this is particularly noticeable with the Tian-Shan 27 and China 42 varieties. The codeine content decreases in the other direction, from Vologda to Krasnodar.

Comparing the soil and climatic conditions under which the poppy was grown in these districts, it can be said that from south to north the natural fertility of the soil and total temperature during the growing period decrease. Total rainfall is much the same in all these districts, but its effect is necessarily different because of the great differences in temperature. Clearly, the changes in the humidity/warmth ratio, and in soil conditions are responsible for this variation in the morphine and codeine content of the opium.

West of Vologda, poppy was grown in the Tartu district (Estonian SSR) and east of Vologda in the Kirov district (see Table 2). In the mild, damp, warm climate of Tartu, the opium has a higher morphine content and a lower codeine content than in Vologda. On the other hand, with the low temperatures in the Kirov district, the morphine content is lower and the codeine content higher.

Sowings were also made west of Krasnodar, in Poltava Province (Table 3) and east of Krasnodar, in Kuibyshev Province. It can be said of the opium from these districts that it has a lower codeine content than that from the more northerly districts.

In a number of districts, the geographical poppy sowings were continued over a period of years, and the results of these experiments show that in the same district the composition of the opium was not uniform where weather conditions

Table 2

District where grown	Variety	Percentage of alkaloids content of opium					Total for all alkaloids
		Morphine	Codeine	Papaverine	Thebaine	Narcotine	
Tartu	Tarbagatai 20 .....	13.10	1.58	0.94	0.67	5.68	34.20
"	Tian-Shan 27 .....	11.20	1.95	0.53	0.58	8.70	40.10
"	China 42 .....	13.28	0.90	0.17	traces	6.70	39.80
Kirov	Tarbagatai 20 .....	11.40	2.30	0.01	0.30	6.00	39.50
"	Tian-Shan 27 .....	10.50	2.20	0.27	1.10	12.20	40.10
"	China 42 .....	11.10	2.00	0.10	1.60	10.10	39.80

Table 3

District where grown	Variety	Percentage of alkaloids content of opium					Total for all alkaloids
		Morphine	Codeine	Papaverine	Thebaine	Narcotine	
Poltava Province	Tarbagatai 20 .....	10.60	1.39	0.31	1.30	6.50	31.00
" "	Tian-Shan 27 .....	7.80	1.30	0.30	—	9.96	36.10
" "	China 42 .....	7.85	1.05	1.75	1.86	5.20	26.30
Kuibyshev Province	Tarbagatai 20 .....	11.10	1.57	1.08	0.14	8.4	26.90
" "	Tian-Shan 27 .....	9.60	1.06	1.78	traces	4.90	40.30
" "	China 42 .....	10.50	0.36	2.30	none	6.60	36.90

Table 4

## PERCENTAGE OF MORPHINE AND CODEINE CONTENTS OF ABSOLUTELY DRY OPIUM

No.	District where grown	Year when grown	Tarbagatai 20		Tian-Shan 27		China 42	
			Morphine	Codeine	Morphine	Codeine	Morphine	Codeine
1.	Tartu	1946 .....	9.40	2.80	7.28	2.24	8.20	2.40
"	"	1947 .....	13.10	1.58	11.20	1.95	13.28	0.90
2.	Bitzy, Moscow Province	1947 .....	12.00	2.30	8.00	2.20	9.48	2.10
"	" "	1949 .....	14.20	1.80	12.50	1.50	9.10	2.40
"	" "	1950 .....	14.26	1.80	—	—	—	—
"	" "	1951 .....	11.74	2.13	—	—	—	—
3.	Voronezh	1945 .....	14.50	1.13	11.10	0.95	14.35	0.60
"	"	1947 .....	10.40	1.79	8.18	1.25	10.20	1.62
4.	Krasnodar	1946 .....	12.34	2.04	10.40	1.60	13.60	2.20
"	"	1947 .....	13.10	1.49	13.00	1.00	13.50	1.27
5.	Kuibyshev	1945 .....	10.20	1.88	8.10	1.86	10.10	1.50
"	"	1947 .....	11.10	1.57	9.60	1.06	12.20	2.0

differed during different years: where a higher morphine content occurred in any one year, the codeine content of the opium was usually lower, whereas a decrease in morphine content was accompanied by an increase in the codeine content (see Table 4).

In view of the close genetic relation between morphine and codeine, it can be assumed that reciprocal conversions of the one alkaloid into the other are possible, depending on the conditions under which the poppy is grown. Observations have shown that deficient moisture during the early period of growth, or excessive moisture in the latter half of the development period, generally have the effect of reducing the morphine content of the opium.

As regards papaverine, a point to be noticed is that opium from Vologda contained none of it whatever (see Table 1), whereas opium from Kuibyshev, according to data over a three-year period, had a very high papaverine content (Table 5).

Table 5

	Percentage of papaverine content of opium		
	Tarbagatai 20	Tian-Shan 27	China 42
Kuibyshev 1945 .....	1.43	1.74	2.60
" 1946 .....	1.30	1.30	1.00
" 1947 .....	1.08	1.78	2.30

The Kuibyshev district compared with the others has a small amount of rainfall and fairly high temperatures during the growing period. Under these conditions, the plants experience a shortage of moisture, and this apparently promotes the formation of papaverine in the opium. This assumption is confirmed by the following data (Table 6).

The years 1946 at Krasnodar and 1950 at Tartu were hot, dry ones, whereas 1947 and 1951 were very wet.

So far it has not been possible to establish any clear principles governing changes in the thebaine and narcotine contents of the opium.

The total alkaloids content of the opium is a little higher in northern districts than in southern ones, but it cannot be concluded from this that alkaloids form more readily in the northern districts, seeing that the absolute yield of alkaloids is considerably greater in the south owing to the heavier opium crop.

## Conclusions

1. The percentage content in the six main alkaloids and the total alkaloids content of the opium are subject to variation according to the soil and climatic conditions of the district where the poppy is grown.

2. The morphine content decreases from south to north, according to the latitude in which the poppy is grown; the codeine content and the total alkaloids content change in the opposite direction, while the absolute yield of alkaloids is higher in the south owing to the heavier opium crop obtained there.

Table 6

District where grown and year	Percentage of papaverine content		
	Tarbagatai 20	Tian-Shan 27	China 42
Krasnodar 1946 .....	1.54	0.59	1.25
" 1947 .....	0.41	0.48	traces
Tartu 1950 .....	0.84	0.35	—
" 1951 .....	traces	traces	—

3. Increased humidity in the first half of the poppy's growing and development period combined with optimum temperatures promotes the formation of morphine.

Lower temperatures promote the formation of codeine. A drop in morphine content as a result of any particular set of conditions is accompanied by an increase in codeine content. Lower humidity in conjunction with higher temperatures stimulates the formation of papaverine (Kuibyshev), whereas no papaverine is formed where temperatures are lower and humidity higher (Vologda).

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# The part played by fertilizers in increasing opium poppy yields

by V. V., Sheberstov

All-Union Institute for Scientific Research on Medicinal and Aromatic Plants (VILAR)

Since 1932, the All-Union Institute for Scientific Research on Medicinal and Aromatic Plants and some of its regional experimental stations have been devoting attention to the question of how to apply fertilizers to the opium poppy grown in the Soviet Union. The bulk of the work has been done by the Przhewalsk Regional Experimental Station in the Kirghiz SSR, where the opium poppy is generally grown on irrigated plots.

The opium poppy is grown in Kirghizia, in rotation in succession to winter wheat, after fallow or half fallow (sain-foin). Sowings are made in early spring using tractors, seed-drills and sowing in well-spaced rows with 60 to 70 cm. between them. Irrigation is carried out before the land is ploughed (pre-ploughing moisture-charging) and once or twice during the growing period. Final irrigation has to be done not later than the budding stage. Late irrigation when the poppy is in flower has an adverse effect on the yield of raw opium and its alkaloid content. The poppy capsules are repeatedly lanced until the latex stops flowing.

On irrigated plots the Tian-Shan variety is grown, and on those which are not artificially irrigated the Tarbagatai sub-variety. The poppy seed is gathered in by means of combine harvesters.

It should be noted that apart from the effect of agricultural methods on the yield and quality of the opium, climatic

**Table 2**  
EFFECT OF MANURE, WITH BASIC APPLICATIONS—1942

No.	Variants	Yield of absolutely dry opium		
		kg/ha	percentage of control	percentage of morphine
1.	Control, no fertilizer applied	7.85	100	12.31
2.	Manure 20 tons/ha .....	9.63	123	10.94
3.	Manure, 30 tons/ha .....	12.9	164	13.36

conditions also play a large part, the result being that yields in different areas may vary considerably although the cultivation methods are the same.

The question of the application of fertilizer to the opium poppy has now been fairly well worked out, thanks to the investigations made.

Both organic and artificial fertilizers have been used, and the experiments lasted from 1932 to 1955.

The results of the experiments to determine the action of organic fertilizers are set out in Tables 1 and 2, and show that the use of manure during ploughing considerably increases the opium yield.

**Table 1**  
EFFECT OF VARIOUS DOSES OF MANURE ON OPIUM YIELD—1932

No.	Test variants	Yield of absolutely dry opium		
		kg/ha	percentage of control	Percentage of morphine content of absolutely dry weight
1.	Control, no fertilizer applied	11.2	100	10.80
2.	Manure, 10 tons/ha .....	16.1	144	11.58
3.	Manure 20 tons/ha .....	20.8	186	11.93
4.	Manure 30 tons/ha .....	20.8	186	11.53

**Table 3**  
EFFECTIVENESS OF MANURE IN THE SECOND YEAR AFTER APPLICATION—1936

No.	Variants	Yield of absolutely dry opium	
		kg/ha	percentage of control
1.	Control, no fertilizer .....	8.8	100
2.	Manure, 15 tons/ha .....	13.5	156
3.	Manure, 30 tons/ha .....	16.9	192

**Table 4**  
EFFECT OF FERTILIZERS ON OPIUM YIELD AND MORPHINE CONTENT—1937

No.	Variants	Yield of air-dried opium		Percentage morphine content of absolutely dry weight	Morphine yield	
		kg/ha	%		kg/ha	%
1.	No fertilizer .....	10.08 ± 0.32	100	10.1	1.018	100
2.	N <sub>60</sub> kg/ha .....	10.75 ± 0.4	106	9.37	1.007	98
3.	P <sub>60</sub> kg/ha .....	14.68 ± 0.38	145	10.17	1.483	145
4.	K <sub>60</sub> kg/ha .....	8.89 ± 0.30	88	9.68	0.860	84
5.	(N P) <sub>60</sub> kg/ha .....	13.37 ± 0.50	132	10.51	1.405	138
6.	(N K) <sub>60</sub> kg/ha .....	8.20 ± 0.27	81	9.18	0.753	74
7.	PK <sub>60</sub> kg/ha .....	13.37 ± 0.49	131	10.1	1.340	131
8.	(NP, k) <sub>60</sub> kg/ha .....	12.45 ± 0.29	123	9.69	1.206	118

**Table 5**  
EFFECT OF VARIOUS DOSES OF SUPERPHOSPHATE ON OPIUM YIELD AND MORPHINE CONTENT

No.	Variants	Yield of absolutely dry opium		Percentage of morphine content of absolutely dry weight	Morphine yield	
		kg/ha	%		kg/ha	%
1.	No fertilizer .....	11.4 ± 0.2	100	11.40	1.300	100
2.	Pc45 during ploughing .....	14.08 ± 0.7	123.5	12.54	1.765	136
3.	Pc60 during ploughing .....	14.47 ± 0.5	127	12.48	1.805	139
4.	Pc75 during ploughing .....	14.82 ± 0.4	130	12.51	1.854	142
5.	Pc90 during ploughing .....	13.90 ± 0.8	122	12.32	1.712	132
6.	Pc60 during cultivation .....	16.07 ± 0.3	141	12.57	2.020	155

With 20-30 tons of manure applied per hectare, the opium yield increased by 22-86%. The poppy comes as the second crop after the application of fresh manure, as the presence of weeds following direct application of manure considerably hampers the poppy sowing. The effectiveness of the manure still remains fairly high during the second year after application.

Experiments to determine the effect on yield of artificial fertilizers have shown that the greatest increase occurs with the use of phosphate fertilizers (Table 4).

Potash fertilizers used both alone or with other fertilizers reduce the opium yield and amount of morphine produced. The use of nitrogenous fertilizers by themselves reduces the morphine content of the opium by 0.73%, but the morphine content increases by 0.4% when they are used with superphosphates.

The reason for this effect of nitrogenous and potash fertilizers is that they were applied during cultivation and their high solubility resulted in a high concentration of salts on the surface of the soil, with an adverse effect on the development of the extraordinarily sensitive poppy shoots.

The correctness of this assumption was confirmed by subsequent tests.

It is first necessary, however, to refer to the tests made to determine the dosage and methods of applying phosphate fertilizers, the results of which are set out in Tables 5, 6, 7, 8, 9, 10, 11 and 12.

**Table 6**

EFFECT ON OPIUM YIELD OF METHODS OF APPLYING SUPERPHOSPHATE—1937

No.	Variants	Yield of absolutely dry opium	
		kg/ha	%
1.	Control, no fertilizer .....	14.2	100
2.	Pc 50 kg/ha during cultivation .....	25.4	179
3.	Pc 50 kg/ha during harrowing .....	27.6	194

With superphosphate, the opium yield increases from 23 to 94%—in other words, it is almost doubled in some cases. The greatest effect of doses introduced at ploughing time was with 45-60 kg of P<sub>2</sub>O<sub>5</sub> per hectare. An increase to 90 kg/ha of P<sub>2</sub>O<sub>5</sub> has little effect on the yield.

The morphine content for all the variants of the experiment (Table 5) was practically uniform and worked out at 0.92-1.17 above the control figure. A further point is that the effectiveness of the superphosphate increases where the fertilizer is covered by a shallower layer of soil (see Table 5, Variant 6, and Table 6, Variants 2 and 3).

Similar results were obtained in a second experiment (Table 7).

**Table 7**  
EFFECT ON OPIUM YIELD AND MORPHINE CONTENT OF SUPERPHOSPHATE APPLIED BEFORE SOWING—1940

No.	Variants	Yield of absolutely dry opium		Percentage of morphine content of absolutely dry weight	Morphine yield	
		kg/ha	%		kg/ha	%
1.	No fertilizer .....	4.23 ± 0.11	100	7.15	0.302	100
2.	Pc60 during ploughing .....	6.53 ± 0.25	154	7.80	0.509	168
3.	Pc90 during ploughing .....	6.85 ± 0.20	161	7.83	0.536	177
4.	Pc60 during ploughing + Pc30 during cultivation .....	7.84 ± 0.17	185	7.90	0.629	208

**Table 8**  
EFFECT OF BASIC SLAG ON OPIUM POPPY YIELD—1938

No.	Variants	Yield of absolutely dry opium			Seed yield	
		kg/ha	percentage of control	percentage of morphine	kg/ha	percentage of control
1.	Control, no fertilizer .....	6.65	100	12.90	216	100
2.	Basic slag, 30 kg/ha P <sub>2</sub> O <sub>5</sub> .....	15.42	231.8	12.78	645	298
3.	Basic slag, 60 kg/ha P <sub>2</sub> O <sub>5</sub> .....	21.43	322.3	12.45	838	388
4.	Basic slag, 90 kg/ha P <sub>2</sub> O <sub>5</sub> .....	22.15	333.1	11.58	853	395

Table 9

EFFECT OF VARIOUS DOSES OF SUPERPHOSPHATE ON FORMATION OF CAPSULES AND OPIUM YIELD—1937

No.	Variants	Number of capsules cut per 100 plants	Yield of absolutely dry opium in g per count	
			Per 100 plants	Per 100 capsules
1.	No fertilizer .....	121	14.25	11.77
2.	Pc45 during ploughing ..	143	17.60	12.30
3.	Pc60 during ploughing ..	145	18.08	12.47
4.	Pc75 during ploughing ..	132	18.52	14.03
5.	Pc90 during ploughing ..	130	17.35	13.34
6.	Pc60 during cultivation ..	146	20.08	13.75

The results of this experiment show that the application of 90 kg of  $P_2O_5$  per hectare in two doses—60 kg/ha during ploughing and 30 kg/ha during cultivation (Variant 4) are much more effective than the full dose at ploughing time (Variant 3).

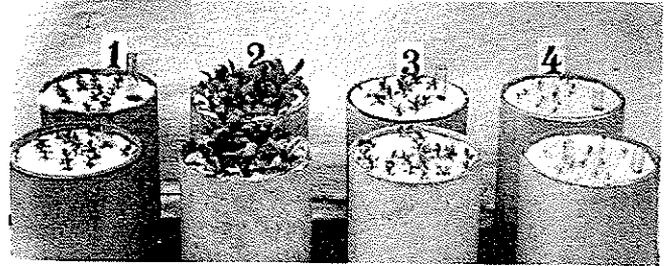
Other types of phosphate fertilizers were tried out, including basic slag, which was also highly effective (Table 8).

The most effective dose of this fertilizer was found to be 60 kg of  $P_2O_5$  per hectare. Concurrently with the sharp rise in opium yield, there was a considerable increase in seed yield. It should be noted that its effect was to reduce the morphine content of the opium, especially where the dose was 90 kg per hectare. However, there is no reason to attribute this decrease to the action of the phosphorus, as the other elements in the fertilizer may have been responsible in this case.

The increased yield consequent on the use of phosphate fertilizers is due to the better development of the plant and the formation of a larger number of capsules and also, as shown by the figures in Table 9, to the increased flow of latex produced by them.

The last-mentioned fact seems to be connected with the effect of the superphosphate on the number of lactic vessels in the capsules and the fact that they are better filled.

The results of the experiments described above prove that the use of superphosphate and other phosphate fertilizers has an extremely favourable effect on opium yield. The results also prove that the effectiveness of phosphate fertilizers increases when they are allowed to come into direct contact with the seed.



PHOTOGRAPH 1

1. No fertilizer                      3.  $K_{100}(NP) 20$   
 2.  $(PK)_{100} N 20$                     4.  $K_{100} N 20$   
 (2 g of each of the active substances = 100)

This last-mentioned fact provided grounds for a further study of this question. Experiments conducted during growth (Photograph 1) show quite clearly that the opium poppy demands a high level of phosphate feed after its initial period of development. Accordingly, the further study of the effectiveness of phosphate fertilizers was directed towards fully covering the initial stage of the poppy's development by means of phosphate feeding.

Experiments were therefore carried out to test the effect of successive applications of fertilizer, the superphosphate being applied in the form of small granules in the drills together with the seed. The experiments showed the application of granular superphosphate in the drills along with the seed at sowing time to be very effective (see Tables 10 and 11).

Table 10 shows that the use of 3 kg of  $P_2O_5$  per hectare increased the opium yield by 36%, while the use of a double dose increased it by 55%. A further increase of the dose to 10 kg per hectare brought practically no increase in yield.

Table 10

EFFECT ON THE PRODUCTIVITY OF THE OPIUM POPPY OF DOSES OF GRANULAR SUPERPHOSPHATE APPLIED IN THE DRILLS—1946

No.	Variants	Yield of absolutely dry opium		Seed yield	
		kg/ha	%	quintals/ha	%
1.	No fertilizer .....	16.6	100	5.9	100
2.	$P_2O_5$ , 3 kg/ha in drills ...	22.6	136	7.1	120
3.	$P_2O_5$ , 6 kg/ha in drills ...	25.7	155	7.2	122
4.	$P_2O_5$ , 10 kg/ha in drills ...	26.4	158	7.6	129

Table 11

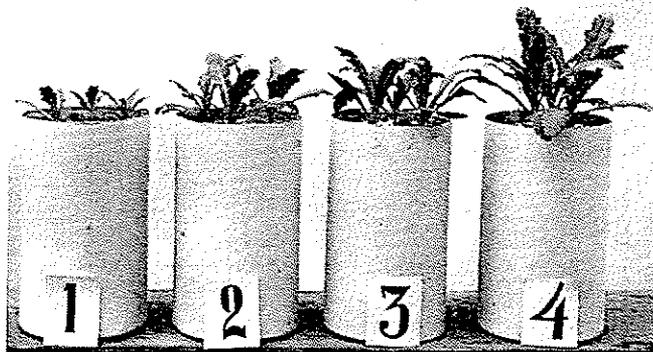
EFFECT ON THE OPIUM POPPY YIELD OF APPLICATIONS OF GRANULAR SUPERPHOSPHATE IN THE DRILLS

Year	Variants	Yield of absolutely dry opium		Percentage morphine content of absolutely dry weight	Seed yield	
		kg/ha	%		quintals/ha	%
1945	No fertilizer .....	18.9	100	7.84	7.9	100
	$P_2O_5$ , 6 kg/ha in drills .....	22.3	118	8.39	9.6	121
	$P_2O_5$ , 30 kg/ha scattered .....	22.8	120	9.64	10.6	134
1946	No fertilizer .....	18.5	100	morphine content	5.6	100
	$P_2O_5$ , 6 kg/ha in drills .....	23.2	125	not determined	8.7	155
	$P_2O_5$ , 60 kg/ha scattered .....	24.3	131		10.1	180

Table 12

EFFECT OF MANURE AND SUPERPHOSPHATE ON OPIUM  
AND SEED YIELD

No.	Variant	Yield of air-dry opium		Seed yield	
		kg/ha	%	quintals/ha	%
1.	Control, no fertilizer	21.7	100	6.2	100
2.	Pc90	39.4	181	13.0	209
3.	Manure, 15 tons	33.9	156	11.2	180
4.	Manure, 30 tons	31.8	146	11.5	185
5.	Pc90 + 15 tons manure	42.0	193	13.2	213
6.	Pc90 + 30 tons manure	43.1	198	13.3	214



PHOTOGRAPH 2

1. Full dose of mineral fertilizers.
  2. Full dose, but nitrogenous fertilizers applied in  $\frac{1}{2}$  doses.
  3. Full dose, but nitrogenous fertilizers applied in  $\frac{1}{5}$  doses.
  4. Full dose, nitrogenous and potash fertilizers applied in  $\frac{1}{5}$  doses.
- Full dose consists of 2 g of active substances ( $P_2O_5$ ,  $K_2O$ , N) per container.

The greater effectiveness of granular superphosphate applied in the drills at sowing time as compared with powdered superphosphate scattered at random was observed in all subsequent experiments. Thus it can be seen from Table 11 that the opium yield is 18-25% higher in the former case. The same effect is observed when applying 30 kg of  $P_2O_5$  per hectare of ordinary superphosphate, but here the amount of fertilizer used is five times greater.

The results of all these experiments prove that phosphate fertilizers are no less effective than manure.

This is confirmed by the results of yet another experiment (Table 12).

As can be seen from the table, the effect on the opium yield of superphosphate applied in doses of 60 kg of  $P_2O_5$  per hectare exceeds that of manure applied at the rate of 15 tons as well as 30 tons per hectare. Simultaneous application of manure and superphosphate does not significantly increase the opium yield as compared with the application of superphosphate by itself. A similar effect is observed also on seed productivity.

The next step is to examine the results of the experiments on the effect of nitrogenous and potash fertilizers on the opium yield.

As shown above (Table 4), the application of nitrogenous fertilizers was found to be ineffective whereas that of potash fertilizers reduced the opium yield and morphine content. Even with irrigation the effect of nitrogen fertilizers applied before sowing was very limited (Table 13).

As already noted, the reason why these fertilizers had this effect was because of the formation in the top layer of soil of a high concentration of nitrogenous fertilizers to which young poppy shoots are very sensitive.

To determine the most effective use of nitrogenous and potash fertilizers, experiments were conducted during growing time which showed that the poppy in fact requires less nitrogen and potash feed during the initial period of development (Photograph 2).

However, the opium poppy, to provide a big yield, needs a considerable increase in the amount of nitrogenous feed during the rosette and budding stages, as is confirmed by the experimental results given in Tables 14 and 15.

In addition, the application of nitrogenous fertilizers during the growing period increases not only the opium yield but also morphine content—a most important fact. Potash fertilizers applied at two periods—half a dose when filling the containers and another half at the rosette stage (Table 14)—had a beneficial effect on vegetation but reduced the opium

Table 13

EFFECT OF NITROGENOUS AND POTASH FERTILIZERS  
ON OPIUM YIELD

No.	Variant	Yield of air-dried opium			
		kg/ha	%	quintals/ha	%
Average for 4 years	No fertilizer	14.3	100	6.2	100
	N	15.1	105	13.0	209
	P	20.0	139	11.2	180
	NP	20.9	146	11.5	185

Table 14

OPIUM POPPY YIELD DEPENDING ON VARYING APPLICATIONS OF FERTILIZER (EXPERIMENT ON GROWING)—1939

No.	Time of application	Yield of air-dried above-ground mass		Yield of air-dried opium		Percentage of morphine content of absolutely dry substance
		g/container	Percentage (PK <sub>100</sub> )	mg/container	Percentage (PK <sub>100</sub> )	
1.	No fertilizer	19.0 ± 0.31	61	210	60	10.85
2.	(NPK) <sub>100</sub>	31.11 ± 0.95	100	350	100	11.33
3.	(PK) <sub>100</sub> N <sub>10</sub>	47.22 ± 1.31	151	560	160	12.57
4.	P <sub>100</sub> K <sub>50</sub> N <sub>10</sub>	49.95 ± 1.24	160	470	134	12.30
5.	P <sub>50</sub> K <sub>100</sub> N <sub>10</sub>	38.01 ± 0.65	122	417	119	12.10
6.	(NPK) <sub>25</sub>	35.87 ± 1.21	115	455	130	12.10

Table 15  
EFFECT OF NITROGEN FEED ON OPIUM YIELD AND MORPHINE CONTENT—1948

On filling containers	Variants		Yield of air-dried above-ground mass		Yield of air-dried opium		Percentage of morphine content of absolutely dry weight of opium
	Rosette stage	Budding stage	g/container	%	mg/container	%	
(PK) <sub>100</sub> N <sub>20</sub>	—	—	40.1 ± 1.4	100.6	156.4	100	9.35
(PK) <sub>100</sub> N <sub>20</sub>	N <sub>30</sub>	N <sub>30</sub>	53.5 ± 1.9	133.0	296.0	189	12.50

yield. The application of phosphate fertilizers in two doses (Variant 5, Table 14)—half a dose when filling the containers and another half at the budding stage—reduced the yield of above-ground mass as well as opium yield and morphine content.

Thus phosphate and potash fertilizers used during experiments on growing produced a more beneficial effect on opium yield and morphine content when applied before sowing.

The use of a complete fertilizer (NPK) in equal portions at all stages increased the opium yield by 30% and the morphine content by 37% compared with the results obtained by applying a full dose when filling the containers (Variant 6). On the other hand, the yield with this variant was considerably less than that obtained with Variant 3, in which the full dose of phosphate and potash fertilizers as well as a small amount of nitrogen was given when the containers were filled; the rest of the nitrogen was given during the growing period.

Judging from the plant's development and the yield obtained, the application of fertilizer in this manner went a long way towards satisfying the opium poppy's demand for nutritious matter.

In the field experiments carried out, data was obtained which tally completely with the results of the growing period experiments (Tables 16, 17).

The data in Table 16 show that the most effective method of using nitrogenous fertilizers, where not applied at ploughing time, is to apply them in two stages: 30 kg of nitrogen per hectare during cultivation and 30 kg/ha during the growing period in order to feed up the plants. Applying the fertilizer in this way, a larger opium yield was obtained with a greater

morphine content. With an application of nitrogenous fertilizers in doses of 60 kg of nitrogen per hectare during cultivation (Variant 3), the effect on opium yield was nil, and a background of P<sub>60</sub>K<sub>45</sub> was negative in its result (Variant 7).

It should be noted that the application of nitrogenous fertilizers at depth during ploughing was also effective.

Potash fertilizers applied in the field experiments had a negative effect in all cases on opium yield and morphine content. A specially sharp fall in morphine content was observed when using potash fertilizers at two stages. In this case, the morphine content dropped by 1.39%.

Experiments over many years have shown (Table 17) that nitrogenous fertilizers applied at the rosette stage in doses of 60 kg of nitrogen per hectare, accompanied by adequate phosphate feeding, produces a substantial increase in opium yield. The morphine content, as a result of the application of nitrogenous fertilizers rose by 0.65% on average. These experiments provided a demonstration of how to use nitrogenous fertilizers effectively.

It may be taken as established, on the basis of the above considerations, that the opium poppy's need for fertilizers at the development stage is not uniform. During the initial period of development, it needs heavy phosphate feeding but very little nitrogen, and an abundance of nitrogenous fertilizers has an adverse effect on the opium yield. During the next period, beginning with the rosette stage when the plant grows rapidly, the need for nitrogen sharply increases. The amount of potash fertilizers required is insignificant, and an excess of potash in the soil lowers the opium yield and morphine content.

From the experiments carried out, it can be concluded that the system of feeding the poppy calls for the use of fertilizers

Table 16  
EFFECT OF NITROGENOUS AND POTASH FERTILIZERS ON OPIUM YIELD AND MORPHINE—1940

No.	Time of applying fertilizer			Yield of absolutely dry opium		Percentage morphine content of absolutely dry weight	Morphine yield	
	During ploughing	During cultivation	For feeding purposes	kg/ha	%		kg/ha	%
1.	No fertilizer			9.66 ± 0.25	100	10.22	0.985	100
2.	Pc <sub>60</sub>	—	—	11.84 ± 0.20	123	10.65	1.260	127
3.	Pc <sub>60</sub>	N <sub>60</sub>	—	11.70 ± 0.75	121	10.56	1.233	125
4.	Pc <sub>60</sub>	N <sub>30</sub>	N <sub>30</sub>	13.53 ± 0.31	140	11.21	1.516	154
5.	Pc <sub>60</sub>	(NK) <sub>3</sub>	N <sub>30</sub> K <sub>15</sub>	12.82 ± 0.25	133	9.82	1.259	128
6.	Pc <sub>60</sub> K <sub>45</sub>	—	—	11.70 ± 0.11	121	10.10	1.181	120
7.	Pc <sub>60</sub> K <sub>45</sub>	N <sub>60</sub>	—	10.76 ± 0.45	111	10.37	1.115	113
8.	Pc <sub>60</sub> K <sub>45</sub>	N <sub>30</sub>	N <sub>30</sub>	12.27 ± 0.32	127	10.87	1.334	135
9.	N <sub>60</sub> Pc <sub>60</sub>	—	—	13.01 ± 0.20	135	10.96	1.426	145
10.	(NPK) <sub>60</sub> K <sub>45</sub>	—	—	11.32 ± 0.34	117	10.77	1.219	124

**Table 17**  
EFFECT OF NITROGEN FEED ON OPIUM AND MORPHINE YIELDS (AVERAGE FOR SIX YEARS)

No.	Test variants	Yield of absolutely dry opium		Morphine content	Morphine content	
		kg/ha	%		kg/ha	%
1.	No fertilizer .....	17.3	100	12.13	2.1	100
2.	90 kg/ha P <sub>2</sub> O <sub>5</sub> at ploughing time .....	22.5	130	13.75	3.1	147
3.	90 kg/ha P <sub>2</sub> O <sub>5</sub> at ploughing time .....	26.3	152	14.40	3.78	176
	N60 for feed-up purposes at the rosette stage .....					

at the main cultivation stage, at the time of sowing, and later, for feeding.

It is usual in practice to apply 60-90 kg P<sub>2</sub>O<sub>5</sub> per hectare at the ploughing stage, and another 6 kg/ha in the form

of granulated superphosphate at sowing time along with the seed.

At the rosette stage the plants are fed with nitrogenous fertilizers at the rate of 40-60 kg of nitrogen per hectare.