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The Effects of Fertilizers on two Subsequent Generations of Winter Wheat

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Introduction

Large after-effects due to fertilizer treatment were reported by DURRANT (2) in an inbred variety of fibre flax. The treatment of the flax plants with all combinations of N, P and K induced large differences in plant weight in the subsequent generation grown from the seed of these treated plants. The large differences persisted through at least six generations grown in uniform soil. Genetic variability in the original seed sample or a selective effect of the fertilizer treatments could not satisfactorily explain these after-effects.

In an investigation with two varieties of winter wheat, which was carried out to see whether similar after-effects could be detected, fertilizer treatments were applied in the same way as that reported by DURRANT (loc. cit.), but at no time were the plants placed in a warm greenhouse. No plant mortality occurred during the treatments, and a sample of seed was obtained from each variety under all treatments.

Materials and Methods

The two varieties of winter wheat used in this investigation were Wilma and Little Joss. Two plants, one of each variety, were grown to maturity in soil in 10 inch pots to which were applied all eight combinations of N, P and K. The pots were placed in an unheated greenhouse. Two sowings of eight pots each were made; the first was at approximately the normal seeding time for winter wheat, and the second seven weeks later in January.

The fertilizers were applied in solution, made up by dissolving 30 gms. of each fertilizer in two litres of water. Sulphate of ammonia, triple superphosphate and muriate of potash were used to supply N, P and K, respectively. Each of the 16 pots in the experiment received 100 ml. of one of the eight solutions, plus 100 ml. of water, at monthly intervals beginning the second week after germination. After five months inside, the plants were staked and placed outside the greenhouse on clay saucers. Each ear on every plant was tagged and dated as it emerged from the leaf sheath. The plants were returned to the cool greenhouse to mature under good conditions, and the grain was completely ripe when harvested. Each ear was threshed separately, and the grain yield and 1000 K weight obtained for it.

With the seed from the fertilizer treated plants four experiments were carried out. In all four the plants from different treatments were grown in uniform soil. The experiments were as follows:

1. Seeds from each of the 32 combinations of fertilizer treatment, variety and sowing date, were sown in 7 inch pots. Three replicates were used. One plant per pot was grown to maturity, and the grain yield and 1000 K weight recorded. This was a check, therefore, of the first generation following treatment.
2. Seeds from fertilizer treatments NPK, NK, NP and O (check, no treatment), both varieties and both sowing dates were grown as in 1. Two replicates were used. This was a repeat check of the first generation following treatment, and was carried out in a different season to 1.
3. Seeds from the NPK, NK, NP and O treated plants of Wilma, with both sowing dates, were sown. In this case all eight types of seed were sown in the same 7 inch pot, and in order to increase crowding even more, two plants of each combination were grown to maturity. There were, therefore, sixteen plants in each pot; no fertilizer was added during growth. Eight replicates were used.
4. Seed from the plants grown in experiment 1 was used to check the second generation for possible after-effects. The seed was taken from plants whose parents had received NPK, NK, NP and O. Both varieties and both sowing dates were included. Two replicates were used. One plant per pot was grown to maturity as in 1 and 2.

In all four experiments the seed used was taken from ears which had emerged from the leaf sheath at, or near to, the mean emergence date of all ears on the particular plant.

The four experiments above may be summarized as follows:

			Experiment No.
Season 1.		Parental or treated generation.	
Season 2.		First generation in uniform soil; Single plants per pot.	1
Season 3.	(a)	First generation in uniform soil; single plants per pot.	2
	(b)	First generation in uniform soil; 16 plants per pot. No fertilizers used during growth.	3
	(c)	Second generation in uniform soil; single plants per pot.	4

Results

Parental Generation

Large differences, as would be expected, were caused by the direct applications of the fertilizers.

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Mean grain weights, expressed as 1000 K weights (Table 1), and total grain yields (Table 2) reflected the heavy dosages of fertilizer applied. The differences in 1000 K weight attributable to variety, sowing date and fertilizer treatment were all highly significant. Interactions between N, P and K were also all significant with the exception of NP. With total grain yield, only fertilizer treatment caused significant differences, although here all N, P and K interactions were significant.

Table 1. *1000 K weights (Kg.) of seed produced by plants of Wilma and Little Joss at two sowing dates with eight combinations of N, P and K.*

Fertilizer treatments

Variety	Sowing date	NPK	NP	NK	N	PK	P	K	O	Mean
Wilma	1	.049	.023	.031	.026	.034	.038	.031	.034	.033
	2	.042	.015	.028	.021	.034	.034	.025	.027	.028
Little Joss	1	.042	.028	.031	.026	.037	.046	.043	.035	.036
	2	.043	.026	.029	.030	.037	.038	.032	.032	.033
Mean		.044	.023	.030	.026	.035	.039	.033	.032	

Varietal Means		Sowing Date Means	
Wilma	.031	1st	.035
Little Joss	.035	2nd	.031

Table 2. *Total weight of grain (gms.) from plants of Wilma and Little Joss at two sowing dates with eight combinations of N, P and K.*

Fertilizer treatments

Variety	Sowing date	NPK	NP	NK	N	PK	P	K	O	Mean
Wilma	1	40.68	15.41	10.90	10.01	9.20	6.65	7.77	7.99	13.58
	2	32.23	5.56	19.68	11.94	11.38	12.67	6.53	5.52	13.19
Little Joss	1	24.76	12.98	16.43	6.36	14.72	3.72	7.99	10.02	12.12
	2	28.66	10.72	5.89	11.39	9.79	8.87	8.38	8.30	11.50
Mean		31.58	11.17	10.15	9.92	11.27	7.98	7.67	7.96	

Varietal Means		Sowing Date Means	
Wilma	12.85	1st	13.38
Little Joss	12.34	2nd	11.81

Table 3. *1000 K weights (Kg.) of seed produced by first generation of Wilma and Little Joss grown at two sowing dates each with eight fertilizer treatments. Means over three replicates. Experiment (1).*

Fertilizer treatments

Variety	Sowing date	NPK	NP	NK	N	PK	P	K	O	Mean
Wilma	1	.036	.039	.040	.044	.040	.040	.036	.037	.039
	2	.045	.039	.045	.038	.045	.041	.039	.040	.041
Little Joss	1	.044	.042	045	.044	.044	.039	.045	.044	.043
	2	.043	.046	.043	.044	.044	.047	.042	.040	.044
Mean		.042	.041	.043	.042	.043	.042	.040	.040	

Varietal Means		Sowing Date Means	
Wilma	.040	1st	.041
Little Joss	.043	2nd	.042

Table 4. *Total weight of grain (gms.) produced by first generation of Wilma and Little Joss grown at two sowing dates each with eight fertilizer treatments. Means over three replicates. Experiment (1).*

Fertilizer treatments

Variety	Sowing date	NPK	NP	NK	N	PK	P	K	O	Mean
Wilma	1	31.81	36.79	34.06	43.30	38.02	32.97	37.32	31.51	35.72
	2	36.73	40.49	34.85	37.59	28.31	35.38	33.82	38.64	35.73
Little Joss	1	32.44	35.14	36.63	32.87	33.07	34.45	32.83	35.77	34.15
	2	35.87	39.47	39.34	36.46	30.82	38.58	39.01	37.59	37.14
Mean		34.21	37.97	36.22	37.55	32.55	35.34	35.74	35.88	

Varietal Means		Sowing Date Means	
Wilma	35.72	1st	34.93
Little Joss	35.64	2nd	36.43

First Generation: Experiment 1.

Differences in 1000 K weight (Table 3) and total grain yield (Table 4) were much smaller than those in the plants under treatment. Analyses of variance on these two characters (Table 5) showed that variety was the only significant factor in 1000 K weight, although there was also a significant interaction between N and P. In total grain yield, a significant depressant effect of K (comparing all treatments containing K with all those lacking it) was found. Over all other treatments, progeny of plants not receiving K gave a 5.8% greater yield than progeny of plants receiving K. The percentage difference between the highest and lowest treatments, namely, PK and NP, summed over varieties and sowing dates, was 16.6 per cent.

There was a close correlation between the 1000 K weights (Table 1) of the seed from the parental generation and the first generation total grain yields (Table 4) after summing over varieties and sowing dates. The regression of total grain yield on 1000 K weight was negative ($b = -0.2031 \pm 0.0618$) and significant (P 0.05). This implies that the smaller the seeds, the greater the grain yield of the plants grown from them. There was, however, no significant regression of total grain yield on 1000 K weight after removal of the effects of fertilizer treatments, varieties and sowing dates, so that the significant relation between total grain yield and 1000 K weight, with respect to the fertilizer treatments, cannot be considered due to intrinsic differences in seed weight produced by the fertilizers, but rather to other effects of the fertilizers.

Table 5. *Analyses of data from first generation. Experiment (1).*

1000 K weight

Item	Degrees of freedom	Mean square	Variance ratio
Total S. S.	95		
Replicates	2	47.04	1.85
Varieties	1	253.50	10.00**
Sowing dates	1	63.37	2.50
Fertilizers	7	14.16	—
N	1	18.37	—
P	1	2.66	—
K	1	13.50	—
Error	84	25.35	

Total grain yield

Item	Degrees of freedom	Mean square	Variance ratio
Total S. S.	95		
Replicates	2	124.08	5.13**
Varieties	1	0.15	—
Sowing dates	1	54.90	2.27
Fertilizers	7	36.99	1.53
N	1	63.37	2.62
P	1	43.20	1.78
K	1	98.41	4.07*
Error	84	24.21	

** Significant at P = 0.01. — * Significant at P = 0.05

First Generation: Experiment 2

The data on grain yield (Table 6) show considerable variation, but in spite of larger differences between fertilizer treatments than those in experiment (1), no significant fertilizer differences were obtained. There was no correlation between these grain yields and the 1000 K weights (Table 1) of the seed used to produce the plants; there was also no correlation between the corresponding fertilizer treatments of experiments (1) and (2). The variation in the data of Table 6, for example the particularly low value of Little Joss, 1st sowing, PK treatment, has no ready explanation. Differences between experiments (1) and (2) might be the result of growth in different seasons, or possibly an aging effect in the seed used for experiment (2), or a combination of these factors.

Table 6. *Total grain yield produced by first generation of Wilma and Little Joss grown at 2 different dates with 4 fertilizer treatments. Means over 2 replicates (gms.). Experiment (2).*

Variety	Sowing dates	NPK	NP	PK	O	Mean
Wilma	1	19.5	14.5	18.5	15.5	17.0
	2	22.0	12.5	11.5	20.0	16.5
Little Joss	1	14.5	11.5	4.5	11.0	10.37
	2	14.5	19.0	20.5	13.5	16.87
Mean		17.62	14.37	13.75	15.0	

Varietal Means		Sowing Date Means	
Wilma	16.75	1st	13.69
Little Joss	13.62	2nd	16.69

First Generation: Experiment 3.

The negative correlation noted in experiment (1) was the main reason for the third experiment on the first generation. This was a competition experiment where 16 plants were grown in each pot. The very low overall 1000 K weights (Table 7) and total grain yields (Table 8) reflected the low level of nutrient per plant. Analyses of variance of these data (Table 9) showed no significant differences in 1000 K weights ascribable to the fertilizer treatments applied to the parents whereas total grain yield showed highly significant differences due to these parental treatments.

Table 7. *1000 K weights (Kg.) of seed produced by first generation of Wilma grown at two sowing dates with four fertilizer treatments. Means over eight replicates. Experiment (3).*

Fertilizer treatments

Variety	Sowing date	NPK	NP	PK	O	Mean
Wilma	1	.036	.035	.036	.036	.036
	2	.036	.037	.035	.037	.036
Mean		.036	.036	.036	.037	

In comparing the 1000 K weights (Table 2) and the total grain yields (Table 8) for the four fertilizer categories in this experiment, it appeared that the correlation between the two characters was positive. The regression of yield on 1000 K weight, was positive and highly significant (P 0.01). A significant negative correlation was found in experiment (1) with all eight parental fertilizer treatments and both varieties, but examination of the data shows that this negative correlation also occurs with these four treatments and Wilma alone. Under competition the relation between seed size and subsequent plant yield is, therefore, reversed.

Table 8. *Total weight of grain (gms.) produced by first generation progeny of Wilma grown at two sowing dates with four fertilizer treatments. Means over eight replicates. Experiment (3).*

Fertilizer treatments

Variety	Sowing date	NPK	NP	PK	O	Mean
Wilma	1	1.58	0.94	0.84	0.90	1.06
	2	1.09	0.58	0.84	0.96	0.87
Mean		1.33	0.76	0.84	0.93	

Table 9. *Analyses of data from competition. Experiment (3).*

1000 K weight

Item	Degrees of freedom	Mean square	Variance ratio
Total S. S.	62		
Replicates	7	0.403	4.20**
Sowing dates	1	0.013	—
Fertilizers	3	0.021	—
Error	51	0.096	

Total grain yield

Item	Degrees of freedom	Mean square	Variance ratio
Total S. S.	62		
Replicates	7	0.132	1.53
Sowing dates	1	0.622	7.23**
Fertilizers	3	1.051	12.22**
Error	51	0.086	

Second Generation: Experiment 4.

The second generation was grown from the first generation plants in Tables 3 and 4. Although differences appeared between the fertilizer treatments (Table 10) these were not significant (P 0.20—0.05). There was no significant correlation between them and the 1000 K weights (Table 3) of the seed from which the second generation was grown. The contrast between these results and those of experiment (1) may be due to differences in growing season, or to an additional generation's removal from the parents, or to a combination of these factors.

Table 10. *Total grain yield (gms.) produced by second generation progeny of plants of Wilma and Little Joss grown at two sowing dates with four fertilizer treatments. Mean values over two replicates. Experiment (4).*

Variety	Sowing date	NPK	NP	PK	O	Mean
Wilma	1	21.5	16.16	21.16	17.33	19.04
	2	17.83	13.16	17.16	21.16	17.33
Little Joss	1	17.5	13.5	12.16	17.66	15.20
	2	12.33	14.66	14.83	16.33	14.54
Mean		17.29	14.37	16.33	18.12	

Varietal Means		Sowing Date Means	
Wilma	18.18	1st	17.12
Little Joss	14.87	2nd	15.93

Conclusions

Although information about the induction of long-lasting differences in plants by environmental or other factors is very scanty, some data is available on the effects of 1000 K weight on yield; it would be relevant to mention some of the work here very briefly.

VOELKER (3) obtained data from wheat plants grown singly in pots which suggested that there was no advantage in growing plants from large seed, and, in fact, the tail corn could probably produce more grain and straw. VOELKER's results in wheat do not altogether agree with those of BRENCHLEY (1) in barley; in these studies the plants were grown in water culture, with one plant per bottle. In barley, a steady and considerable rise in the dry weight of the mature plants occurred as the 1000 K weight of the seed which produced these plants increased. It was noted, though, that with prolonged periods of growth, the advantage of the heavier seed was gradually eliminated. WALDRON (4), again working with wheat, found that under field conditions the yield advantage of heavy seed declined as growing conditions improved, and also, as might be expected, as the 1000 K weight differences become smaller.

These exploratory experiments reported in this paper give some evidence that parental fertilizer treatments influence the yield of the progeny in two varieties of winter wheat. This influence is particularly pronounced when the progeny are grown under competitive conditions, where 1000 K weight appears to confer an initial advantage on the seedlings that is maintained to maturity. Under fertile conditions intrinsic 1000 K weight seems to have little effect, but the differences in 1000 K weight produced by the parental fertilizer treatments are negatively correlated with the yield of the offspring. Large differences in yield occur in the second generation which, although not significant, may yet be due to the original parental treatments.

There is no evidence that any carry-over which does occur is not due to a straight maternal effect influencing the size and vigor of the seedlings, which are played upon by the prevailing environmental conditions. The results of these pot experiments cannot be extrapolated to field conditions, but they suggest that field experiments might be undertaken.

Acknowledgements

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Summary

The effects of all combinations of nitrogen, phosphorus and potassium, with two different sowing dates, were studied using two varieties of winter wheat grown in pots. As well as studying the direct effects of these treatments on mean grain weight (1000 K weight) and grain yield, particular attention was paid to investigating any possible after-effects of these treatments in the first and second generations of the treated plants.

The fertilizer treatments were applied in liquid form to the two varieties at intervals during the growing season. Seed was taken from the fertilizer treated plants and sown in uniform soil of high fertility. Grain yield and 1000 K weight were recorded from the treated plants and from their offspring (first generation) grown in the uniform soil. A second generation of offspring was grown in uniform soil with seed taken from the first generation.

Potassium had a depressant after-effect on grain yield in one of two tests with the first generation offspring. There were no significant after-effects in the second generation. The 1000 K weight of seed from the treated plants in one of two tests was negatively correlated with the grain yield of the first generation plants grown from this seed. Highly significant yield differences were obtained among the first generation offspring when offspring from plants differently treated were crowded together in pots and competition was presumably severe.

Zusammenfassung

Die Wirkung aller Kombinationen von Stickstoff-, Phosphor- und Kali-Gaben mit zwei verschiedenen Aussaatterminen wurde an zwei in Gefäßen angezogenen Winterweizensorten untersucht. Die Prüfung erstreckte sich auf die direkte Wirkung dieser Behandlungen auf das durchschnittliche Korngewicht (Tausendkorngewicht) und den Kornertrag, besonders aber auf etwaige Nachwirkungen in der 1. und 2. Generation.

Die beiden Sorten erhielten die Düngergaben in flüssiger Form in bestimmten Zeitabständen während der Wachstumsperiode. Kornertrag und Tausendkorngewicht der behandelten Pflanzen und ihrer Nachkommenschaft (1. Generation), die aus Samen der behandelten Pflanzen in einheitlichem, gutem Boden angezogen wurde, werden mitgeteilt. Aus Samen der 1. Generation wurde noch eine 2. Generation aufgezogen.

Bei der 1. Generation zeigte sich in einem von zwei Versuchen eine depressive Nachwirkung des Kaliums auf den Kornertrag, in der 2. Generation jedoch blieben signifikante Nachwirkungen aus. Das Tausendkorngewicht der Samen der behandelten Pflanzen war in einem von 2 Versuchen mit dem Kornertrag der aus diesen Samen aufgewachsenen Pflanzen der 1. Generation negativ korreliert. Hochsignifikante Ertragsdifferenzen ergaben sich in der 1. Generation, wenn die Nachkommenschaften verschieden behandelter Pflanzen im Gemisch in Gefäßen kultiviert wurden und die Konkurrenz vermutlich stark war.

Literature

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Monogerme Zuckerrüben, ihre Genetik, Züchtung und Bedeutung für den Zuckerrübenbau*

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Mit 4 Abbildungen

Die steigenden Preise am internationalen Zuckermarkt zeigen, daß der Zuckerverbrauch schneller wächst als die Produktion. Während die Zuckerrübenflächen der Sowjetunion und der Vereinigten Staaten von Nordamerika in den letzten Jahren wesentlich vergrößert wurden, hindert in Europa der immer größere Mangel an landwirtschaftlichen Arbeitskräften eine Ausweitung der Anbauflächen. Nur eine Vollmechanisierung, vor allem eine Mechanisierung der mühevollen mit der Hand durchgeführten Vereinzelungsarbeiten kann dieses Problem lösen! Voraussetzung hierfür ist der Anbau von monogermem Rübensaatgut.

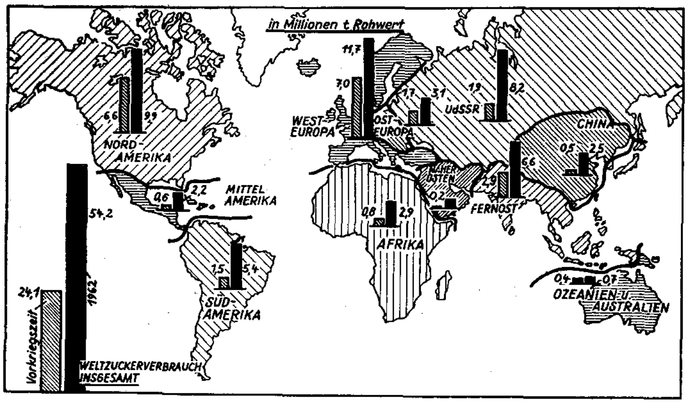

Abb. 1. Weltzuckerverbrauch — Zentrifugalzucker (1934/38 und 1962). Der Weltzuckerverbrauch ist seit der Vorkriegszeit (1934/38) um mehr als das Doppelte gestiegen; neben der Bevölkerungszunahme ist dies vor allem auf das schnelle Ansteigen des Zuckerverbrauches in der UdSSR und den Entwicklungsländern zurückzuführen. (Aus: BARTENS-MOSLOFF: Zuckerwirtschaftliches Taschenbuch 1963.)

Während in den Vereinigten Staaten heute fast ausschließlich genetisch monogermer Samen gebaut wird und in der Sowjetunion über eine Million Hektar mit monogermen Sorten bestellt wird, konnten sich in Westeuropa die genetisch monogermen Sorten noch nicht durchsetzen. Die amerikanischen und russischen Monogermen haben hier versagt, und man mußte sich mit mechanisch erzeugtem Präzisionssaatgut begnügen. Heute wissen wir, daß dies nur eine Zwischenlösung sein kann: auch in Europa gehört die Zukunft den genetisch-monogermen Rüben!

In der Sektion *vulgares* der Gattung *Beta* stehen die kleinen zwittrigen Blüten in den ährigen Blütenständen in Gruppen zusammen und verwachsen zu einem Rübenknäuel, einer Sammelfrucht mit 1—5 Samen. Die aus einem solchen Knäuel erwachsenden Pflanzen stehen eng und oft miteinander verflochten beisammen und müssen mit der Hand vereinzelt werden, was nicht nur viel mühsame Handarbeit verlangt, sondern zu einer Beschädigung der belassenen Rüben und zu einer Unterbrechung ihrer Entwicklung führt, die besonders ertragsdrückend wirkt, wenn man sich mit dem Vereinzeln verspätet. Bedenkt man, daß mindestens 90% der aufgegangenen Rüben beim Vereinzeln entfernt werden müssen und diese große Nährstoffmengen den belassenen Jungpflanzen entziehen, dann ist es klar, daß die Züchtung monogermer Rüben einem alten Wunsch entspricht.

Lange aber wurde die Knäuelfrüchtigkeit der Rübe als eine artspezifische Gegebenheit betrachtet und in dem Versuch, einkeimige Rüben zu züchten, sah noch FRUWIRTH eine Utopie, die nie erreicht werden könnte.

Da es aber in der Gattung *Beta* Arten mit einzelstehenden einsamigen Früchten gibt, ließ die Theorie VAVILOVS über Parallelvariationen die Entstehung einzelfrüchtiger Mutanten in unseren Kulturrüben als möglich erscheinen.

Tatsächlich führte eine gigantische Suchaktion sowjetischer Forscher im Anfang der dreißiger Jahre zur Auffindung monokarper Zuckerrüben. Unter mehr als 22 Millionen untersuchten Samenrüben

Tabelle 1. *Zusammenhang zwischen Gewicht der einzelnen Samen eines Knäuels und dem der daraus erwachsenen Rüben.*
(Aus: KOLOMIEC, O. K., 1956.)

Gewicht des einzelnen Samens (mg)	5.2	4.0	3.1	2.0	1.5
Rübengewicht (g)	503	423	326	270	150

Selbst im Falle einer idealen Segmentierung des Knäuels in seine einzelnen Teile wären diese nicht gleichwertig.

* Nach einem Vortrag, gehalten auf der Arbeitstagung der Vereinigung österr. Pflanzenzüchter in Gumpenstein 1963.