Vitis 12, 207—213 (1973)

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Use of nitrogen and potassium reserves during growth of grape vine cuttings

by

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Die Nutzung von Stickstoff- und Kaliumreserven beim Wachstum von Rebstecklingen

Zusammenfassung. — Einaugenstecklinge von Rebenholz, das sich in der Ruhephase befand, wurden analysiert, um die relativen Mengen von löslichem und unlöslichem Stickstoff und von Kalium zu bestimmen, die im Rinden- und Holzteil bzw. Nodus und Internodium eingelagert waren. In Nährlösungen, die entweder vollständig waren oder in denen N oder K fehlten, wurden Stecklinge angezogen und an ihnen ermittelt, in welchem Ausmaß diese Elemente für das Wachstum neuer Sprosse und Wurzeln genutzt wurden.

Wuchsen die Stecklinge 10 Wochen lang ohne zusätzlichen Stickstoff, so wurden 87% des löslichen und 43% des unlöslichen Stickstoffs für das neue Wachstum genutzt. Bei unbeschränktem Vorrat an Düngerstickstoff wurden 82% des löslichen und 20% des unlöslichen Stickstoffs für das neue Wachstum während derselben Periode genutzt. Selbst in Reben, die ausreichend mit Dünger-Stickstoff versorgt waren, wurde vorzugsweise der im Holz eingelagerte Stickstoff für das neue Wachstum verwendet.

Rebstecklinge, die 10 Wochen lang ohne zusätzliches Kalium wuchsen, nutzten 48% der Kalium-Reserve in dem ruhenden Rebholz für die Entwicklung neuer Sprosse und Wurzeln. In die Sprosse wurde fünf mal so viel Kalium wie in die Wurzeln befördert. Nach einem Kalium-Zusatz zur Nährlösung stieg der Kaliumgehalt im Stecklingsholz (Ausgangsholz) gegenüber dem im Ausgangsstück, wobei gleiche Mengen in Sprosse und Wurzeln befördert wurden. Es hat den Anschein, als ob bei der Bildung neuer Sprosse und Wurzeln das eingelagerte Kalium — im Gegensatz zum Stickstoff — nicht bevorzugt verwertet würde.

Introduction

A number of studies have been made of the storage and utilization of the reserves of nitrogen and potassium in fruit trees and grape vines. Studies on both young and mature peach trees indicate that soluble organic forms of nitrogen provide the bulk of the nitrogen reserve in this plant (Taylor 1967 a, 1967 b, Taylor and May 1967, Taylor and van den Ende 1969). For apples Oland (1954, 1959) also concluded that nitrogen is stored mainly in soluble organic form. However, both these workers suggest that insoluble nitrogeneous compounds can also act as reserves.

In a study of seasonal fluctuations of total nitrogen content of Sultana vines grown under field conditions in Australia, Alexander (1957) found that total nitrogen in the annual aerial growth accumulated until leaf fall or fruit removal. From the commencement of leaf fall in January there was an accumulation of nitrogen in roots and trunks until July. Kliewer (1967) described seasonal changes in both soluble and insoluble nitrogen in 5 year-old vines growing in the field under Californian conditions. He found that the concentration of free amino acids increased in roots,

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canes, trunk wood and buds immediately before bud burst, and he suggested that these may have been formed from stored proteins. This suggestion was supported by a decrease in the percentage of insoluble nitrogen in the roots and woody tissues during this period.

In sand culture experiments with Concord grape vines BERGMAN *et al.* (1958) found that the level of potassium in canes varied closely with nutrient level. At low-, standard-, and high nutrient levels they found 0.30, 2.37 and 2.82 percent potassium respectively in canes after a 16 week growing period. WINKLER (1962), reported that mature canes of field grown grape vines have a potassium content of about 0.25 percent.

This paper describes experiments in which data were obtained on the changes that occur in both nitrogen and potassium when dormant one year old vine canes were grown into small plants. Information was assembled on the distribution of and extent to which the stored, soluble and insoluble nitrogen compounds and potassium, can be utilized for spring growth.

Materials and Methods

1. Nitrogen experiment: Single-node cuttings (6th and 7th nodes) were collected from one year old canes of field grown vines, *Vitis vinifera* cv. Sultana. The cuttings were planted in perlite and rooted with bottom heat. After two weeks when buds had burst, the cuttings were separated into two visually equal sets of 8 plants and maintained in a glasshouse in which the temperature was controlled between 20 and 30° C. One set was supplied with fertilizer nitrogen for the ensuing eight weeks by adding 25 ml of Hoagland solution (HOAGLAND and ARNON 1950) twice weekly to each pot (+N treatment). The other group of plants was provided twice weekly with 25 ml of a Hoagland solution lacking nitrogen (—N treatment). The plants were watered daily with distilled water.

Ten weeks after planting cuttings into perlite the plants were harvested and dry weights of shoots, canes (original cuttings) and roots taken. The shoots, canes and roots of the harvested plants together with ten replicate dormant cuttings were analysed for both soluble and insoluble nitrogen. Samples of bark and wood of both nodal and internodal tissues from a further set of dormant cuttings were also analysed for soluble and insoluble nitrogen. Nitrogen was determined by a modified Kjeldahl method essentially similar to that described by BROWN and POSSINGHAM (1957).

2. Potassium experiment: The single-node cuttings used in this experiment were also collected from dormant field grown Sultana vines. To provide information about the potassium content of the original cuttings, a sample composed of the nodes proximal and distal to each selected cutting was taken from the same cane and analysed. The potassium content of this sample was taken as the content of the selected cutting. The cuttings, which were grown in a mixture of washed river sand and quartz gravel, were initially kept in a cold room and supplied with bottom heat until roots commenced growing. They were then transferred to a glasshouse in which the temperature was controlled between 20 and 30° C.

Based on the assessed potassium levels the selected cuttings were divided into two groups having similar potassium contents. One group of plants was supplied with complete Hoagland nutrient solution and the other with an equal volume of nutrient solution lacking potassium (HOAGLAND and ARNON 1950).

The plants were harvested after a total growth period of 10 weeks at which stage the plants which had not received supplemental potassium showed severe

Table 1

Distribution of dry weight and of soluble, insoluble, and total nitrogen between shoot, cane and root in 10 week old Sultana vines grown with either complete nutrients (+N) or in nutrient lacking nitrogen (—N)

Verteilung des Trockengewichtes sowie des löslichen, unlöslichen und gesamten Stickstoffes auf neuen Sproß, Stecklingsholz und Wurzel bei 10 Wochen alten Sultana-Stecklingen, die entweder in vollständiger (+N) oder in stickstofffreier (—N) Nährlösung gezogen worden waren

	Initial cutting[1]	Ten week old vines[2] —N	Ten week old vines[2] +N	L.S.D. $P < 0.05$
Dry weight (g/vine)				
Shoot		0.52	1.72	0.12
Cane	1.95	1.99	2.04	N.S.
Root		0.51	1.20	0.11
Total	1.95	3.02	4.96	0.21
Soluble N (mg/vine)				
Shoot		0.61	2.44	0.23
Cane	7.83	1.02	1.40	0.30
Root		0.44	1.08	0.13
Total (mg/vine)	7.83	2.07	4.92	0.33
percent	.402	.069	.096	
Insoluble N (mg/vine)				
Shoot		5.39	26.60	1.95
Cane	8.26	4.69	6.60	0.48
Root		3.37	11.01	0.73
Total (mg/vine)	8.26	13.45	44.21	0.90
percent	.424	.445	.862	
Total N (mg/vine)	16.09	15.52	49.13	1.45
percent	.826	.514	.958	

[1]) Mean of 10 replicates.
[2]) Mean of 8 replicates.

potassium deficiency. Dry weight of shoots, canes, and roots on each vine were measured and samples of these plant parts were analysed for potassium.

Two separate samples of single node cuttings similar to those used in the experiment were separated into bark and wood and into node and internode, and samples of this material were analysed for potassium.

Results

Nitrogen experiment: In the initial cuttings the ratio of soluble to insoluble nitrogen was almost 1 : 1 but in the 10 week old plants insoluble nitrogen far exceeded soluble nitrogen in all tissues (Table 1). Although total nitrogen in the +N vines was almost three times that in the —N vines the distribution between soluble and insoluble was similar for both.

During growth the total amount of soluble nitrogen decreased in both the —N and +N plants from approximately 8 mg in the initial cutting to 2 and 5 mg in

—N and +N plants respectively. By contrast the total insoluble nitrogen content of both the —N and +N plants was higher than that of the initial cutting.

In the cane the amount of insoluble nitrogen decreased from approximately 8 mg in the initial cutting to approximately 5 and 7 mg in the —N and +N plants respectively. The higher content of insoluble nitrogen in +N vines was mainly in shoots and roots as cane contents were very little different from those of —N vines. The distribution of dry matter and of soluble and insoluble nitrogen between bark and wood and between node and internode is shown in Table 2.

Table 2

Distribution of dry weight and total, soluble, and insoluble nitrogen and of potassium in the bark and wood of nodal and internodal tissue of dormant Sultana vine canes
Verteilung des Trockengewichtes, des gesamten, löslichen und unlöslichen Stickstoffes sowie des Kaliums auf Rinden- und Holzteil von Nodus- und Internodiengewebe ruhender Sultanaruten

	Total	Bark		Wood		L.S.D.
		Node	Internode	Node	Internode	$P < 0.05$
Dry weight (g)[1]	4.83	0.32	1.16	0.69	2.66	0.31
Total N (mg)[1]	38.10	2.83	8.79	5.74	20.74	
percent	.788	.884	.757	.832	.779	NS
Sol. N (mg)	20.08	1.10	2.78	3.23	12.96	
percent	.415	.344	.239	.468	.487	.063
Insol. N. (mg)	18.02	1.73	6.01	2.51	7.78	
percent	.373	.540	.518	.364	.292	.040
L.S.D. $P < 0.05$						
percent	.057	.056	.036	.058	.056	
Potassium[2])						
percent	.520	.587	.589	.549	.465	

[1]) Means of 8 replicates.
[2]) Means of 2 replicates.

The cuttings used in this part of the nitrogen experiment were larger than those used to provide plants. The nitrogen content of both cuttings have been presented on a percent dry weight basis to permit comparisons between the two groups. The percentage of total nitrogen was similar in wood and bark of both node and internode. However, the percentage of soluble nitrogen was lower and that of insoluble nitrogen was higher in bark than in wood. In bark soluble nitrogen was higher in the node than in the internode whereas their content in wood did not differ significantly between node and internode. By contrast the insoluble nitrogen content of both wood and bark were higher in the node than in the internode.

Potassium experiment: The results (Table 3) indicate that potassium addition had little effect on dry matter production of vine cuttings, although it had a marked effect on the potassium content of the various plant parts. Plants provided with potassium contained more potassium in each plant part. The effect was most striking in roots where the difference in K level was more than 17 fold whereas in shoots and canes the difference was only 4 and 2 fold respectively.

When potassium was not provided approximately half of the stored potassium of the original cutting was utilized for growth and translocated from the cane to the

Table 3

Distribution of dry weight and of potassium between shoot, cane and root in Sultana vines grown from cuttings in either complete nutrient (+K) or nutrient lacking potassium (—K)

Verteilung des Trockengewichtes und des Kaliums auf neuen Sproß, Stecklingsholz und Wurzel bei Sultanareben aus Stecklingen, die in vollständiger (+K) oder in kaliumfreier (—K) Nährlösung gezogen worden waren

Plant part	Initial cutting[1])	Ten weeks old vines[1])		L.S.D.
		—K	+K	$P < 0.05$
Dry weight (g/vine)				
Shoot		1.09	1.11	NS
Cane	2.34	2.03	2.02	NS
Root		0.50	0.67	NS
Total	2.34	3.62	3.80	
K content				
Shoot (mg/vine)		5.30	21.60	4.45
percent		.486	1.946	
Cane (mg/vine)	12.8	6.60	14.20	1.81
percent		.325	.703	
Root (mg/vine)		1.10	19.00	3.68
percent		.220	2.836	
Total (mg/vine)	12.8	13.00	54.80	5.06
percent	.547	.359	1.442	

[1]) Mean of 12 replicates.

developing shoots and roots. The majority of the potassium transported from the cane was transferred to the shoot and only a small proportion (17%) to the root.

The distribution of potassium between bark and wood of node and internode is given in Table 2. The percentage was higher in bark than in wood. There was no difference between bark of node and internode, but there was more potassium in node wood than internode wood.

Discussion

In our experiments with small cuttings where it was possible to assemble total balances, we have been able to demonstrate that up to 65 percent of the nitrogen and up to 48 percent of the potassium in dormant vine canes can be reutilized for the formation of new shoots and roots.

The total nitrogen content of the cuttings used in these experiments was similar to that found in Sultana vine canes immediately before budburst by Alexander (1957) in Australia and Kliewer (1967) in California. The concentrations of soluble and insoluble nitrogen in the initial cuttings differed only slightly from the values reported by Kliewer (1967) with his field trials.

Our results indicate that both the soluble and insoluble nitrogen are reutilized. Furthermore it seems clear that even when adequate fertilizer nitrogen is supplied the nitrogen reserves of the cane are preferentially utilized for the growth of new shoots and roots. While there is a greater reutilization of soluble nitrogen, it is clear that insoluble nitrogen can also be broken down for growth. It is suggested that the situation is analogous in some respects to that of the carbohydrate reserves of grape vines where in late winter the starch of canes is converted to sugar which is used for spring growth (WINKLER and WILLIAMS 1945, BUTTROSE 1966).

The potassium content of the cuttings in our experiment was higher than that in mature vine canes described by WINKLER (1962). By contrast WILHELM (1950) and GÄRTEL (1960) report lower potassium contents in the canes of one-year-old vines than we found. However, the potassium levels (0.325%) in the canes of the vines not receiving supplemental K in the present experiments, were similar to the levels reported by other workers as typical for K deficient vines. For example GÄRTEL (1960) found deficiency levels varied between 0.22 and 0.37 percent while BERGMAN *et al.* (1960) found depressed growth of vines occurred when the potassium content fell below 0.27 percent.

A surprising feature of the present experiments with small cuttings was the lack of a response in terms of dry weight to potassium. A more positive growth response may have been obtained had the vines been grown for a longer period as at the 10 week harvest the —K plants displayed visual symptoms of severe K deficiency.

It seems clear that the K reserves of vine cuttings can also be used for new growth, especially of shoots and to a lesser extent roots. However, there was no evidence from the present experiment that the potassium reserves of cuttings are used preferentially for growth when adequate levels of fertilizer are provided.

It is of interest that the K reserves of the cuttings used in these experiments were sufficient for 10 weeks growth. By contrast the N reserves in the cuttings were insufficient. In these experiments this difference was increased because cuttings for the N experiments were of lower dry weight than the canes used in the K experiment. Nonetheless these data have implications for the growth of vine cuttings in nurseries, where the application of N fertilizers more-so than K fertilizers would be necessary for good growth.

Summary

Single node cuttings of dormant grape vine canes were analysed to determine the relative amounts of soluble and insoluble nitrogen, and of potassium that are stored in bark and wood and in node and internode respectively. The amounts of these constituents that can be utilized for the growth of new shoot and roots were determined in experiments in which cuttings were grown in nutrient solutions which were either complete or lacking in nitrogen or potassium.

When cuttings were grown for ten weeks with no added nitrogen 87 percent of the soluble nitrogen and 43 percent of the insoluble nitrogen was utilized for new growth. When cuttings were grown with an unrestricted supply of fertilizer nitrogen 82 percent of the soluble nitrogen and 20 percent of the insoluble nitrogen was utilized for new growth during the same period. Even in vines adequately supplied with fertilizer nitrogen, stored nitrogen of the cane is used preferentially for new growth.

Vine cuttings grown for ten weeks with no supplemental potassium utilized 48 percent of the potassium reserve in the dormant cane for the growth of new shoot and roots. The amount translocated to the shoots was five times the amount transferred to roots. When supplemental potassium was supplied in the nutrient solution the potassium level in plant canes (initial cutting) was increased relative to that in the original cutting with equal amounts being translocated to both shoots and roots. It would appear that in contrast to nitrogen, stored potassium is not used preferentially for the growth of new shoot and roots.

Acknowledgements

The authors thank Mr. K. Cellier, CSIRO Division of Mathematical Statistics, Adelaide, for statistical analyses, and the Australian Mineral Development Laboratories, Adelaide, and Mr. T. Buckingham, CSIRO Division of Horticultural Research, Merbein, for potassium analyses.

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Eingegangen am 21. 12. 1972

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