(approximately 4930 g) the following year, a considerably better than normal yield.

Stock-scion interactions. All combinations of 4 highbush cultivars on 2 rabbiteye stocks were successfully grown, but certain scions performed better on one stock than the other after 4 or 5 seasons at Castle Hayne (Table 5). 'Angola' grew significantly taller on 'Homebell' than on 'Garden Blue' stock whereas 'Croatan' and 'Murphy' were significantly taller on 'Garden Blue' stock. 'Angola' and 'Wolcott' produced plants of about equal width on either stock; 'Croatan' and Murphy' were slightly broader on 'Garden Blue' than 'Homebell' stock. All cultivars produced fewer canes on 'Homebell' than on 'Garden Blue' stocks. Using flower buds per plant as a measure of potential productivity, 'Wolcott' should have produced better grafted on 'Homebell' than on 'Garden Blue' because of its larger number of fruiting shoots per cane. The other 3 cultivars were expected to yield better on the 'Garden Blue' stock. These expectations were confirmed by the weighed yield per bush during the 5th year.

However, blueberry yield measured by weight is determined by the factors fruit number and fruit size, both weighted by the proportion of crop ripe at a given time. The fruit size component was not evaluated. 'Angola' and 'Wolcott' had a higher fruit number on the 'Homebell' stock and 'Croatan' and 'Murphy' had more fruits on the 'Garden Blue' stock. These differences in fruit number seemed related more to the number of fruiting shoots and fruit clusters per shoot than to the number of berries per cluster.

The scion cultivar performances with respect to each other did not change appreciably as a result of grafting. The differential responses of blueberry scions to different rootstocks was similar to those reported for persimmons, apples, plums, and grapes (6).

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Evaluation of the Potassium Nutrient Status of Seedling Lettuce by Plant Analysis[1]

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Abstract. Lettuce seedlings were grown in a modified Hoagland's solution at concentrations of 0.03 to 8.0 mM/liter of K. In the low K solutions the lettuce seedlings developed K deficiency symptoms which were atypical in that chlorosis followed by random necrotic lesions were the predominant symptoms while the typical symptom of marginal scorch did not develop. Tissue levels of K in 13 day-old deficient seedlings (thinning stage of development) dropped to a low of 0.3% K. The critical level for the evaluation of the K nutrient status in the conductive, lamina, and root tissue were respectively: 2, 1.8 and 1.3% K on a dry wt basis. Seedling lettuce was reduced in yield (weight) when the concentration of K remaining in the culture solution at harvest time was less than 0.01 mMK and they were unable to reduce the concentration of K below 0.001 mMK.

The success of mechanization of the lettuce industry depends on the ability to produce uniform growth throughout the season, beginning with the seedlings stage. One of the factors influencing uniformity is nutrition, which has to be continuously evaluated and cultural practices designed to maintain adequate nutrition throughout the entire growth period. Although plant analysis is commonly used as a tool to determine the nutrient status of lettuce, there is a paucity of information on young plants. Tyler and Lorenz (6) have established critical levels for evaluating the nutritional status of N, P, and K in mature lettuce tissue. Other workers (5, 9) who have developed criteria for determining the nutrient status of plants generally, defined the critical level in terms of the mature tissue. The extrapolation of this information to old tissue or in the opposite direction to young or meristematic tissue is not valid. Therefore, the objective of this paper is to develop criteria for evaluating the K nutritional status of seedling lettuce by means of plant analysis.

Materials and Methods

Seeds of lettuce (*Lactuca sativa* L. cv. Calmar) were imbibed in a 1:20 dilution of Hoagland's solution (3) modified by adding NaCl at the rate of 0.5mM/liter. One gram of seed per liter of solution was used. The seeds had been sized such that the width was greater than 1.102 mm and the density (wt) between 0.83 and 1.03 mg/seed. After imbibing for 6 hr the seeds were spread on a saran screen which was floated on a large volume of fresh 1:20 nutrient solution. For germination they were then placed in an incubator with a day temp of 23°C and a night temp of 20°C. The day length was 16 hr at 500 ft-c. Four days after the seeds were imbibed, when the cotyledons were fully expanded, the seedlings were transferred to 10 cm X 10 cm X 15 cm acrylic containers that contained 200 cc of nutrient solution.

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The solution in each container was constantly aerated and mixed with an air pump. Nine seedlings supported on a styrofoam float were placed in each acrylic container. These containers were placed in a growth chamber with the following environmental conditions: light 3300 ft-c, day length 16 hr, day temp 23°C, night temp 20°C, and an ambient RH of 45%.

The culture solution was a modified Hoagland's solution. At the start of the experiment the culture solution had the following composition, expressed in millimoles per liter: 3.75 $Ca(NO_3)_2$, 1.0 $Ca(H_2PO_4)_2$, 0.5 NaCl and 1.0 $MgSO_4$. Micro elements in mg per liter were 0.25 B, 0.25 Mn, 0.025 Zn, 0.01 Cu and 0.005 Mo. Iron, 2.5 mg per liter, was added as the ferric ammonium ethylenediamine tetraacetate complex (4). A second addition of these salts in concentrated form was added to the original solution on the seventh day after imbibing. There were 9 K treatments from 0.0313 mM K/liter to 8 mM K/liter in increasing steps that differed by a factor of 2 (Table 1). The potassium treatments were added on K_2SO_4. Water loss due to transpiration or evaporation was made up daily with redistilled water.

progressively appeared on the higher K treatments up through treatment 4. The symptoms which appeared as the result of K stress were somewhat atypical from the usual visual symptoms denoting K deficiency (2). The expected marginal scorch was not present even when the plants were severely afflicted. The symptoms commenced as a general overall chlorosis of the cotyledon leaves. Chlorosis became more acute as the deficiency progressed and necrotic lesions appeared. Necrotic areas appeared first on the distal end of the leaf and progressed to the proximal end. The necrotic lesions occurred randomly over the surface of the leaf but the interveinal areas were somewhat more severely afflicted. In extreme K stress, the leaves were chlorotic and densely covered with necrotic lesions.

The relationship of K supply to seedling growth is given in Table I. Where the supply of K was small the yield (fresh wt) of the seedling lettuce was also small. As the supply of K was increased the yield (weight) of the lettuce increased until treatment 7 was reached. Further increase in K supply (treatments 8-9) did not result in further increases in the yield of lettuce. The appearance of visual K deficiency symptoms, except for a small lag, was associated with the observed yield. These symptoms were found in treatments 1-4 with decreasing severity, indicating that these treatments were under K stress, but did not appear in treatments 5-9. The lack of visual symptoms in treatments 5-7 where a yield decrease occurred, reinforces the general conclusion that visual symptoms are relatively insensitive.

Table 1. Effect of K supply on fresh and dry weight of lettuce seedlings.^{x,y}

Treat. no.	K supply mM/liter	K supply mg/pot	Fresh wt Tops mg/pot	Fresh wt Roots mg/pot	Dry wt Tops mg/pot	Dry wt Roots mg/pot	Total dry wt mg/pot	% Dry wt Tops	% Dry wt Roots
1	0.0313	2.5	740^{a}	473^{a}	84^{a}	26^{a}	110^{a}	11.4^{ab}	5.5^{d}
2	0.0625	5	1018^{ab}	671^{a}	119^{ab}	38^{a}	156^{a}	11.8^{a}	5.7^{cd}
3	0.125	10	1461^{bc}	994^{b}	158^{bc}	59	217^{b}	10.8^{abc}	5.9
4	0.250	20	1706^{c}	1199^{b}	180^{c}	73	252^{b}	10.5^{bc}	6.1^{bc}
5	0.500	40	2610	1482^{c}	301^{d}	112^{b}	413^{c}	11.4^{ab}	7.5^{a}
6	1.00	80	3225	1556^{cd}	316^{de}	105^{b}	422^{c}	9.7^{dc}	6.7^{a}
7	2.00	160	4052	1825^{d}	358^{ef}	117^{b}	475^{cd}	8.8^{d}	6.4^{b}
8	4.00	320	5488^{d}	2131^{e}	408^{fh}	107^{b}	521^{de}	7.4^{e}	4.9^{e}
9	8.00	640	5988^{d}	2379^{e}	439^{h}	105^{b}	544^{e}	7.4^{e}	4.4^{e}

^{x}All values are means of 5 replications.

^{y}Means with a common letter denote homogeneous subsets at 5% level.

At harvest, 13 days after imbibition (when the plants were at the thinning stage of development, 5 cm in size) the plants in each acrylic chamber were separated at the cotyledonary node into tops and roots, and fresh weights were taken. The tops were then separated into lamina and conductive tissues. The conductive tissue consisted of the petiole and midribs of each leaf. The plant material was dried at 80°C in a forced air oven. The total dry sample was weighed, dried and ashed at 500°C. The procedure of Berry and Johnson (1) was used for cation analysis by atomic absorption spectroscopy.

Table 2. Potassium in plant tissues at harvest.^{x,y}

Treat. no.	Lamina % K	Conductive % K	Root % K
1	$.34^{a}$	$.63^{a}$	$.57^{a}$
2	$.42^{a}$	$.55^{a}$	$.58^{a}$
3	$.60^{a}$	$.94^{a}$	$.66^{a}$
4	$.75^{a}$	1.16^{a}	$.83^{a}$
5	$.92^{a}$	1.19^{a}	$.81^{a}$
6	1.95	2.73	1.21^{a}
7	3.19	4.78	1.63
8	6.42^{b}	8.09	4.27
9	6.76^{b}	8.99	7.90

^{x}All values are means of 5 replications on dry wt basis.

^{y}Means with common letter denote homogeneous subsets at 5% level.

Results and Discussion

The plants in all treatments continued to grow well after the transfer from the complete germinating solution to the culture solution until the 8th day when growth differences were noted between the high and low K treatments. Visible symptoms of K deficiency other than growth difference were not observable until the 11th day. The symptoms first showed up on the lowest K treatment and on succeeding days similar symptoms

The dry wt percentages of the tops were higher under low levels of K supply (Table 1). This was associated with the occurrence of the deficiency symptoms. However, the dry wt percentage of the roots reached a peak at treatment 5 and fell off in both the higher and lower treatments.

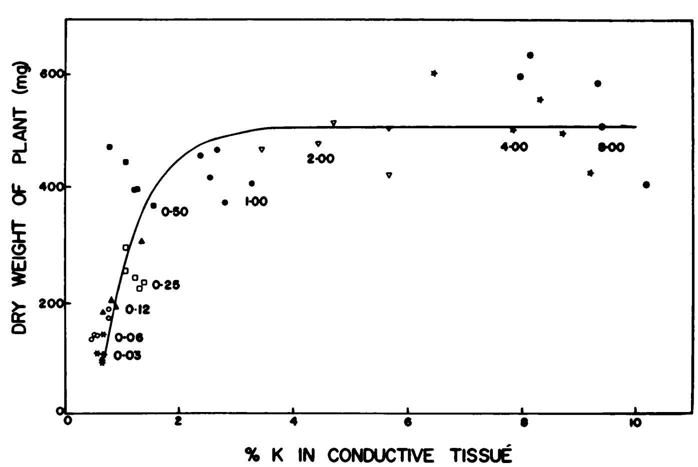

Fig. 1. Relationship of dry weight of lettuce seedlings to K percentage in the conductive tissue. The numbers in the graph refer to mM/liter of K added as K_2SO_4. The critical K level is about 2% K at 10% reduction of growth.

The plant nutrient calibration curves given in Figs. 1-3 relate yield to the K concentration in the lamina, conductive and root tissues. In Fig. 1 it can be seen low yields are related to low concentration of K in the conductive tissue. It can also be seen that this is associated with low K supply. Starting with the points of the lowest K supply in treatment 1 (0.0313 mM K/liter), there is an associated increase in yield as the K supply is increased. The increase in yield associated with increasing K supply is continuous through treatment 7 (2 mM K/liter). However, there is no appreciable increase in the K content of the tissue resulting from this increase in K supply. Thereafter, increasing the K supply does not significantly increase the yield but instead increases the K content of the tissue. The resulting curve is a typical plant nutrient calibration curve containing the 3 characteristic zones: a) the zone of the deficiency with a steep, almost vertical slope, b) the zone of adequacy with a horizontal slope, and c) the transition zone between the 2 previous ones. If the critical level is defined as the K concentration in the tissue associated with a 10% reduction in yield (7), the critical nutrient level for this tissue would be 2% K on a dry wt basis.

The yield-concentration curves for the other 2 tissues, lamina and root tissue, shown in Figs 2 and 3, have the same general shape, only the transition zone is sharper. If the same 10% yield reduction is used as the criteria for establishing the critical level, these 2 tissues, respectively, have critical levels of 1.8% and 1.3% K on a dry wt basis. The similarity of the nutrient calibration curves for the lamina and conductive tissue indicate that a relative small error would be introduced if 2% K was used as the critical level for the whole tops.

The 2% K critical level reported here should not be confused with the same numerical value reported by Tyler and Lorenz (6) as the critical level for the midrib of mature lettuce at heading time. The value reported here refers to a constant reference critical concentration as defined by Ulrich and Hills (8) and not to the declining critical level used by Tyler and Lorenz (6).

This type of experiment also gives additional information on the effectiveness of K absorption by seedling plants. In Fig. 4 the yield is plotted against the concentration of K remaining in the culture solution at harvest time. This plot gives a measure of the seedling's ability to utilize K from nutrient solution. Under the conditions of this experiment the plants showed a yield decrease wherever the culture solution contained less than 0.01 mM of K. Where the plants had remained in the culture solution for a period of time after they became deficient (treatments 1-4) they were able to further reduce the concentration of K to 0.001 mM K/liter.

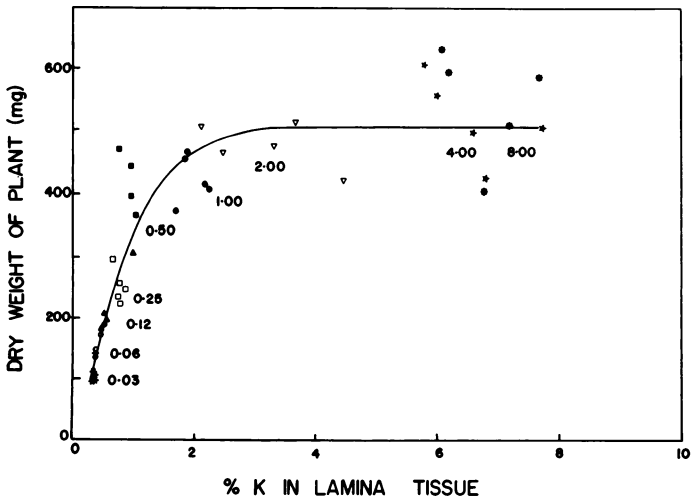

Fig. 2. Relationship of dry weight of lettuce seedlings to K percentage in the lamina tissue. The numbers in the graph refer to mM/liter of K added as K_2SO_4. The critical K level is about 1.8% K at 10% reduction of growth.

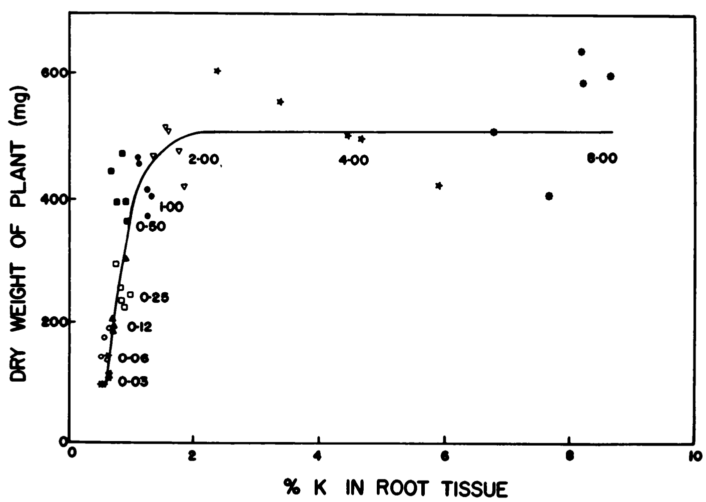

Fig. 3. Relationship of dry weight of lettuce seedlings to K percentage in the root tissue. The numbers in the graph refer to mM/liter of K added a K_2SO_4. The critical K level is about 1.3% K at 10% reduction of growth.

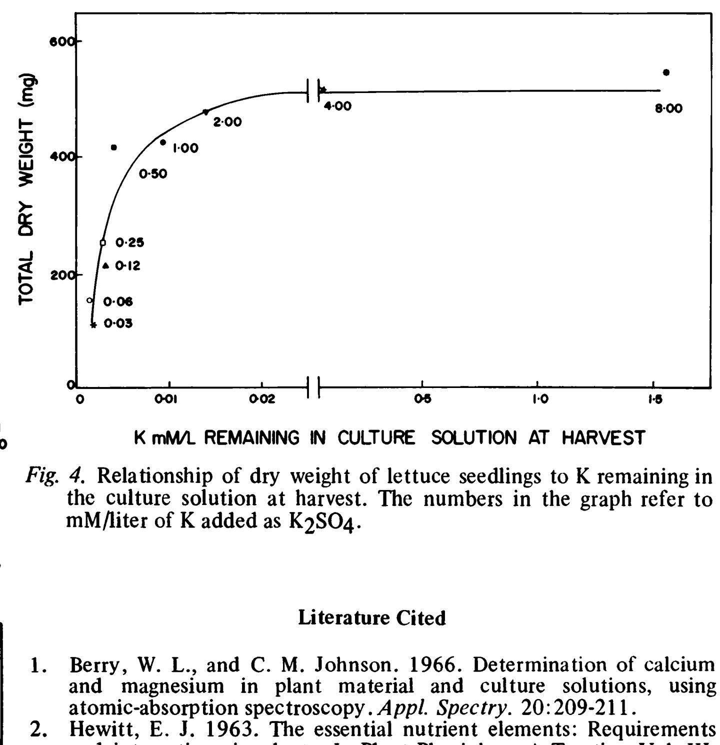

Fig. 4. Relationship of dry weight of lettuce seedlings to K remaining in the culture solution at harvest. The numbers in the graph refer to mM/liter of K added as K_2SO_4.

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