

eKonomics

K Photosynthesis



PotashCorp

Growth and CO₂ Assimilation by Corn as Related to Potassium Nutrition and Simulated Canopy Shading¹

A. E. Smid and D. E. Peaslee²

ABSTRACT

Radiant flux density and K are potentially limiting factors in CO₂ assimilation by corn leaves having the common property of being more accessible to the upper leaves than to lower leaves of the plant canopy. In this experiment, the effects of K nutrition and shading on growth and CO₂ assimilation were evaluated in the absence of confounding factors such as differentials in moisture supply, rooting volume, and availability of other nutrients that often accompany studies having variable plant populations. Corn was grown outdoors in sand cultures receiving solutions containing 15, 45, 135, or 400 µg of K/ml. Plant populations of 33,000, 98,800, and 118,000 plants/ha were simulated by progressive artificial shading of each plant with layers of shade cloth during growth. Rates of CO₂ assimilation by selected leaves, yield of dry matter, and leaf concentrations of K were measured at the silking stage. In general, CO₂ assimilation rates increased with K levels, with simulated population, and with proximity to the plant top. However, these relationships were complex as evidenced by a significant interaction of K × leaf location and K × population × leaf location. The interactions apparently were associated with increases in leaf K concentrations due to less growth with shading and to movement of K from lower into upper leaves under conditions of K stress. Across all treatment combinations, CO₂ assimilation was highly correlated ($r = 0.89$) with tissue levels of K. Thus, the effects of shading and leaf position were indirect through their influence on the concentrations of K in leaf tissue. Measured assimilation rates (mg/hour) at canopy illumination levels for leaves 5, 7, and 9, when the entire leaf surface was considered uniformly photosynthetic provided indices that were highly correlated ($r = 0.96$, significant at the 0.01 level) with yields of dry matter per plant.

Additional index words: Photosynthesis, Critical levels of K, Leaf areas, *Zea mays* L.

POTASSIUM nutrition is usually considered adequate for optimum grain yields when the concentration of K in corn leaves near the ear at time of silk emergence is between 1.5 and 2% (4). At concentrations <1.5%, however, markedly decreased rates of apparent CO₂ assimilation have been observed (3, 11). These decreased rates were related to stomatal resistances (12) and the effect of K on guard cell action (14).

As corn planting densities are increased, average illumination of leaves in the middle and lower canopy is appreciably decreased. It is not surprising that grain yields of individual corn plants were decreased as population was increased (2), since shading of one corn leaf by another can sufficiently reduce illumination to cause a 50% decrease in apparent CO₂ assimilation (8).

Increasing plant populations may cause both light stress and nutritional stress of plants. Total effect of "population stress" upon CO₂ assimilation rates and dry matter accumulation rates per plant is now relatively well documented. However, combined effects of K stress and light intensity stress have received only limited attention. In a study with tomatoes (*Lycopersicon esculentum* Mill.), shading decreased pro-

¹Contribution from the Dep. of Agronomy, Kentucky Agric. Exp. Stn., Lexington, KY 40506. This paper (no. 74-3-70) is published with the approval of the Director of the Ky. Agric. Exp. Stn. Financial assistance from the Am. Potash Inst. is gratefully acknowledged. Received 9 May 1974.

²Former graduate research assistant and professor of Agronomy. The senior author is now instructor of field crops, Ridgetown College of Agricultural Technology, Ridgetown, Ontario, Canada.

duction of dry matter and increased concentration of K in leaf tissue (6). Rice yields (*Oryza sativa* L.), on the other hand, were decreased under shading, but relative yield response to K was greater under shading than under nonshaded conditions (10). Our objectives in this study were to determine effects of light environment and K nutrition on growth and apparent CO₂ assimilation rates in corn.

MATERIALS AND METHODS

Corn (*Zea mays* L., 'Kentucky 105') was germinated in vermiculite and individual seedlings were transplanted outdoors into 11-liter plastic pots containing 16.7 kg of washed Ottawa silica sand. A plastic cover with an opening for a single plant was fitted to the pots which were placed on boards in a randomized, complete block design with three replications. Each replication consisted of 12 pots (three populations; four K levels) which were arranged in four rows, 2.43 m apart. Pots were spaced 2.13 m apart within rows and equidistant from pots in adjacent rows. Plant populations of 33,000, 98,800, and 118,000 plants/ha were simulated by placing single layers of plastic saran (1.52 × 0.41 m) above and at sides of enclosures for leaves 3 to 5, 6 to 8, 9 to 11, and 12 to 13 of each plant (numbered from top of plant) at 56, 49, 46, and 35 days after planting, respectively. Leaves were fully developed when enclosed with shading. Material for each enclosure was selected from six densities of cloth to provide illumination levels in the canopy equal to that required for the three populations. Illumination requirements for enclosures were determined from a graph on which calculated illumination levels in canopies of three nonsimulated populations (17) were plotted against plant population for canopy depths of 0, 50, 100, 150, and 200 cm. Calculated illumination levels were obtained using Monsi's modification of Beer's law as described by Stevenson and Tanner (17) and associating their accumulative leaf area indices with corresponding extinction coefficients in corn canopies. We assumed that the maximum level of incident light was 10.8 lumens/cm². The data of Stevenson and Tanner (17) were extrapolated for estimating values of 118,000 plants/ha.

"Minus-K" nutrient solution (5) was enriched with K₂SO₄ to provide 15, 45, 135, and 400 µg of K/ml of solution. Micronutrients other than iron were supplied from a stock solution (5). Sufficient FeCl₃ to provide 1 µg Fe/ml of solution was mixed with an equal weight of nitrilotriacetic acid in 0.25 N NaOH, and enough FeCl₃ to provide an additional 3 µg of Fe/ml was mixed with an equal weight of N-(carboxymethyl)-N'-(2-hydroxyethyl)-N,N'-ethylenediglycine. These two solutions were added separately to the nutrient solution to provide 4 µg of Fe/ml. The pH of the nutrient solution was adjusted to pH 5 with NH₄OH. The pots were flushed three times daily with nutrient solution.

Illumination of leaves 2, 4, 7, 10, and 12 were measured between solar noon and solar noon + 3 hours by shading the sensor (1-m distance) of a model 756 Weston sunlight illumination meter. A shaded sensor was used to permit a more accurate evaluation of light extinction properties of the canopy. Discontinuity of direct light in a canopy causes difficulty in assigning average illumination values based upon point readings with an unshaded sensor. Apparent CO₂ assimilation rates and K concentrations in leaves 5, 7, and 9 were determined at silking time. Plants were individually transferred to a field laboratory and net CO₂ exchange was measured with an infrared gas analyzer while leaves were receiving radiant flux densities ranging from 0.8 to about 7.5 lumens/cm² of direct light from an incandescent source (11). The leaves were nearly light saturated at 7.5 lumens/cm² under the conditions of our experiment. Different levels of illumination were established by varying the number of layers of nylon screen between the light source and the leaf chamber. From smoothed curves relating CO₂ assimilation rates to illumination levels, rates at specific levels could be estimated. After measurement of CO₂ assimilation, the leaves and the remainder of the plant were harvested and dried at 65 C for 48 hours and ground in a Wiley mill. Potassium concentrations in the leaves were measured with a flame emission spectrophotometer after digesting with a 10:1 nitric-perchloric acid mixture, evaporating a dryness, and dissolving the residue in 1 N HCl.

Table 1. Illumination from diffuse, scattered light measured within the canopies of simulated corn plant populations.

Simulated population plants/ha	Leaf number from top				
	2	4	7	10	12
	Illumination, lumen/cm ²				
33,000	4.50†	3.00	2.44	2.16	1.76
98,800	4.51	1.79	0.82	0.67	1.18
118,000	4.58	1.15	0.58	0.42	0.62
Difference‡ from real canopy:					
33,000	0	-0.55	-0.08	+0.27	+0.23
98,800	0	-0.28	-0.03	+0.04	+0.78
118,000	0	+0.01	+0.04	+0.10	+0.40

† Means of three replications and four K levels.

‡ Differences between measured diffuse illumination at leaves 2, 4, 7, 10, and 12 and calculated illumination at canopy depths of 0, 50, 100, 150, and 200 cm in three nonsimulated populations assuming maximum diffuse illumination is that received at leaf 2 (4.5 lumens/cm²).

Significance of treatment means were tested with analysis of variance (16) and Waller-Duncan's new L.S.D. tests (19) with corrected "t" tables.

RESULTS AND DISCUSSION

Illumination from diffuse or scattered light within each leaf enclosure is shown in Table 1. Illumination at leaf 2 was measured above the shade cloth and represented the maximum diffuse light. Note that the relative changes in illumination with different canopy shadings were used to describe light extinction patterns; these extinction patterns were used to assign illumination values for selected leaf levels in the canopy assuming maximum direct illumination at the canopy top to be 10.8 lumens/cm². The small differences between the assigned values and real canopy values calculated from data of Stevenson and Tanner (17) indicated that light extinction patterns in simulated and nonsimulated populations were similar. Illumination at leaf 12 at the two highest plant populations were slightly higher than at leaf 10 because of the greater amount of light reflected from the soil surface into this portion of the canopy. However, because of the data of Pendleton and Hammond (13) we concluded the small differences in reflected light intensity probably were inconsequential.

CO₂ Assimilation Near Light Saturation. The apparent CO₂ assimilation rates per unit of green leaf area by leaves receiving about 7.5 lumens/cm² of incandescent light were markedly increased as the level of K in the nutrient solution was increased (Table 2), although the magnitude was influenced by leaf position. Assimilation rates for leaves in position 7 were equal to or greater than rates for leaves in position 9. Differences in leaf concentrations of K for plants under K stress and concomitant changes in CO₂ assimilation have been reported earlier (9). Only rates for leaves in position 9 were significantly increased by increasing simulated populations; these increases occurred primarily when levels of K in the solution were >15 µg/ml.

At 15 and 45 µg of K/ml and populations of 33,000 and 98,800 plants/ha, leaves in position 9 were significantly lower in CO₂ assimilation than leaves 5 and 7. Leaf position affected assimilation rates of leaves only slightly when plants were receiving solutions contain-

ing at least 135 $\mu\text{g/ml}$; the rates for plants receiving 400 $\mu\text{g/ml}$ were significantly greater, however, than for plants receiving 135 $\mu\text{g/ml}$. These data confirm effects of leaf position of corn as reported in a previous study (9) in which plants were supplied either with adequate or inadequate K.

CO₂ Assimilation Below Light Saturation. An interaction between leaf position in canopy, simulated plant population, and concentration of K in the nutrient solution was evident in the response to illumination levels during the measurement of CO₂ assimilation (Table 2). At low simulated populations and low K levels, CO₂ assimilation rates increased with increasing illumination for leaf 5, but increased only slightly for leaf 9; at low simulated populations and high K levels, CO₂ assimilation increased for both leaves. In general, the highest rates of CO₂ assimilation near light saturation were reached as canopy shading and/or K levels were increased. Furthermore, as assimilation rates were increased due to treatment, the level of incident light required to reach light saturation was increased.

K Concentrations. Table 3 shows increasing K concentrations in leaves with increasing degrees of canopy shading and K levels in culture solutions. Apparently growth was decreased in response to lower levels of illumination; within any K treatment, plant growth was less relative to supply, thereby causing an increase in tissue levels of K. Leaf 9 had the lowest K concentrations in treatments receiving low K and relatively little canopy shading, whereas at high levels of K and relatively large amounts of canopy shading, leaf 9 had the highest leaf concentrations of K. Shading, therefore, was not detrimental to retention of K by leaves.

Since the CO₂ assimilation and concentrations of K in leaves were both influenced by treatment, we evaluated relationships between these two variables as shown in Fig. 1. The highly significant curvilinear relation ($r = 0.89^{**}$) suggests that underlying effects of shading and K nutrition relate to concentrations of K in tissue and its effect upon CO₂ assimilation near light saturation. Similar curvilinear relations between grain yield and K concentrations of leaves were noted by Loué (7) and Hanway et al. (4). The deviation of data from the line of best fit in Fig. 1 is greater than indicated in previous work (11) with corn, but similar to data for alfalfa (*Medicago sativa* L.) (1). In the present study, however, we used leaves that were necrotic and chlorotic which may have introduced more variability in the active photosynthetic area and the K distribution in tissues (15). There is a clear suggestion in Fig. 1, however, that the critical level of K, below which CO₂ assimilation rates were seriously reduced, was about 1.7 to 2.0%. This critical range was also reported to be the critical level of K for yield of corn grain in the field (4, 7). With younger plants and with leaves having no necrosis, 0.75 to 1.0% K (3) and 1.5% K (11) had been suggested as critical levels for CO₂ assimilation.

Dry Matter Yields. The influence of K nutrition and simulated population on the dry matter accumulated by each plant is shown in Fig. 2. Significant

Table 2. Influence of simulated population, K nutrition, and illumination on the assimilation of CO₂ per unit of green leaf area.

Simulated population	K level	Leaf number from top	Light intensity, lumens/cm ² †				
			7.5	4.8	3.2	1.6	0.8
plants/ha	µg/ml		— CO ₂ assimilation, mg/cm ² /hour —				
33,000	15	5	21.9†	20.5§	18.0	13.3	7.1
		7	14.5	13.8	11.3	7.8	4.6
		9	3.0	3.0	2.6	1.8	1.0
	45	5	26.9	24.9	22.5	17.9	10.5
		7	31.8	28.4	23.0	16.2	9.6
		9	8.0	8.0	6.5	4.6	2.5
	135	5	23.9	22.6	19.7	14.7	10.3
		7	31.5	31.1	31.4	21.5	12.1
		9	26.1	25.5	21.4	14.9	8.6
	400	5	39.4	35.2	29.4	20.0	12.2
		7	37.5	33.0	27.1	18.4	11.5
		9	37.4	36.0	33.5	27.5	17.9
98,800	15	5	22.6	21.9	20.1	15.8	10.1
		7	21.7	20.4	17.2	13.6	8.6
		9	3.9	3.6	2.9	2.3	1.5
	45	5	28.8	27.9	25.0	19.3	12.5
		7	26.2	24.6	21.7	16.2	10.4
		9	16.1	14.6	11.5	19.1	6.2
	135	5	32.8	31.6	27.2	19.4	12.2
		7	32.9	31.7	29.0	20.0	11.9
		9	33.2	29.1	24.4	17.2	12.6
	400	5	35.3	33.4	28.2	20.1	11.5
		7	41.8	38.7	32.6	22.6	14.0
		9	39.4	35.1	29.0	20.2	12.2
118,000	15	5	21.3	19.1	17.1	11.8	7.3
		7	22.7	13.8	15.5	11.4	7.0
		9	5.2	5.2	4.4	3.7	2.1
	45	5	25.4	21.3	18.5	15.6	10.7
		7	32.0	31.1	24.5	15.6	9.7
		9	28.7	31.1	22.8	15.5	10.1
	135	5	28.4	26.5	23.3	18.8	12.4
		7	30.2	26.3	22.2	18.8	11.9
		9	31.2	27.5	26.0	20.1	12.2
	400	5	49.1	46.0	39.3	28.6	15.3
		7	46.0	41.5	35.5	25.9	15.2
		9	46.2	43.7	38.2	24.8	13.6
	¶		DPopulation	DK level	DLeaf number		
	5		ns	6.5		3.7	
	7		ns	8.8		3.7	
	9		6.5	7.1			

† Supplied from an incandescent source.

§ Rates at 4.8 to 0.8 lumens/cm² were estimated from smooth curves based on single measurements.

¶ At 7.5 lumens/cm², differences between treatment means that are greater than the corresponding D values are significantly different, $p = 0.05$.

Table 3. Influence of simulated plant population and K nutrition on the concentration of K in corn leaves.

Simulated population	K level	Leaf number from top		
		5	7	9
plants/ha	$\mu\text{g/ml}$	K, % of dry matter		
33,000	15	0.45	0.36	0.17
	45	0.73	0.78	0.21
	135	1.20	1.41	1.08
	400	2.66	2.93	3.11
98,800	15	0.50	0.52	0.20
	45	0.85	0.85	0.71
	135	2.03	2.19	2.07
	400	2.51	3.24	3.31
118,000	15	0.60	0.54	0.23
	45	1.03	1.17	1.23
	135	2.18	2.36	2.47
	400	3.13	3.35	3.47
DPopulation		0.57	0.40	0.49
DK level		0.50	0.37	0.46
DLeaf number			0.16	0.16

* Differences between treatment means in appropriate rows or columns that are greater than the corresponding D values are significantly different, $p = 0.05$.

** Significant at the 0.01 level.

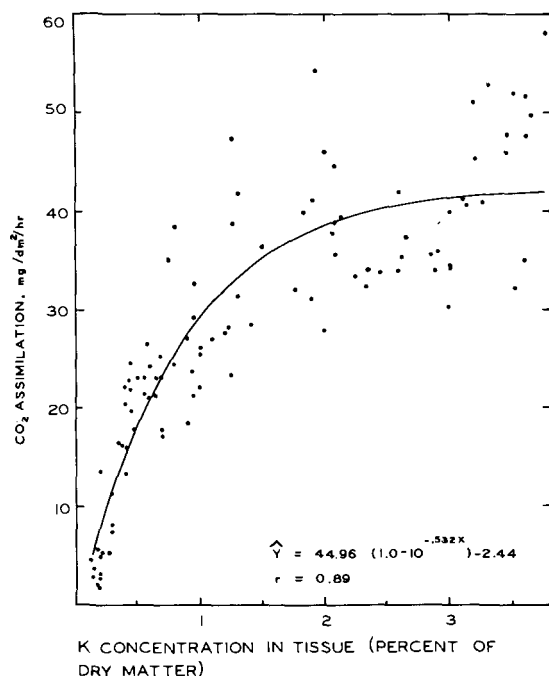


Fig. 1. Relation between apparent CO₂ assimilation rates and K concentrations in corn leaves from various levels of K nutrition and simulated populations.

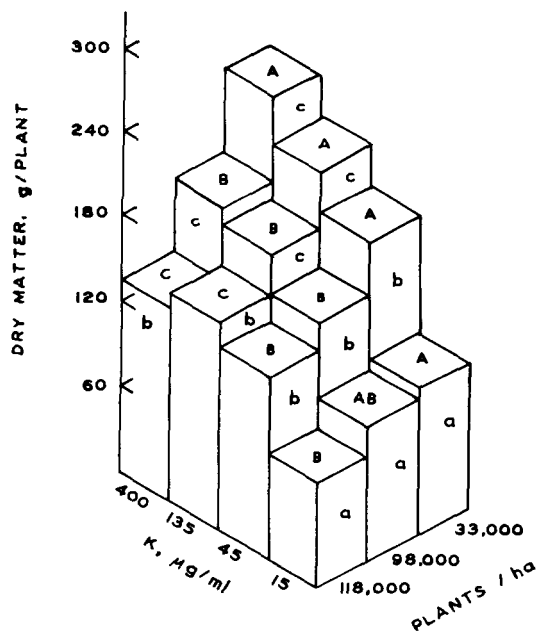


Fig. 2. Dry matter accumulation of corn plants to the silking stage as affected by K nutrition and simulated plant population.

differences between populations are reflected by letters on top of columns; differences between K treatments are indicated by letters on a face of the columns. The interaction between K nutrition and degree of simulated canopy shading was significant: yield per plant decreased for each level of shading for plants receiving more than 45 μg of K/ml, whereas plants receiving 15 μg of K/ml were less affected by changes in

Table 4. Influence of simulated plant population and K nutrition on total leaf area and area of selected leaves of corn.

Simulated population	K level	Area of leaf number			Plant leaf area
		5	7	9	
plants/ha	µg/ml	dm ²			
33,000	15	5.4†	4.6	4.6	44.2 (2.9)‡
	45	5.8	5.9	3.3	40.6 (1.7)
	135	5.8	6.1	5.2	55.2 (0.5)
	400	6.4	5.8	4.9	55.8 (5.9)
98,800	15	5.7	5.0	4.1	51.9 (2.8)
	45	6.6	5.6	4.8	51.9 (8.1)
	135	5.9	6.1	5.4	53.6 (3.1)
	400	7.2	6.6	6.0	59.8 (6.1)
118,000	15	5.9	5.2	4.5	48.5 (7.3)
	45	5.8	5.5	4.6	47.5 (3.8)
	135	5.3	5.1	4.7	51.3 (8.2)
	400	5.5	5.3	4.0	47.3 (7.5)

† Mean of three replications.

‡ Standard deviation of mean leaf area for three plants.

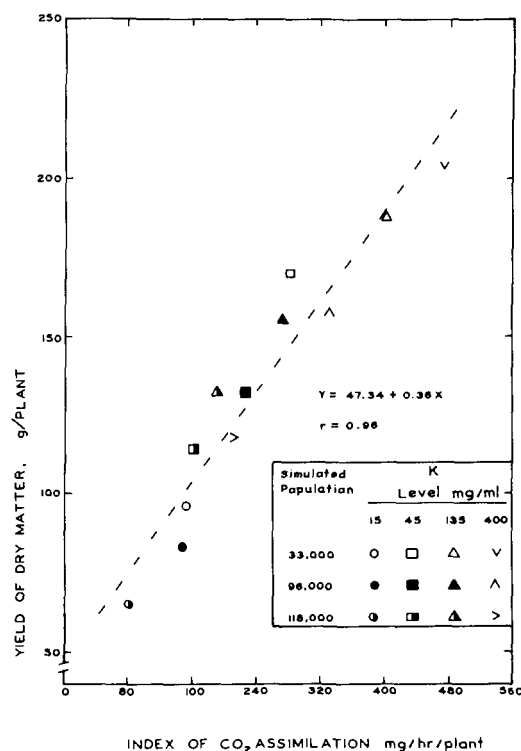


Fig. 3. Relation between dry matter yields of corn plants from varying levels of K nutrition and simulated populations and indices of CO₂ assimilation rates for the plants.

canopy shading. Apparently at this K level (all leaves contained less than 1% K), growth was relatively more limited by K nutrition than by light. Conversely, at a simulated population of 118,000 plants/ha, light intensity appeared to be more limiting because yields per plant became less dependent on K.

Assimilation Indices. Rates of CO₂ assimilation per unit of leaf area and leaf area available for assimilating CO₂ should be correlated with the dry matter accumulation of a plant. However, light environment of leaves and the leaf areas were continually changing during growth and development of the plants to silking. To determine to what degree measurements at the silking stage (CO₂ assimilation, light intensity

distributions in the simulated canopies, and areas of leaves 5, 7, and 9) correlated with plant weights, we used data in Tables 1 and 2 to estimate rates of assimilation for these leaves as it would be expected to occur in a canopy assuming 10.8 lumens/cm² were received at the canopy top. These rates were then multiplied by corresponding leaf areas (Table 4) to obtain an index of the mean rates per plant for each treatment. The potential of leaves from different canopy levels to contribute to photosynthesis can be estimated from these calculations. If CO₂ supplies and photosynthate transport from leaves 5 and 9 are not limiting to CO₂ assimilation, our data suggested that leaf 9 could contribute between 9 and 89% as much photosynthate as leaf 5. Calculated assimilation by leaf 9 was minimal under low population, low K supply and maximal under low population, high K supply. Mean assimilation by leaf 9 was calculated to be 40% that of leaf 5 at the two highest populations and K levels. Tripathy et al. (18) found that somewhat higher percentages of ¹⁴C-labelled material were translocated from leaf 4 compared to leaf 11 of corn at silking. Their studies did not evaluate relative CO₂ assimilation by the two leaves.

The relationship between assimilation indices and yield of dry matter per plant is shown in Fig. 3. The correlation coefficient ($r = 0.96^{**}$) suggested that light environment of selected leaves and potentials of these leaves to assimilate CO₂, even when evaluated at silking, were reflected in dry matter production per plant under that environment. When illumination and assimilation measurements were made, leaf illumination in the canopy was largely a function of leaf position and the shade cloth characteristics associated with different simulated populations. Both canopy shading and K markedly affected assimilation rates but had only a slight effect on leaf areas.

In summary, rates of CO₂ assimilation of individual leaves as measured at high levels of illumination were correlated with the concentrations of K in the leaves. The rates were independent of environment during growth and development, except to the extent that environment had affected K concentrations in the tissues. Shading was not detrimental to retention of K by leaves. Adjusting CO₂ assimilation rates per unit area for selected leaves at silking from each treatment on the basis of their light environment, and taking into consideration the area of these leaves resulted in an index of assimilation that was highly correlated with dry matter accumulated to the silking stage. Our data suggest that assimilation of CO₂ by leaves in the central portion of the canopy (leaf numbers 5, 7, and 9) may be indicative of dry matter production of a plant, and that the ratio of CO₂ assimilation by leaf 9/leaf 5 may be as high as 0.89, depending on nutrition and simulated population.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the assistance of John Byars and Dr. Paul Cornelius for aid and advice in statistical analyses.

LITERATURE CITED

- Cooper, R. B., R. E. Blaser, and R. H. Brown. 1967. Potassium nutrition effects on net photosynthesis and morphology of alfalfa. *Soil Sci. Soc. Am. Proc.* 31:231-235.
- Duncan, W. G. 1958. The relationship between corn population and yield. *Agron. J.* 50:82-84.
- Estes, G. O., D. W. Koch, and T. F. Bruetsch. 1973. Influence of potassium nutrition on net CO₂ uptake and growth in maize (*Zea mays* L.). *Agron. J.* 65:972-975.
- Hanway, J. J., S. A. Barber, R. H. Bray, A. C. Caldwell, M. Fried, L. J. Kurtz, K. Lawton, J. T. Pesek, M. Reed, and F. W. Smith. 1962. North Central regional potassium studies. III. Field studies with corn. *Iowa Agric. and Home Econ. Exp. Stn. Res. Bull.* 503.
- Hoagland, D. R., and D. I. Arnon. 1950. The water-culture method for growing plants without soil. *Calif. Agric. Exp. Stn. Circ.* 347.
- Johnston, E. S., and D. R. Hoagland. 1929. Minimum potassium level required by tomato plants grown in water cultures. *Soil Sci.* 27:89-110.
- Loué, A. 1963. A contribution to the study of the inorganic nutrition of maize with special attention to potassium. *Fertilité* 20:33-57.
- Moss, D. N. 1964. Optimum lighting of leaves. *Crop Sci.* 4:131-136.
- , and Doyle E. Peaslee. 1965. Photosynthesis of maize leaves as affected by age and nutrient status. *Crop Sci.* 5:280-281.
- Noquchi, V., and J. Sugawara. 1966. Potassium and Japonica rice. *Int. Potash Inst., Bern.*
- Peaslee, D. E., and D. N. Moss. 1966. Photosynthesis in K- and Mg-deficient maize (*Zea mays* L.) leaves. *Soil Sci. Soc. Am. Proc.* 30:220-223.
- , and ———. 1968. Stomatal conductivities in K-deficient leaves of maize (*Zea mays*, L.). *Crop Sci.* 8:427-430.
- Pendleton, J. W., and J. J. Hammond. 1969. Relative photosynthetic potential for grain yields of various leaf canopy levels of corn. *Agron. J.* 61:911-913.
- Sawhney, B. L., and Israel Zelitch. 1969. Direct determination of potassium ion accumulation in guard cells in relation to stomatal opening in light. *Plant Physiol.* 44:1350-1354.
- Smid, A. E., R. I. Barnhisel, and D. E. Peaslee. 1972. An X-ray emission technique for determining potassium in corn leaves. *Agron. J.* 64:78-80.
- Steel, R. G. D., and J. H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill Book Co., New York.
- Stevenson, K. B., and J. W. Tanner. 1970. Use of plastic plant models for investigating light distribution within a corn canopy. *Can. J. Plant Sci.* 50:319-329.
- Tripathy, P. C., John A. Eastin, and L. E. Schrader. 1972. A comparison of ¹⁴C-labelled photosynthate export from two leaf positions in a corn (*Zea mays* L.) canopy. *Crop Sci.* 12:495-497.
- Waller, R. A., and D. B. Duncan. 1969. A Bayes rule for symmetric multiple comparisons problem. *J. Am. Stat. Assoc.* 64:1484-1503.

eKonomics

THE BUSINESS OF CROP NUTRITION

PotashCorp-eKonomics.com

..... BY



PotashCorp

Helping Nature Provide