# DRY-MATTER PRODUCTION, AND NUTRIENT UPTAKE AND REMOVAL BY *SOLANUM ANDIGENA* IN THE PERUVIAN ANDES[1,2]

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## ABSTRACT

A Field experiment with *Solanum andigena* (cv. Renacimiento) at three levels of fertilization was conducted in the Mantaro Valley (Central Sierra) of Peru during the 1967-68 growing season. Dry matter and nutrient accumulation in tops and tubers of Renacimiento potatoes were determined at 3-week intervals between 72 and 172 days after planting (42 and 142 days after emergence).

Tuber initiation took place during the interval 116-137 days after planting, and top growth reached its maximum shortly thereafter. Total growth rates of 200 kg/ha/day[4] (178 lb/a/day) where estimated under medium and high fertilization, and tuber dry matter accounted for 70-75% of the total dry matter produced.

Final tuber yields (fresh, 21% dry matter) ranged from 10 m.t./ha (89 cwt/a) without fertilizer to 41 m.t./ha (366 cwt/a) when fertilized with 160 kg each of N, $P_2O_5$ and $K_2O$/ha (143 lb/a).

Under high fertilization, total N, P, and K accumulation was estimated at 141, 19, and 403 kg/ha (126, 17, and 359 lb/a), respectively, with 77 kg (68 lb/a) of N, 14 kg (12 lb/a) of P, and 224 kg (200 lb/a) of K being removed in the tubers.


## INTRODUCTION

Knowledge about total dry matter production, rate of growth, nutrient accumulation, and nutrient removal in the harvested portion of economic plants is of fundamental importance in developing fertilization practices. Such information permits useable inferences about total nutrient demand, intensity of untrient uptake at various stages of growth, possible residual effects of applied fertilizers, and the relationship (s) between nutrient concentration in pertinent plant parts and ultimate yield.

The potato is the most important food crop in the Peruvian Andes, and a high percentage of the total agronomic research effort in Peru is devoted to this plant. Field experiments during the last decade have shown that responses to fertilization are phenomenal, and reliable yield-response curves for the major nutrients have been constructed (7). On the other hand, quantitative data on rates of nutrient uptake, total nutrient accumulation, and nutrient removal for native potato cultivars are scarce.

Literature on the mineral nutrition of potatoes is considerable (1, 2, 4, 5, 6, 8, 9); but most of the detailed studies have been conducted in the

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[4]Kg/ha × 0.892 = lb/a.

northern hemisphere with *S. tuberosum*, the predominant production species in North America and Europe. On the other hand, the sub-species *S. andigena* predominates in the Andes; and, under this somewhat unique environment, the production cycle for most of the Peruvian cultivars is about 60 days longer than that for most tuberosums. Published data from the northern hemisphere may not, therefore, be transferable to Andean varieties and environments. The study with which this report deals was a "first step" toward providing quantitative data on the mineral nutrition of *S. andigena* which could be compared with similar data from tuberosum in other environments.

## Materials and Methods

The experiment was conducted in the Mantaro Valley (Central Sierra) at an elevation of 3300 m (app. 10,700ft.) above sea level. Soils in this area are characteristically red to reddish brown, fine-textured, and shallow-to-moderately deep with calcareous subsoils. The classification of the soil and pertinent physical and chemical properties of the surface horizon for the experimental site were as follows: Huachac clay loam (Inceptisol); 1.4% O.M.; pH 5.7; cation exchange capacity—20 me/100 gm; base saturation—42%; available $P_2O_5$ (Olsen)—51 kg/ha (medium); available $K_2O$ (Olsen)—210 kg/ha (medium); exchangeable Ca—5.1 me/100 gm; and exchangeable Mg—2.7 me/100 gm. Climatic data during the crop year for the area are summarized in Table 1.

After the land was prepared by routine plowing and smoothing, rows were marked off at one-meter intervals; and appropriate mixtures of $NH_4NO_3$, superphosphate (20% $P_2O_5$) and KCl were applied in the open row. One-half of the total nitrogen and all of the P and K were applied in this manner. Three fertilizer treatments of 0-0-0, 80-80-80, and 160-160-160 kg/ha ($N$-$P_2O_5$-$K_2O$) were applied in four replications using a randomized-complete-block design. The fertilizer was then covered with about one inch of loose soil to separate it from the potato seed tuber and reduce the probability of salt injury. Plots were four rows wide and 10 m (33 ft.) long.

Whole tubers weighing 60-80 gm each (2-3 oz.) of the cultivar Renacimiento were planted 30 cm (12 in.) apart (33,333 plants/ha or 13,333 plants/a) on October 17. Renacimiento is presently the most widely-grown commercial potato in Peru, principally because of its high yield potential and some tolerance or resistance to pathogens. Other general characteristics of this cultivar have been described by Christiansen (3).

The remaining half of the nitrogen was applied on December 13, 57 days after planting, just prior to the first hilling operation (*aporque*).

Beginning on the 72nd day from seeding, whole plant samples were taken at approximately 3-week intervals until the final harvest was completed at 193 days from planting. A sample consisted of four plants (two plants from each of the two center rows), each of which was under normal interplant competition. The samples were washed free of soil and separated into various plant parts according to their stage of development. The first two samples were separated into tops and "roots," the root fraction consisting of the below-ground portion of the main stems and those roots and stolons recoverable with routine hand-tools. The third sample was separated into leaves, stems, and roots. The tubers made a fourth fraction for

TABLE 1.—*Climatic data registered during the 1967-68 potato growing season in the Mantaro Valley of Peru.*[1]

| Month | Temp. in shade (°C)[2] | | | Relative humidity (%) | | | Precipitation (mm)[3] | | Hours of sun (daily avg.) | Solar radiation cal/cm²/day |
|---|---|---|---|---|---|---|---|---|---|---|
| | Avg. max. | Avg. min. | Daily avg. | Av. max. | Av. min. | Daily avg. | 1967-68 | 46-yr. avg. | | |
| Oct. '67 | 18.2 | 6.2 | 11.0 | 96 | 36 | 74 | 99 | 67 | 5.9 | 607 |
| Nov. | 20.5 | 5.4 | 12.4 | 86 | 22 | 55 | 44 | 72 | 7.9 | 695 |
| Dec. | 19.5 | 5.6 | 11.7 | 90 | 26 | 65 | 66 | 91 | 6.7 | 652 |
| Jan. '68 | 17.4 | 6.8 | 11.0 | 96 | 39 | 77 | 152 | 123 | 4.8 | 547 |
| Feb. | 18.4 | 6.1 | 11.2 | 93 | 33 | 72 | 94 | 117 | 6.0 | 589 |
| Mar. | 16.7 | 5.9 | 10.4 | 96 | 42 | 78 | 118 | 113 | 5.0 | 522 |
| April | 18.8 | 2.4 | 10.0 | 96 | 27 | 70 | 41 | 53 | 7.6 | 592 |
| May | 18.4 | 0.0 | 8.9 | 95 | 24 | 62 | 2 | 26 | 8.0 | 540 |

[1]Source: Observatorio Meterorlogico de Huayao, Huancayo. Instituto Geofisico del Peru. Lima.
[2]Degrees Fahrenheit (°F) = 1.8 (°C) + 32.
[3]Millimeters (mm) .04 = inches.

all subsequent samplings. Since root recovery could not be called quantitative, it should be emphasized that the only reliable data about roots pertained to the nutrient concentration in them. For this reason, no extrapolations based on root weight were made.

The leaf, stem and root fractions were washed successively with 0.1 *N* HCl and distilled water, dried to constant weight in a forced-air oven, weighed, and ground to pass a 40-mesh screen. Weighed sub-samples of sliced tubers were similarly dried, weighed again (for d.m. determination), and ground. Total N was determined by a semimicro Kjeldalh procedure modified to include nitrates. Phosphorus was determined in a dry-ashed sample by the vanadomolybdophosphoric yellow method; K, Mg, and Ca were determined in the sample by atomic absorption spectrophotometry.

## RESULTS

Sprout emergence was essentially complete at 30 days after seeding. With two exceptions, the plants developed normally. Early growth may have been retarded by limited precipitation during November and December (Table 1), and a light frost during the flowering period killed the flowers and eliminated further fruit development which is usually profuse in the Andean environment. Precipitation during the remainder of the season was adequate however, and there were no other damaging frosts until late in the season.

Final, fresh-weight yields of tubers for the three fertilizer treatments (Table 2) were in the order of magnitude obtained in previous experiments (7). The treatments imposed represent the range in fertilization practices employed by farmers throughout the Peruvian Andes, but a description of the growth pattern for potatoes under adequate nutrition was

TABLE 2.—*Tuber yields and nutrient removal by S. andigena (cv. Renacimiento) at varying levels of fertilization in the Mantaro Valley of Peru.*

| Treatment (kg/ha)[1] | | | Tuber yield (kg/ha)[1] | | Removed in tubers (kg/ha)[1] | | | | |
|---|---|---|---|---|---|---|---|---|---|
| N | $P_2O_5$ | $K_2O$ | Fresh | Dry | N | P | K | Ca | Mg |
| 0 | 0 | 0 | 10,063 | 2,090 | 17 | 5 | 67 | 1.1 | 2.3 |
| 80 | 80 | 80 | 28,852 | 5,936 | 48 | 10 | 174 | 3.5 | 6.4 |
| 160 | 160 | 160 | 41,124 | 8,222 | 77 | 14 | 224 | 4.2 | 9.2 |

[1]kg/ha x 0.892 = lb/a

a principal objective in this experiment; and the remaining discussion will be devoted primarily to data from the highly fertilized plots.

*Accumulation of dry matter:*

Periodic yields of total dry matter for low, medium, and high rates of fertilization are shown in Fig. 1. Total growth under low and medium fertilization was essentially complete at 156 days, but the adequately-fertilized plants continued to accumulate dry matter until at least 172 days after planting. A hard frost during the 3-week interval between 172 and 193 days killed the foliage and eliminated the possibility of further quantitative sampling of top growth. Killing frosts any time after April 1 are not uncommon.

Plants on all treatments were sparsely flowered at 116 days, but most of the flowering (and their subsequent killing by frost) occurred during the following 3 weeks. Tuber initiation and flowering coincided quite closely (Fig. 2) but the sampling frequency did not permit a precise pinpointing of either date. Top growth reached a maximum at about 137 days. It is of interest to note that more than 90% of the total growth occurred after the plants were 95 days old and that about 70% of the total measurable dry matter produced under high fertilization was stored in the tubers. Under low and medium fertilization, tuber dry matter accounted for 82% and 75%, respectively, of the total.

Although the sampling frequency was not sufficiently intense for a precise measure of growth rates, this quantity can be estimated from the slope of the total-accumulation curve in Fig. 2. At the highest level of fertilization, the maximum rate of dry matter accumulation, 198 kg/ha/day (175 lb/a/day), occurred during the 3-week interval between 137 and 156 days from planting. The curves for total and tuber dry matter are nearly parallel during this interval, indicating that photosynthesis and the storage of photosynthate in tubers were occurring at about the same rate. Total growth rates for low and medium fertilization during the same interval were estimated at 47 and 205 kg/ha/day (42 and 183 lb/a/day), respectively.

*Nutrient concentration in dry tissue:*

The concentrations of selected nutrient elements in different parts of the potato plant are shown in Table 3. The principal feature of these data

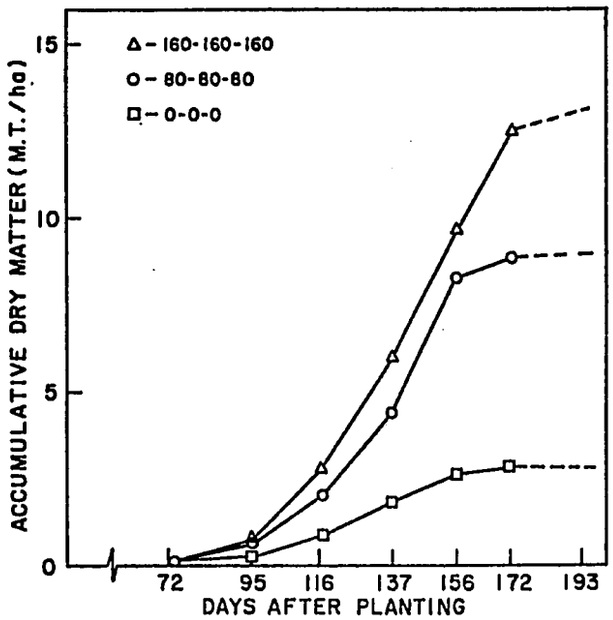


FIG. 1.—Total dry matter production by Renacimiento potatoes a differing levels of fertilization (Numbers after symbols indicate rates of N-$P_2O_5$-$K_2O$ in Kg/ha).

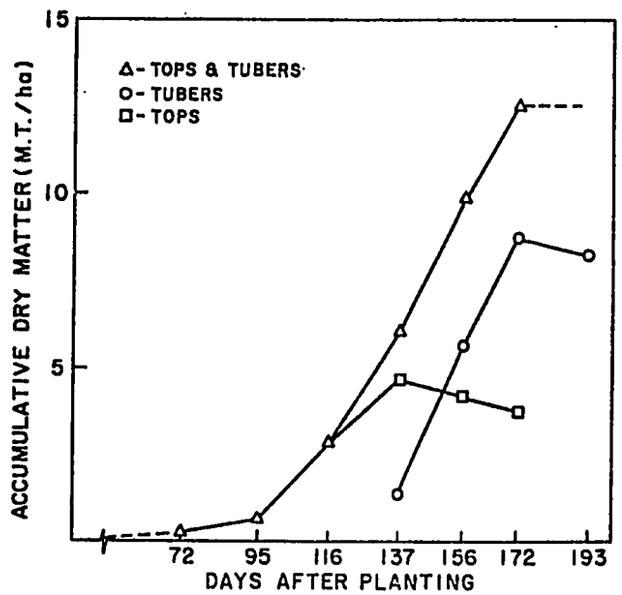


FIG. 2.—Accumulative yield of dry matter and its distribution between tops and tubers by Renacimiento potatoes (Fertilization in Kg/ha = 160 N-160 $P_2O_5$-160 $K_2O$ = 143-143-143 lb/a).

TABLE 3.—*Dry matter production by and nutrient concentration in potato tissues (S. andigena, cv. Renacimiento) at different stages of growth. (Fertilization in kg/ha = 160 N — 160 $P_2O_5$ — 160 $K_2O$ = 143-143-143 lb/a).*

| Plant part | Days after planting | Dry wt. (kg/ha)[2] | Composition (% of dry wt.) N | P | K | Ca | Mg |
|---|---|---|---|---|---|---|---|
| Leaves | 72[1] | 239 | 4.49 | 0.44 | 8.63 | 1.58 | 0.61 |
| | 95[1] | 615 | 4.18 | 0.37 | 7.72 | 1.51 | 0.64 |
| | 116 | 1626 | 3.34 | 0.26 | 5.15 | 1.60 | 0.74 |
| | 137 | 2686 | 3.32 | 0.21 | 4.80 | 1.51 | 0.70 |
| | 156 | 2025 | 3.39 | 0.22 | 3.52 | 1.48 | 0.69 |
| | 172 | 1658 | 2.84 | 0.20 | 4.00 | 1.47 | 0.64 |
| | 193 | .... | .... | .... | .... | .... | .... |
| Stems | 72[1] | .... | .... | .... | .... | .... | .... |
| | 95[1] | .... | .... | .... | .... | .... | .... |
| | 116 | 1193 | 1.83 | 0.22 | 8.81 | 0.82 | 0.44 |
| | 137 | 1948 | 1.40 | 0.12 | 6.15 | 0.84 | 0.49 |
| | 156 | 2125 | 1.18 | 0.17 | 4.38 | 0.70 | 0.38 |
| | 172 | 2117 | 0.81 | 0.08 | 4.69 | 1.03 | 0.50 |
| | 193 | .... | .... | .... | .... | .... | .... |
| Roots (Roots = roots, stolens and below-ground stems) | 72 | .... | 2.14 | 0.37 | 6.29 | 1.38 | 0.40 |
| | 95 | .... | 1.64 | 0.23 | 5.01 | 1.65 | 0.52 |
| | 116 | .... | 1.58 | 0.21 | 3.88 | 0.99 | 0.32 |
| | 137 | .... | 1.24 | 0.20 | 2.56 | 0.92 | 0.40 |
| | 156 | .... | 1.05 | 0.12 | 1.83 | 0.84 | 0.32 |
| | 172 | .... | 0.95 | 0.11 | 1.77 | 0.95 | 0.39 |
| | 195 | .... | .... | .... | .... | .... | .... |
| Tubers | 72 | .... | .... | .... | .... | .... | .... |
| | 95 | .... | .... | .... | .... | .... | .... |
| | 95 | .... | .... | .... | .... | .... | .... |
| | 116 | .... | .... | .... | .... | .... | .... |
| | 137 | 1356 | 1.13 | 0.22 | 3.62 | 0.09 | 0.12 |
| | 156 | 5615 | 0.87 | 0.17 | 2.86 | 0.06 | 0.11 |
| | 172 | 8724 | 0.88 | 0.16 | 2.81 | 0.04 | 0.10 |
| | 195 | 8222 | 0.89 | 0.17 | 2.64 | 0.06 | 0.11 |

[1]Plant tops were not separated into leaves and stems on first and second sampling dates.
[2]kg/ha x 0.892 = lb/a

is a fairly consistent downward trend in concentration of major nutrients with time for all plant parts. This trend is more drastic for K in "root" tissue, which exhibited a drop from 6.29 % on the first sampling date to 1.77% at 172 days. In contrast, the data for Mg, although somewhat erratic, show little change with time in a given plant part. Similar trends at progressively lower nutrient concentrations were found for medium and low fertilization.

*Total nutrient uptake and nutrient removal*

Total uptake of N, P, K, Ca, and Mg is plotted as a function of plant age in Figs. 3 through 7. Leaf drop, whether due to shading, senescence, or disease was evident after 137 days. Since reductions in weight due to

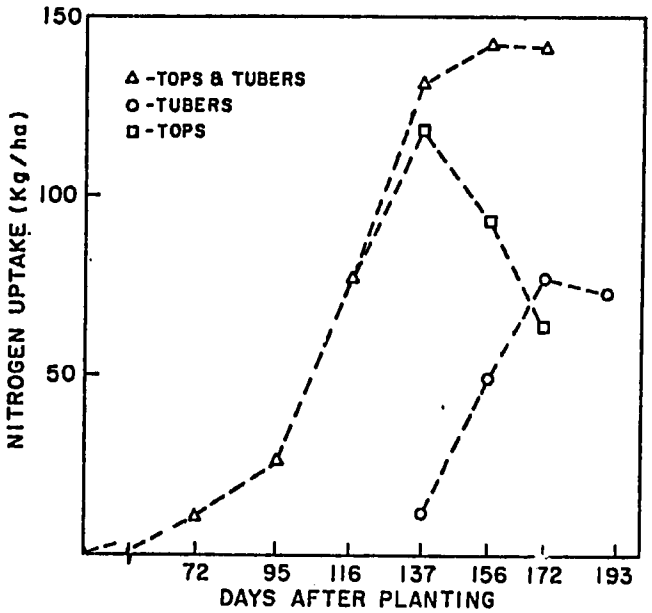


FIG 3.—Nitrogen accumulation in tops and tubers of Renacimiento potatoes (Fertilization as shown in FIG. 2).

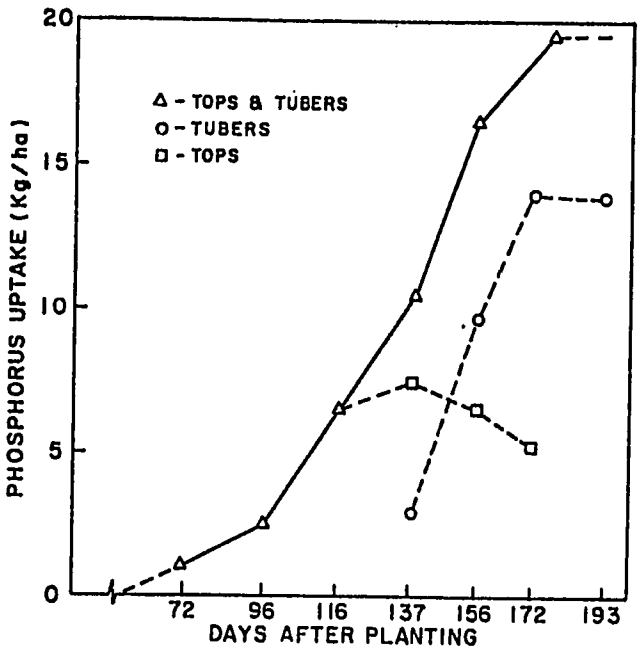


FIG. 4.—Phosphorus accumulation in tops and tubers of Renacimiento potatoes (Fertilization as shown in FIG. 2).

loss of leaves could not be quantitatively accounted for, computed values for nutrient uptake based on dry weights of tissue are necessarily conservative.

Total N uptake in tops and tubers was estimated at 141 kg/ha (124 lb/a), some 54% of which was removed in the harvested tubers. Nitrogen accumulation was essentially linear with time between 95 and 137 days after planting, and the slope of the curve during this interval shows that N was being accumulated at about 2.5 kg/ha/day (2.2 lb/a/day). Between 137 and 172 days, the rate of N storage in tubers was approximately 1.8 kg/ha/day (1.6 lb/a/day).

Phosphorus accumulation was essentially linear with time throughout the grand growth period (95-172 days), and the shape of the P-uptake curve during the latter part of this period is its principal feature in comparison with N uptake. Whereas total N accumulation was nearly complete at 137 days, some 40% of the total P was accumulated after this date (Fig. 3 *vs.* Fig. 4). The rate of P uptake over the 95- to 172-day interval was about 0.22 kg/ha/day (0.2 lb/a/day). Enlarging tubers accumulated P at a rate of 0.32 kg/ha/day (0.29 lb/a/day).

The general pattern of K accumulation (Fig. 5) showed a closer similarity to P than to N, but total K uptake exceeded P accumulation by a factor of 10. The steepest portion of the K curve fell between 95 and 116 days, and the rate of K accumulation during this interval exceeded 6.6 kg/ha/day (5.9 lb/a/day). Growing tubers accumulated K at about 5.6 kg/ha/day (5 lb/a/day).

Calcium and Mg had similar uptake patterns, both of them reaching a maximum of 60 and 31 kg/ha (54 and 28 lb/a), respectively, at 137 days. The fairly sharp drop in both elements after this date is perhaps best explained as a decrease in the weight of potato tops due to leaf drop.

## Discussion

It is of interest to compare pertinent growth characteristics of *S. andigena* with those of *S. tuberosum*. Studies from which comparable quantities can be extracted have been conducted in various places throughout the northern hemisphere (1, 2, 4, 5, 6, 8, 9), and the data in Table 4 represent our attempt to compare some of those quantities which we consider somewhat characteristic of either the cultivar or of the environment in which it is grown. In making these comparisons, however, we should emphasize that we have taken considerable liberties with some of the published data because they were not always presented in a format appropriate for direct comparison.

The most striking characteristic of Renaciniento is the duration of its production cycle. Whereas most *S. tuberosum* cultivars mature in less than 120 days, Renaciniento requires some 165-180 days in the Andean environment. It is also obvious that much of this tardiness character is attributed to the long period of vegetative growth before tuber initiation. Once initiated, however, tuber bulking rates for Renaciniento compare favorably with *S. tuberosum*. It is of further interest to note that tuber bulking rates among *S. tuberosum* are roughly in inverse proportion to the latitude in which they are grown. For example, the highest rates of tuber growth have been recorded in Colorado and North Carolina whereas the lowest bulking rates occur in Maine and England.

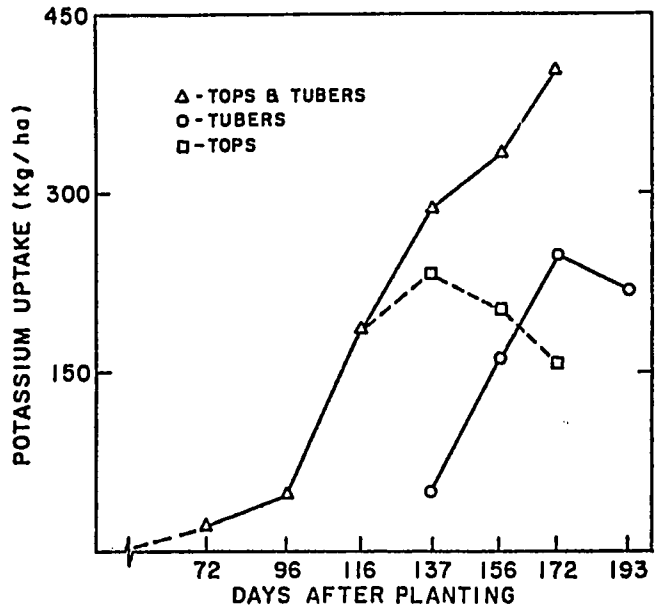


FIG. 5.—Potassium accumulation in tops and tubers of Renacimiento potatoes (Fertilization as shown in FIG. 2).

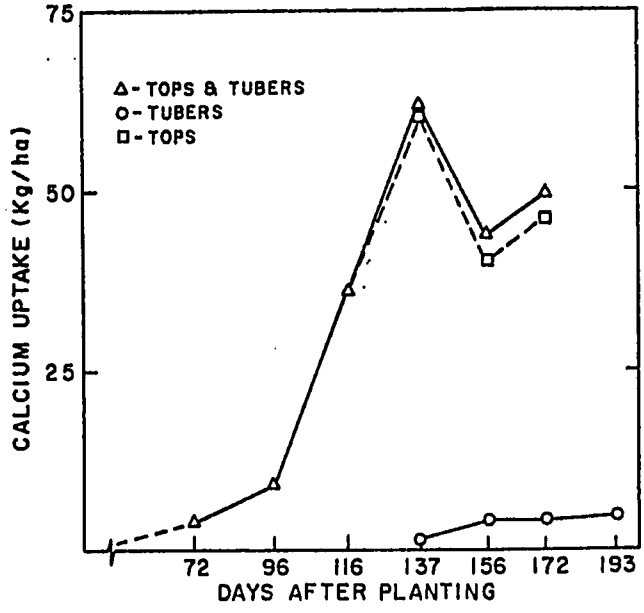


FIG. 6.—Calcium accumulation in tops and tubers of Renacimiento potatoes..

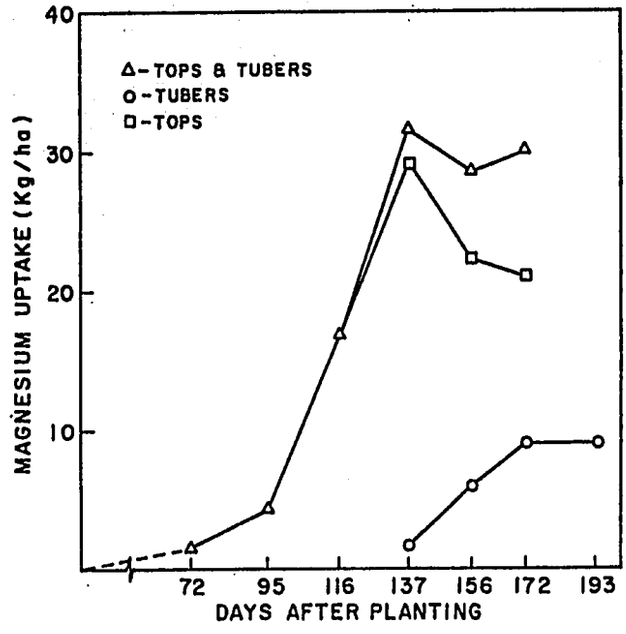


FIG. 7.—Magnesium accumulation in tops and tubers of Renacimiento potatoes.

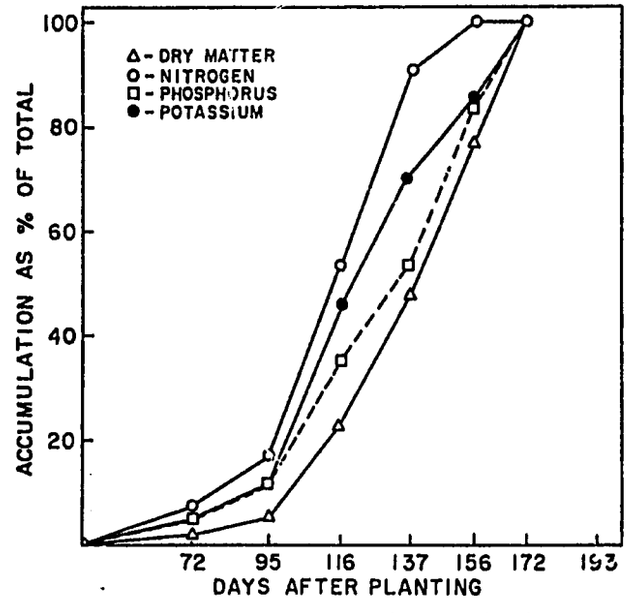


FIG. 8.—Periodic accumulation of dry matter, nitrogen, phosphorus, and potassium relative to total accumulation by Renacimiento potatoes.

TABLE 4.—*Selected characteristics of the Peruvian Potato cultivar "Renacimiento" as compared to U. S. and European cultivars.*

| Variable / Source of data (location and reference) | Estimated value of variable[1] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Peru | Colo. (8)[2] | Utah (5) | Calif. (6) | Me. (4) | Me. (2) | N.C.[3] | Neth. (9) | Eng. (1) |
| Variety (or no. of varieties) | Renac. | 3 var. | Russet Burbank | White Rose | Grn. Mtn. | 4 var. 4 yr. | Pungo | Mentor | 3 var. |
| Population (plants/ha X $10^{-3}$) | 33.3 | 45.6 | ? | 43.0 | 35.9 | 35.9 | 37.7 | 40.0 | 31.0 |
| Planting to tuber initiation (days) | 125 | 44-51 | 60 | 60-65 | 60 | 48-60 | 50 | 48 | 43-52 |
| Planting to harvest (days) | 180 | 109 | 138 | 119-124 | 112 | 89-97 | 100 | 120 | 140 |
| Total D.M. Prod. (tops and tubers—M.T./ha) | 12.6 | 11.9-18.6 | 9.9 | 10.6-12.7 | 7.9 | 4.5-8.8 | 7.5 | 10.2 | 9.2-15.2 |
| Ratio tuber D.M./total D.M. | 0.70 | 0.77-0.82 | 0.77 | 0.75-0.85 | 0.75 | 0.60-0.80 | 0.83 | 0.95 | 0.52-0.76 |
| Rate of tuber growth (kg/ha/day) | 224 | 280-360 | 170 | 180-290 | 141 | 132-204 | 350 | 184 | 110-140 |
| % N in dry tops at tuber initiation | 2.6 | 5.0 | 3.9 | 4.9-5.6 | 5.7 | 3.9-5.6 | 5.5 | .... | .... |
| % P in dry tops at tuber initiation | 0.21 | 0.40 | 0.24 | 0.23-0.44 | 0.42 | 0.31-0.41 | 0.33 | .... | .... |
| % K in dry tops at tuber initiation | 5.8 | 5.0 | 3.4 | 5.4-5.5 | 6.5 | 4.0-6.9 | 5.9 | .... | .... |
| % N in dry tubers at harvest | 0.9 | 1.5 | 1.4 | 1.1-1.3 | 1.8 | 1.1-1.8 | 1.6 | 1.1 | .... |
| % P in dry tubers at harvest | 0.18 | 0.20 | 0.14 | 0.15 | 0.18 | 0.17-0.26 | 0.25 | .... | .... |
| % K in dry tubers at harvest | 2.6 | 1.3 | 1.4 | 1.5-1.7 | 1.8 | 1.5-2.5 | 2.1 | .... | .... |
| Rate of N uptake (kg/ha/day) | 2.5 | 2.5-4.0 | 2.2 | 3.2-3.3 | 4.2 | 1.7-5.1 | 3.3 | 1.7 | .... |
| Rate of P uptake (kg/ha/day) | 0.22 | 0.38-0.45 | 0.25 | 0.30-0.48 | 0.39 | 0.14-0.50 | 0.22 | .... | .... |
| Rate of K uptake (kg/ha/day) | 6.6 | 4.7-5.6 | 2.6 | 3.8-6.3 | 5.8 | 2.6-6.9 | 4.5 | .... | .... |

[1]Where a range in "estimated value" is given, the quantities represent more than one variety or more than one year.
[2]Numbers in parenthesis refer to literature citations.
[3]Unpublished data of R. E. McCollum, North Carolina State University.

The results from this experiment do not permit any separation of the varietal character for tardiness from environmental factors. It is known, however, that the production cycle for Renacimiento can be shortened measurably, even in the Sierra, under the "best" of environmental conditions. Unpublished data from the coast of Peru show that the time from planting to tuber initiation is around 75 to 80 days for this cultivar as compared to some 116 days in this Sierra experiment.

Another feature of the data in Table 4 which appears peculiar to Renacimiento concerns the concentration of certain nutrients in pertinent tissues. The percentage of N in Renacimiento tops at tuber initiation and in the tubers at harvest are the lowest values recorded. On the other hand, the concentration of K in tubers at maurity is higher than any cultivar of tuberosum. Tissue concentrations, especially in top growth, can be markedly influenced by fertilization practices, but all of the derived data in Table 4 came from comparable fertilizer regimes. They should, therefore, approximate the norm for their area of origin.

The ratio of tuber dry matter to total dry matter produced by Renacimiento is surprisingly high. Under optimum environmental conditions, this cultivar produces tall, dense vegetative growth; and casual estimates based on field observation would suggest that the tops made up more than 30% of the total dry matter. In this experiment, however, the ratio (tuber d.m.: total d.m. = 0.70) compares favorably with observed values for *S. tuberosum*.

Dry matter accumulation by Renacimiento tops peaked during the period of tuber initiation (Fig. 2). In addition, about 80% of the total N had been taken up by this time (Fig. 3). Most of the data for cultivars of tuberosum suggest that topgrowth coninues for some 30 to 40 days after tubers are initiated and that the N accumulated prior to tuber initiation is generally less than 50% of the total. Both of these characteristics of Renacimiento are probably related to the long period of vegetative growth prior to the initiation of tubers.

The patterns of dry matter and nutrient accumulation (Fig. 8) provide some pertinent inferences about the timing (and perhaps the methods) of fertilizer applications. Since most of the N is taken up prior to tuber initiation, it follows that the total N supply should be provided before the plants reach 116 days of age. (The current recommendation in Peru is to apply one-half of the total N at planting and the remainder at the first cultivation—generally 60 to 75 days from planting). On the other hand, the curves for P and dry matter suggest that P accumulation and growth closely parallel each other throughout the production cycle, indicating that the supply of available P should be continuous. Recent, unpublished data from Peru show that P applied later than the first cultivation is largely uneffective for the current crop. The K-accumulation curve is somewhat intermediate between those for N and P. Positive responses to applied K have been quite sporadic, even on soils testing low by routine analyses; but the fact that the K accumulation curve showed no tendency to level off suggests that K uptake continues throughout the potato's production cycle.

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