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CARBOHYDRATE TRANSLOCATION IN BLUE GRAMA, BUFFALO GRASS, AND WESTERN WHEATGRASS AS INFLUENCED BY TEMPERATURE AND GROWTH STAGE

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ABSTRACT

A study was undertaken to examine the effects of temperature and stage of growth on the translocation of ^{14}C to blue grama, buffalo grass, and western wheatgrass roots. Accumulation of ^{14}C in blue grama and western wheatgrass roots was significantly affected by temperature and growth stage, respectively. Temperature and growth stage did not significantly influence ^{14}C accumulation in buffalo grass roots.

INTRODUCTION

Over the past 15 years studies on the movement and distribution of organic solutes within plants has drawn the interest of many investigators and given this field considerable impetus, especially with the advent of radioactive tracers. The long-lived radioisotope of carbon (^{14}C) has been particularly helpful in following the path of carbon through the plant after assimilation. With the results of these tracer studies a consistent pattern of translocation is being derived which will help clarify some growth analysis observations. These studies are essential to the understanding of how climate and agricultural practices affect plant growth. With this knowledge it should be possible to select plants capable of producing the highest yields possible under the existing environmental conditions.

The purpose of this study was to examine the effects of temperature and growth stage on translocation of carbon in blue grama (*Bouteloua gracilis* H.B.K.), buffalo grass (*Buchloe dactyloides* Nutt.), and western wheatgrass (*Agropyron smithii* Rydb.). The study was divided into three separate experiments. Experiment 1 was conducted: (i) to determine the necessary amount of radioactive ^{14}C needed for adequate plant labeling, (ii) to test the apparatus designed for use in labeling plants, and (iii) to determine some translocation characteristics of each grass. Experiment 2 was designed to determine the time course of sucrose labeling for the three grasses. The effect of temperature and growth stage on carbon translocation and photosynthate distribution in each grass was determined by Experiment 3.

REVIEW OF LITERATURE

Carbohydrate Movement From the Leaf

Following a buildup of assimilates in the photosynthetic tissue of a leaf, there seems to be a movement of only a certain amount and kind of substances into the conducting phloem tissue. Sugars, usually sucrose, but in some plants stachyose or other carbohydrates, generally constitute the bulk of organic material moving through the phloem. A considerable number of nitrogenous compounds and steroids are also known to be translocated (Biddulph and Cory, 1965; Clauss, Mortimer, and Gorham, 1964; Mittler, 1953; Mortimer, 1965; Trip, Nelson, and Krotkow, 1965; Webb and Burley, 1962, 1964; Zimmermann, 1958). Generally, this movement of assimilates into the conducting tissue occurs against a concentration gradient (Bieleski, 1966; Phillis and Mason, 1933; Roeckl, 1949). Also, energy is required for the transfer of assimilates from photosynthetic to conducting tissue (Ullrich, 1962; Ziegler, 1956). A reason for a reduction in light intensity reducing not only the photosynthetic rate but also the proportion of assimilates moved from leaves (Hartt, Kortschak, and Burr, 1964; Hartt and Kortschak, 1967) may be related to an alteration in the products of photosynthesis, but part of the effect may be that the energy required to transfer the assimilates from leaf to conducting tissue may have also dropped. Limiting the rate of photosynthesis by reducing the carbon dioxide concentration, however, has been shown to increase the transfer of assimilates to conducting tissue (Nelson, 1963). Although this effect may be related to a failure to divert carbon into leaf storage products during low rates of carbon dioxide fixation, there is also the possibility that because less energy is used for carbon dioxide fixation, more energy is available for transfer.

Pristupa (1964) demonstrated the movement of assimilates from the photosynthetic tissue into the conducting vessels of small vascular bundles and within 3 hr into the phloem of large bundles with a series of microautoradiographs of cereal leaves treated with $^{14}CO_2$. The rate of movement of assimilates out of the leaf can vary. For example, in tobacco 46% of the carbon assimilated at any one time may have left the leaf in 3 hr (Clauss et al., 1964) and 68% in 96 hr. Porter and Bird (1962) found a much slower initial loss of assimilates from a tobacco leaf that had been kept in darkness for 48 hr prior to the assimilation of $^{14}CO_2$. Joy (1964) found that about 50% of the carbon assimilated was translocated from the leaf of a sugar beet within 24 hr and about 70% in 3 days; however, Mortimer (1965) showed that up to 60% of the assimilated carbon could be exported within 4 hr. The movement from the leaf of labeled carbon assimilated during grain development in wheat may be almost complete in 24 hr, or it may take several days (Lupton, 1966). It has been reported that only 20% of the assimilated carbon was exported from a tomato leaf 24 hr after assimilation (Khan and Sagar, 1966). Less than 30% of the assimilates moved out of a pine seedling branch in 3 days (Balatinecz, Forward, and Bidwell, 1966); however, there probably was actively growing tissue within the branch itself which could explain the slow movement.

Although a general translocation pattern seems to exist with an initial rapid transfer of assimilates from the leaf which is followed by a slower movement (Clauss et al., 1964), it is not always clear from published data as to the cause of the great variations of assimilate transfer from a fully grown leaf. It is dependent not only upon factors within the leaf but also upon the ability of other parts of the plant to use or store the available assimilates (Hansen, 1967; Hew, Nelson, and Krotkov, 1967; King, Wardlaw, and Evans, 1967). Where leaf area is large relative to the growth requirements for carbohydrates, the demand for assimilates per unit leaf area will be small. Removal of the upper part of a leaf in *Lolium temulentum* L., thus reducing leaf area relative to growth, stimulated the transfer of carbohydrates from the remaining basal area (Evans and Wardlaw, 1964). However, in sugarcane the opposite effect was obtained from removal of the upper part of a leaf blade. A reduction in flow of assimilates from the remainder of the leaf was incurred (Hartt, et al., 1964). Another factor in the modification of carbohydrate movement from the leaf may be the ability of a leaf to temporarily store excess carbohydrates (Mortimer, 1965).

Very young leaves obtain their carbohydrates as exports from older leaves. Not until they reach one-third to one-half of the maximum leaf area is their assimilation of carbohydrates high enough to meet the growth requirements and is the export of assimilates started (Forde, 1965; Webb and Gorham, 1964). Leaves have been shown to be most active in exporting assimilates soon after reaching their maximum size, and the rate of export declines steadily with age (Clauss et al., 1964; Vyvyan, 1924).

Assimilate Distribution in Relation to Leaf Position

There is a pattern of assimilate distribution in most plants that shows a relation to leaf position. The lower leaves act as the main source of assimilates for the shoot apex. The intermediate leaves may transport assimilates in either direction. This pattern has been shown to occur in many plants, and even grasses and cereals (Evans and Wardlaw, 1964; Williams, 1964). When considering the direction of movement of assimilates, it must be remembered that a living plant is not a static organism and that the position of the leaf relative to the shoot is forever changing. Thus, a typical pattern of distribution of assimilates has been shown for wheat (Doodson, Manners, and Myers, 1964) and the perennial grass, timothy (Williams, 1964). This pattern indicates that initially a young leaf exports to the adjacent shoot apex; but as development advances and more leaves separate this leaf from the shoot apex, an increasingly greater proportion of the assimilates move to the roots. One exception to this general pattern is the observation by Khan and Sagar (1966) that in tomato plants ^{14}C assimilated by the lower leaves moved upward to the shoot apex, while assimilates from the upper leaves moved downward. The upward movement from the lower leaves might be explained by a redistribution of assimilates that first moved downward and then subsequently moved back to the shoot apex through the xylem (Winter and Mortimer, 1967). Also, Bonnemain (1965) has demonstrated that the vascular traces of a tomato leaf unite with the other vascular traces only at the node below the point of insertion of the leaf. Therefore, the assimilates have to travel through one internode downward before moving up to the shoot apex. In the work by Khan and Sagar (1966) the flow of assimilates from the upper leaves was very slow so that, at the time of harvest, it would have appeared that many of the assimilates were still traveling that passage through the internode and actually appeared to be moving downward.

Assimilate Demand

During early growth a leaf will require carbohydrates from other parts of the plant. Once the leaf is fully developed, it is no longer capable of importing assimilates, even when placed in darkness (Aronoff, 1955; Doodson et al., 1964; Rabideau and Burr, 1945; Williams, 1964). Some exceptions occur and appear to involve the redistribution of leaf assimilates back through the xylem (Eschrich, 1966; Williams, 1964) or occur when movement into the leaf has been stimulated by the addition of growth substances (Booth et al., 1962).

Movement of assimilates away from the site of assimilation may continue even when the leaves are detached or isolated by ringing. However, this movement is greatly enhanced by growing tissues and storage organs (Aronoff, 1955; Hartt, 1962; Hartt and Kortschak, 1964; Humphries, 1963). Tissues differ in their demand for assimilates, and there are a number of mechanisms that can cause these differences. First, there is the ability to deplete the supply of carbohydrates and, thus, create a concentration gradient in favor of movement to the certain organ. Consequently, either the intensity of metabolism and the active unloading of the vein system (Geiger, 1966), or the number of sites of utilization and the size of a growing organ may be important. Distance from the site of assimilation to the organ may be important in developing and maintaining a concentration gradient. Secondly, growth substances, moving out from the organ, may either suppress the development of alternate sites of assimilate utilization or alternately stimulate translocation of assimilates through the vascular system to the sites of utilization (Booth et al., 1962; Davies and Wareing, 1965; Hew et al., 1967; Muller and Leopold, 1966; Seth and Wareing, 1967).

It has been suggested (Wardlaw, 1968) that flowers are a weak sink and fruits a strong sink in grapes. Regrowth of corn following removal of the cob (Loomis, 1945) suggests that fruits develop at the expense of vegetative growth (Lenoard, 1962). Dominance of reproductive over vegetative organs has been illustrated several times by the pattern of assimilate distribution or changes in pattern following leaf or fruit removal (Bonnemain, 1965; Hansen, 1967; Khan and Sagar, 1966; Wardlaw, 1965), whereas in trees, heavy seed production may be associated with decreased secondary thickening (Kozlowski and Keller, 1966). Although in cereals there may be some movement of assimilates from the ear to the developing stem during the initial stages of grain development, this movement seems to stop as stem development stops, and an increased movement of assimilates to the grain is noticed (Buttrose and May, 1965). This same restriction in movement is evident in pods of bean plants; however, up to half of the assimilates could be exported from a green pod if this was the only portion of the plant illuminated (Wanner and Bachofen, 1961). The exported assimilates are then moved to other pods of the plant. The sugar beet (Geiger, 1966) also appears to dominate vegetative growth in a manner similar to fruits.

Growth of established shoots appears to have priority over root and bud growth where conditions simulate assimilate deficiency (Evans and Wardlaw, 1963). In *Pinus*, Nelson (1964) observed that translocation of assimilates to the roots under low light intensities was less than under high light intensities. Roots and buds appear to be parts of the plants that are low in priority for assimilates compared to other organs in a plant and only receive assimilates in excess of the requirements of other parts.

The relative abilities of roots and buds to obtain assimilates depend on many conditions. Roots on intact shoots growing under low light conditions will continue to grow slowly, although bud development is almost totally inhibited. However, if the shoot apex is removed, as often occurs with severe defoliation of pasture species, the buds are released from apical dominance and then grow at the expense of the root system (Milthorpe and Davidson, 1966).

Within the shoot there may be competition for assimilates between the shoot apex, leaves at different stages of development, and expanding stem tissue. The apex, because of its small size, will not have a large demand for assimilates, but the intensity of this demand may be high. The actual apex, if relatively inactive, might be expected to show retarded development during periods of general assimilate deficiency. Friend, Helson, and Fisher (1962) working with wheat found that differences in light intensity had only slight effects on the development of the apex.

A leaf at the stage of most rapid development seems to retard the growth of the next youngest leaf above it (Vyvyan, 1924). Stem expansion could occur at the same time leaf expansion is occurring and may compete with young leaves for assimilates. However, studies of this phenomenon have not been undertaken to show its importance. Competition between the stem and developing ear for assimilates in cereals has been shown by Friend (1965), when he found that both stem height an ear length increased with increasing light intensity up to 2,500 footcandles.

Although storage organs actively accumulate assimilates, the leaves, stem, and roots have some capabilities for holding excess carbohydrates such as starch, oligosaccharides, or simple sugars. Temporary storage of assimilates in the stem of cereals, at the time of anthesis, is followed by a redistribution of these materials to the ear and new shoots (Stoy, 1965).

Environmental Factors Affecting Carbohydrate Distribution

After considering the previous factors, it should be evident that the environment can control the distribution of assimilates in one or more ways. Environmental factors may affect assimilate distribution by causing changes in the rate of growth of developing organs (which also may be influenced by hormonal levels, by alterations in photosynthetic levels, and by outflow of assimilates from leaves) or by directly affecting movement of assimilates. Also, changes in plant development, e.g., from leaf production to flower and fruit formation, will add to the above effects.

Temperature. With shifts in temperature there is often a marked change in the development pattern of plants, much of which is presumably caused by direct growth rate change of the developing organs. The accumulation of soluble carbohydrates at low temperatures suggests that growth rates are affected more by temperature than are photosynthetic rates (Evans and Wardlaw, 1964); however, the differences in response may be due somewhat to a limitation of photosynthesis at higher temperatures through an inadequate supply of carbon dioxide (Gaastra, 1963). Reduced growth due to low temperatures has been shown to reduce the rate of assimilate translocation (Hartt, 1965*a*; Vernon and Aronoff, 1952; Whittle, 1964); however, since translocation itself is a metabolic process, it may be directly affected by temperature. For example, where the photosynthetic rate does not fall with low temperatures, but shoot growth declines, more assimilates will become available for the growth of roots and buds. Therefore, the change in distribution of assimilates with falling temperature is not necessarily associated with differences in the optimum temperature for growth of different plant organs. Friend (1966) found the optimum temperature for growth of attached roots in wheat to be about 15°C while that for isolated roots in a sterile culture was 25°C. Translocation of assimilates from the leaves of sugarcane was found to be more dependent on root than shoot temperature (Burr et al., 1958). Part of this effect could be related to the production of tillers from the base of the sugarcane plant where temperatures will be close to those of the root system. Also, any change in temperature may affect nutrient uptake.

Although there is evidence to infer that movement of assimilates through conducting tissue is associated with metabolically active cells and may be dependent upon temperature, there is no conclusive evidence that reduced translocation is ever the primary cause of limiting growth under conditions of low temperatures. There is little indication from most work that the optimum temperature for translocation differs from that for growth. Hsia, Waon, and Wang (1963) concluded from their work on wheat, in which they lowered the temperature on the ear, stem, and flag leaf separately, that the effect of temperature on the distribution of assimilates from the flag leaf was primarily dependent on the growth of the ear and to a lesser extent on the function of the leaf. Lowering the temperature of the stem from 20°C down to 8°C had no observable effect on assimilate distribution. The effect of temperature on the regions of growth and assimilate movement out of the leaf was assumed to be related to the energy requirements of these processes (Geiger, 1966; Ullrich, 1962). The failure of Hsia et al. (1963) to find any direct effect of temperature on translocation is not in accordance with the results of several other workers who have shown that local stem or petiole temperatures from 0°C to 5°C inhibited the movement of applied ^{32}P

and of ^{14}C assimilates (Swanson and Whitney, 1953; Webb, 1967; Webb and Gorham, 1965).

The effect of temperature on translocation may be transient as shown by the work of Swanson and Geiger (1967) on sugar beets. Whittle (1964) has suggested that the recovery of translocation under low temperatures could be related to a buildup of sugars in the supply regions of the plant, and hence, the development of a steeper sugar concentration gradient through the cooled zone. However, Ford and Peel (1966) concluded, from their work on the relation between temperature and movement of ^{14}C through a willow stem to an aphid colony, that lateral movement out of the sieve tubes is metabolic and dependent on temperature, whereas longitudinal movement down the length of the sieve tubes is independent of temperature. Perhaps temperature effects on cell-membrane permeability and lateral release of assimilates could explain some of the effects of temperature on translocation. It is apparent that this aspect still needs clarification not only in relation to the effects of temperature on the pattern of assimilate distribution but also in relation to the mechanism of translocation. However, it seems likely that the primary effect of temperature on assimilate distribution is associated with growth rather than sugar conduction, as the shifts in distribution of assimilates with reduced temperature are the reverse of the changes normally associated with a decrease in assimilate supply.

Light. Even though the pattern of assimilate movement is influenced by the relative ability of different organs to "attract" the available carbohydrate, it is also influenced by the rate of assimilate production in photosynthesis, which is regulated by the duration of intensity of light. Root and bud growth are inhibited to a greater extent than shoot growth by a reduction in light. Nelson et al. (1961) observed reduced movement of ^{14}C assimilates from the needles to roots in conifers grown under low light.

Although root growth is more restricted than shoot growth under low light, there are some instances where it has been shown that, of the assimilates leaving a leaf, the proportion moving to the root system is greater in the dark than in the light (Nelson, 1964; Nelson and Gorham, 1957). Thrower (1964) has shown that a reduction in the rate of photosynthesis of an expanding soybean leaf, due either to darkening or a reduction in the supply of carbon dioxide, results in a smaller demand and reduced import of assimilates into the growing leaf. Such an effect could explain the observed differences in assimilate distribution pattern between light and dark. Translocation of assimilates to the growing organs throughout a normal 24-hr cycle may occur largely in the dark period or largely in the light period (Mason and Maskell, 1928). However, under low light conditions with less accumulation of carbohydrates in leaves and stems, translocation during the dark period is likely to become far less important than during the light period. Therefore, by reducing movement of assimilates during darkness, the over all effect would be to increase the relative proportion of assimilates reaching the shoot.

Movement of assimilates out of a leaf, as mentioned earlier, is influenced by light energy. Therefore, not only is the rate of photosynthesis reduced under low light but also the proportion of assimilated carbon leaving the leaf. Hartt and Kortschak (1964) and Hartt (1965*b*) have suggested that there is a light process involved in translocation in a sugarcane leaf, with a maximum response at low intensities (approximately 100 footcandles). However, Shan'gina (1965), working with tomatoes, has found that a decrease in light intensity from about 3,600 down to 900 footcandles, which has only a small effect on leaf photosynthetic rate, results in a slower outflow of assimilates and an increase in leaf polysaccharides. This response of translocation to decreasing light intensities, at higher levels than those reported by Hartt (1956*b*), suggests that either sugarcane leaves respond in a different manner than leaves of other species or the response may have been affected by detaching the sugarcane leaves.

Day length, through changes in plant development, will have a considerable indirect effect on the distribution of assimilates. Nelson (1963) noted that movement of assimilates in larch was affected by day length through effects on root and shoot development. Perhaps the more conspicuous effects of day length are related to the change from vegetative to floral development, and probably the greater translocation of assimilates in long-day plants under long days and short-day plants under short days is the result of this developmental process.

Water. Gates (1955*a*) has already pointed out that the effect of water stress on growth and therefore on the distribution of photosynthetic assimilates is not fully understood. Elongation growth commonly shows an early response to water stress, whereas photosynthesis and the accumulation of assimilates continues for some time after stress is evident in the elongation of the plant (Iljin, 1957). The observation by Slayter (1957) that dry weight accumulation ceased earlier than stem elongation in tomato plants is an exception. Other forms of growth are not so easily altered by stress as is elongation. For example, grain development in cereals may be unaffected by a stress that causes wilting of the leaves (Asana, Saini, and Ray, 1958). The response to water stress depends on the organs involved.

Iljin (1957) suggested that cells, such as those found in seeds, buds, and storage organs, which generally lack vacuoles and are filled with food reserves will be the most resistant to desiccation. It is resistance to desiccation rather than the ability of an organ to function with a low water content that appears to give an organ the ability to withstand water stress.

There are often marked alterations in the pattern of assimilate distribution when plants are subject to water stress. These alterations may be the direct result of reduced growth rates or of reduced photosynthetic rates, although there is some evidence for a more direct effect of stress on the conduction of assimilates.

The observation by Hartt (1967) of an increase in the sugar content of the stem when sugarcane plants are under water stress seems to fit Iljin's (1957) theory, i.e., "reduced growth under stress results in the accumulation of sugars." Hartt favors a direct cause-and-effect explanation in which sugar accumulation is the result of a reduced velocity of movement through the conducting system. This is somewhat similar to a view expressed earlier by Gates (1955*a*,*b*) who suggested that changes in the weight ratios of different plant organs when under stress were due to a modification of translocation. Roberts (1964) observed that water stress increased the upward movement of assimilates in yellow poplar. Also, during grain development of wheat, a water stress that caused reduced photosynthetic activity in the leaves resulted in an increased movement of assimilates from the lower leaves to the ear (Wardlaw, 1967). This is similar to translocation that occurs when assimilation is reduced under low light intensities.

The work of Plaut and Reinhold (1965) on the movement of applied sucrose in bean plants under water stress has been interpreted as showing that water stress directly alters translocation. Certainly, changes in xylem tension affect pressures within the sieve tubes of the phloem, as Peel and Weatherley (1962, 1963) demonstrated by measuring the exudation of phloem sap through aphid stylets. However, where growing organs are not subject to the same stress as the rest of the plant, as with the ear of wheat during grain development, velocity of movement of labeled assimilates through the conducting tissue was found to be relatively insensitive to stress (Webb and Burley, 1964). This is evidence, in part, for the suggestion by Nelson (1963) that water stress affects the movement of assimilates into but not through the conducting tissue. There is ample evidence that there is a reduction in the rate of movement of assimilates out of the photosynthetic tissue during water stress (Hartt, 1967; Plaut and Reinhold, 1965; Roberts, 1964; Wardlaw, 1967; Wiebe and Wihrheim, 1962). The close interaction between growth and translocation makes it difficult to assess the relative importance of these processes in determining the pattern of distribution of assimilates in plants under water stress. In the few instances where growth has been eliminated as a factor it appears that translocation is relatively insensitive to stress. Also, the observation by McWilliam (1968) of a significant movement of assimilates from stem to roots and buds in the perennial grass (*Phalaris tuberosa* L.O.) when the plants are dormant due to a restricted water supply, suggests that the transport system is insensitive to desiccation.

METHODS AND MATERIALS

Experiment 1

Blue grama, buffalo grass, and western wheatgrass seed harvested at Eads, Colorado; Lubbock, Texas; and Newell, South Dakota, respectively, was obtained from the Longmont Seed Co., Longmont, Colorado. Seedlings were started in flats of sand and then transplanted, one plant per pot, into plastic pots (12 cm in diameter by 13 cm in depth with drainage holes) containing sand when the plants were 5 to 10 cm in height. Plants were watered daily and given one-fifth strength Hoagland's solution (Hoagland and Arnon, 1950) once a week. The plants were maintained in a growth chamber with a 26.7°C day/21.1°C night temperature regime and an 18-hr photoperiod from cool-white fluorescent lamps and incandescent bulbs. The light source produced about 23,680 lux over the visible spectrum as measured with a Weston light meter.

Plants were labeled with ^{14}C, 8 to 9 weeks after transplanting by exposing two plants in a 6" × 12" × 18" plexiglass chamber to 40 μc $^{14}CO_2$/plant for 10 min. The $^{14}CO_2$ was released by dripping $Na^{14}CO_3$ solution into 2 N H_2SO_4 and then circulating it through the plexiglass chamber with an air pump. After 10 min the remaining $^{14}CO_2$ was trapped by circulating the gas stream through a 1 N NaOH solution. The plexiglass chamber was removed and the plants remained in the growth chamber until harvest.

Two plants of each species were harvested 3, 9, and 24 hr after labeling. They were then washed and blue grama and buffalo grass were sectioned into upper and lower roots, crown (2-cm section above the roots), and herbage. Western wheatgrass was additionally sectioned into upper and lower rhizomes. Plant parts were immediately frozen with dry ice, freeze-dried, weighed, and ground with a ball mill grinder. Samples of the plant material were then assayed for ^{14}C activity by a modified Schoniger combustion technique (Schoniger, 1955) (Fig. 1). A weighed plant sample (10 to 25 mg) was wrapped in black weighing paper and placed within a nichrome wire coil suspended from the rubber stopper of a 250-ml Erlenmeyer flask. Ethanolamine (1 ml) was placed in the flask which was then purged with pure oxygen and tightly stoppered. The sample was ignited with an infrared light source, and the flask was allowed to set overnight to allow complete carbon dioxide diffusion to the trapping reagent. Ethylene glycol monomethyl ether (1 ml) was added to the flask and mixed. A 1-ml aliquot was added to 15 ml of a 1.3:1.9 (v/v) ethylene glycol monomethyl ether:toluene cocktail solution (Jeffay and Alvarez, 1961) and counted on a Beckman LS-150 liquid scintillation counter. The toluene cocktail was made by dissolving 5.5 g of 2,5-diphenyl-oxazole (PPO) and 0.3 g of 1,4-bis(2-(4-methyl-5-phenyloxazolyl))-benzene (dimethyl-POPOP) in one liter of toluene.

Results of radioactivity in each section are presented as percent of total plant activity.

Experiment 2

A sod of blue grama, buffalo grass, and western wheatgrass was obtained from the Pawnee Site north of Nunn, Colorado, and maintained in the greenhouse. Tillers of blue grama and western wheatgrass and stolons of buffalo grass were obtained from the sod and started in flats of sand on a rooting bench. Plants 5 to 10 cm tall were transplanted (one plant per pot) into plastic pots (12 cm in diameter by 13 cm in depth with drainage holes) containing sand. They were watered daily and given one-fifth strength Hoagland's solution (Hoagland and Arnon, 1950) once every week. Growth conditions were the same as in Experiment 1.

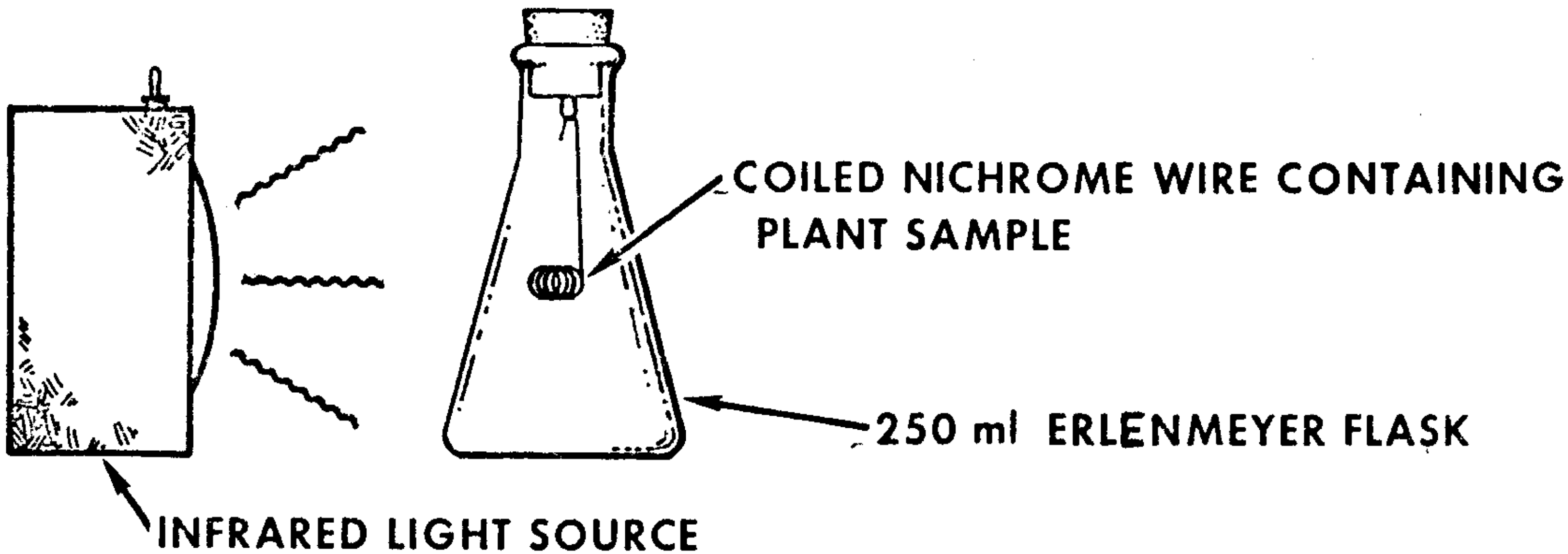

Fig. 1. Diagram of combustion apparatus.

Plants were labeled with ^{14}C at the vegetative growth stage by exposing 21 plants to 8.5 μc $^{14}CO_2$/plant for 5 min in a plastic tent. A small fan inside the tent facilitated air movement. Method of ^{14}C exposure was as described in Experiment 1.

Plants were harvested 0.5, 1, 2, 3, 4, 5, and 6 hr after labeling; washed; and sectioned into herbage, crown (2 cm above the roots), and root tissue. The sectioned material was then treated as previously described in Experiment 1 except the dried tissue was ground to 40 mesh with a Wiley mill.

Sugars were extracted from the root tissue with 85% ethanol (v/v), filtered through Whatman no. 1 filter paper, and concentrated to approximately 3 ml in a rotary-evaporator with reduced pressure at 45°C. The extract was transferred to 13 × 100 mm test tubes, taken to dryness, and re-extracted with ethylacetate:water (1:1 v/v) to remove nonpolar constituents. The upper phase containing much of the pigmentation in the sample was discarded. The lower phase was redried and taken up in 100 μliter of 85% ethanol. Sugars were separated by thin-layer chromatography on cellulose precoated plastic sheets obtained from Brinkman Instruments, Inc. Six samples containing 10 to 50 μg sucrose in 20 μliter were spotted on each plate with two standards and one blank spot. Sugars were separated according to a procedure described by Vomhoff and Tucker (1965). After separation the two outer strips containing the sugar standard markers were cut from the plate, sprayed with 0.1 g of p-anisidine HCl in 10 ml of 95% ethanol, and placed in a 110°C oven for development. The separated sucrose spots were located with the standard markers, scraped into a 15-ml centrifuge tube, and eluted with 2 ml of distilled water. The solution was mixed and centrifuged at 1,000 rpm for 10 min. Two 0.5-ml aliquots were taken for sucrose analysis, and one 0.5-ml aliquot was taken for determination of radioactivity. The latter aliquot was added to toluene cocktail containing 9% (v/v) Biosolve-3[1/] and counted in a Beckman LS-150 liquid scintillation counter. Sucrose was determined by a ferricyanide technique (Furuholmen et al, 1964; Ting, 1956) modified to determine micro-quantities of sugar. The samples were hydrolyzed with 0.2 N H_2SO_4 for 15 min in a boiling water bath, cooled, and heated again under the same conditions after addition of 5 ml of ferricyanide reagent (see Appendix I). After cooling, 3 ml of 7 N H_2SO_4 were slowly added, and the samples were mixed thoroughly to remove all gas. Finally, 4 ml of arsenomolybdate reagent (see Appendix II) were added and mixed immediately. Percent transmission of each sample was then read on a Bausch and Lomb Spectronic 20 spectrometer at 745 nm. A standard curve containing 0, 12.5, 25.0, 37.5, and 50.0 μg sucrose was determined with each set of samples and was used to obtain the μg of sucrose in each sample. The sucrose and radioactive data were used to calculate sucrose specific activity (dpm/μg sucrose).

Experiment 3

Blue grama, buffalo grass, and western wheatgrass plants were started as described in Experiment 2. Plants were grown on a greenhouse bench, grouped according to stage of growth, and then transferred to growth chambers with 32.2/26.7°C, 26.7/21.1°C, and 21.1/15.6°C day/night temperature regimes 1 week before labeling. All other growth conditions were the same as described for Experiment 2. Growth stages were selected as described in Table 1.

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Table 1. Criteria for selection of growth stages.

Species	Growth Stage Number	Plant Description
Blue grama	1	Less than 50% of the heads at anthesis
	2	50% or more of the heads at anthesis
Buffalo grass	1	Two stolons or less per plant
	2	Three stolons or more per plant
Western wheatgrass	1	Less than 50 cm in height
	2	Greater than 50 cm in height

Plants were labeled as described in Experiment 2 except the tent was enlarged to facilitate 24 plants instead of 21.

Harvesting was carried out as described in Experiment 2 at 2 and 6 hr after labeling. Plants were divided into shoot and root sections, frozen, freeze-dried, weighed, and ground. Samples were combusted in duplicate as previously described to determine the radioactivity in each section. Results are presented as percent of total plant activity.

Statistical Analysis

All results were analyzed statistically with standard procedures, and Duncan's Multiple Range Test (Steel and Torrie, 1960) was used to compare treatment means. The experimental design for Experiment 1 was a split plot, and Experiments 2 and 3 were completely randomized.

The percentage data from Experiments 1 and 3 had to be transformed so that the linear additive models for standard statistical procedures would apply. Root and crown data were transformed with square roots. Shoot and herbage data were transformed by determining the square root of the difference between the total plant activity (100%) and the percent of total plant activity in the shoots or herbage. Therefore, in Experiment 3 the transformed values from roots and shoots are the same.

RESULTS AND DISCUSSION

Experiment 1

Distribution of ^{14}C among plant parts at three time periods after exposing each of the entire plant growing vegetatively to 40 μc $^{14}CO_2$/plant for 10 min is shown in Table 2. It appeared that each grass translocated labeled carbon at different rates. Buffalo grass retained nearly all of the ^{14}C in the herbage while only 80% of the plant activity in blue grama

Table 2. Distribution of ^{14}C within plant parts at three time periods after exposing entire plants growing vegetatively at 26.7/21.1°C to 40 μc CO_2/plant for 10 min.

Species	Plant Part	Percent Total Plant Activity		
		3 hr	9 hr	24 hr
Blue grama	Herbage	79.5	81.0	80.5
	Crown	13.1	10.5	12.4
	Upper roots	4.8	4.2	3.3
	Lower roots	2.6	4.2	3.8
Buffalo grass	Herbage	99.3	98.8	95.2
	Crown	0.3	0.4	1.7
	Upper roots	0.2	0.3	0.9
	Lower roots	0.1	0.5	2.2
Western wheatgrass	Herbage	81.0	72.6	64.9
	Crown	5.4	3.5	7.8
	Upper roots	10.4	12.7	17.6
	Lower roots	3.2	11.2	9.7

and western wheatgrass remained in the herbage after 3 hr. Translocation of ^{14}C from herbage continued up to 24 hr (the last sample period) in western wheatgrass. In contrast movement of ^{14}C activity out of blue grama herbage was nearly complete after 3 hr, and it only continued at a slow rate in buffalo grass. Western wheatgrass moved more ^{14}C from herbage to crown and root plant parts than the other two grasses. Blue grama accumulated more of the translocated ^{14}C in crown that root section while western wheatgrass accumulated more translocated ^{14}C in the root sections. Translocation of ^{14}C in buffalo grass was too small to establish a partitioning trend between crown and root sections. Except for western wheatgrass, distribution of ^{14}C activity between upper and lower roots within grasses was nearly equal after 9 hr. The higher percentage of total plant activity in upper roots as compared to lower roots of western wheatgrass was probably due to the presence of more rhizomes in the upper root section.

Continued loss of ^{14}C activity from the herbage of western wheatgrass indicates that this grass was still transporting carbon to the roots after 24 hr. Since these grasses were in early vegetative growth, the extra partitioning of radioactive photosynthate in western wheatgrass as compared to the other grasses was probably used for root and rhizome growth rather than for energy storage. Similarly, the lack of ^{14}C accumulation in roots of buffalo grass probably reflects partitioning of photosynthate to rapidly growing stolons.

It was concluded from these results that partitioning of photosynthate within the three grasses at early vegetative growth stages was basically different. It was also found that it was not necessary to use 40 μc of $^{14}CO_2$ to label each plant as the method of analysis could detect lesser quantities of radioactivity. The chamber used to label the plants was expanded to facilitate more plants and reduce the time involved in labeling.

Experiment 2

This study was designed to learn how rapidly and to what extent labeled sucrose entered the roots of buffalo grass, blue grama, and western wheatgrass and equilibrated with root sucrose pools. Fig. 2 shows the time course of root sucrose labeling in each grass after exposing entire plants to 8.5 μc $^{14}CO_2$/plant for 5 min. Radioactive sucrose entering the roots of blue grama and western wheatgrass caused a rapid increase in the specific activity of the root sucrose pool for 2 to 3 hr after labeling. The decline in the specific activity of root sucrose after 3 hr indicated that some of the soluble sucrose pool was being used to form other types of carbon compounds. Therefore, the root sucrose pool appeared to be in dynamic exchange with the translocation stream.

The root sucrose labeling pattern of buffalo grass differed from the other two grasses in that two peaks in sucrose specific activity were observed. Furthermore, the specific activity of sucrose was not as high as in the other two grasses. However, buffalo grass did have the same characteristic rapid increase in sucrose specific activity from the 0.5- to 2-hr translocation period.

Further study and analysis of radioactivity within plant root carbohydrate fractions might better explain carbohydrate transformations in blue grama and western wheatgrass after the 3-hr translocation period and in buffalo grass after the 2-hr translocation period. Also, longer translocation periods should be used to determine how much of the labeled sucrose remains in the soluble sucrose pool. The results of this experiment

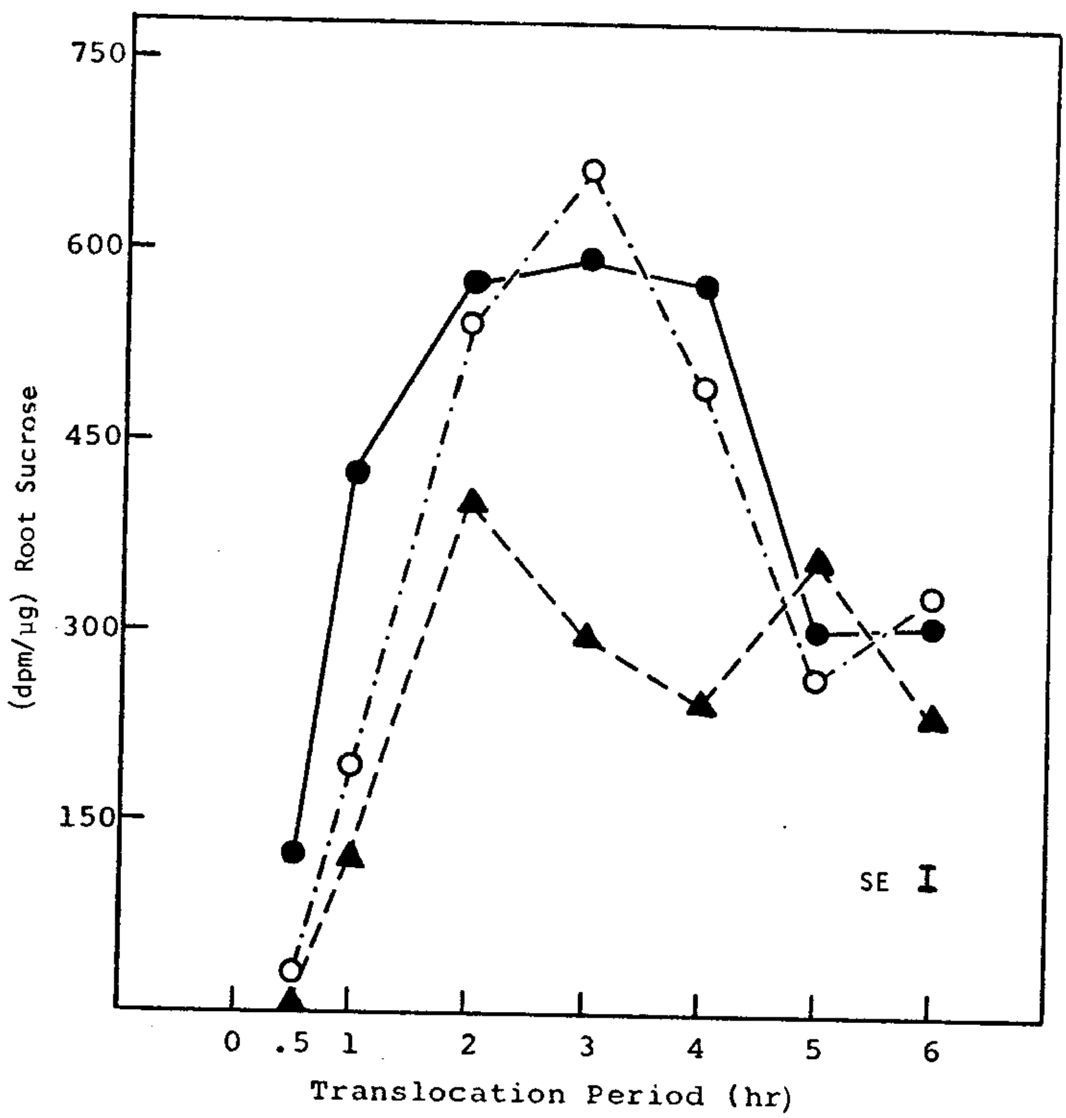

Fig. 2. Time course of root sucrose labeling in blue grama (—●—), buffalo grass (–▲–), and western wheatgrass (-·○·-) after exposing entire plants to 8.5 µc $^{14}CO_2$ for 5 min.

indicated that the root sucrose pool was in equilibrium with the translocation stream.

Experiment 3

As indicated in the literature review, many environmental and plant morphological factors can affect carbon translocation. Studies were conducted to characterize the effect temperature and plant growth stage have on carbon translocation of blue grama, buffalo grass, and western wheatgrass.

Analysis of variance results are summarized in Appendix Table 3. Carbon partitioning between tops and roots, as indicated by ^{14}C distribution, was affected by temperature in blue grama only when averaged over both translocation periods and growth stages. The significant time and temperature interaction (Appendix Table 3a) and the nonsignificant temperature effect at the 6-hr translocation period (Appendix Table 3g) indicated that the temperatures used influenced ^{14}C distribution in blue grama more at the 2-hr than the 6-hr translocation period. Therefore, it was concluded that temperature did not significantly affect final photosynthate partitioning in the three grasses in the temperature regimes used in the study. It must be remembered, however, that all plants used in each temperature regime were grown on a greenhouse bench and were acclimated at the treatment temperature for only 1 week before beginning the translocation experiment. Therefore, these results do not reflect long-term growing conditions at the temperatures used in the experiments.

Plant growth stage significantly influenced partitioning of ^{14}C in western wheatgrass but not in blue grama or buffalo grass (Appendix Table 3). More of the total ^{14}C activity in western wheatgrass was found in roots at the earlier, as compared to the latter, growth stage (Appendix Table 5).

These significant differences may, however, be due to sampling before ^{14}C partitioning was complete.

Fig. 3 graphically represents the interaction of temperature and translocation period on the percent total plant ^{14}C activity in the roots. Accumulation of ^{14}C in the roots of blue grama significantly increased with an increase in temperature (Appendix Table 5). As the temperature increased from 21.1/15.6°C to 26.7/21.1°C the rate at which ^{14}C was partitioned to the roots more than doubled. Nearly all of the ^{14}C activity observed in blue grama roots at 6 hr after labeling in the 26.7/21.1°C temperature regime was already present 2 hr after labeling. As the temperature increased to 32.2/26.7°C rate of ^{14}C translocation declined again, but it was higher than at 21.1/15.6°C.

Accumulation of ^{14}C in the roots of buffalo grass and western wheatgrass was not significantly affected by temperature (Appendix Table 3). However, an increase in temperature resulted in less transport of ^{14}C to the roots of buffalo grass. Temperature did not influence the rate at which ^{14}C was moved to roots of buffalo grass as indicated by the parallel lines representing root ^{14}C activity at 2 and 6 hr after labeling (Fig. 3). Most of the ^{14}C activity observed in the roots at 6 hr was already present 2 hr after labeling. Although not statistically significant, distribution of ^{14}C to the roots of western wheatgrass was the highest at the 26.7/21.1°C temperature regime 6 hr after labeling. Initial rate of ^{14}C translocation was lowest in western wheatgrass compared to the other grasses as shown by the low activity at the 2-hr sample period. Translocation rate increased slightly with temperature.

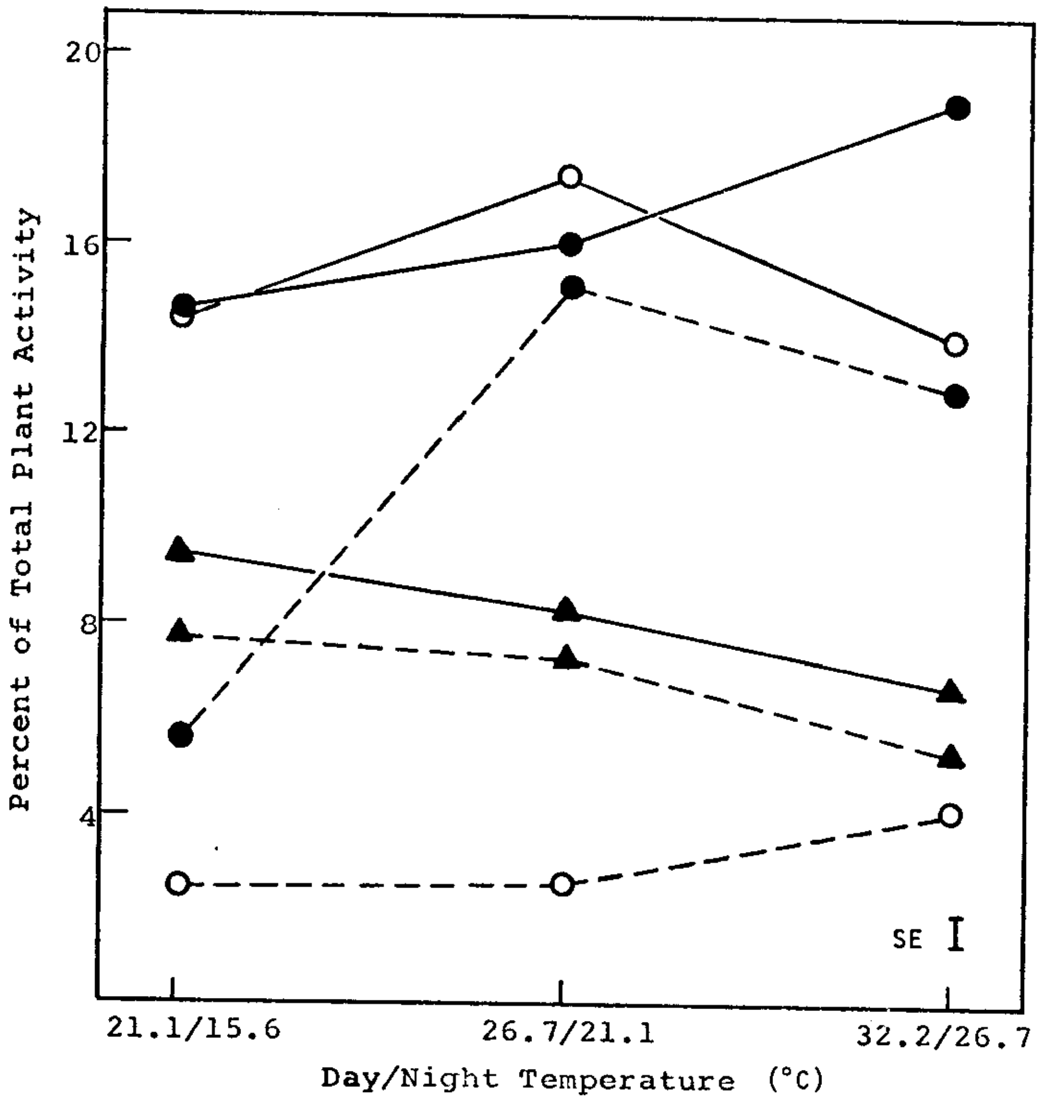

Fig. 3. Comparison of the percent total plant ^{14}C activity in roots of blue grama (●), buffalo grass (▲), and western wheatgrass (O). The interaction of the three temperature regimes and the 2-hr (— — —) and 6-hr (———) translocation periods averaged over two growth stages is shown.

These results indicated that temperature influenced the accumulation of ^{14}C in the roots of the three grasses although final partitioning of ^{14}C between shoots and roots was not significantly affected by temperature.

Fig. 4 presents the interaction of total ^{14}C activity in roots of the three grasses among temperatures and species averaged over time. Nonsignificant time × temperature and time × species × temperature interactions at growth stages 1 and 2 (Appendix Table 3d and Table 3e, respectively) indicated that these interaction relationships were similar at both the 2- and 6-hr sample periods. At growth stage 1, partitioning of ^{14}C to roots of blue grama increased as the temperature changed from 21.1/15.6°C to 26.7/21.1°C and then declined somewhat. In contrast, ^{14}C partitioning in buffalo grass and western wheatgrass was similar over the temperature range studied. At growth stage 2, ^{14}C accumulation in the roots of blue grama increased from the coolest to the warmest temperature regime. However, ^{14}C activity in growth stage 2 roots at 32.2/26.7°C was slightly lower than roots of growth stage 1 at the 26.7/21.1°C temperature regime. Buffalo grass responded to increasing temperature with a slight but steady decline in accumulation of ^{14}C in the roots. At growth stage 2 western wheatgrass accumulated more ^{14}C in roots at 26.7/21.1°C than at either higher or lower temperatures. Differences in partitioning of ^{14}C between tops and roots may reflect differences in root growth or reserve energy storage.

It must be remembered that data in Fig. 4 reflect the temperature and species interaction averaged over time. Consequently, temperature and growth stage effects on ^{14}C distribution to roots of each grass are not demonstrated for each translocation period. However, it was evident that ^{14}C distribution averaged over time was affected by temperature and growth stage.

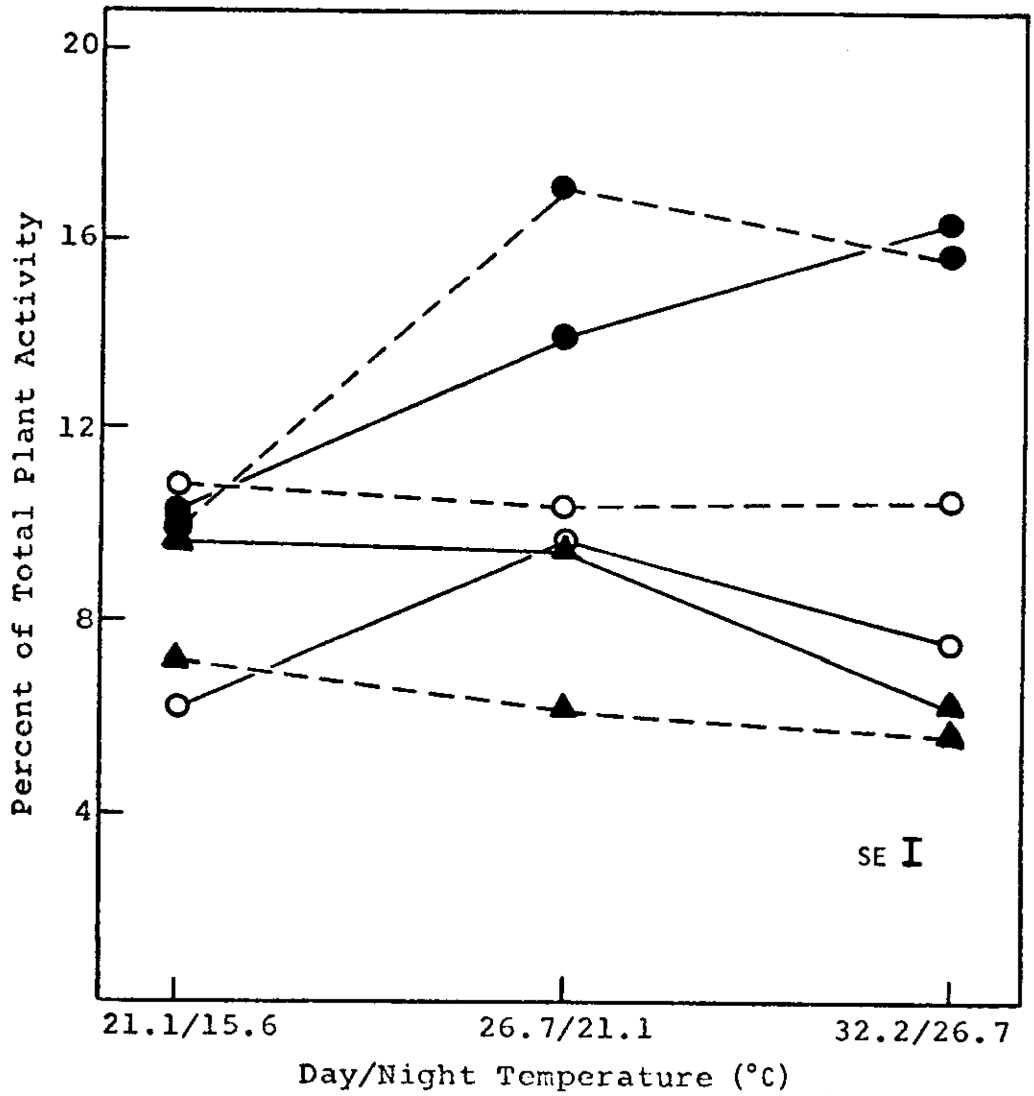

Fig. 4. Percent total plant ^{14}C activity in roots of blue grama (●), buffalo grass (▲), and western wheatgrass (O). Comparison of growth stages 1 (— — —) and 2 (———) for an interaction of temperature and species averaged over time.

Interaction of species and time on ^{14}C partitioning between tops and roots averaged over temperature is shown in Fig. 5. Although slope of the lines for each species was slightly different between growth stages, the growth stage × time interaction of ^{14}C partitioning for each species was not significant (Appendix Tables 3a, 3b, and 3c). Buffalo grass and blue grama accumulated at least half of the total ^{14}C detected in their roots by the 2-hr sample period. In contrast, western wheatgrass accumulated most of the total ^{14}C observed in the roots between the 2- and 6-hr translocation period. Since the final distribution of ^{14}C between tops and roots of blue grama and western wheatgrass was similar at growth stage 1, the rate of distribution apparently was higher in blue grama than western wheatgrass.

The literature was inconclusive as to whether carbon translocation is affected directly by temperature (Burr et al., 1958; Ford and Peel, 1966; Friend, 1966; Swanson and Geiger, 1967; Wardlaw, 1968; Webb, 1967) or through the growth rates of various organs as influenced by temperature (Ford and Peel, 1966; Hartt, 1965*a*; Hsia et al., 1963; Ullrich, 1962; Webb and Burley, 1964). The results from this study also seem inconclusive in this respect. However, they tend to show there is a distinct interaction between the effect of temperature and growth stage on the partitioning of ^{14}C to the roots of blue grama, buffalo grass, and western wheatgrass. Western wheatgrass was the only grass in which stage of growth had a significant effect on ^{14}C distribution (Appendix Table 3c). Distribution of ^{14}C in buffalo grass was not significantly affected by temperature, translocation period, or growth stage (Appendix Table 3b). However, certain trends, such as a decrease in ^{14}C accumulation with an increase in temperature at each growth stage, could be seen. Temperature and stage of growth influenced

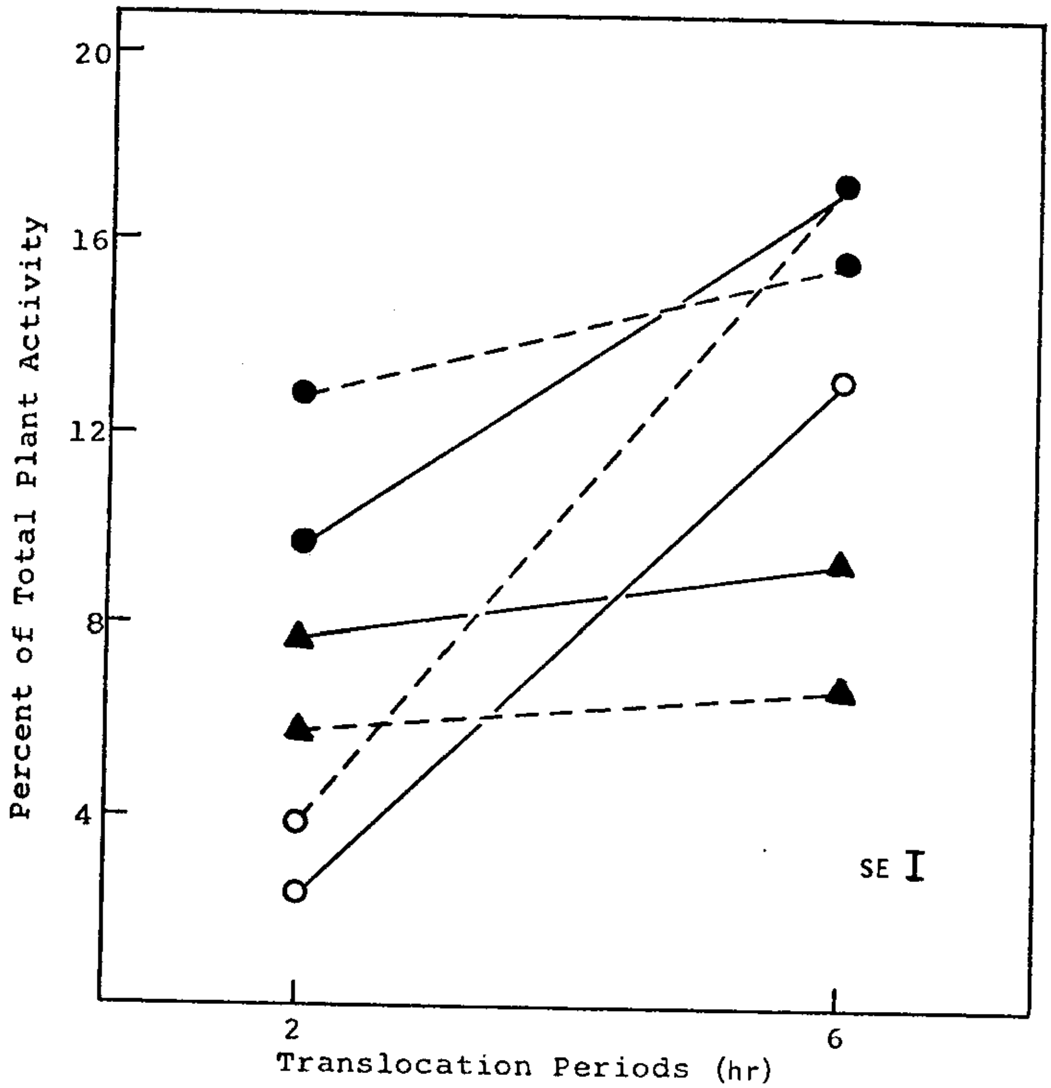

Fig. 5. Percent total plant ^{14}C activity in roots of blue grama (●), buffalo grass (▲), and western wheatgrass (O). Comparison of growth stages 1 (— — —) and 2 (———) for the interaction of species and time averaged over three temperatures.

translocation in blue grama quite differently than buffalo grass and western wheatgrass. Accumulation of ^{14}C in the roots 6 hr after labeling appeared to increase as temperature increased. The variation in ^{14}C accumulation in the roots due to growth stage could be an indication of the variation in assimilate demands as a result of differences in maturity.

This study attempted to demonstrate how temperature and growth stage affect translocation to the roots of blue grama, buffalo grass, and western wheatgrass. The results indicated that further study be conducted to obtain more information about the effect of growth stage on distribution of assimilates. The author contends there is a distinct interaction between these two parameters since roots at each growth stage of each grass accumulated ^{14}C in varying amounts. Methods which should be considered in additional study include:

1. The use of a greater range of growth stages.
2. Analysis of sucrose specific activity as a measure of actual assimilate translocation.
3. Temperature control on various plant parts to determine if temperature does affect translocation directly or through the growth rates of the various plant parts.

SUMMARY

The main objective of this study (Experiments 1, 2, and 3) was to determine the effect of temperature and stage of growth on the distribution of ^{14}C to the roots of blue grama, buffalo grass, and western wheatgrass. The following conclusions were made from the results.

Experiment 1

1. The apparatus used to label the plants was adequate for this study; yet, the chamber could be enlarged to facilitate more plants and reduce time of labeling.
2. Labeling of plants with 40 μc $^{14}CO_2$/plant was not necessary as the method of analysis used for plant analysis could detect lesser quantities of ^{14}C.
3. Blue grama accumulated the highest percentage of total plant ^{14}C activity in the roots 9 hr after labeling as compared to 3 and 24 hr after labeling.
4. Buffalo grass translocated the lease amount of ^{14}C to the roots as compared to blue grama and western wheatgrass, but it increased slightly in percent total plant activity as ^{14}C moved to roots up to 24 hr after labeling.
5. A loss in ^{14}C from the lower roots after the 9-hr translocation period and an increase in percentage ^{14}C in the crown tissue and upper roots of western wheatgrass 24 hr after labeling could indicate a slight upward movement of ^{14}C or a loss in the other plant parts due to respiration.

Experiment 2

1. The rapid increase of sucrose specific activity in the roots of each grass from 0.5 to 2 hr after labeling indicates that a rapid interchange occurred between the translocation stream and the sucrose pool in the roots.

Experiment 3

1. All three grasses accumulated more total plant ^{14}C activity in the roots at 6 hr than at 2 hr after labeling.
2. Temperature significantly affected translocation in blue grama with the highest percentage (16%) of ^{14}C activity occurring in roots of the plants grown at the highest temperature (32.2/26.7°C). Buffalo grass roots decreased slightly in percent ^{14}C activity with increasing temperatures. Accumulation of ^{14}C in roots of western wheatgrass was highest at the 26.7/21.1°C temperature regime and declined at higher and lower temperature regimes.
3. Blue grama and western wheatgrass at growth stage 1 accumulated more ^{14}C in 2 hr after labeling than plants of both grasses at growth stage 2. Buffalo grass reacted in the reverse of blue grama and western wheatgrass. Plants at growth stage 2 accumulated more ^{14}C for both translocation periods than those at growth stage 1.

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APPENDIX I. ALKALINE FERRICYANIDE REAGENT

Dissolve 160 g anhydrous sodium carbonate and 150 g disodium phosphate hepta hydrate in 850 ml distilled water. Add 4.0 g potassium ferricyanide and dilute to 1 liter. Store in a brown bottle. Reagent is stable for 2 to 3 months.

APPENDIX II. ARSENOMOLYBDATE SOLUTION

Dissolve 25 g of ammonium molybdate tetrahydrate in 450 ml distilled water. Add 21 ml concentrated H_2SO_4 followed by 3 g disodium arsenate in 25 ml distilled water. Heat to 55°C for 30 min with constant stirring in a water bath or in an incubator at 37°C for 24 to 48 hr. Store in a brown bottle. Reagent is stable for 2 to 3 months.

APPENDIX III

APPENDIX TABLES

Appendix Table 1. Analysis of variance summary table of plant radioactivity from Experiment 1. The square root of the percent of total activity in various sections is given.

Source	df	Mean Square	F
	a. Herbage Section		
Species	2	23.890	22.072 *
Error (a)	3	1.083	--
Time	2	1.555	2.436 NS
Species × time	4	0.387	0.608 NS
Error (b)	6	0.638	--
	b. Crown Section		
Species	2	9.835	15.598 *
Error (a)	3	0.630	--
Time	2	0.620	1.028 NS
Species × time	4	0.082	0.139 NS
Error (b)	6	0.601	--
	c. Upper Roots		
Species	2	13.445	97.931 **
Error (a)	3	0.136	--
Time	2	0.225	1.237 NS
Species × time	4	0.235	1.299 NS
Error (b)	6	0.181	--

Appendix Table 1 (continued).

Source	df	Mean Square	F
		d. Lower Roots	
Species	2	5.170	13.518 *
Error (a)	3	0.383	--
Time	2	1.485	4.916 NS
Species × time	4	0.300	0.985 NS
Error (b)	6	0.301	--

* Significant F value at 0.5 level.

** Significant F value at 0.1 level.

NS Non-significant.

Appendix Table 2. Analysis of variance summary table of plant radioactivity from Experiment 2. Root sucrose specific activity (dpm/μg).

Source	df	Mean Square	F
Species	2	146,826.00	7.211 *
Error (a)	6	20,361.00	--
Time	6	220,955.80	17.471 **
Species × time	12	30,789.70	2.435 *
Error (b)	33	12,647.10	--

* Significant F vlaue at 0.5 level.

** Significant F value at 0.1 level.

Appendix Table 3. Analysis of variance summary table of plant radioactivity from Experiment 3. Square root of the percent of total activity in tops and roots of various species and various growth stages is given.

Source	df	Mean Square	F
		a. Blue Grama	
Temperature (Te)	2	3.530	9.289 **
Error (a)	9	0.376	--
Growth Stage (GS)	1	0.060	0.176 NS
GS × Te	2	0.345	1.015 NS
Error (b)	9	0.340	--
Time (ti)	1	6.730	29.088 **
Ti × Te	2	1.555	6.721 **
Ti × GS	1	0.864	3.736 NS
Ti × Te × GS	2	0.300	1.298 NS
Error (c)	16	0.231	--
		b. Buffalo Grass	
Temperature (Te)	2	1.365	3.262 NS
Error (a)	9	0.420	--
Growth Stage (GS)	1	2.230	3.279 NS
GS × Te	2	0.105	0.147 NS
Error (b)	9	0.680	--
Time (Ti)	1	0.490	0.643 NS
Ti × Te	2	0.012	0.015 NS
Ti × GS	1	0.013	0.017 NS
Ti × Te × GS	2	0.153	0.199 NS
Error (c)	17	0.769	--

Appendix Table 3 (continued).

Source	df	Mean Square	F
		c. Western Wheatgrass	
Temperature (Te)	2	0.380	1.086 NS
Error (a)	9	0.350	--
Growth Stage (GS)	1	2.750	7.051 *
GS × Te	2	0.460	1.179 NS
Error (b)	9	0.390	--
Time (Ti)	1	52.240	145.552 **
Ti × Te	2	0.558	1.550 NS
Ti × GS	1	0.072	0.199 NS
Ti × Te × GS	2	0.030	0.083 NS
Error (c)	17	0.360	--
		d. Growth Stage 1	
Temperature (Te)	2	0.398	1.401 NS
Error (a)	9	0.284	--
Species (Sp)	2	9.127	18.857 **
Sp × Te	4	1.244	2.570 NS
Error (b)	18	0.484	--
Time (Ti)	1	15.753	26.812 **
Ti × Te	2	0.371	0.632 NS
Ti × Sp	2	6.737	11.466 **
Ti × Te × Sp	4	0.752	1.279 NS
Error (c)	25	0.588	--

Appendix Table 3 (continued).

Source	df	Mean Square	F
		e. Growth Stage 2	
Temperature (Te)	2	0.924	2.119 NS
Error (a)	9	0.436	--
Species (Sp)	2	6.848	17.469 **
Sp × Te	4	1.188	3.031 *
Error (b)	18	0.392	--
Time (Ti)	1	21.308	64.941 **
Ti × Te	2	0.363	1.106 NS
Ti × Sp	2	4.772	14.543 **
Ti × Te × Sp	4	0.184	0.562 NS
Error (c)	25	0.328	--
		f. 2 hr-Translocation Period	
Temperature (Te)	2	1.745	2.815 NS
Error (a)	9	0.620	--
Growth Stage (GS)	1	0.260	1.036 NS
GS × Te	2	0.047	0.187 NS
Error (b)	9	0.251	--
Species (Sp)	2	14.416	38.151 **
Sp × Te	4	2.272	6.011 **
Sp × GS	2	1.268	3.355 *
Sp × GS × Te	4	0.442	1.169 NS
Error (c)	36	0.378	--

Appendix Table 3 (continued).

Source	df	Mean Square	F
	g. 6 hr-Translocation Period		
Temperature (Te)	2	0.074	0.463 NS
Error (a)	9	0.160	--
Growth Stage (GS)	1	0.037	0.061 NS
GS × Te	2	0.225	0.369 NS
Error (b)	9	0.610	--
Species (Sp)	2	9.914	18.619 **
Sp × Te	4	0.457	0.858 NS
Sp × GS	2	1.949	3.660 *
Sp × GS × Te	4	0.067	0.126 NS
Error (c)	32	0.532	--

* Significant F value at .05 level.

** Significant F value at .01 level.

NS Non-significant.

Appendix Table 4. Percent of total plant ^{14}C activity (radioactivity) in the roots of blue grama, buffalo grass, and western wheatgrass averaged over four replicates.

Temperature (°C)	Translocation Period			
	Growth Stage 1		Growth Stage 2	
	2 hr (%)	6 hr (%)	2 hr (%)	6 hr (%)
	Blue grama			
21.1/15.6	5.94	14.07	5.31	15.24
26.7/21.1	19.16	15.33	11.07	16.96
32.2/26.7	13.29	17.81	12.92	20.08
	Buffalo grass			
21.1/15.6	7.10	7.52	8.39	11.44
26.7/21.1	6.27	6.16	8.75	10.54
32.2/26.7	4.42	7.12	6.43	6.30
	Western wheatgrass			
21.1/15.6	3.62	18.22	1.71	10.67
26.7/21.1	2.75	18.04	2.64	16.77
32.2/26.7	5.39	16.03	3.01	12.13

Appendix Table 5. Influence of translocation period, temperature, and growth stage on percent of total ^{14}C activity in roots of blue grama, buffalo grass, and western wheatgrass after exposing entire plants to 8.5 μc $^{14}CO_2$/plant for 5 min. Values within each paramenter and species followed by the same letter are not significantly different at the 0.05 level.

Parameter	Species		
	Blue Grama (%)	Buffalo Grass (%)	Western Wheatgrass (%)
Translocation Period			
2 hr	11.3 a	6.9 a	13.8 a
6 hr	16.6 b	8.2 a	15.3 b
Temperature (°C)			
32.2/26.7	16.0 b	6.1 a	9.1 a
26.7/21.1	15.6 b	7.9 a	10.0 a
21.1/15.6	10.1 a	8.6 a	8.6 a
Growth Stage			
1	14.3 a	6.4 a	10.7 b
2	13.6 a	8.6 a	7.8 a

APPENDIX IV

FIELD DATA

Translocation data collected by Daniel P. Knievel is found in data sets A2U00F0, A2U00G0, and A2U00HB. Field definitions and data listings follow.

A2U00F0

Data Field	Columns	Format
SAMPLID	1- 6	(A6)
REPLICATE	8- 8	(A1)
SPECIES	10- 10	(A1)
TEMP	12- 12	(A1)
GROWTHSTG	13- 13	(A1)
TLOCPER	14- 14	(A1)
PLANTPART	16- 16	(A1)
PARTWT	18- 21	(F4.2)
SAMPLWT1	24- 26	(F3.1)
DPM1	28- 34	(F7.0)
SAMPLWT2	36- 38	(F3.1)
DPM2	40- 46	(F7.0)
SUCRSAMP	48- 50	(F3.1)
SUCROSE	51- 55	(F5.1)
SUCRACTIV	57- 62	(F6.2)

Printed listing follows:

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     NOTES ON DATA FIELDS:
SPECIES
    1 BLUE GRAMA
    2 BUFFALO GRASS
    3 WESTERN WHEATGRASS
TEMP. (F)    DAY (18 HRS)    NIGHT (6 HRS)
    1              70             60
    2              80             70
    3              90             80
GROWTHSTG    GROWTH STAGE (SEE FORTHCOMING PAPER BY SCHMER AND KNIEVEL)
    1 EARLY (A)
    2 LATE (B)
TLOCPER    TRANSLOCATION PERIOD
    1 2-HR
    2 6-HR
PLANTPART    PLANT PART
    1 ROOTS
    2 STEM BASE
    3 HERBAGE
PARTWT    WEIGHT (G) OF PLANT PART
SAMPLWT1    WEIGHT (MG) OF COMBUSTED SAMPLE, DUPLICATE 1
DPM1    TOTAL DPM (DISINTEGRATIONS / MINUTE) OF COMBUSTED SAMPLE, DUPLICATE 1
SAMPLWT2    WEIGHT (MG) OF COMBUSTED SAMPLE, DUPLICATE 2
DPM2    TOTAL DPM OF COMBUSTED SAMPLE, DUPLICATE 2
SUCRSAMP    WEIGHT (MG) OF PLANT-PART SAMPLE FOR SUCROSE EXTRACTION
SUCROSE    SUCROSE IN EXTRACT (MICROGRAMS)
SUCRACTIV    SPECIFIC ACTIVITY OF EXTRACTED SUCROSE (DPM / MICROGRAM)

1234567890123456789012345678901234567890123456789012345678901234567890123456789
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71T026	1	1	111	1	82	85	14918	113	17480	253	8123	4566
71T018	1	1	112	1	40	99	118150	98	117444	251	6538	18939
71T082	1	1	121	1	53	90	19771	120	35782	250	7427	5972
71T090	1	1	122	1	61	113	49444	100	60793	250	2358	16170
71T010	1	1	211	1	102	100	82317	93	63924	258	2308	26353
71T002	1	1	212	1	15	84	111154	107	142985	246	305	27078
71T074	1	1	221	1	11	101	51788	95	53815	255	3135	7909
71T066	1	1	222	1	77	100	45217	101	38031	250	1860	5507
71T042	1	1	311	1	47	91	53259	96	56717	252	2818	33202
71T034	1	1	312	1	132	123	67670	99	64266	250	1780	21959
71T050	1	1	321	1	160	113	55464	114	53899	246	2923	37793
71T058	1	1	322	1	83	100	85235	90	85684	259	2645	31468
71T122	1	2	111	1	18	96	163643	105	220193	259	8287	31048
71T114	1	2	112	1	20	91	96466	81	80290	259	9592	16135
71T178	1	2	121	1	36	119	49462	114	48448	244	8490	5098
71T186	1	2	122	1	24	132	80957	117	89464	255	7129	7362
71T106	1	2	211	1	29	103	44348	120	46648	258	5456	17570
71T098	1	2	212	1	14	82	73113	110	79195	247	1206	18913
71T146	1	2	221	1	60	98	50113	101	41502	261	501	16741
71T154	1	2	222	1	54	106	47551	104	54955	247	1033	9458

71T130	1	2	311	1	24	98	111832	99	123068	252	4933	48689
71T138	1	2	312	1	14	95	28122	97	24326	258	2824	11362
71T162	1	2	321	1	42	96	79099	103	71010	253	6951	12908
71T170	1	2	322	1	47	103	142779	117	134719	251	5359	20737
71T226	1	3	111	1	26	79	18202	108	34477	251	6051	4446
71T234	1	3	112	1	41	98	136359	116	174496	262	2506	14308
71T250	1	3	121	1	34	93	1278	128	1438	254	8794	17
71T242	1	3	122	1	45	83	20998	111	25031	256	2050	4383
71T210	1	3	211	1	83	105	9442	110	9044	250	522	3470
71T218	1	3	212	1	59	91	131643	101	176043	257	579	19464
71T258	1	3	221	1	224	132	3136	94	3569	255	709	2811
71T266	1	3	222	1	163	105	30266	93	27038	251	2271	2819
71T194	1	3	311	1	68	90	24753	91	20862	245	4724	8199
71T202	1	3	312	1	67	117	35275	102	31249	254	5248	6389
71T274	1	3	321	1	66	99	7462	98	15533	248	4072	3575
71T282	1	3	322	1	204	101	23686	127	30911	254	3583	4167
71T028	2	1	111	1	90	93	43046	100	53739	250	6956	11551
71T020	2	1	112	1	42	110	159712	95	141263	246	5730	22578
71T084	2	1	121	1	93	130	38517	87	29823	251	10629	5499
71T092	2	1	122	1	112	92	40182	150	56257	260	5372	10246
71T012	2	1	211	1	69	179	153510	154	162412	257	1633	30985
71T004	2	1	212	1	342	99	12040	101	24260	247	1432	4804
71T076	2	1	221	1	144	111	26764	100	18684	247	65	3640
71T068	2	1	222	1	87	99	39897	100	41686	256	1036	6025
71T044	2	1	311	1	70	117	40040	116	45982	256	2039	43864
71T036	2	1	312	1	73	95	78199	117	98115	260	2974	15934
71T052	2	1	321	1	77	155	75221	116	102635	247	2782	59425
71T060	2	1	322	1	91	115	148605	98	173076	244	3299	31576
71T124	2	2	111	1	14	93	122279	100	142990	250	3474	27692
71T116	2	2	112	1	18	86	83355	111	95661	259	8027	9410
71T180	2	2	121	1	20	109	83615	114	84166	250	7843	13907
71T188	2	2	122	1	48	98	93199	90	104857	249	10276	11760
71T108	2	2	211	1	32	85	43691	105	60451	258	901	22122
71T100	2	2	212	1	23	99	61797	95	58571	250	1094	19588
71T148	2	2	221	1	45	107	39344	97	44242	248	544	30107
71T156	2	2	222	1	21	89	62546	93	55035	250	1104	16431
71T132	2	2	311	1	24	104	36937	103	23475	255	4767	3567
71T140	2	2	312	1	38	98	83106	98	95970	255	6071	18066
71T164	2	2	321	1	14	90	46291	97	47440	242	5001	6963
71T172	2	2	322	1	33	106	129893	109	125245	254	3558	21865
71T228	2	3	111	1	26	107	53853	92	57344	246	3830	13595
71T236	2	3	112	1	113	119	70704	90	67357	254	1345	8026
71T252	2	3	121	1	239	100	9978	110	12258	250	2195	2852
71T244	2	3	122	1	76	92	32406	84	25453	257	3423	5002
71T212	2	3	211	1	72	101	14633	116	13695	259	796	4047
71T220	2	3	212	1	61	92	83975	107	82486	255	1422	13428
71T260	2	3	221	1	147	123	3256	119	2502	254	1023	834
71T268	2	3	222	1	139	92	17402	92	12811	247	968	2298

71T196	2	3	311	1	147	100	9873	87	8302	258	4386	2850
71T204	2	3	312	1	96	96	54173	121	51008	253	4022	14214
71T276	2	3	321	1	81	117	747	97	616	247	6042	51
71T284	2	3	322	1	93	94	23946	98	31815	248	3969	6883
71T030	3	1	111	1	81	92	31646	112	38297	255	10725	6922
71T022	3	1	112	1	35	96	117414	107	144972	251	10428	20536
71T086	3	1	121	1	64	89	21504	100	25920	245	7803	6571
71T094	3	1	122	1	88	92	53748	114	57761	262	5657	8057
71T014	3	1	211	1	118	102	43424	106	39935	253	4115	18887
71T006	3	1	212	1	97	99	89581	101	84650	247	1294	10829
71T078	3	1	221	1	195	094	10169	92	10922	255	898	5322
71T070	3	1	222	1	89	90	38631	103	37717	241	4002	9467
71T046	3	1	311	1	43	91	111899	99	143305	250	1829	113689
71T038	3	1	312	1	119	102	74317	96	78619	244	4137	15209
71T054	3	1	321	1	43	100	88615	82	75570	253	2898	47083
71T062	3	1	322	1	86	109	104161	100	121310	252	2797	31165
71T126	3	2	111	1	26	96	108948	96	98515	247	7959	20642
71T118	3	2	112	1	30	133	123579	112	94675	250	8960	11693
71T182	3	2	121	1	34	84	64264	91	68695	254	10421	9717
71T190	3	2	122	1	28	114	86586	115	79033	244	9025	8717
71T110	3	2	211	1	38	116	94575	87	78726	253	6618	22650
71T102	3	2	212	1	21	81	68557	104	93065	258	693	21798
71T150	3	2	221	1	250	113	28406	99	21326	244	939	13687
71T158	3	2	222	1	44	101	65810	86	55564	256	929	8593
71T134	3	2	311	1	25	92	60699	98	57835	249	4184	24766
71T142	3	2	312	1	20	107	277891	108	228978	255	4797	25816
71T166	3	2	321	1	43	102	64904	116	87050	242	9431	12853
71T174	3	2	322	1	37	109	149465	113	167003	256	1980	26450
71T230	3	3	111	1	40	118	5575	91	4740	251	6040	619
71T238	3	3	112	1	31	110	99541	100	81521	254	1965	11679
71T254	3	3	121	1	79	89	6542	95	7798	251	5198	1734
71T246	3	3	122	1	104	109	72997	93	78070	256	5148	7429
71T214	3	3	211	1	141	114	12289	126	15498	249	1213	7455
71T222	3	3	212	1	23	87	69533	97	102028	247	484	14932
71T262	3	3	221	1	101	92	4462	95	3500	243	2111	580
71T270	3	3	222	1	131	85	27078	113	32833	257	315	8813
71T198	3	3	311	1	92	98	15398	117	13929	251	3146	10327
71T206	3	3	312	1	51	88	64557	104	80655	255	272	49632
71T278	3	3	321	1	111	103	7024	99	9084	245	3693	2113
71T286	3	3	322	1	132	117	24146	97	22680	247	3575	4620
71T032	4	1	111	1	63	90	19442	102	21035	248	7921	7772
7T024	4	1	112	1	42	91	77826	91	66097	257	3455	13704
71T088	4	1	121	1	82	107	28189	101	25371	250	7183	5639
71T096	4	1	122	1	98	104	60275	92	56233	250	4101	8023
71T016	4	1	211	1	140	107	92666	119	101090	246	2530	55448
71T008	4	1	212	1	55	91	61790	92	65628	245	863	14972
71T080	4	1	221	1	84	111	51397	100	38329	257	3413	14731
71T072	4	1	222	1	114	111	51059	109	52557	255	707	9195

71T048	4	1	311	1	106	80	106232	36	94555	255	1340	73923
71T040	4	1	312	1	83	99	129096	98	121181	255	2766	30215
71T056	4	1	321	1	105	115	65175	115	68815	243	2692	45158
71T064	4	1	322	1	83	113	73644	113	105170	256	2447	30452
71T128	4	2	111	1	22	101	128396	103	103997	253	3284	23770
71T120	4	2	112	1	30	114	63755	101	81353	267	314	15250
71T184	4	2	121	1	31	144	109952	139	109874	248	6857	14011
71T192	4	2	122	1	43	103	33115	118	85850	255	7260	8782
71T112	4	2	211	1	17	92	15669	113	20286	255	1139	11063
71T104	4	2	212	1	24	89	86299	83	70784	250	1492	25729
71T152	4	2	221	1	22	114	76193	112	68024	257	1253	10121
71T160	4	2	222	1	39	105	105026	99	76195	241	3626	15776
71T136	4	2	311	1	50	102	38320	117	41946	256	3105	22643
71T144	4	2	312	1	10	101	46973	114	57675	259	4758	11616
71T168	4	2	321	1	42	93	90764	102	101741	251	5791	18908
71T176	4	2	322	1	16	105	97437	98	74013	255	3335	18408
71T232	4	3	111	1	34	90	8329	110	10335	256	3013	1560
71T240	4	3	112	1	62	109	102234	102	107791	257	1939	11338
71T256	4	3	121	1	80	85	3329	110	3698	251	4487	492
71T248	4	3	122	1	141	86	22862	100	27238	256	6734	3868
71T216	4	3	211	1	182	130	9707	124	9473	253	1709	3647
71T224	4	3	212	1	75	106	68104	94	74508	263	900	13594
71T264	4	3	221	1	90	97	6527	117	11855	248	659	906
71T272	4	3	222	1	184	123	12742	93	9635	249	416	1750
71T200	4	3	311	1	112	121	18842	99	13731	255	1981	12550
71T208	4	3	312	1	29	94	82950	96	73464	254	2987	20919
71T280	4	3	321	1	75	88	9262	95	8224	258	7331	2093
71T288	4	3	322	1	111	91	17373	102	22404	259	5091	4670

A2U00G0

Data Field	Columns	Format
REPLICATE	1- 1	(A1)
TEMP	3- 3	(A1)
GROWTHSTG	5- 5	(A1)
SPECIES	7- 7	(A1)
TLOCPER	9- 9	(A1)
TOPSACTIV	11- 14	(F4.2)
ROOTSACTIV	16- 19	(F4.2)

Printed listing follows:

NOTES ON DATA FIELDS:

TEMP. (F)	DAY (18 HRS)	NIGHT (6 HRS)
1	90	80
2	80	70
3	70	60

GROWTHSTG GROWTH STAGE (SEE FORTHCOMING PAPER BY SCHMER AND KNIEVEL)
1 EARLY (A)
2 LATE (B)
SPECIES
1 BLUE GRAMA
2 BUFFALO GRASS
3 WESTERN WHEATGRASS
TLOCPER TRANSLOCATION PERIOD
1 2-HR
2 6-HR
TOPSACTIV PERCENT OF TOTAL PLANT C14 ACTIVITY CONTRIBUTED BY TOPS
ROOTSACTIV PERCENT OF TOTAL PLANT C14 ACTIVITY CONTRIBUTED BY ROOTS

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1234567890123456789012345678901234567890123456789012345678901234567890

1 1 1 1 1 9155  845
1 1 1 1 2 8007 1993
1 1 1 2 1 9036  937
1 1 1 2 2 9863  137
1 1 1 3 1 9106  894
1 1 1 3 2 8219 1781
1 1 2 1 1 8724 1276
1 1 2 1 2 7844 2156
1 1 2 2 1 9169  831
1 1 2 2 2 8981 1019
1 1 2 3 1 9628  372
1 1 2 3 2 8874 1126
1 2 1 1 1 8037 1963
1 2 1 1 2 8777 1223
1 2 1 2 1 9362  638
1 2 1 2 2 9300  700
1 2 1 3 1 9817  183
1 2 1 3 2 7264 2736
1 2 2 1 1 8719 1281
1 2 2 1 2 8713 1287
1 2 2 2 1 9229  771
1 2 2 2 2 9201  799
1 2 2 3 1 9705  295
1 2 2 3 2 7909 2091
1 3 1 1 1 9626  374
1 3 1 2 1 8843 1157
1 3 1 2 2 8957 1043
1 3 1 3 1 9615  385
1 3 1 3 2 7425 2575
1 3 2 1 1 9540  460
1 3 2 1 2 8373 1627
1 3 2 2 1 9372  628
1 3 2 2 2 9107  893
1 3 2 3 1 9975   25
1 3 2 3 2 9498  502
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2	1	1	1	1	9132	868
2	1	1	1	2	8543	1457
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2	1	1	2	2	8874	1126
2	1	1	3	1	9670	330
2	1	1	3	2	8418	1582
2	1	2	1	1	8571	1429
2	1	2	1	2	7470	2530
2	1	2	2	1	9820	180
2	1	2	3	1	9876	124
2	1	2	3	2	8868	1132
2	2	1	1	1	7762	2238
2	2	1	1	2	7934	2066
2	2	1	2	1	9078	922
2	2	1	2	2	9501	499
2	2	1	3	1	9698	302
2	2	1	3	2	8353	1647
2	2	2	1	1	8730	1270
2	2	2	1	2	8409	1591
2	2	2	2	1	9506	494
2	2	2	2	2	9316	684
2	2	2	3	1	9796	204
2	2	2	3	2	9005	995
2	3	1	1	1	8884	1116
2	3	1	1	2	8116	1884
2	3	1	2	1	9441	559
2	3	1	2	2	9639	361
2	3	1	3	1	9234	766
2	3	1	3	2	8574	1426
2	3	2	1	1	9241	759
2	3	2	1	2	8357	1643
2	3	2	2	1	9300	700
2	3	2	2	2	8450	1550
2	3	2	3	1	9553	447
2	3	2	3	2	8769	1231

3	1	1	1	1	8809	1191
3	1	1	1	2	8311	1689
3	1	1	2	1	9779	221
3	1	1	2	2	8490	1510
3	1	1	3	1	9673	327
3	1	1	3	2	8512	1488
3	1	2	1	1	8859	1141
3	1	2	2	1	9336	664
3	1	2	2	2	9126	874
3	1	2	3	1	9543	457
3	1	2	3	2	9215	785
3	2	1	1	1	8869	1131
3	2	1	1	2	8348	1652
3	2	1	2	1	9154	846
3	2	1	2	2	9355	645
3	2	1	3	1	9671	329
3	2	1	3	2	8596	1404
3	2	2	1	1	9242	758
3	2	2	1	2	8664	1336
3	2	2	2	1	8325	1675
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3	2	2	3	1	9796	204
3	2	2	3	2	7491	2509
3	3	1	1	1	9515	485
3	3	1	1	2	8572	1428
3	3	1	2	1	9276	724
3	3	1	2	2	8989	1011
3	3	1	3	1	9904	96
3	3	1	3	2	8374	1626
3	3	2	1	1	9559	441
3	3	2	1	2	8867	1133
3	3	2	2	1	8788	1212
3	3	2	2	2	9432	568
3	3	2	3	1	9856	144
3	3	2	3	2	8450	1550

4	1	1	1	1	7588	2412
4	1	1	1	2	8017	1983
4	1	1	2	1	9560	440
4	1	1	2	2	9925	75
4	1	1	3	1	9397	603
4	1	1	3	2	8438	1562
4	1	2	1	1	8679	1321
4	1	2	1	2	8512	1488
4	1	2	2	1	9104	896
4	1	2	2	2	9541	459
4	1	2	3	1	9748	252
4	1	2	3	2	8192	1808
4	2	1	1	1	7670	2330
4	2	1	1	2	8808	1192
4	2	1	2	1	9897	103
4	2	1	2	2	9380	620
4	2	1	3	1	9715	285
4	2	1	3	2	8570	1430
4	2	2	1	1	8882	1118
4	2	2	1	2	7429	2571
4	2	2	2	1	9438	562
4	2	2	2	2	8399	1601
4	2	2	3	1	9648	352
4	2	2	3	2	8888	1112
4	3	1	1	1	9598	402
4	3	1	1	2	8872	1128
4	3	1	2	1	9600	400
4	3	1	2	2	9407	593
4	3	1	3	1	9798	202
4	3	2	1	1	9536	464
4	3	2	1	2	8308	1692
4	3	2	2	1	9183	817
4	3	2	2	2	8434	1566
4	3	2	3	1	9934	66
4	3	2	3	2	9017	983

A2U00HB

Data Field	Columns	Format
SAMPLID	1- 6	(A6)
REPLICATE	8- 8	(A1)
SPECIES	10- 10	(A1)
TLOCPER	12- 12	(A1)
SAMPLDATE	14- 15	(A2)
PLANTPART	17- 17	(A1)
LABLTIME	21- 24	(A4)
LABLHR	21- 22	(I2)
LABLMIN	23- 24	(I2)
HARVTIME	26- 29	(A4)
HARVHR	26- 27	(I2)
HARVMIN	28- 29	(I2)
FROZTIME	31- 34	(A4)
FROZHR	31- 32	(I2)
FROZMIN	33- 34	(I2)
PARTWT	36- 38	(F3.2)
SAMPLWT1	40- 42	(F3.1)
DPM1	44- 47	(F4.0)
SAMPLWT2	49- 51	(F3.2)
DPM2	53- 56	(F4.0)
SUCRSAMP	58- 60	(F3.1)
SUCROSE	62- 66	(F5.2)
SUCRACTIV	68- 72	(F5.3)

Printed listing follows:

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     NOTES ON DATA FIELDS:
SAMPLID   SAMPLE IDENTIFICATION (71 = YEAR, K = KNIEVEL, 123 = SAMPLE NO.)
SPECIES
     1 BLUE GRAMA
     2 BUFFALO GRASS
     3 WESTERN WHEATGRASS
     4 SEDGE
TLOCPER   TRANSLOCATION PERIOD
     1 2-HR
     2 6-HR
SAMPLDATE   SAMPLE DATE
     1 MAY  4           8 JUNE 24
     2 MAY 12           9 JULY  1
     3 MAY 19          10 JULY 15
     4 MAY 26          11 JULY 29
     5 JUNE  2         12 AUGUST 12
     6 JUNE  9         13 AUGUST 26
     7 JUNE 15
PLANTPART   PLANT PART
     1 ROOTS
     2 STEMBASE
     3 SHOOTS ABOVE STEM BASE
(TIMES ARE MST, 24-HR CLOCK)
LABLTIME   TIME OF C14 LABELING
HARVTIME   TIME OF PLANT HARVEST
FROZTIME   TIME FROZEN
PARTWT   DRY WEIGHT (G) OF PLANT PART
SAMPLWT1   WEIGHT (MG) OF COMBUSTED SAMPLE, DUPLICATE 1
DPM1   DPM (DISINTEGRATIONS / MINUTE) OF COMBUSTED SAMPLE, DUPLICATE 1
SAMPLWT2   WEIGHT (MG) OF COMBUSTED SAMPLE, DUPLICATE 2
DPM2   DPM OF COMBUSTED SAMPLE, DUPLICATE 2
SUCRSAMP   WEIGHT (MG) OF ROOT SAMPLE FOR SUCROSE EXTRACTION
SUCROSE   SUCROSE (MICROGRAMS) IN EXTRACT
SUCRACTIV   SPECIFIC ACTIVITY (DPM / MICROGRAM) OF EXTRACTED SUCROSE

123456789012345678901234567890123456789012345678901234567890123456789
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71K050	1	1	1	2	1	955	1203	1309	166	101	400	102	361	256	12808	4129
71K052	2	1	1	2	1	955	1203	1309	119	95	314	77	275	249	14323	4599
71K054	3	1	1	2	1	955	1203	1309	197	93	220	110	257	243	12748	1874
71K056	4	1	1	2	1	955	1203	1309	120	73	350	92	366	255	14193	6688
71K102	1	1	1	3	1	1009	1203	1325	86	80	85	67	75	247	2536	4465
71K104	2	1	1	3	1	1009	1203	1325	157	99	89	113	100	248	3988	5614
71K106	3	1	1	3	1	1009	1203	1325	155	78	21	76	20	248	9127	608
71K108	4	1	1	3	1	1009	1203	1325	142	128	77	83	67	246	11511	2401
71K158	1	1	1	4	1	930	1143	1230	121	114	398	107	540	250	32239	4271
71K160	2	1	1	4	1	930	1143	1230	150	101	367	101	394	247	14868	8942
71K162	3	1	1	4	1	930	1143	1230	86	102	142	107	172	246	25815	1461
71K164	4	1	1	4	1	930	1143	1230	135	102	425	104	582	249	22900	2525
71K214	1	1	1	5	1	948	1153	1310	166	103	307	103	440	247	26974	6190
71K216	2	1	1	5	1	948	1153	1310	213	102	154	104	215	258	27520	3580
71K218	3	1	1	5	1	948	1153	1310	350	109	375	103	373	257	35563	9040
71K220	4	1	1	5	1	948	1153	1310	116	106	176	107	162	253	18858	7870
1K270	1	1	1	6	1	942	1148	1242	189	103	214	109	187	246	28655	1876
71K272	2	1	1	6	1	942	1148	1242	98	110	40	106	222	246	38041	587

71K274	3	1	1	6	1	942	1148	1242	95	105	42	105	39	248	36566	448
71K276	4	1	1	6	1	942	1148	1242	87	105	38	104	24	242	36998	403
71K326	1	1	1	7	1	943	1150	1230	149	107	514	104	503	505	80046	8854
71K328	2	1	1	7	1	943	1150	1230	131	102	1439	104	1526	506	116066	12516
71K330	3	1	1	7	1	943	1150	1230	224	103	251	103	216	502	38176	8305
71K332	4	1	1	7	1	943	1150	1230	85	103	439	109	441	497	73511	7190
71K382	1	1	1	8	1	1000	1153	1256	98	104	46	105	51	493	52515	271
71K384	2	1	1	8	1	1000	1153	1256	46	103	48	104	141	498	109719	151
71K386	3	1	1	8	1	1000	1153	1256	80	105	62	107	84	493	59772	754
71K388	4	1	1	8	1	1000	1153	1256	98	106	48	104	40	504	59091	180
~~71K438~~	~~1~~	~~1~~	~~1~~	9	1	955	1153	1247	104	100	56	100	104	497	22791	3827
71K440	2	1	1	9	1	955	1153	1247	18	101	244	101	347	400	50943	2436
71K442	3	1	1	9	1	955	1153	1247	61	102	153	104	144	498	8730	1954
71K444	4	1	1	9	1	955	1153	1247	90	101	123	100	120	491	8237	1461
71K066	1	2	1	2	1	939	1155	1245	158	117	148	90	264	251	10430	3106
71K068	2	2	1	2	1	939	1155	1245	76	75	157	66	141	255	8948	1915
71K070	3	2	1	2	1	939	1155	1245	73	121	382	74	282	247	18846	3833
71K072	4	2	1	2	1	939	1155	1245	270	101	118	118	116	253	10438.	2472
71K118	1	2	1	3	1	941	1151	1245	101	100	240	142	270	245	13072	3691
71K120	2	2	1	3	1	941	1151	1245	170	116	804	117	773	241	7715	1133
71K122	3	2	1	3	1	941	1151	1245	96	114	628	115	744	257	7312	116
71K124	4	2	1	3	1	941	1151	1245	182	140	1322	110	1226	257	6039	3145
71K174	1	2	1	4	1	958	1135	1255	67	103	432	102	700	254	25610	9493
71K176	2	2	1	4	1	958	1135	1255	63	103	997	104	916	253	32912	12545
71K178	3	2	1	4	1	958	1135	1255	122	106	567	110	789	249	24209	11985
71K180	4	2	1	4	1	958	1135	1255	52	103	1351	102		247	30776	11071
71K230	1	2	1	5	1	1000	1157	1300	79	102	610	105	663	246	12930	14554
71K232	2	2	1	5	1	1000	1157	1300	55	102	423	102	338	246	17121	17025
71K234	3	2	1	5	1	1000	1157	1300	56	103	930	103	740	257	27967	18943
71K236	4	2	1	5	1	1000	1157	1300	95	103	842	104	814	251	23424	24110
71K286	1	2	1	6	1	1003	1200	1305	157	105	226	103	164	244	19280	7157
71K288	2	2	1	6	1	1003	1200	1305	170	105	1544	105	1341	249	52879	14046
71K290	3	2	1	6	1	1003	1200	1305	73	102	266	108	463	243	24991	12248
71K292	4	2	1	6	1	1003	1200	1305	88	103	1154	106	693	257	39873	17290
71K342	1	2	1	7	1	907	1158	1300	142	103	509	103	508	491	46087	4498
71K344	2	2	1	7	1	907	1158	1300	68	103	873	102	869	502	42184	10615
71K346	3	2	1	7	1	907	1158	1300	110	104	898	103	661	497	48003	9038
71K348	4	2	1	7	1	907	1158	1300	89	102	938	102	768	501	38677	8381
71K398	1	2	1	8	1	950	1150	1245	133	102	52	102	58	502	23158	504
71K400	2	2	1	8	1	950	1150	1245	86	105	381	106	207	491	18545	2455
71K402	3	2	1	8	1	950	1150	1245	110	103	180	104	151	494	18201	1429
71K404	4	2	1	8	1	950	1150	1245	117	105	189	103	667	497	16046	1758
71K454	1	2	1	9	1	943	1150	1230	62	101	83	103	90	508	46994	1760
71K456	2	2	1	9	1	943	1150	1230	48	104	93	102	92	505	78899	1146
71K458	3	2	1	9	1	943	1150	1230	94	100	51	106	141	500	69525	1473
71K460	4	2	1	9	1	943	1150	1230	92	102	332	103	256	494	86342	3101
71K082	1	3	1	2	1	920	1130	1215	22	73	2324	72	2122	241	27355	28701
71K084	2	3	1	2	1	920	1130	1215	100	75	1052	105	1552	251	9360	17960
71K086	3	3	1	2	1	920	1130	1215	142	87	929	111	1322	256	6856	24194
71K088	4	3	1	2	1	920	1130	1215	69	81	1643	117	2113	245	12250	21013
71K135	1	3	1	3	1	956	1157	1300	14	119	704	113	627	252	22055	11372
71K138	2	3	1	3	1	956	1157	1300	28	102	171	101	203	249	7057	5918
71K141	3	3	1	3	1	956	1157	1300	14	98	928	101	1022	241	22011	10941
71K144	4	3	1	3	1	956	1157	1300	40	110	548	100	575	253	17449	7334

71K191	1	3	1	4	1	943	1150	1240	27	110	2261	107	2191	242	20305	30309
71K194	2	3	1	4	1	943	1150	1240	5	103	3339	103	3839	211	23083	15039
71K197	3	3	1	4	1	943	1150	1240	16	105	2161	113	1187	241	14346	19480
71K200	4	3	1	4	1	943	1150	1240	44	104	1629	102	1535	252	13346	32730
71K247	1	3	1	5	1	1014	1203	1300	98	103	1036	105	1095	247	30882	17516
71K250	2	3	1	5	1	1014	1203	1300	79	108	674	102	506	248	24042	16667
71K253	3	3	1	5	1	1014	1203	1300	37	102	1895	102	2451	251	25928	38809
71K256	4	3	1	5	1	1014	1203	1300	76	106	523	106	459	248	27722	8654
71K303	1	3	1	6	1	952	1153	1249	50	108	408	107	436	254	116928	2136
71K306	2	3	1	6	1	952	1153	1249	37	102	1666	104	1621	247	32142	27580
71K309	3	3	1	6	1	952	1153	1249	11	103	132	104	73	241	25363	780
71K312	4	3	1	6	1	952	1153	1249	27	102	1436	110	1443	245	27329	26409
71K359	1	3	1	7	1	956	1155	1240	21	106	2301	103	2134	500	42434	25710
71K362	2	3	1	7	1	956	1155	1240	32	107	3351	102	3314	496	45921	37837
71K365	3	3	1	7	1	956	1155	1240	90	104	2224	105	2702	497	40126	34701
71K368	4	3	1	7	1	956	1155	1240	50	103	2698	103	2871	495	36697	43872
71K415	1	3	1	8	1	939	1147	1225	25	103	201	103	269	505	60095	1824
71K418	2	3	1	8	1	939	1147	1225	94	105	160	104	181	494	49829	1151
71K421	3	3	1	8	1	939	1147	1225	74	105	333	105	277	495	57133	1956
71K424	4	3	1	8	1	939	1147	1225	25	101	67	101	74	505	53649	2587
71K471	1	3	1	9	1	1007	1158	1257	11	101	2	100	9	436	43023	148
71K474	2	3	1	9	1	1007	1158	1257	14	105	163	101	129	500	55719	1591
71K477	3	3	1	9	1	1007	1158	1257	26	103	519	105	531	492	55677	6940
71K480	4	3	1	9	1	1007	1158	1257	97	107	207	103	265	495	58711	3800
71K494	1	1	1	10	1	933	1142	1217	128	103	5	104	1	491	34630	063
71K496	2	1	1	10	1	933	1142	1217	101	106	23	104	12	491	98411	163
71K498	3	1	1	10	1	933	1142	1217	108	106	9	106	9	500	67863	317
71K500	4	1	1	10	1	933	1142	1217	82	109	4	102	1	503	30708	233
71K550	1	1	1	11	1	941	1129	1210	66	103	80	103	114	507	47716	762
71K552	2	1	1	11	1	941	1129	1210	56	102	26	105	44	499	59940	261
71K554	3	1	1	11	1	941	1129	1210	34	105	31	109	46	504	108926	066
71K556	4	1	1	11	1	941	1129	1210	51	107	96	106	68	497	30967	1353
71K606	1	1	1	12	1	942	1137	1217	58	102	25	103	132	491	66742	249
71K608	2	1	1	12	1	942	1137	1217	65	101	3	102	2	507	50307	096
71K610	3	1	1	12	1	942	1137	1217	152	103	24	102	13	490	26745	366
71K612	4	1	1	12	1	942	1137	1217	92	105	8	102	11	495	39310	200
71K510	1	2	1	10	1	943	1142	1250	48	103	1	104	7	506	73355	085
71K512	2	2	1	10	1	943	1142	1250	70	106	6	101	8	506	96461	013
71K514	3	2	1	10	1	943	1142	1250	28	104	43	105	26	501	087067	117
71K516	4	2	1	10	1	943	1142	1250	38	104	7	108	12	497	58516	087
71K566	1	2	1	11	1	952	1132	1235	75	110	61	106	75	509	45175	521
71K568	2	2	1	11	1	952	1132	1235	50	107	15	109	26	490	43595	078
71K570	3	2	1	11	1	952	1132	1235	23	115	100	106	39	492	55251	592
71K572	4	2	1	11	1	952	1132	1235	74	118	23	108	28	502	38379	160
71K622	1	2	1	12	1	954	1140	1234	20	105	13	102	6	494	75808	013
71K624	2	2	1	12	1	954	1140	1234	19	103	10	100	9	462	62264	014
71K626	3	2	1	12	1	954	1140	1234	48	104	7	104	7	494	91456	019
71K628	4	2	1	12	1	954	1140	1234	27	104	12	101	3	491	92918	011
71K527	1	3	1	10	1	955	1150	1234	12	102	18	107	12	508	60260	186
71K530	2	3	1	10	1	955	1150	1234	28	105	90	101	56	494	58237	494
71K533	3	3	1	10	1	955	1150	1234	47	103	22	103	16	496	49598	007
71K536	4	3	1	10	1	955	1150	1234	49	103	18	109	17	491	60217	009
71K583	1	3	1	11	1	1004	1137	1218	51	109	31	106	21	504	54916	008
71K586	2	3	1	11	1	1004	1137	1218	37	113	22	109	17	497	84520	006

71K589	3	3	1	11	1	1004	1137	1218	28	111	93	111	16	508	57454	277
71K592	4	3	1	11	1	1004	1137	1218	51	112	14	107	12	495	29522	022
71K639	1	3	1	12	1	1004	1145	1241	52	104	10	102	12	490	51118	167
71K642	2	3	1	12	1	1004	1145	1241	37	111	11	102	10	498	39784	182
71K645	3	3	1	12	1	1004	1145	1241	16	109	11	106	14	63	10744	299
71K648	4	3	1	12	1	1004	1145	1241	37	108	9	111	9	493	56506	007
71K058	1	1	2	2	1	815	1417	1450	170	78	243	91	295	256	7556	6795
71K060	2	1	2	2	1	815	1417	1450	161	75	373	110	368	255	11435	5249
71K062	3	1	2	2	1	815	1417	1450	155	133	743	77	516	255	14220	7466
71K064	4	1	2	2	1	815	1417	1450	158	99	652	74	538	258	14535	8008
71K110	1	1	2	3	1	825	1428	1505	87	80	614	70	524	258	17457	15022
71K112	2	1	2	3	1	825	1428	1505	98	130	802	119	769	252	6263	19937
71K114	3	1	2	3	1	825	1428	1505	191	112	628	146	742	250	6601	11621
71K116	4	1	2	3	1	825	1428	1505	101	133	1325	114	1217	243	5236	20542
71K166	1	1	2	4	1	853	1447	1535	141	104	472	107	647	246	12116	9589
71K168	2	1	2	4	1	853	1447	1535	131	101	360	104	465	247	21612	5554
71K170	3	1	2	4	1	853	1447	1535	160	103	315	102	308	248	13041	4079
71K172	4	1	2	4	1	853	1447	1535	100	101	298	104	276	256	27887	3543
71K222	1	1	2	5	1	825	1425	1535	174	105	346	103	384	242	41547	5780
71K224	2	1	2	5	1	825	1425	1535	83	103	424	109	422	256	19915	8720
71K226	3	1	2	5	1	825	1425	1535	228	103	325	102	325	244	12790	8687
71K228	4	1	2	5	1	825	1425	1535	266	103	372	100	452	250	27405	10281
71K278	1	1	2	6	1	825	1413	1510	158	104	417	106	427	242	24626	6383
71K280	2	1	2	6	1	825	1413	1510	81	106	327	109	318	243	55386	3433
71K282	3	1	2	6	1	825	1413	1510	139	103	176	100	195	246	23444	4106
71K284	4	1	2	6	1	825	1413	1510	164	106	294	108	234	245	34547	4341
71K334	1	1	2	7	3	815	1356	1450	212	105	283	108	441	498	5972	8607
71K336	2	1	2	7	3	815	1356	1450	58	109	1008	104	855	496	16687	10704
71K338	3	1	2	7	1	815	1356	1450	130	102	1169	103	1011	498	119701	7982
71K340	4	1	2	7	1	815	1356	1450	98	102	520	103	696	496	119701	6534
71K390	1	1	2	8	1	749	1354	1435	156	106	518	102	534	503	36701	6721
71K392	2	1	2	8	1	749	1354	1435	99	103	1176	105	1290	503	66438	8903
71K394	3	1	2	8	1	749	1354	1435	177	104	258	106	306	507	26726	4300
71K396	4	1	2	8	1	749	1354	1435	177	103	648	105	511	503	35894	5860
71K446	1	1	2	9	1	809	1418	1501	71	100	286	103	204	502	11028	4483
71K448	2	1	2	9	1	809	1418	1501	48	102	336	102	371	498	23885	4563
71K450	3	1	2	9	1	809	1418	1501	57	101	258	101	296	507	25680	4717
71K452	4	1	2	9	1	809	1418	1501	125	101	449	100	635	501	23614	6101
71K074	1	2	2	2	1	753	1410	1515	93	79	154	87	168	255	8789	4626
71K076	2	2	2	2	1	753	1410	1515	161	117	486	99	134	255	10287	18259
71K078	3	2	2	2	1	753	1410	1515	246	125	159	78	150	248	8898	5247
71K080	4	2	2	2	1	753	1410	1515	135	85	204	108	209	246	3991	2800
71K126	1	2	2	3	1	848	1439	1535	63	125	238	110	270	258	19710	7970
71K128	2	2	2	3	1	848	1439	1535	47	121	76	134	50	257	19880	9678
71K130	3	2	2	3	1	848	1439	1535	206	140	266	124	239	256	6834	10198
71K132	4	2	2	3	1	848	1439	1535	173	130	488	145	582	241	12570	9977
71K182	1	2	2	4	1	827	1439	1518	102	105	451	104	495	257	25951	5938
71K184	2	2	2	4	1	827	1439	1518	63	105	697	103	572	246	24410	8055
71K186	3	2	2	4	1	827	1439	1518	62	100	790	102	742	242	25174	7054
71K188	4	2	2	4	1	827	1439	1518	98	107	1096	104	811	255	18013	9734
71K238	1	2	2	5	1	812	1420	1516	82	101	286	102	316	250	11153	11669
71K240	2	2	2	5	1	812	1420	1516	54	104	511	102	260	244	13006	14748
71K242	3	2	2	5	1	812	1420	1516	101	105	269	104	341	247	16855	9901
71K244	4	2	2	5	1	812	1420	1516	68	101	553	103	531	248	28405	12053

71K294	1	2	2	6	1	757	1403	1451	41	107	263	106	2655	246	34212	3489
71K296	2	2	2	6	1	757	1403	1451	63	105	351	105	417	254	52048	4203
71K298	3	2	2	6	1	757	1403	1451	81	104	390	104	373	258	37490	6554
71K300	4	2	2	6	1	757	1403	1451	46	103	167	103	167	251	31400	3259
71K350	1	2	2	7	1	748	1349	1438	114	103	507	101	505	500	17486	6274
71K352	2	2	2	7	1	748	1349	1438	100	103	554	110	621	508	35248	4820
71K354	3	2	2	7	1	748	1349	1438	130	103	815	102	815	492	56268	6413
71K356	4	2	2	7	1	748	1349	1438	134	104	669	103	560	494	31707	6593
71K406	1	2	2	8	1	801	1357	1505	223	101	296	104	274	497	20139	2698
71K408	2	2	2	8	1	801	1357	1505	133	102	249	101	213	501	23878	1758
71K410	3	2	2	8	1	801	1357	1505	161	102	200	104	178	493	62771	1868
71K412	4	2	2	8	1	801	1357	1505	128	104	334	103	364	497	69184	3447
71K462	1	2	2	9	1	819	1421	1517	131	106	141	102	179	490	32757	2184
71K464	2	2	2	9	1	819	1421	1517	46	103	432	101	307	491	55255	3963
71K466	3	2	2	9	1	819	1421	1517	88	100	234	105	261	492	50766	3767
71K468	4	2	2	9	1	819	1421	1517	79	102	130	102	166	507	37223	4368
71K091	1	3	2	2	1	900	1510	1545	64	71	1238	76	1206	252	20170	14470
71K094	2	3	2	2	1	900	1510	1545	47	77	202	63	214	256	14427	5143
71K097	3	3	2	2	1	900	1510	1545	104	105	1106	83	957	245	32318	8510
71K100	4	3	2	2	1	900	1510	1545	62	75	540	62	456	255	23515	5621
71K147	1	3	2	3	1	838	1436	1520	11	113	3517	101	4039	248	28696	19789
71K150	2	3	2	3	1	838	1436	1520	15	123	2994	108	2788	255	31948	16480
71K153	3	3	2	3	1	838	1436	1520	54	116	1335	102	964	249	20829	15860
71K156	4	3	2	3	1	838	1436	1520	110	101	926	113	996	251	22570	10204
71K203	1	3	2	4	1	840	1443	1523	32	116	616	109	611	253	25828	6830
71K206	2	3	2	4	1	840	1443	1523	96	104	2216	104	2459	243	21661	19400
71K209	3	3	2	4	1	840	1443	1523	56	105	1264	103	1114	250	20787	14480
71K212	4	3	2	4	1	840	1443	1523	132	106	783	102	760	251	26439	11160
71K259	1	3	2	5	1	757	1415	1453	25	104	624	103	770	252	38462	7636
71K262	2	3	2	5	1	757	1415	1453	31	118	916	111	858	240	31317	12721
71K265	3	3	2	5	1	757	1415	1453	6	104	4025	104	3795	194	36743	15419
71K268	4	3	2	5	1	757	1415	1453	12	100	469	109	556	247	16067	12829
71K315	1	3	2	6	1	812	1410	1433	31	106	388	101	297	505	36437	8886
71K318	2	3	2	6	1	812	1410	1433	15	103	186	104	138	495	41117	2908
71K321	3	3	2	6	1	812	1410	1433	53	109	1406	102	1315	497	39088	12386
71K324	4	3	2	6	1	812	1410	1433	139	103	917	105	962	507	50064	8167
71K371	1	3	2	7	1	801	1353	1418	30	104	2052	103	2070	498	34899	25769
71K374	2	3	2	7	1	801	1353	1418	52	105	1691	103	1690	496	46570	16287
71K377	3	3	2	7	1	801	1353	1418	25	104	1547	107	1657	496	38786	17715
71K380	4	3	2	7	1	801	1353	1418	37	107	2334	104	2107	494	49855	21094
71K427	1	3	2	8	1	813	1402	1448	24	104	1258	103	1227	493	49366	20767
71K430	2	3	2	8	1	813	1402	1448	101	108	1091	104	993	492	56279	11759
71K433	3	3	2	8	1	813	1402	1448	68	101	414	101	337	497	60684	4764
71K436	4	3	2	8	1	813	1402	1448	28	102	381	102	327	498	53411	4193
71K483	1	3	2	9	1	757	1416	1447	41	102	838	105	762	495	68593	7083
71K486	2	3	2	9	1	757	1416	1447	82	102	525	101	499	495	68371	5766
71K489	3	3	2	9	1	757	1416	1447	130	101	799	102	798	500	29565	11970
71K492	4	3	2	9	1	757	1416	1447	64	102	926	100	734	496	32705	11754
71K502	1	1	2	10	1	822	1420	1459	36	102	81	104	127	501	108526	674
71K504	2	1	2	10	1	822	1420	1459	103	105	44	103	48	508	77731	483
71K506	3	1	2	10	1	822	1420	1459	148	102	9	100	33	502	35128	205
71K508	4	1	2	10	1	822	1420	1459	55	101	24	103	49	495	65507	542
71K558	1	1	2	11	1	836	1425	1514	126	108	102	105	67	502	36632	1006
71K560	2	1	2	11	1	836	1425	1514	28	105	373	104	542	498	58241	3487

71K562	3	1	2	11	1	836	1425	1514	91	102	103	111	196	491	36274	988
71K564	4	1	2	11	1	836	1425	1514	67	103	176	106	191	494	40399	2724
71K614	1	1	2	12	1	822	1407	1457	62	100	39	101	56	497	37319	342
71K616	2	1	2	12	1	822	1407	1457	48	104	1	100	2	507	57514	074
71K618	3	1	2	12	1	822	1407	1457	52	104	21	103	19	494	63304	055
71K620	4	1	2	12	1	822	1407	1457	55	103	3	101	9	495	66465	035
71K518	1	2	2	10	1	809	1417	1525	129	103	11	107	10	493	75826	083
71K520	2	2	2	10	1	809	1417	1525	57	103	16	101	20	490	84598	082
71K522	3	2	2	10	1	809	1417	1525	71	104	14	103	17	509	107796	031
71K524	4	2	2	10	1	809	1417	1525	48	108	10	106	15	490	86292	076
71K574	1	2	2	11	1	824	1422	1500	37	103	257	108	311	494	103777	2129
71K576	2	2	2	11	1	824	1422	1500	37	103	84	106	117	504	37557	653
71K578	3	2	2	11	1	824	1422	1500	34	107	184	104	150	498	55686	1063
71K580	4	2	2	11	1	824	1422	1500	13	112	197	70	8	493	83070	857
71K630	1	2	2	12	1	809	1404	1445	35	104	40	105	119	497	77577	135
71K632	2	2	2	12	1	809	1404	1445	20	107	9	102	7	491	88572	079
71K634	3	2	2	12	1	809	1404	1445	43	102	6	110	6	497	98888	073
71K636	4	2	2	12	1	809	1404	1445	33	102	6	104	19	497	99301	059
71K539	1	3	2	10	1	757	1412	1506	37	109	57	109	73	494	71291	506
71K542	2	3	2	10	1	757	1412	1506	33	103	286	108	327	494	67979	1777
71K545	3	3	2	10	1	757	1412	1506	77	105	89	103	84	492	61318	589
71K548	4	3	2	10	1	757	1412	1506	76	103	179	100	242	492	53379	1645
71K595	1	3	2	11	1	811	1419	1444	43	100	344	107	395	499	22819	2338
71K598	2	3	2	11	1	811	1419	1444	39	102	366	107	418	494	25583	2987
71K601	3	3	2	11	1	811	1419	1444	18	103	214	100	291	495	29182	2764
71K604	4	3	2	11	1	811	1419	1444	32	109	519	105	544	492	33744	3027
71K651	1	3	2	12	1	756	1401	1428	43	103	15	113	6	495	129933	034
71K654	2	3	2	12	1	756	1401	1428	18	118	28	102	23	507	42825	114
71K657	3	3	2	12	1	756	1401	1428	33	102	25	109	16	491	36964	120
71K660	4	3	2	12	1	756	1401	1428	23	104	5	102	13	498	69907	089
71K042	1	4	2	1	1	815	1415	1440	120	81	245	100	218	252	17225	1464
71K044	2	4	2	1	1	815	1415	1440	145	76	218	87	207	253	38232	951
71K046	3	4	2	1	1	815	1415	1440	203	137	223	83	150	244	22889	1109
71K048	4	4	2	1	1	815	1415	1440	86	101	186	99	175	246	4633	1750
71K010	1	1	2	1	1	715	1315	1330	116	133	224	144	273	246	18168	117
71K012	2	1	2	1	1	715	1315	1330	181	91	153	120	158	252	14858	429
71K014	3	1	2	1	1	715	1315	1330	132	80	198	75	156	252	6704	413
71K016	4	1	2	1	1	715	1315	1330	135	79	331	86	280	256	9711	285
71K026	1	3	2	1	1	745	1345	1410	114	83	114	73	77	256	8491	2033
71K028	2	3	2	1	1	745	1345	1410	263	76	107	75	139	255	9804	1501
71K030	3	3	2	1	1	745	1345	1410	114	105	352	97	350	251	9112	1732
71K032	4	3	2	1	1	745	1345	1410	47	88	625	110	752	246	23699	1495
71K034	1	4	1	1	1	930	1130	1155	260	84	95	132	125	247	13473	1235
71K036	2	4	1	1	1	930	1130	1155	132	90	179	100	182	252	19528	2097
71K038	3	4	1	1	1	930	1130	1155	217	140	105	95	105	250	6906	9252
71K040	4	4	1	1	1	930	1130	1155	116	93	93	130	100	251	12672	1196
71K002	1	1	1	1	1	900	1100	1130	104	91	184	112	173	257	19428	964
71K004	2	1	1	1	1	900	1100	1130	262	75	29	94	58	260	9577	401
71K006	3	1	1	1	1	900	1100	1130	250	66	411	65	276	241	8028	4202
71K008	4	1	1	1	1	900	1100	1130	166	125	220	104	142	251	10104	1212
71K018	1	3	1	1	1	915	1115	1140	51	76	504	97	462	246	16774	2829
71K020	2	3	1	1	1	915	1115	1140	57	115	293	100	236	251	21489	1713
71K022	3	3	1	1	1	915	1115	1140	96	97	427	90	520	252	15092	3484
71K024	4	3	1	1	1	915	1115	1140	46	85	400	126	513	257	8592	3726