conditions of this test, i.e. without controls consisting of standard 'Temple' fruit and only 1 year of testing, it was found that in general decay was low, comparing favorably with results obtained with 'Temple' in other tests. No abnormal peel injury and no stem-end drying even in the larger sizes was observed. Flavor of the fruit was still good 18 days after picking, only 4 days of which were under refrigeration.

Budwood. The most important reason for having limited the data of the 'Sue-Linda Temple' to the 2 selected trees is because these 2 trees provided the budwood for indexing of virus diseases by the Bureau of Citrus Budwood Registration, Budwood Certification Program of the Florida State Department of Agriculture. Indexing has shown these 2 trees to be positive for tristeza, xyloporosis, and exocortis, but negative for psorosis virus. Symptoms of psorosis virus have not been observed during the past 2 cropping seasons on any of the propagated trees or in the original tree. Two years of indexing for psorosis virus have been completed with negative results. Budwood of the 'Sue-Linda Temple' is, therefore, legally available for commercial propagation.

It is proposed that the distribution of budwood be made from the 2 selected 'Sue-Linda Temple' trees under the Validation Program of the Bureau of Citrus Budwood Registration, provided interest in the variety is expressed.

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SOME PHYSICAL AND CHEMICAL CHARACTERISTICS OF A DEEP, WELL-DRAINED SOIL PLANTED TO CITRUS[1,3]

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Abstract. **Several physical and chemical characteristics of Astatula fine sand were studied. The moisture characteristic curve of samples taken from a site in Lake County showed that the major portion of water present in saturated samples was held under very low tension and rapidly drained from the soil, decreasing the water content to only approx 6% by vol at a tension of 70 cm. The low water-retention capacity resulted from the predominance of macropores in the pore space. The distribution with depth of selected macro- and micro-nutrients and Al was determined. Organic matter content and pH decreased with depth. Poor nutrient retention was associated with a low cation exchange capacity (CEC).**

Plant available water was discussed in relation to the applicability of the term field capacity to deep, sandy soils. Measurements of soil moisture indicated that monthly mean soil water contents in the plant root zone were often greater than a commonly used field capacity value.

The central "Ridge" area of Florida, one of the most productive citrus areas of the world, is characterized by sandy soils which have low natural fertility and are somewhat overly drained. Citrus trees are very productive when these soils are properly managed (12), even though they are not generally recognized as ideal for agriculture.

Many of the physical and chemical properties of these soils are known but it is not completely understood how they relate to citrus production problems, such as the leaching loss of applied nutrients. The deep, sandy "Ridge" soils do not readily retain large quantities of mineral elements near the surface, the area generally considered the center of root activity; however, citrus trees root deeply in these soils (3). Roots exist in relatively large amounts in zones below the surface where the character of the environment has not been extensively studied. Therefore,

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the chemical characteristics of the soil environment and the distribution of nutrients within the soil profile may be significant in terms of tree response to management variables.

The maintenance of sufficient soil moisture in the tree root zone is also of primary concern to citrus growers. Plant growth and fruit yield are dependent on an adequate supply of water. Thus, it is important to understand the physical characteristics of a soil and how they affect water storage and availability.

The purpose of this report is to present a portion of data obtained in a study of root structure, function, and environment. The information given here provides a basis for understanding the causes of the low water and nutrient retaining characteristics of 'Ridge' sands. The data is also used to discuss the applicability of the term "field capacity" to such soils and describes the changes with depth in certain chemical aspects of the soil environment.

Materials and Methods

Samples in the study were collected from the site of an 'Orlando' tangelo rootstock trial involving 11 rootstocks, located near Leesburg in Lake County. The 14-year-old trees are part of a commercial tangelo orchard and receive standard care.

The soil of the experiment site, Astatula (formerly Lakeland) fine sand is typical of the "Ridge" area. It is classified according to Great Soil Group as an Entisol. The soil is underlain at depths of 8 to 9 ft by a finer textured (10 to 38% clay) horizon of undetermined thickness (3).

Soil water content was measured by the neutron moderation method (9) for a period of 1 year beginning in April, 1973. Aluminum access tubes were installed just inside the drip line of 16 trees, 4 trees of each rootstock, selected for study in the overall investigation. One tube was installed per tree at either a NE, SE, SW, or NW location. One-min counts were taken twice weekly, at 1 ft depth intervals, beginning at 1 ft, to a depth of 12 ft. Water content of the surface 6-inch zone was determined gravimetrically.

Soil samples for chemical and physical analyses were obtained from borings made during installation of the access tubes. Samples were collected in 1 ft depth increments. Undisturbed soil cores, 1.2 inches thick were also collected at depths of 3, 8, 18, 24, 48, 60, 84, 96, and 108 inches from several locations to determine a soil moisture characteristic curve by the pressure-cell method (11).

The air-dried, screened soil samples were analyzed for cation exchange capacity (CEC) using 1*N* NH_4Ac adjusted to pH 7.0, organic matter (wet digestion), P(Bray No. 2), K, Ca, Mg, Mn, Zn, Cu, Fe, and Al by standard procedures (1). NO_3 and NH_4 were determined by electrode in water and 1.0 *M* KCl extracts, respectively. Soil pH was measured in 0.01 *M* $CaCl_2$ using a 2:1 soln to soil mixture.

Results and Discussion

Water is retained in soil under tension because of the natural attraction of water molecules for each other (cohesion) and for the surfaces of soil particles (adhesion). In order for water to be removed or drained from a soil, a force must exist or be applied which can counteract those natural forces which retain the water. All soil water is not held with equal tension, however. The moisture remaining in a soil at very low water contents is held under considerably higher tension than that which percolates through a soil just after a heavy rainfall when the soil is closer to saturation. Therefore, to determine the quantity of water retained by Astatula fine sand at different tensions, a known force at several different magnitudes was applied to saturated samples. The amount of water retained was recorded as the wt of the soil sample and remaining water. Water content is expressed on a volumetric basis (Fig. 1) and can be converted to acre-inches by multiplying depth of soil by per cent water divided by 100. For example, a layer of soil 12 inches deep with a moisture content of 5% would

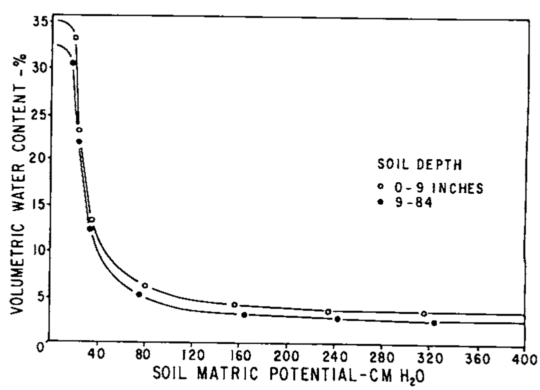

Fig. 1. Moisture characteristic curve for Astatula fine sand.

contain $\frac{12 \times 5}{100}$ or 0.6 acre-inches of water.

Data obtained for Astatula fine sand by the procedure described above constitute the drainage pattern or moisture characteristic curve (Fig. 1). The tension by which water is being held is given on the horizontal axis as soil matric potential. Magnitude is expressed in terms of the force exerted by a column of water where ht was measured in cm. In interpreting Fig. 1, the following statement would be correct. If a saturated sample (zero tension) of Astatula sand, collected from the surface 9 inches of soil, was subjected to a force equal to that of a column of water 110 cm high, the water content would decrease to 5% by vol; or if the water content of the same sample was 5% by vol, this amount of water is being held at a tension of 110 cm. Furthermore, water retained at 40 cm of tension is very loosely held compared to the smaller quantity retained at 400 cm of tension.

Several characteristics of the Astatula drainage pattern are clearly evident in Fig. 1. First, the amount of water held at tensions less than 70 cm was large. Soil water content was reduced to approx 5% at a tension of only 100 cm. Thereafter, changes in water content were relatively small despite a large increase in the force applied to the soil samples. Second, most of the soil water was retained between 20 to 30 cm of tension. Water held at such low tensions would percolate out of well-drained soils. From a practical standpoint then, it is apparent that a soil moisture value in the vicinity of 6% is an important reference point. If the water content of Astatula was 6%, irrigating to bring the water content near saturation would be inefficient because much of this water would percolate out of the profile. It is equally important, however, to prevent the moisture level from falling much below 6% because of the small amount of water remaining in the soil. Fig. 1 implies that this small quantity of water is difficult to extract by plant roots because of the large increases in force required to remove small amounts of water. Moreover, the ability of the soil to conduct water decreases markedly with decreases in water content (2).

Lastly, the higher organic matter content of the surface 9 inches of soil increased the saturation value and slightly modified the moisture characteristic curve of this layer.

The drainage characteristics of a soil under the experimental conditions set forth earlier are a function of pore space. The maximum retentive capacity of a soil depends on the total porosity. Total pore space generally varies according to texture, with sandy soils usually having less total pore space than clay or fine-textured soils. Furthermore, sandy soils often have a greater proportion of large pores than clay soils. It is this distribution of pore sizes, more-so than total porosity, which determines the drainage pattern and storage capacity of a soil.

Pores are commonly divided into 2 groups, the macro- or noncapillary pores which do not retain water against the force of gravity and the micro- or capillary pores which hold water at tensions which are not overcome by gravity. Sandy soils with drainage and retention characteristics similar to those of Astatula (Fig. 1) have a relatively large number of macropores, as shown in Fig. 2, thereby retaining only a limited quantity of soil moisture. In Fig. 2, each bar represents the per cent of the total pore space which drained when the force applied to the soil samples was increased. Also, each bar shows the proportion of water held in the soil between the known values of the applied force. For example, approx 27% of the pore space was occupied by water held in the soil between the tension of 20 and 30 cm. Assuming that macropores include those which cannot retain water at tensions less than 70 cm, it is significant that over 85% of the pore space in Astatula consisted of macropores.

The pore-size distribution of Astatula is such that drainage occurs rapidly and the storage capacity is small. The water remaining after the rate of drainage has markedly decreased is very meaningful because it is this water which is generally considered as available for plant use. Available water is usually taken as the quantity

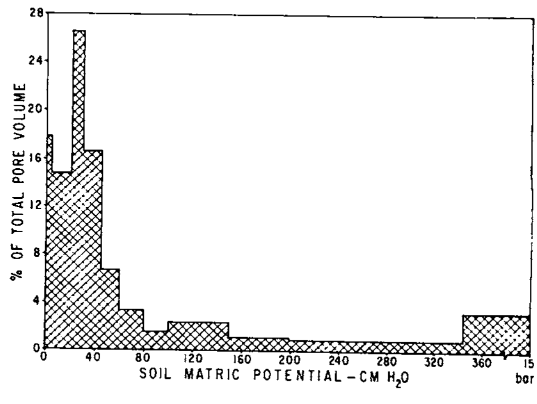

Fig. 2. The mean proportion of the total pore space drained at different moisture tensions for Astatula fine sand.

between the permanent wilting point and field capacity.

The permanent wilting point, or the lower limit of available water, is the soil water content at which plants remain permanently wilted unless water is added to the soil. The value is not a constant but is a range of values. Water in the soil at the permanent wilting point is held at an average tension of 15,450 cm.

Field capacity, the conventional upper limit of available water, was originally a surface soil (0 to 6 inches) measurement. It represented the soil moisture content when the rate of loss under the influence of gravity became negligible. However, the concept of field capacity can be misleading because, as the term implies, the water content at field capacity can only be accurately determined under field conditions. Laboratory determinations are often based on disturbed samples and do not reflect the influence of several important factors, in particular, depth to a water table or a finer-textured horizon which restricts drainage. Also, a saturated soil may initially lose water rapidly as the rate of percolation decreases to a small value and the soil water content approaches a "field capacity" value, but drainage continues to occur.

The water content of a soil at the point when the rate of drainage is considered negligible is a characteristic of the soil environment. Thus, field capacity water content cannot be equated to a specific moisture value or soil moisture tension.

Drainage of a wetted profile occurs in response to a gradient of the forces which cause the downward percolation of water (gravity) and those which oppose this downward movement. Drainage ceases when these forces are in equilibrium. Shallow soils with a water table near the surface, may reach a stable condition very quickly. The water table represents that point in a profile where the soil is saturated, the water tension is zero (Fig. 1) and the downward flow of water is impeded. Therefore, the water table in a shallow soil prevents continued drainage and the water content in the surface 6 inches of such a profile may be higher as compared to that of a deeper profile when drainage essentially ceases. In a deep, well-drained soil, there is no impediment and percolation will continue for a longer period of time. However, drainage can be influenced temporarily in deep soils by the presence of a finer-textured horizon which restricts water movement because of a lower rate of infiltration. Artificial asphalt barriers have also been shown to favorably modify the drainage pattern of a well-drained soil (6, 13).

Field capacity values have been reported for Astatula fine sand. In one case, it was observed that the drainage rate of a model profile was substantially reduced when the water tension was 60 to 70 cm. Tension values of 60 to 70 cm correspond to water contents of 6 to 7% in this study (Fig. 1). These moisture contents agree with those determined in the laboratory (6, 8, 10, 14) and the field (8). Therefore, a field capacity moisture content of 6% by vol for Astatula fine sand was chosen for the purpose of this discussion. This selection is based on the definition of field capacity previously mentioned. Using a 6% field capacity value then, the available water to a depth of 6 ft would be 6.0 to 1.8 (mean wilting point water content) or $\frac{4.2\% \text{ x } 72 \text{ inches}}{100}$ which equals 3.0 acre-inches.

A field capacity concept based on the water content of a soil profile after the drainage rate becomes negligible has limited usefulness when applied to well-drained soils such as Astatula because of the small amount of water remaining. Therefore, it is suggested that a more meaningful approach to determining the available water in a soil profile is to consider mean soil water content observed over an extended period of time. Such measurements have the advantages of considering the quantity of water above field capacity (6%) which actually represents the major portion of the water which can occupy the pore space at any given time; and they are field observations.

Monthly mean soil water contents for this study and 2 additional ones are shown in Fig. 3. These data can vary considerably with the amount of annual rainfall and sampling frequency. In this case, each mean represents the average of only 6 to 9 observations per month. Nevertheless, it can be seen that if field capacity is considered as 6% soil moisture, there were many months when water contents as measured by Koo [K] were above this value. Means obtained in this study [C] were never above 6% probably because of a less-than-average annual rainfall for the year of study and the method of sampling. Means were based on measurements taken at times when most soil water had drained away; however, water contents at 7 ft and those of Hashemi [H] were above 6% due to the presence of a clay horizon which impeded percolation.

If the average monthly water content for only the 6 to 18-inch depth in Astatula is 1% above the "field capacity" value, this represents a meaningful quantity of water to a citrus grower. This amount of water is equal to 0.12 acre-inches or approx the mean daily transpirational loss for a citrus tree based on a 1-year period of study (8). Furthermore, it must be remembered that this water, which was adequate to supply a tree's daily water need, came from a vol of soil only 1 ft in depth.

The importance of the amount of soil water above 6% is also related to the time required to achieve this value. It has been reported that the water content of Astatula fine sand may not decrease to 6% for a period of 6 to 8 days after a rainfall of 2 inches or more (8). Roots are absorbing water during this period. Thus, the available moisture in Astatula fine sand is not only that which lies between field capacity and the wilting point. The water content between periods of rainfall may be considerably greater than 6%.

Astatula fine sand is well-drained and also unretentive of many nutrients because of a low CEC (Table 1). Sand itself has virtually no CEC, therefore cations are held in the soil by the CEC of the organic matter and clay particles present. The CEC of the surface depth zone was only 1.49 meq

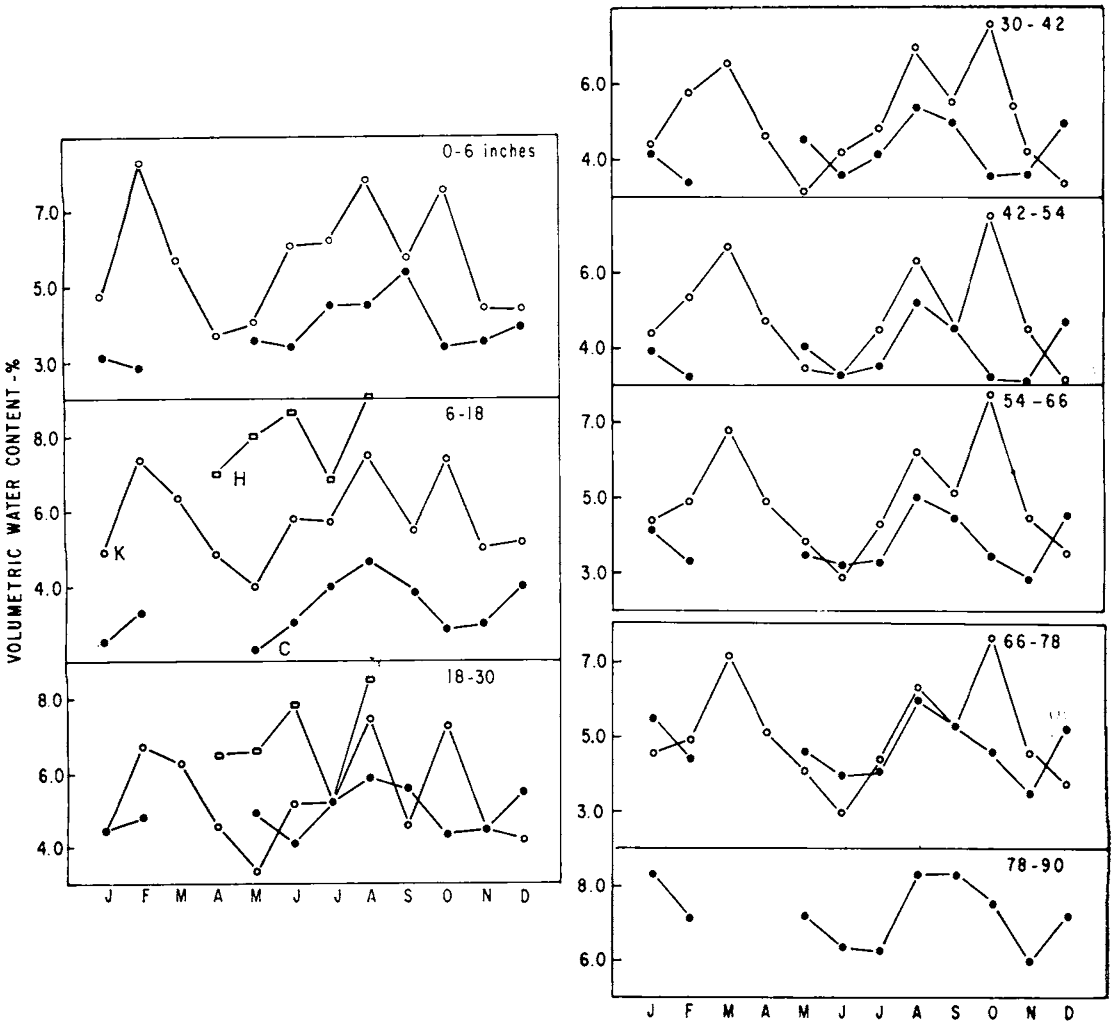

Fig. 3. Mean soil water contents of Astatula fine sand. Data obtained in this study are marked [C]. Means based on the data of Koo (8) and Hashemi (7) are marked [K] and [H], respectively.

and decreased with depth as did the organic matter content. CEC increased in the clay horizon but only to a limited extent because the dominant clay mineral, kaolinite, has a relatively low CEC (5).

The low CEC of Astatula fine sand allows K, Ca, Mg, and NH_4 to readily leach through the soil profile. Soil pH ranged from 5.95 at the surface to 4.1 at 12 ft. Mineral nutrient data in Table 1 show the distribution of ions 2 months after the spring application of fertilizer. The soil level of NH_4 and NO_3 was low; however, NO_3 as well as K, Mg, and Ca content increased near the clay horizon. The P and Ca levels were adequate in the surface 6 inches (12). Micronutrient levels were also satisfactory for growth. Exchangeable Al was virtually absent in the sand but increased in the subsoil clay. It is not known if these levels of Al were toxic to citrus roots.

The data presented showed that water and mineral nutrients are not readily retained in Astatula fine sand. The soil is very porous because of a pore-size distribution dominated by macropores. As a result, the water storing capacity of Astatula is limited and drainage is rapid. Nutrient retention is also poor because of a low CEC. Nutrient loss is further enhanced by the combined action of the soil physical and chemical characteristics which create an environment conducive to loss by leaching.

At first glance, soils such as Astatula fine sand do not seem particularly suitable for the growth of citrus trees. However, the physical and chemical characteristics of the soil environment as shown in this study, when considered in conjunction with root development data, provide a basis for understanding the adaptation of citrus to such soils.

Root studies of trees growing in Astatula fine sand indicated the extent of root development in a deep, "Ridge" soil (3). Also, in another study, deep roots did not appear structurally different from surface roots (4). This similarity implies equal functional potential of deep and shallow roots; however, the actual function of roots in a given location may be more closely related to the nature of the soil in the immediate vicinity of, and in contact with, the roots. Therefore, it is meaningful that the water content in the profile may be substantially higher than "field capacity" over extended periods of time. The physical characteristics of Astatula fine sand are also such that adequate water may be available to deep roots at times when the moisture content of soil near the surface is low. As the surface soil dries, nutrient uptake is reduced. Most plant nutrients are concd in the surface horizon because of the organic matter present. When nutrient uptake is restricted at the surface, some nutrients are available in the soil solution at greater depths for root absorption.

Information pertaining to the physical and chemical characteristics of soils used for citrus production, when coordinated with root distribution and function data, can be valuable in the

Table 1. Chemical characteristics of Astatula fine sand from the experiment site.

Depth[z] (inches)	Organic matter (%)	CEC (meq/100 g)	pH[y]	Nutrient level (lb/acre ft)										
				NH_4	NO_3	P	K	Ca	Mg	Cu	Fe	Zn	Mn	Al
6	0.77	1.49	5.95	20	64	250	185	1279	298	50	385	68	56	2
18			5.57	25	30	52	180	280	106	9	292	53	8	5
30	0.20	0.52	5.46	21	14	33	128	247	64	6	256	34	4	9
42	0.14		5.36	22	8	32	98	181	49	4	191	45	3	10
54	0.11	0.24	5.26	20	8	32	105	164	42	4	146	63	2	12
66	0.10		5.29	23	6	30	110	161	52	4	102	56	3	10
78	0.08	4.00	5.19	22	16	28	263	271	202	5	136	55	4	24
90	< 0.05	3.76	4.58	25	28	39	245	268	136	6	149	47	1	56
102		3.88	4.36	24	29	38	178	228	104	6	131	41	2	71
114		3.36	4.29	20	21	30	183	265	116	6	118	42	1	79
126			4.22	26	22	28	200	265	119	6	134	43	3	92
138			4.10	25	25	26	140	245	109	6	114	62	1	112

[z]Each depth value represents the center of a 12-inch interval.

[y]pH was determined in 0.01 M $CaCl_2$.

management of such soils and improving the efficiency of citrus production.

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GLYPHOSATE: A PROMISING NEW HERBICIDE FOR CITRUS

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Abstract. **Glyphosate is under development as a systemic herbicide for use in citrus and an experimental label is expected within 1 year. Extensive testing has shown glyphosate to be effective against a wide spectrum of weed species, including many of those problem weeds not satisfactorily controlled by presently recommended herbicides. Glyphosate is active as a foliar applied material with excellent properties of translocation and has essentially no soil residual action. Thorough coverage of the weed foliage is essential for optimum results, and a period of 6 hr is suggested between the time of application and the advent of rainfall or irrigation. Contact with the citrus foliage and trunks (with green bark) of recently planted trees should be avoided.**

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Herbicides presently recommended for use in Florida citrus (1, 2, 3) provide a satisfactory degree of weed control under a wide range of grove conditions. However, a number of species, some having a serious economic impact on the industry, are either totally or partially resistant to these materials. The purpose of this paper is to review the information available on this herbicide so that growers will be able to utilize it to their best advantage when it is registered for use in citrus.

Roundup herbicide is a water-soluble formulation of the isopropylamine salt of glyphosate which is the common name assigned to N-phosphonomethyl glycine, the parent acid. The formulated product contains 4 lb. per U.S. gal of the isopropylamine salt of glyphosate. It is a nonselective, broad spectrum translocated herbicide which controls a wide spectrum of annual and perennial grasses, broadleaf weeds and vines. Soil persistence of the herbicide is negligible.

Mode of Action.

Glyphosate is a systemic herbicide, actively translocated from leaf and stem tissue to the underground roots of rhizomes of perennial weeds. It kills by disrupting the basic metabolic processes of the plant. Its initial activity is fairly slow after application depending on the weed species, and obvious responses may not be visible