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DPX-Y6202 (2-[4-[(6-chloro-2-quinoxalinyl)oxy]-phenoxy]-propionic acid,ethyl ester), fluazifop-butyl (butyl 2-[4-[[5-(trifluoromethyl)-2-pyridyl]oxy]phenoxy]propanoic acid), sethoxydim (2-[1-(ethoxyimino)butyl]-5-[2-ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one), clopropoxydim ((E,E)-2-[1- [[(3-chloro-2-propenyl)oxy]imino] butyl]-5-[2-(ethylthio)-propyl]-3-hydroxy-2-cyclohexen-1-one), and haloxyfop-methyl (methyl ester of 2-[4-[[3-chloro-5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]-propanoic acid) are all members of a new group of postemergence grass herbicides that are promising for selective weed control in many dicotyledonous crops. These herbicides exhibit varying degrees of soil activity. In 1984, two field studies were established on a Woodburn silty loam to examine the soil persistence of these five herbicides.

Before establishing the field experiments, a suitable laboratory test for soil activity of these herbicides was

developed. Sweet corn (Zea mays L. 'Jubilee') was used as an indicator species. Shoot and root fresh weights, shoot and root dry weights, and shoot height as a percentage of the untreated check were used as measurements of plant response to herbicidal activity. Correlation coefficients between shoot fresh weight and shoot height were 0.94, 0.99, 0.95, 0.97, and 0.95 for DPX-Y6202, fluazifop-butyl, sethoxydim, clopropoxydim, and haloxyfop-methyl, respectively. Because shoot fresh weight and shoot height were highly correlated, shoot height was used as the measurement of plant response to the herbicides.

In the summer experiment, DPX-Y6202, fluazifop-butyl, sethoxydim, and clopropoxydim were applied to bare soil at rates from 0.14 to 1.12 kg/ha. Jubilee sweet corn was planted in the field at intervals to assess the persistence of these herbicides. Soil samples collected periodically from plots with the highest herbicide rate (1.12 kg/ha) were assayed in the laboratory using Jubilee sweet corn as an indicator plant. An "activity reduction time -50" (ART_{50}) was calculated using regression analysis. This represents the time in days required for the herbicide to lose 50% of its herbicidal activity at day 0. Based on the laboratory assessment, the ART_{50} for DPX-Y6202 was 36 days, for fluazifop-butyl 31 days, for sethoxydim 9 days, and for clopropoxydim 8 days. Based on field assessment, the ART_{50} for the highest rate was 18 days for DPX-Y6202 and fluazifop-butyl, 10 days for sethoxydim, and 11 days for clopropoxydim.

In the winter experiment, DPX-Y6202, fluazifop-butyl, sethoxydim, clopropoxydim, and haloxyfop-methyl were applied, in the field, at 1.12, 0.56, 0.28, and 0.14 kg/ha. Because of the failure of the indicator plant, Italian ryegrass (*Lolium multiflorum* Lam.), to become established, even in check plots, persistence of the 1.12 kg/ha rate for all herbicides was determined only by laboratory assessment with Jubilee sweet corn. ART_{50} for DPX-Y6202 was 29 days, for fluazifop-butyl 38 days, for sethoxydim 12 days, for clopropoxydim 22 days, and for haloxyfop-methyl 59 days.

ACTIVITY AND PERSISTENCE OF FIVE POSTEMERGENCE GRASS HERBICIDES IN SOIL

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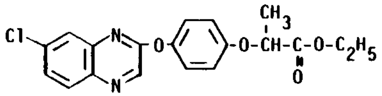
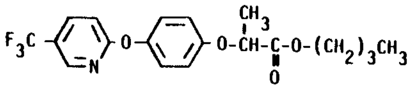
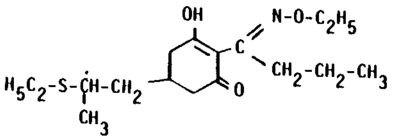
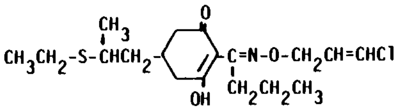
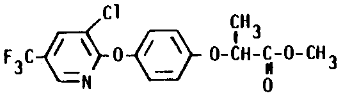
INTRODUCTION

The development of a new group of selective postemergence grass herbicides is one of the most exciting advances in herbicide chemistry within recent times (24). At present, several of these compounds are being assessed for grass control in a wide range of broadleaf crops (2, 44).

Among the herbicides being studied are DPX-Y6202, fluazifop-butyl, sethoxydim, clopropoxydim, and haloxyfop-methyl. The structural formulae and other related information on the chemistry of these five herbicides are presented in Table 1. The members of this herbicide group, when applied postemergence, enter the plant rapidly. Rain within 1 or 2 hours after application results in little or no loss of activity. Once absorbed by the leaf they are rapidly translocated throughout the plant. The sites of action of many of these herbicides are the root and shoot meristems. These postemergence grass herbicides control a very broad range of annual and perennial grasses. There is virtually no activity on broadleaf species and sedges. In the soil, DPX-Y6202 and fluazifop-butyl are biologically degraded. Microbial breakdown of sethoxydim, clopropoxydim, and haloxyfop-methyl has not been confirmed. For several herbicides of this group, early studies indicate low to moderate mobility in soil (10, 64).

Table 1. Structures of the postemergence grass herbicides involved in this study.

Common name	Chemical name	Structural formula	Molecular formula	Concentration and formulation
DPX-Y6202	2-[4-[(6-chloro-2-quinoxalinyl)oxy]-phenoxy]propionic acid, ethyl ester		$C_{19}H_{17}ClN_2O_4$	95.8g ai/L(EC)
fluazifop-butyl	butyl 2-[4-[[5-(trifluoromethyl)-2-pyridyl]oxy]phenoxy]propanoic acid		$C_{19}H_{20}O_4NF_3$	480g ai/L(EC)
sethoxydim	2-[1-(ethoxyimino)butyl]-5-[2-ethylthio)-propyl]-3-hydroxy-2-cyclohexen-1-one		$C_{17}H_{29}O_3NS$	183g ai/L(EC)
clopropoxydim	(E,E)-2-[1-[[(3-chloro-2-propenyl)oxy]imino]butyl]-5-[2-(ethylthio)-propyl]-3-hydroxy-2-cyclohexen-1-one		$C_{18}H_{28}ClNO_3S$	480g ai/L(EC)
haloxyfop-methyl	methyl ester of 2-[4-[[3-chloro-5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]-propanoic acid		$C_{16}H_{13}F_3ClNO_4$	240g ae/L(EC)

Preemergence herbicidal activity, on many grass species has been reported for these postemergence herbicides (1, 3, 28, 35, 48). Bhowmik (8) observed that annual grasses were controlled by the residual preemergence activity of fluazifop-butyl and sethoxydim. Preemergence applications of fluazifop-butyl and haloxyfop-methyl have been reported to satisfactorily control giant foxtail (*Setaria faberii* Herrm.), green foxtail (S. *viridis* (L.) Beauv.), and fall panicum (*Panicum dichotomiflorum* Michx.) in newly sown forage legumes (48).

Applied to the soil, these postemergence grass herbicides sometimes can remain active long enough to control late-germinating grasses. Burrill (14), used a field-bioassay to examine the persistence of six herbicides including fluazifop-butyl, sethoxydim, and haloxyfop-methyl. He found that the persistence of these herbicides differed considerably. Fluazifop-butyl, applied at 1.12 kg/ha, completely controlled Italian ryegrass at 21 days after treatment. At 38 days after treatment, growth of Italian ryegrass was 10% less than the check. Twenty-one days after treatment sethoxydim, applied at 1.12 kg/ha, reduced Italian ryegrass 55%, but at 38 days no herbicidal activity was observed. Haloxyfop-methyl was the most persistent herbicide of the postemergence grass herbicides studied. A 60% reduction in growth of Italian ryegrass was recorded 49 weeks after preemergence treatment of 1.12 kg/ha of haloxyfop-methyl. Buhler and Burnside (10) also found differences in soil persistence among the postemergence grass herbicides. Twenty-one days after treatment, fluazifop-butyl, sethoxydim, and haloxyfop-methyl, applied at 0.56 kg/ha, caused growth reductions in forage sorghum [*Sorghum bicolor* (L.) Moench.] of 60, 6, and, 100%, respectively.

It is important that we know how long these herbicides persist in the soil. This allows us to predict the duration of weed control, and whether there is a likelihood of injury to subsequent, susceptible crops. Persistence is not a fixed property of the herbicide. It is influenced by soil type and by the environmental conditions existing after application. Because these factors vary from site to site and from year to year, the results of any field study of persistence tend to be specific to one particular location and season.

The objective of this study was to use field and laboratory bioassays to compare the persistence of DPX-Y6202, sethoxydim, clopropoxydim, and haloxyfop-methyl in a silty loam soil during the summer and winter.

LITERATURE REVIEW

Herbicide persistence. Herbicides applied to the soil should persist long enough to provide an acceptable period of weed control, but not long enough after crop harvest to limit the choice of subsequent crops. The persistence of a particular herbicide, however, is not a fixed characteristic of that chemical. Soil type and weather conditions after application influence the length of time for which the herbicide remains active in the soil. These factors can vary from site to site and from year to year. This makes the results from any field persistence study specific to one particular location and season. Prediction of a chemical's persistence in different situations requires knowledge of how its degradation rate is affected by soil and environmental factors. The only way for such knowledge to be acquired is by measuring persistence at many sites, which would allow rates of loss to be related to soil or climatic variables (38).

With many herbicides, the degradation rate is more or less proportional to concentration, so that the results can often be interpreted using first-order kinetics. Burschel and Freed (15) and Zimdahl et al. (65) reasoned that because the quantity of herbicide in relation to other components was small, herbicide concentration can be expected to be rate limiting so that first-order reaction kinetics should apply. A plot of the logarithm of concentration against time gives a straight line with the slope proportional to the rate constant. From the line equation the half-life of the compound may be calculated. The half-life in a first-order reaction is independent of initial concentration, but this is not true for other orders of reaction. Therefore, the use of this term should be reserved for cases where it is known that first-order kinetics apply (26, 38).

The degradation of some herbicides, e.g., 2,4-D, dalapon, and chloropropham, are characterized by an initial lag-phase followed by rapid degradation (5). In cases where a lag phase precedes rapid degradation, presentation of half-lives for those herbicides is not as meaningful (38).

Deviations from simple first-order kinetics are often observed. This mainly is due to the complex chemical and biological nature of the soil medium. The availability of the herbicide for degradation might be affected by the kinetics of adsorption and desorption, or the activity of the microorganisms responsible for chemical breakdown in the soil may vary with the availability of nutrients and other energy sources. Hance and McKone (30) showed that neither zero-order, half-order, first-order, nor Michaelis-Menten kinetics adequately described the breakdown of atrazine, linuron, or picloram in the laboratory. They suggested that the total breakdown rate might result from several distinct processes, each with its own rate constant.

There have been several examples of rate constants not being independent of initial concentration. This anomaly has been described for atrazine (5, 30), linuron and picloram (30), and simazine and prometryn (59). Clay and Stott (16), in a study of the persistence of large doses of simazine in uncropped land, made repeated annual applications of simazine at 2.8, 5.6, and 22.4 kg ai/ha. They observed no difference in the rates of loss between simazine at 2.8 and 5.6 kg/ha, but the rate of loss at 22.4 kg/ha was considerably reduced. Some researchers have found no differences in the degradation rate of high and low rates of simazine (36) and ethofumesate (51), but these studies involved a relatively narrow range of concentrations. Hance and McKone (30) suggested that reduced rates of degradation at higher initial concentrations might result from too few reaction sites in the soil.

The influence of soil type on persistence is variable and, as a result, is not well understood. Microorganisms often are responsible for the degradation of herbicides in the soil, and since microbial activity often is enhanced by organic matter, herbicides might be expected to degrade faster in high-organic soils. But organic soils also are highly adsorptive and may reduce the amount of herbicide in the soil solution. Strongly adsorbed compounds tend to be protected from degradation (38). The reports in the literature on the effects of organic matter on rates of degradation are somewhat conflicting. Hamaker (26) suggested that, in mineral soils, organic matter might increase rates of degradation up to a limiting value, above which the rate of loss would be decreased. Ogle and Warren (46) studied the effects of soil type and other edaphic and climatic factors on the degradation of 2,4-D, TCA, chlorpropham, and monuron. They found that rate of breakdown of these herbicides increased progressively from a light sandy soil through a silt loam to an organic soil. Negative correlations, however, between fenac (46) and chloridazon (55) degradation and soil organic matter content have been reported.

The effects of natural and added adsorbents have been studied with varied results. The ability of carboxyl resin to catalyze hydrolysis of atrazine has been demonstrated by Armstrong and Chesters (4). They suggested that the adsorption-catalyzed hydrolysis of atrazine resulted from hydrogen bonding between the adsorbent carboxyl and a nitrogen atom in the atrazine ring. Microbial degradation of DNOC was prevented by addition of 1.25% charcoal (34). Burkhard and Guth (11) reported increasing half-lives of simazine, atrazine, propazine, and terbuthylazine with increased adsorption in unamended soils. On the other hand, Walker and Thompson (61) demonstrated positive correlations between the first-order rate constants for linuron and the adsorption constants for 18 different soils. Not only is the effect of adsorption on degradation rate unclear, but the nature of the relationship between persistence and any soil factor also is not clearly understood (18, 27).

Herbicide degradation in the soil may be affected by soil pH. Soil pH may affect herbicide degradation directly if the stability of the chemical is pH dependent. Degradation, however, may be indirectly affected by pH through its effect on adsorption and its effect on the composition and activity of the microflora. Nearpass

(45), in a study on the effects of liming and soil moisture on simazine persistence in two soils, found that degradation was more rapid at pH 3.9 and 5.4 than at 6.8 and 7.0. Walker and Thompson (61) found a significant negative correlation between rates of simazine degradation and pH in 18 unamended soils. Similar results with atrazine were obtained in amended soils (7). These authors all suggested that the increased rates of degradation were due to increased rates of hydrolysis at lower pH levels. However, when Hance (29) adjusted the pH of two soils in the range 5 to 8 he found only slightly increased decomposition rates for atrazine with decreasing pH in one soil. In the other soil, rates of loss decreased. Best and Weber (7) found slower rates of decomposition for prometryn at lower pH. These workers suggested that at low pH, adsorption increased, and this reduced availability for degradation.

Corbin and Upchurch (17) studied the persistence of several herbicides in two soils with high organic matter contents. The pH levels were adjusted to four levels between 4.3 and 7.5. Maximum degradation rates for dicamba and 2,4-D were observed at pH 5.3. The maximum degradation of dalapon and aminotriazole was at pH 6.5 and that of vernolate at pH 7.5. They found that the degradation rates of diuron and chloramben were unaffected by pH. They suggested that the pH levels at which maximum rates of loss occurred were those favoring the growth of the specific microorganisms involved in herbicide degradation.

The adjustment of pH by the addition of alkali or acid for experimental work, especially where there is no equilibrium period, has been criticized (26). Such treatments tend to cause changes in other soil characteristics in addition to pH.

Herbicide degradation rates, like the rates of other biological and non-biological reactions, tend to increase with increasing temperature (26). This has been demonstrated experimentally by a number of researchers (39, 62, 65). In addition to temperature, the presence of water also has a marked influence on the rate of herbicide degradation in the soil. Water is essential to microbiological activity, it acts as a solvent and transport agent, it serves as a reaction medium for biological and non-biological reactions, and it is a reagent in hydrolytic reactions. There have been several reports of increased rates of degradation with increasing soil moisture. Zimdahl and Gwynn (66) found that the degradation rate of three dinitroaniline herbicides was directly correlated with temperature and moisture content. Six months after treatment, the trifluralin residue in a soil at 25% field capacity was significantly greater than that in the same soil at 50% field capacity.

Many field studies have been conducted confirming that herbicides are degraded faster at increased temperature and soil moisture contents (36, 43, 51, 53, 58). Holly and Roberts (36), using bioassay techniques, measured the persistence of triazine herbicides in soil. They found that variations in persistence between seasons at one site were greater than those between sites, and that disappearance was more rapid in wetter years. In many of the field studies, differences between degradation rates in the summer and those in the winter were examined. Smith and Emmond (53) reported recovering, in March, 50 to 60% of the linuron applied in October of the previous year. However, they recovered, in October, only 3% of what was applied in March of the same year.

In practical field situations, the same herbicide is often applied to the same site each year for a number of years. Under these conditions, residues might accumulate. Fortunately, these accumulations did not occur in three studies (22, 47, 50). Parka and Tepe (47) sampled soils from 107 sites in the USA where trifluralin had been applied in the previous 1, 2, 3, or 4 years. The residues ranged from 0.6 to 17.3% of the amount applied. Most of the values were between 2 to 6% They found no evidence of increased accumulation in fields treated over a number of years. Savage (50) sampled 250 sites and came to the same conclusion for nitralin and trifluralin.

Subsequent treatments with herbicides that are used as microbial energy sources may lead to more rapid degradation than in the first few treatments. This is the result of the adaptation of those microorganisms responsible for the degradation of that particular compound. With subsequent treatments, there is a noticeable reduction in the lag-phase described by Audus (5). This phenomenon has been reported for other herbicides (40, 41).

Since most herbicide applications take place in cropland, the effect of the crop on persistence must be considered. The presence of a crop will probably have an indirect effect on herbicide persistence. Soil temperatures and soil moistures in cropped land are different from those in fallow land. The crop roots are certain to affect soil microbial activity. Sikka and Davis (52) examined the role of corn, sorghum, and johnsongrass in the dissipation of atrazine from a sandy loam soil. In corn and johnsongrass field plots, there was significantly less atrazine in the 0 - 15 cm horizon at 1, 2, 3, and 6 months after planting in plots containing plants than in bare plots. Using pot culture, they found that within 3 months, 25, 25, and 20% of the atrazine incorporated into the soil had been taken up by corn, johnsongrass, and sorghum, respectively. Birk and Roadhouse (9), on the other hand, were able to recover 44% of the initial amount of atrazine applied in cropped land compared with 18% in fallow land. They suggested that the difference probably was due to reduced microbial activity caused by low soil moisture content during the corn-growing season. Burnside et al. (13) studied the persistence of atrazine in irrigated fallow and corn cropped land. At one site, they found that atrazine dissipated faster under fallow than under corn culture but could detect no differences in persistence at two other sites. The effects of a crop on herbicide persistence are extremely difficult to predict as its effects are indirect and are likely to vary with soil, site, and season.

Bioassay. The advantages of the bioassay have been well documented by Santelmann (49), Horowitz (37), Hance and McKone (31), and Behrens (6). These authors all agree that it is relatively easy to develop a bioassay method for herbicides in the soil. In addition, bioassays normally do not need sophisticated and expensive equipment, and they are relatively easy to carry out. They provide a direct measurement of available herbicide in the substrate, which often is of more practical interest than total herbicide. Sensitive plant species have been used as indicators in many persistence and soil activity studies with herbicides. In these studies, bioassay techniques have been used exclusively or in addition to chemical analyses to determine soil residues or herbicide activity (12, 13, 36, 42, 54). The soil activity of the new postemergence grass herbicides also has been investigated using bioassay techniques. Smith and Hsiao (54) used both radiochemical techniques and an oat-root bioassay in a study of the persistence of sethoxydim in Canadian prairie soils. Gillespie and Nalewaja (23) used reduction in fresh weight of oat plants as a measure of the soil activity of clopropoxydim, diclofop, DPX-Y6202, fenoxaprop, fluazifop, haloxyfop, and sethoxydim.

Where both chemical and biological analyses have been studied, results from the two methods have differed. Zimdahl et al. (67) found that the half-life of pendimethalin in soil based on chemical analysis was approximately 47 days while the half-life based on biological analysis was 78 to 111 days.

In laboratory experiments on persistence, there usually is less variation within and among experimental units than in the field. In these experiments, the soil is screened and therefore relatively uniform. This improves the uniformity of the herbicide distribution in the soil. The environmental conditions of incubation also can be precisely controlled. In the field, such precision is not possible. Inequalities in the initial distribution of herbicide on the soil surface is responsible for a large part of the variation in the field. In a long-term experiment, Fryer and Kirkland (22) demonstrated the possible size of these errors. Over 6 years, they made repeated treatments of MCPA, simazine, linuron, and triallate. The initial recoveries of the applied rate varied from 42 to 100% with MCPA, 37 to 90% with triallate, 60 to 104% with simazine, and 32 to 144% with linuron. Harris et al. (33) observed that initial recovery of atrazine and fenac varied from 70 to 90%. Walker (59, 60) reported similar variations with simazine, prometryne, and propyzamide.

The deposition of the spray application is another source of variation in field experiments. Fryer and Kirkland (22) measured the point-to-point variation in the deposition of a linuron spray application, at three different times, by placing 12.9 cm^2 filter papers at random on the soil. The deposition varied from 65 to 94% of the theoretical quantity with coefficients of variation ranging from 11 to 60%.

Where mechanical incorporation is employed, these variations may increase. Wauchope et al. (63) used $CuSO_4 \cdot 5H_2O$ as a tracer in a study of the efficiency of several tillage implements in incorporating herbicides. They found a 50% decrease in the applied $CuSO_4 \cdot 5H_2O$ in the center of the path of the disk harrow. The sample-to-sample variations from a single disk incorporation had a coefficient of variation of 50%. There have been reports of variations in residual concentrations increasing with time (22, 32) and variation due to vertical and horizontal redistribution in the treated area (16, 22). Taylor (57) found that the most practical sampling method, bulking 12 cores per plot, had a coefficient of variation of 20%. Coefficients of variation in residues measured in samples from replicate field plots varying from 5 to 80% (19) and 5 to 78% (31) have been reported.

MATERIALS AND METHODS

During 1984, two experiments were established, one in late July and one in late November. The first was located at the Oregon State University Schmidt Research Farm near Corvallis, Oregon, and the second was at the Oregon State University Hyslop Research Farm. The two sites are 1.6 km apart.

The soil at both sites was a Woodburn silt loam. This soil is moderately well drained and a member of the fine-silty, mixed, mesic family of Aquultic Argixerolls. The Woodburn series has a mechanical analysis of 9% sand, 70% silt, and 21% clay in the Ap horizon (0 to 18 cm). The Ap horizon has an organic matter content of about 3%, a pH of 5.4, and a cation exchange capacity of about 15.5 meq/100 g.

Laboratory procedure. Before establishing field experiments, a laboratory procedure for the assessment of residual herbicide activity was developed. In 1984, researchers of the Crop Science Department of Oregon State University evaluated nine grass herbicides, including DPX-Y6202, fluazifop-butyl, sethoxydim, and haloxyfop-methyl, for control of seedlings of several grass species. Jubilee sweet corn was one of the species most sensitive to these herbicides (20). Because it produces a fast-growing, robust seedling, Jubilee corn was used in a laboratory procedure for assessing soil herbicidal activity of these five herbicides.

Soil collected from the experimental site was screened through a 2-mm sieve. To 800 g of screened soil was added a sufficient volume of each herbicide, in 40 ml water, to give the desired soil concentration. Check samples received 40 ml of distilled water. Thus samples were fortified with 0.0, 0.0625, 0.125, 0.25, 0.5, 1.0, and 2.0 ppm (w/w dry soil) of DPX-Y6202, fluazifop-butyl, sethoxydim, clopropoxydim, or haloxyfop-methyl. Following the addition of the herbicidal solutions, the soil samples were placed in a laboratory mixer and mixed for 20 minutes. After mixing, the treated soil was placed in open bags and stored on the greenhouse bench for 1 week before planting the corn.

Jubilee sweet corn seeds, selected for uniform size, were placed on moist germination paper and incubated in the dark at 25^{o}C for 40 hours. Germinated seeds were selected for uniform radicle length and five seeds per pot were planted 1 cm deep in pots, 7.6 cm by 7.6 cm, containing 200 g of treated soil. Each herbicide treatment was replicated four times, and checks were replicated six times.

The pots were then placed in the growth chamber and incubated at a day temperature of 30^{o}C and a night temperature of 25^{o}C. Day length was set at 14 hours. Lighting was from a mixed fluorescent and incandescent source 34 cm above the soil surface. The light source provided a photosynthetic photon flux density of 100 $uE \cdot m^{-2} \cdot s^{-1}$. The soil was maintained at field capacity by subirrigation.

After 2 days, the plants were thinned to three plants per pot. One week after planting, the soil was carefully washed from the roots, and the roots were kept covered with water until the fresh weights of the roots and shoots and the plant height could be measured. The roots and shoots were blotted dry before being weighed. Plant height was measured as the distance from the soil surface to the tip of the longest leaf. After weighing the shoots and roots and measuring the shoot, plant materials were placed in paper envelopes and oven-dried for 2 days at 75°C. The dry weight of the shoots and the roots were then obtained.

Each of the measurements taken was expressed as a percentage of the check. For each herbicide, the correlation coefficient between shoot fresh weight and shoot height was calculated using the equation:

$$r = \frac{\sum xy - \frac{\sum x \sum y}{n}}{\left\{ \left(\sum x^2 - \frac{(\sum x)^2}{n} \right) \cdot \left(\sum y^2 - \frac{(\sum y)^2}{n} \right) \right\}^{\frac{1}{2}}}$$

Root weights were difficult to measure accurately. Weights were variable and therefore, were not considered to be a reliable measure of herbicidal activity.

Summer experiment. In the spring, the land was plowed, disked, harrowed, and fertilized with 560 kg/ha of 16-20-0. The harrowing was done 1 week before the herbicide treatments were applied.

A strip-plot design was used with herbicide treatments as the vertical factor and time of planting as the horizontal factor (25). Vertical plots were 5 by 3 m and horizontal plots were strips 1 m wide which ran across blocks 66 m long . Herbicide treatments and check plots were randomly assigned to the 22 vertical strips in each of four blocks. There were two check plots in each replicate. In a similar manner, times of planting were randomly assigned to the 6 horizontal strips in each of four blocks.

The herbicides were applied on July 21, 1984. The herbicide treatments included DPX-Y6202, fluazifop-butyl, sethoxydim, and clopropoxydim each at 0.14, 0.28, 0.56, and 1.12 kg ai/ha. All herbicide treatments were applied broadcast with a bicycle-wheel plot sprayer using 234 L/ha of spray solution. Application was made to bare soil.

At 0, 7, 14, 21, 42, and 77 days after treatment (DAT), two rows of Jubilee sweet corn were planted in the horizontal plots. The corn was planted with a "Planet Jr" pushplanter. Row spacing was 30 cm and seeding depth was 2.5 cm. The seeding rate averaged 50 seeds/m of row.

An estimation of herbicide activity was made by visually evaluating corn growth 3 weeks after planting. Because of the poor plant stand produced by the 42DAT planting no visual assessment was made. Soil samples for laboratory assessment of herbicide activity were taken from each main plot treated with the highest herbicide rate. The samples were taken at 0, 7, 13, 15, 21, 42, and 82 days after application. At each sampling date, subsamples were taken from each main plot and combined into one main sample. Each composite sample consisted of four subsample cores from the 0- to 5-cm soil layer. Core diameter was 7.6 cm. Main samples averaged 600 g of soil.

Plots were kept relatively weed free by occasional hoeing. Overhead irrigation was applied once weekly to the entire experiment. The experiment was irrigated immediately after each planting.

Winter experiment. The land was plowed, disked, and fertilized with 336 kg/ha of 16-20-0, and harrowed 1 week before the herbicide treatments were applied. The same experimental design and plot sizes were used as in the summer experiment.

The herbicide treatments were applied on November 22, 1984. The herbicide treatments included DPX-Y6202, fluazifop-butyl, sethoxydim, clopropoxydim, and haloxyfop-methyl at 0.14, 0.28, 0.56, and 1.12 kg ai/ha. All herbicide treatments were applied broadcast with a bicycle-wheel plot sprayer using 234 L/ha of spray solution. Application was made to bare soil.

Failure of ryegrass to germinate, even in untreated plots, when planted at 0, 7, and 21 days after application, prompted the abandonment of a field assessment of herbicide activity. However, soil sampling was continued. Soil samples were taken at 0, 7, 21, 42, 59, 70, and 110 days after application. The method of sampling was the same as in the summer experiment.

Laboratory assessment of residual activity. Immediately after collection, the soil samples were placed in a freezer for storage until they could be assayed. On removal from the freezer, the samples were spread on benches in the greenhouse and air-dried. After 1 week, the soil was screened through a 2-mm sieve, and 200 g of each sample was placed in a pot 7.6 cm by 7.6 cm. Five pregerminated Jubilee sweet corn seedlings were planted in the pots. The plants were then incubated in the growth chamber. Day temperature was set at 30°C with night temperature set at 25°C. Day length was set at 14 hours. Lighting was from a mixed fluorescent and incandescent source 34 cm from the soil level. The light source provided a photosynthetic photon flux density of 100 $\mu E \cdot m^{-2} \cdot s^{-1}$. The soil was maintained at field capacity by subirrigation. After 2 days, the plants were thinned to three plants per pot. One week after planting, heights of the plants were measured. The height was considered as the distance from the soil surface to the tip of the longest leaf. The percentage reduction in topgrowth compared with untreated checks was calculated. This value was used to derive the percentage of the initial herbicidal activity.

Statistical analysis. For each herbicide at each rate, the means of the percentage of the initial activity were regressed on time. The time taken for the initial herbicidal activity to be reduced by 50% was designated the activity reduction time-50 (ART_{50}). Regression equations were used to obtain the ART_{50} values of each herbicide at each rate. Confidence intervals, where practical, were obtained using the method of Draper and Smith (21). They used the equation:

$$\left.\begin{matrix} X_u \\ \\ X_l \end{matrix}\right\} = \hat{X}_o + \frac{(\hat{X}_o - \bar{X})g \pm (ts/b_1) \left\{[(\hat{X}_o - \bar{X})^2/Sxx] + (1 - g)/n\right\}^{\frac{1}{2}}}{1 - g}$$

where,

X_u and X_l = upper and lower fiducial limits.

$\hat{X}_0$ = predicted value.

b_1= regression coefficient.

Sxx=

t = t(v,1 - a/2) is the usual t percentage point, and v is the number of degrees of freedom of s^2.

$g = t^2 s^2/(b_1{}^2 Sxx)$

In simple regression, the variance of the regression coefficient enters into the expression for the inverse fiducial range as g. When g is 0.05 or smaller, it can be set g=0 for an approximate answer. Where g is larger than 0.20, inverse estimation is not of much practical value. One factor which tends to make g large is a small or badly determined b_1, in which case s^2 will be large or Sxx will tend to be small or both.

RESULTS AND DISCUSSION

Jubilee sweet corn used in a laboratory procedure to assay the soil activity of DPX-Y6202, fluazifop-butyl, sethoxydim, clopropoxydim, and haloxyfop-methyl proved to be a suitable species. There was a gradual increase in shoot height and shoot fresh and dry weights with increasing soil herbicide concentration (Figures 1 to 5). The response of Jubilee sweet corn was similar with all the herbicides in this study. Root fresh and dry weights were taken but were considered too variable to be a reliable measure of herbicide response. The variability was mainly due to the breaking and subsequent loss of some roots during washing to remove soil. When shoot fresh weight, shoot dry weight, and shoot height were plotted against soil herbicide concentration, shoot height appeared to be positively correlated with shoot fresh weight. Calculation of correlation coefficients for shoot height and fresh weight confirmed the relationship (Table 2).

Table 2. Correlation coefficients of shoot fresh weight and shoot height of Jubilee sweet corn grown in herbicide-treated soil for 7 days in the growth chamber.

Herbicide	r
DPX-Y6202	0.94
fluazifop-butyl	0.99
sethoxydim	0.95
clopropoxydim	0.97
haloxyfop-methyl	0.95

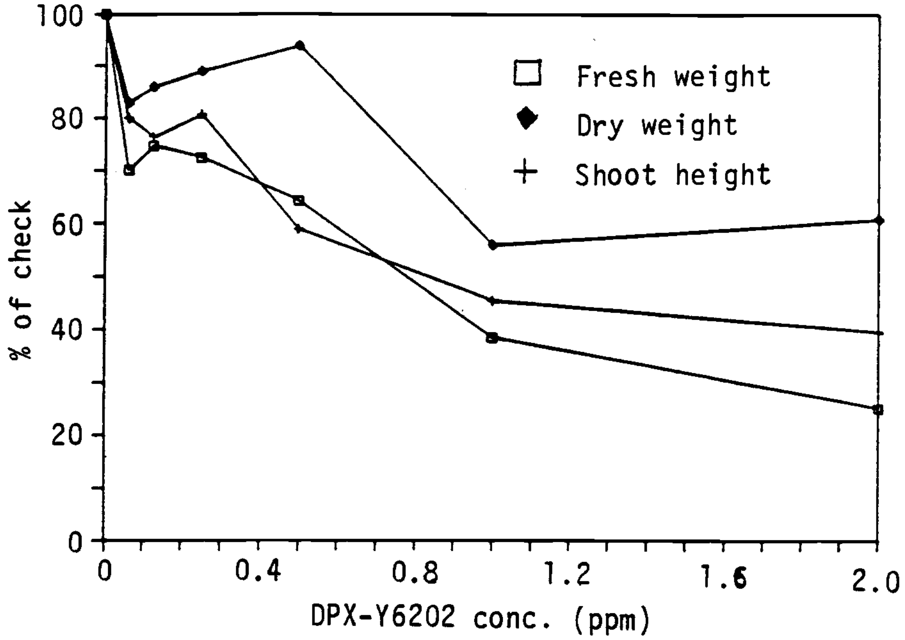


Figure 1. Dose-plant response relationship for Jubilee sweet corn grown in DPX-Y6202 - treated soil for 7 days in the growth chamber.

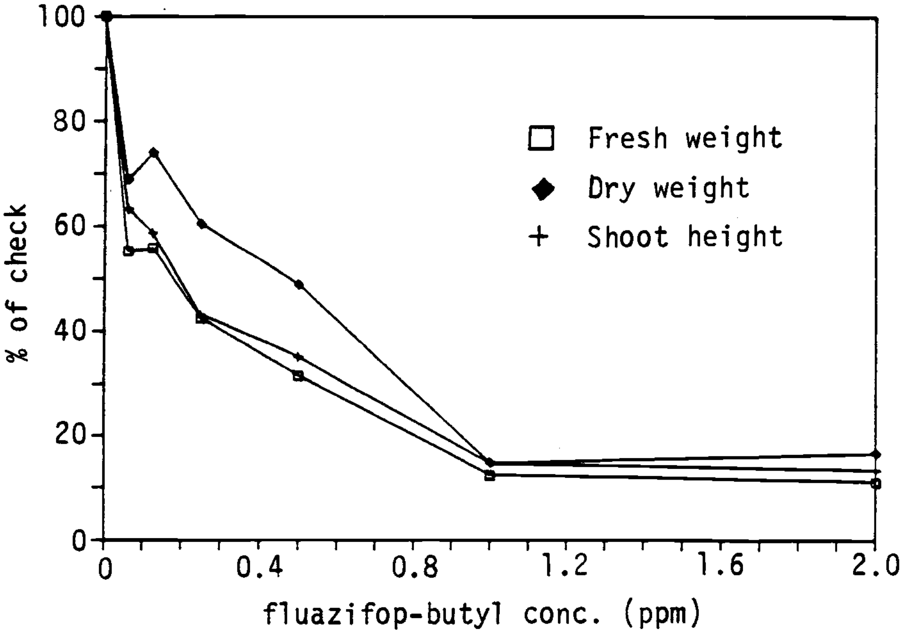


Figure 2. Dose-plant response relationship for Jubilee sweet corn grown in fluazifop-butyl - treated soil for 7 days in the growth chamber.

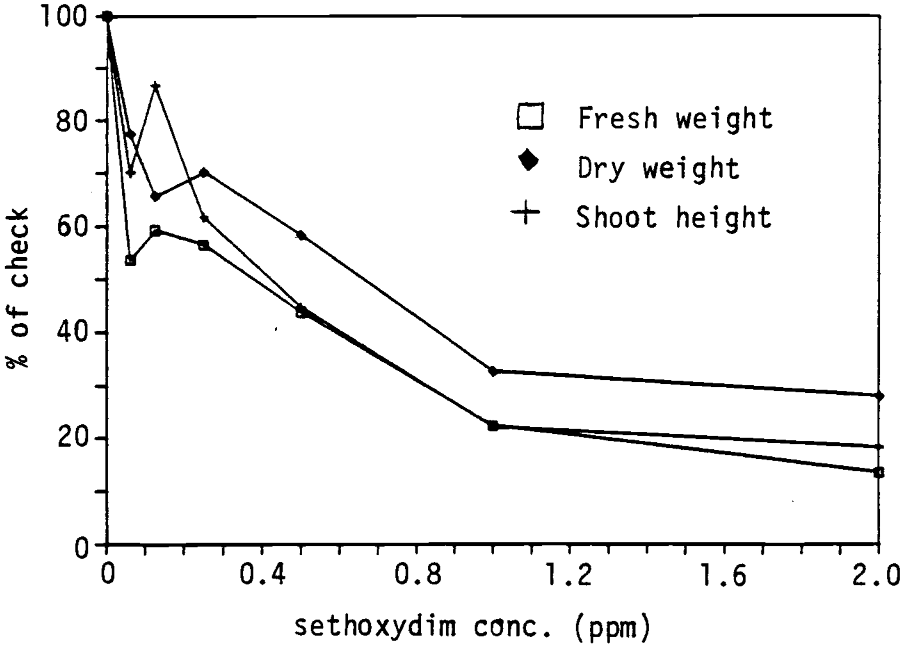


Figure 3. Dose-plant response relationship for Jubilee sweet corn grown in sethoxydim - treated soil for 7 days in the growth chamber.

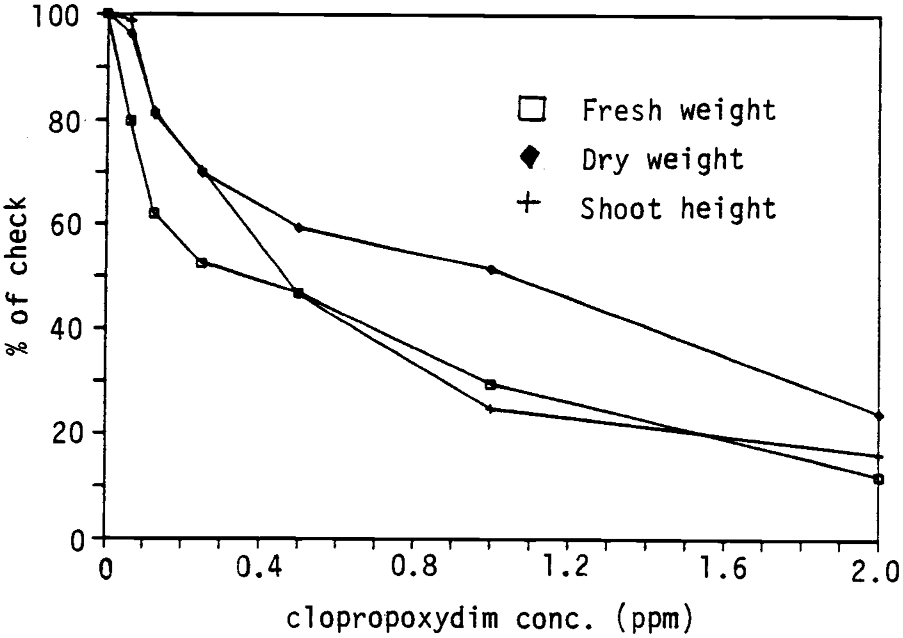


Figure 4. Dose-plant response relationship for Jubilee sweet corn grown in clopropoxydim - treated soil for 7 days in the growth chamber.

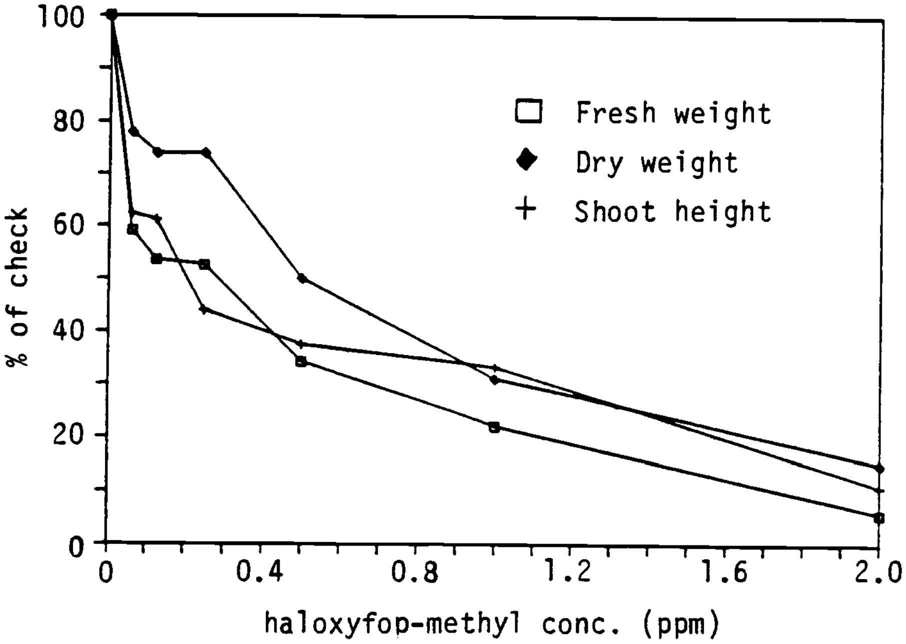


Figure 5. Dose-plant response relationship for Jubilee sweet corn grown in haloxyfop-methyl - treated soil for 7 days in the growth chamber.

This experiment demonstrated that concentrations as low as 0.06 ppm (w/w dry soil), of any of the herbicides in this study, could be detected in soil using this laboratory assay method.

For fluazifop-butyl, clopropoxydim, and haloxyfop-methyl, the exponential equation (decay curve) gave a reasonably good fit to the data collected from the summer and winter laboratory assays (Tables 3 and 6). For DPX-Y6202 and sethoxydim, a logarithmic equation gave a better fit. The exponential equation:

$$Y = ae^{bx}$$

was used to calculate the ART_{50} (activity reduction time) for fluazifop-butyl, clopropoxydim, and haloxyfop-methyl. The logarithmic equation:

$$Y = a + b(\ln X)$$

was used to calculate the ART_{50} values for DPX-Y6202 and sethoxydim. Confidence intervals, where practical, were determined using inverse regression (21) ($P = 0.05$). These ART_{50} values are presented in Tables 4 and 5.

The ART_{50} values for the 1.12 kg/ha rate, as determined by laboratory assay, show that DPX-Y6202 tended to be the most persistent in the summer, with an ART_{50} value of 36, followed in turn by fluazifop-butyl with 31, sethoxydim with 9, and clopropoxydim with 8. At the end of the summer experiment (82 DAT), the laboratory assay indicated that the activity of DPX-Y6202 and fluazfop-butyl had decreased to 28 and 13% of the initial activity, respectively (Table 3, Figures 10 and 11). Sethoxydim,

Table 3. Residual activity of 1.12 kg/ha DPX-Y6202, fluazifop-butyl, sethoxydim, and clopropoxydim applied preemergence at the Schmidt Research Farm during the summer, 1984. Residual activity is measured as a percentage of the initial activity as determined by laboratory assay using Jubilee sweet corn as an indicator plant.

	Time (DAT)						
Herbicide	0	7	13	15	21	42	82
	% Initial activity[a]						
DPX-Y6202	100 ± 0	71 ± 6	61 ± 4	62 ± 2	59 ± 4	51 ± 4	28 ± 1
fluazifop-butyl	100 ± 0	75 ± 6	77 ± 2	73 ± 2	71 ± 2	51 ± 4	13 ± 1
sethoxydim	100 ± 0	66 ± 6	47 ± 4	38 ± 4	1 ± 1	1 ± 1	0
clopropoxydim	100 ± 0	61 ± 3	33 ± 4	26 ± 3	15 ± 1	0	0

[a] % Initial activity = $\frac{ht \times 100}{ho}$

ht = mean percentage reduction in height from check of Jubilee sweet corn at t DAT

ho = mean percentage reduction in height from check of Jubilee sweet corn at 0 DAT

Mean and standard error from 12 plant measurements.

Table 4. Persistence of DPX-Y6202, fluazifop-butyl, sethoxydim, clopropoxydim, and haloxyfop-methyl applied at 1.12 kg/ha during the summer and winter of 1984. ART_{50} values are based on laboratory assay using Jubilee sweet corn as an indicator plant.

	ART_{50} values[a]			
Herbicide	Summer	Confidence interval	Winter	Confidence interval
DPX-Y6202	36	29 - 49	28	17 - 50
fluazifop-butyl	31	24 - 39	38	27 - 48
sethoxydim	9	1 - 17	12	5 - 19
clopropoxydim	8	7 - 9	22	20 - 23
haloxyfop-methyl	-	-	59	46 - 86

[a] ART_{50} represents the time in days required to lose 50% of its herbicidal activity at day 0.

Confidence intervals determined by inverse regression (22); $P = 0.05$.

and clopropoxydim were essentially inactive after 42 days (Table 3, Figures 12 and 13).

ART_{50} values as determined by field assessment, were shorter for DPX-Y6202 and fluazifop-butyl and similar for sethoxydim and clopropoxydim when compared to values determined by lab assessment. Applications of sethoxydim at 0.14 kg/ha produced no observable soil activity in the summer experiment. Field results were more variable (Table 5, Figures 6 to 9) than laboratory results.

Table 5. Persistence of premergence applications of DPX-Y6202, fluazifop-butyl, sethoxydim, and clopropoxydim as measured by ART_{50} values. Values are based on visual rating of growth reduction of Jubilee sweet corn in the field 21 days after planting at Schmidt Research Farm during the summer, 1984.

	Rate kg/ha			
Herbicide	1.12	0.56	0.28	0.14
	ART_{50} (days)			
DPX-Y6202	19	19	14	11
fluazifop-butyl	18	35	24	8
sethoxydim	10	6	4	-
clopropoxydim	11	3	3	10

In the winter, experiment haloxyfop-methyl was included as a treatment. The exponential curve gave the best fit to the percent initial ativity values of haloxyfop-methyl. ART_{50} values were determined in the same way as for the summer experiment. Haloxyfop-methyl was the most persistent with an ART_{50} value of 59

Table 6. Residual activity of 1.12 kg/ha DPX-Y6202, fluazifop-butyl, sethoxydim, clopropoxydim, and haloxyfop-methyl applied preemergence at the Hyslop Research Farm during the winter, 1984. Residual activity is measured as percentage of the initial activity as determined by laboratory assay using Jubilee sweet corn as an indicator plant.

	Time (DAT)						
Herbicide	0	7	20	42	39	70	110
	% Initial activity[a]						
DPX-Y6202	100 ± 0	72 ± 3	52 ± 2	49 ± 2	44 ± 2	45 ± 3	42 ± 5
fluazifop-butyl	100 ± 0	71 ± 2.4	62 ± 2.4	40 ± 4.4	37 ± 2.2	31 ± 3.4	22 ± 3.4
sethoxydim	100 ± 0	70 ± 3.2	27 ± 5.7	21 ± 6.0	3 ± 1.6	3 ± 1.6	2 ± 0.7
clopropoxydim	100 ± 0	70 ± 2.8	60 ± 2.6	31 ± 8.4	14 ± 3.2	14 ± 3.6	6 ± 1.4
haloxyfop-methyl	100 ± 0	76 ± 1.2	66 ± 2.4	55 ± 2.6	53 ± 3.8	46 ± 2.0	33 ± 2.5

[a] $\% \text{ Initial activity} = \frac{\text{ht} \times 100}{\text{ho}}$

ht = mean percentage reduction in height from check of Jubilee sweet corn at t DAT

ho = mean reduction in height from check of Jubilee sweet corn at 0 DAT

Mean and standard error from 12 plant measurements.

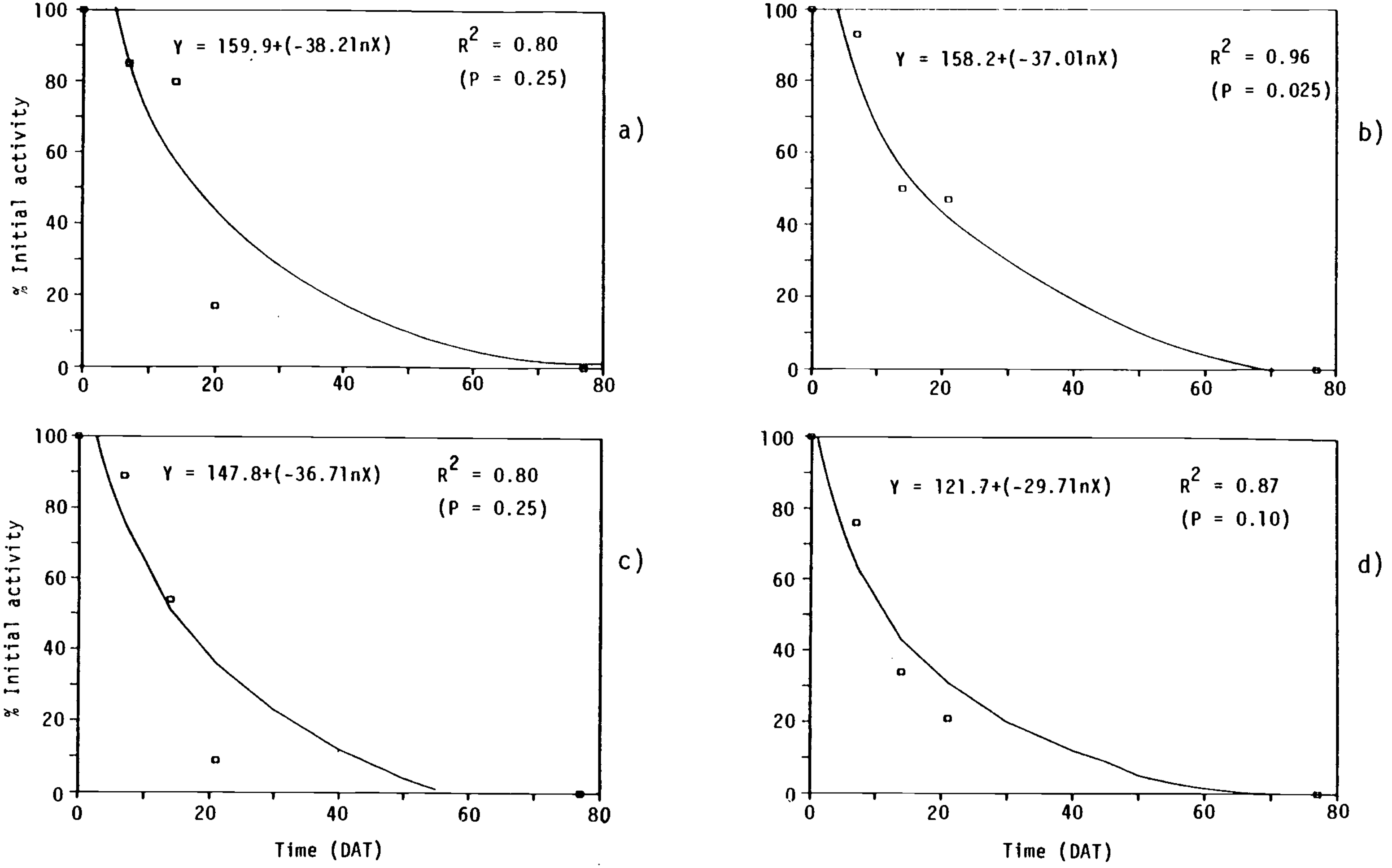


Figure 6. The reduction of residual activity of preemergence applications of DPX-6202 measured by visual rating of reduction in growth of Jubilee sweet corn 21 days after planting at Schmidt Research Farm during the summer, 1984.
a) 1.12 kg ai/ha, b) 0.56 kg ai/ha, c) 0.28 kg ai/ha, d) 0.14 kg ai/ha.

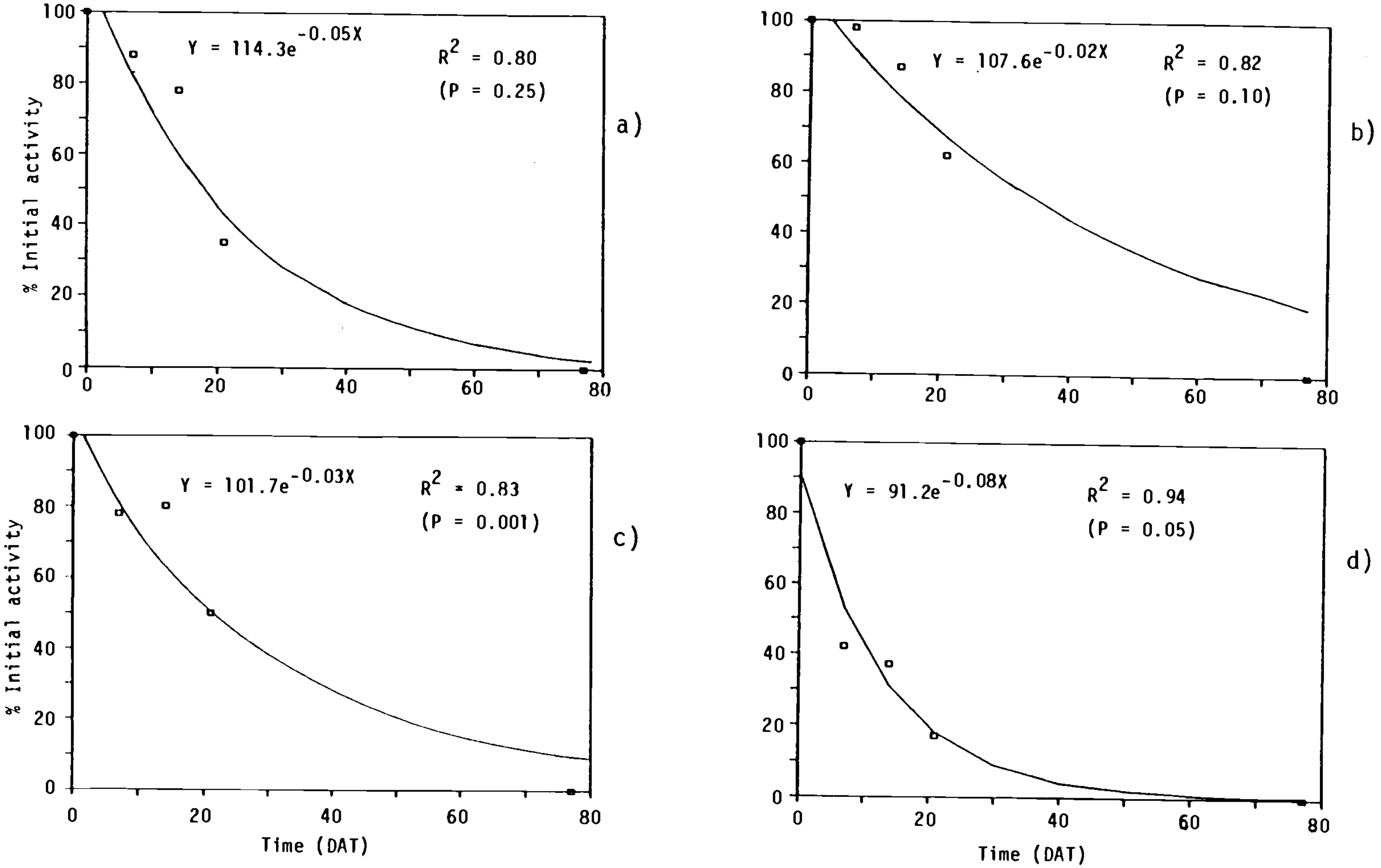


Figure 7. The reduction of residual activity of preemergence applications of fluazifop-butyl measured by visual rating of reduction in growth of Jubilee sweet corn 21 days after planting at Schmidt Research Farm during the summer, 1984.
a) 1.12 kg ai/ha, b) 0.56 kg ai/ha, c) 0.28 kg ai/ha, d) 0.14 kg ai/ha.

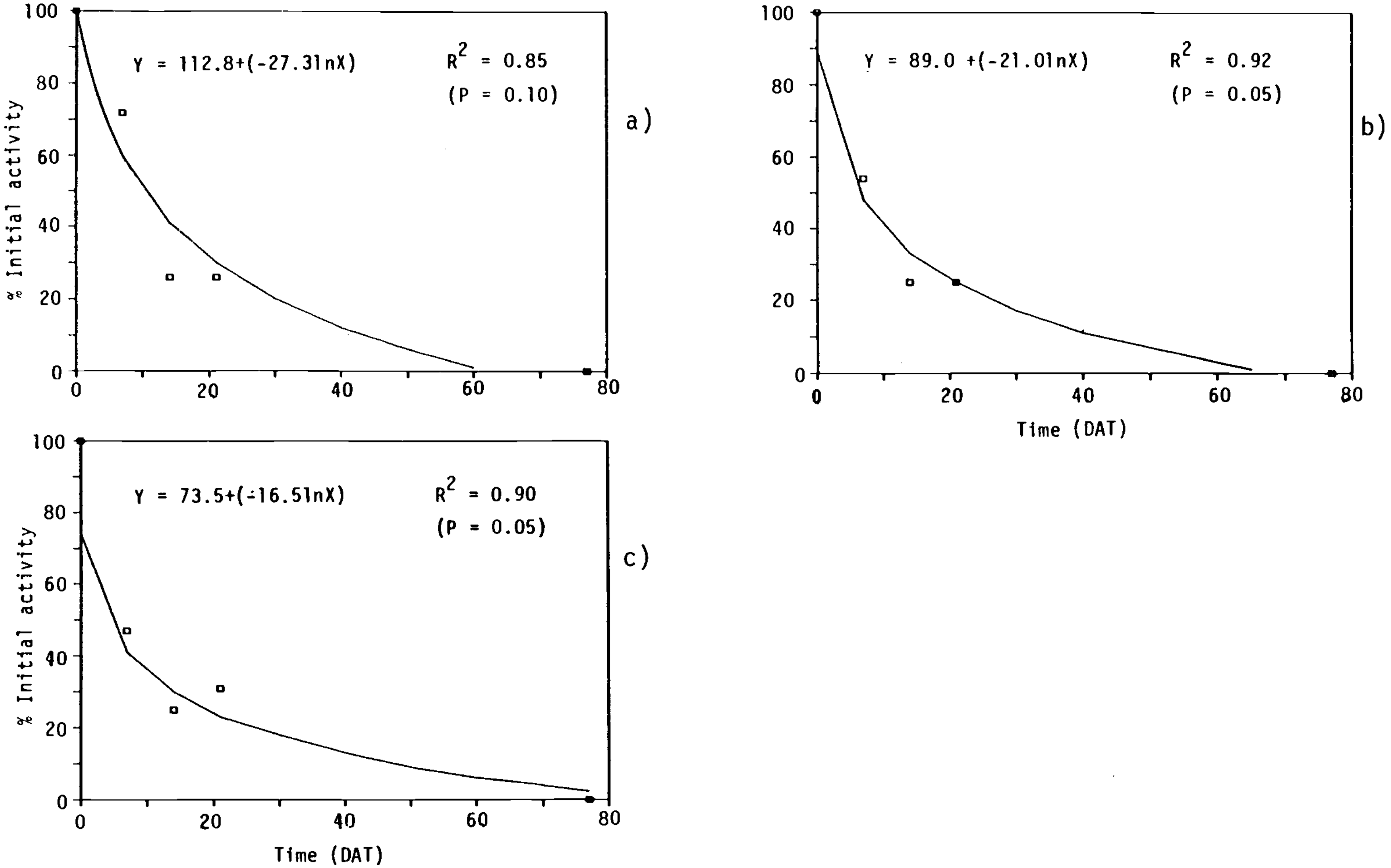


Figure 8. The reduction of residual activity of preemergence applications of sethoxydim measured by visual rating of reduction in growth of Jubilee sweet corn 21 days after planting at Schmidt Research Farm during the summer, 1984.
a) 1.12 kg ai/ha, b) 0.56 kg ai/ha, c) 0.28 kg ai/ha.

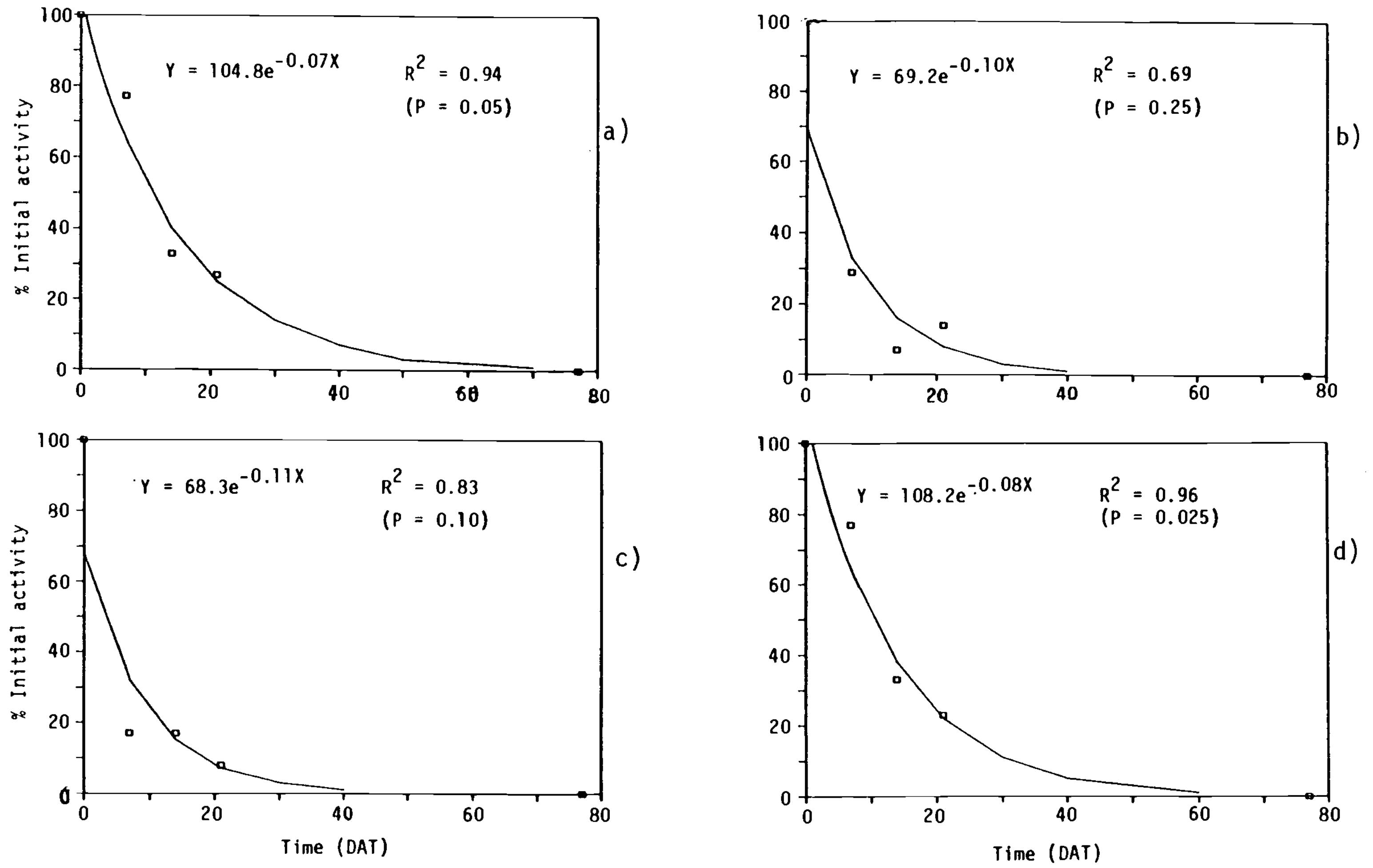


Figure 9. The reduction of residual activity of preemergence applications of clopropoxydim measured by visual rating of reduction in growth of Jubilee sweet corn 21 days after planting at Schmidt Research Farm during the summer, 1984.
a) 1.12 kg ai/ha, b) 0.56 kg ai/ha, c) 0.28 kg ai/ha, d) 0.14 kg ai/ha.

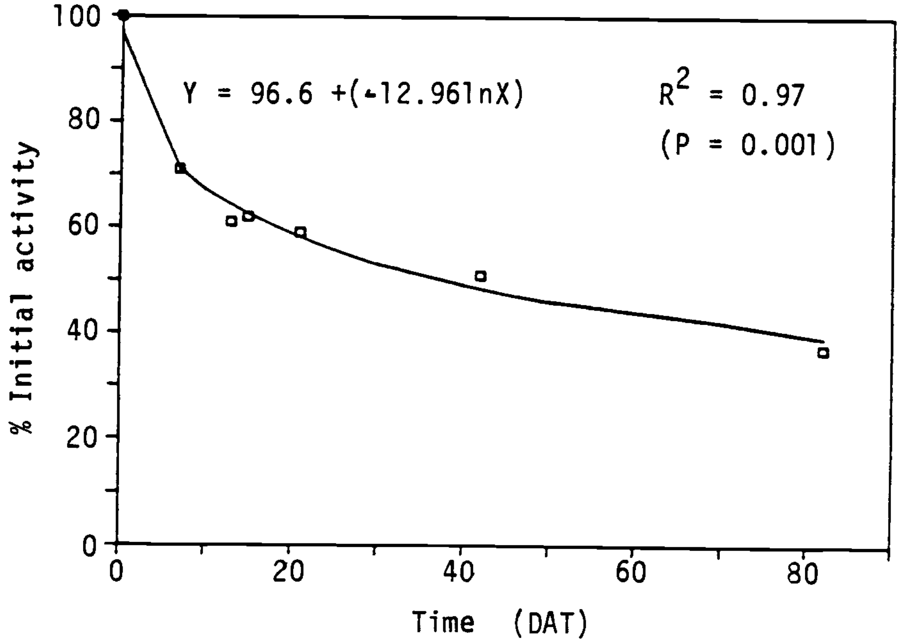


Figure 10. The reduction of residual activity, with time, of DPX-Y6202 applied preemergence at 1.12 kg/ha at the Schmidt Research Farm during the summer, 1984. The percent initial activity was determined in the laboratory using Jubilee sweet corn as a plant indicator.

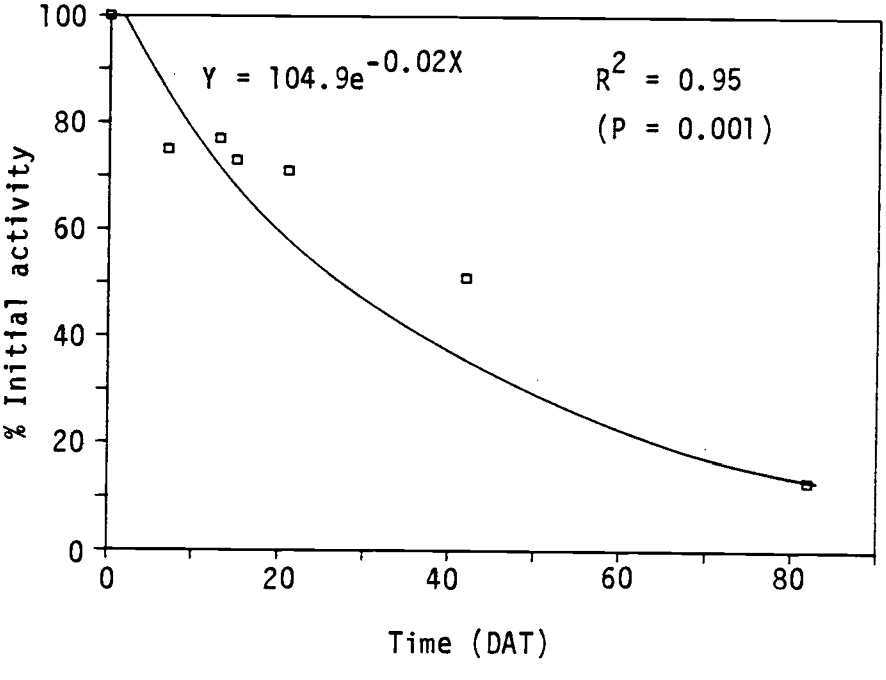


Figure 11. The reduction of residual activity, with time, of fluazifop-butyl applied preemergence at 1.12 kg/ha at the Schmidt Research Farm during the summer, 1984. The percent initial activity was determined in the laboratory using Jubilee sweet corn as a plant indicator.

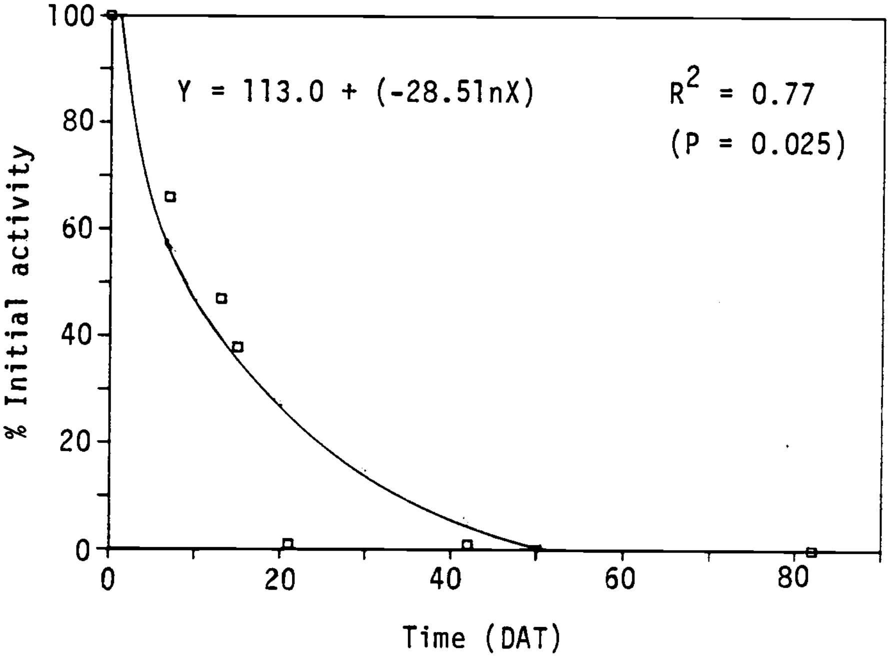


Figure 12. The reduction of residual activity, with time, of sethoxydim applied preemergence at 1.12 kg/ha at the Schmidt Research Farm during the summer, 1984. The percent initial activity was determined in the laboratory using Jubilee sweet corn as a plant indicator.

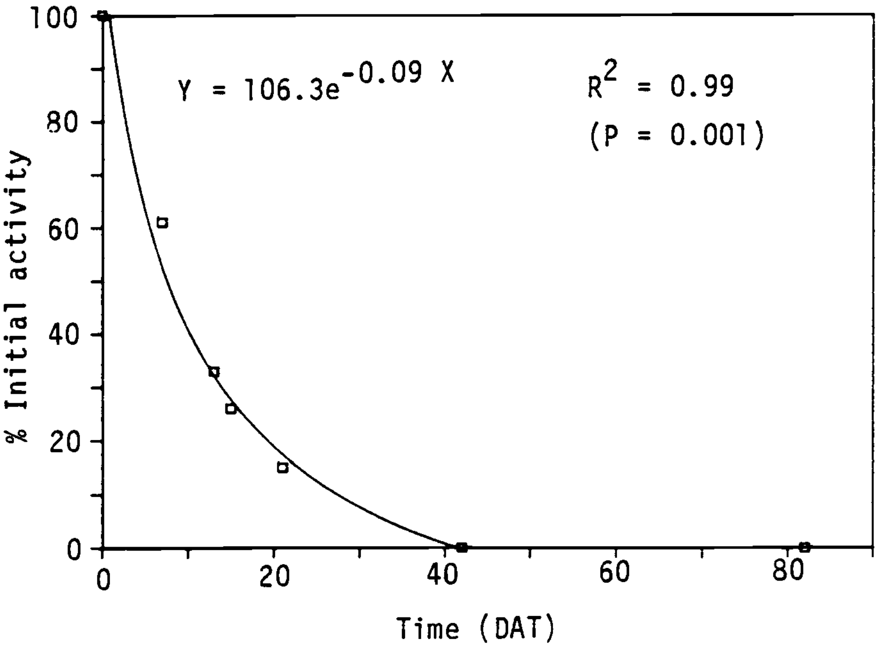


Figure 13. The reduction of residual activity, with time, of clopropoxydim applied preemergence at 1.12 kg/ha at the Schmidt Research Farm during the summer, 1984. The percent initial activity was determined in the laboratory using Jubilee sweet corn as a plant indicator.

days followed in turn by fluazifop-butyl with 38, DPX-Y6202 with 28, clopropoxydim 22, and sethoxydim 12. Of those herbicides tested in the summer and winter, there was a tendency for fluazifop-butyl, sethoxydim, and clopropoxydim to be more persistent in the winter than in the summer. In the winter experiment, clopropoxydim was markedly more persistent than in the summer experiment (Table 4). At the end of the winter experiment (110 DAT), DPX-Y6202, fluazifop-butyl, sethoxydim, clopropoxydim, and haloxyfop-methyl exhibited 42, 22, 2, 6, and 33% initial activity, respectively (Figures 14 to 18).

In the summer experiment where both laboratory and field assessments of herbicidal activity were used, the laboratory assessment appeared to be the more sensitive method. At 77 DAT, the field assay method could detect no activity of DPX-Y6202 at 1.12 kg/ha. However, at 82 DAT, the laboratory assay method detected 28% of the initial activity. A similar trend was observed in treatments of fluazifop-butyl and clopropoxydim at 1.12 kg/ha. The laboratory assay also appeared to be less variable than the field assay. The lower variability likely was due to the controlled conditions of the growth chamber and the shorter growing time of the plants. Increased persistence in the winter experiment was similar to the findings of other researchers and can be attributed to reduced degradation rates caused by the effects of low temperatures on biological and non-biological reactions (43, 51, 53, 56, 58). It is possible that reduced plant uptake of herbicides, due to the absence of test plants, could have contributed to the greater persistence observed in the winter experiment.

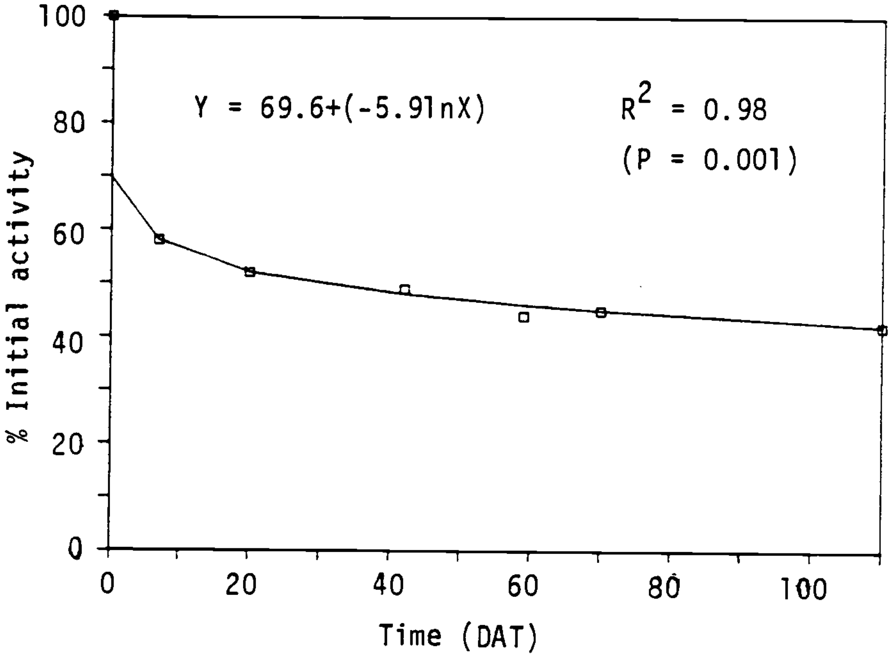


Figure 14. The reduction of residual activity, with time, of DPX-Y6202 applied preemergence at 1.12 kg/ha at the Hyslop Research Farm during the winter, 1984. The percent initial activity was determined in the laboratory using Jubilee sweet corn as a plant indicator.

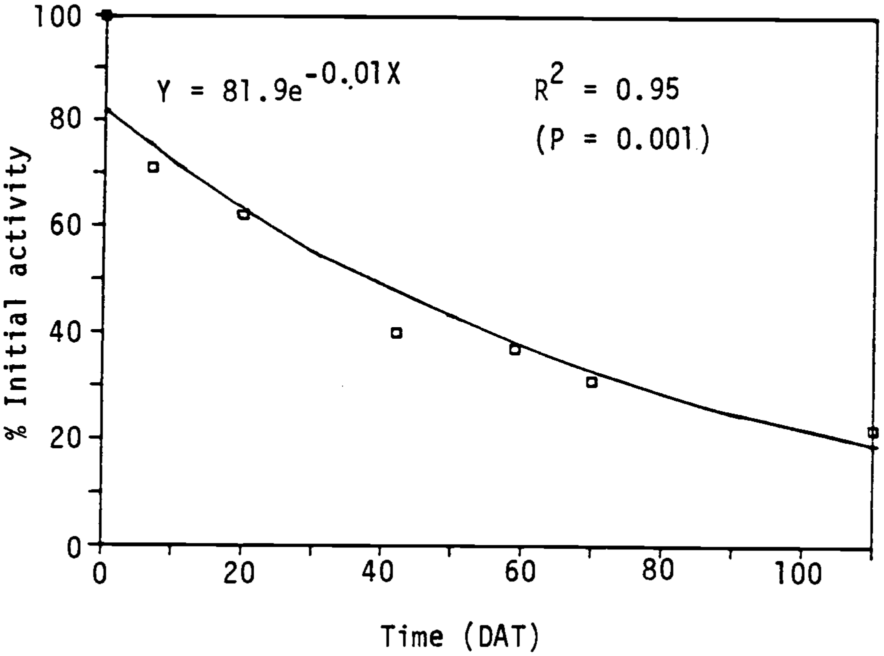


Figure 15. The reduction of residual activity, with time, of fluazifop-butyl applied preemergence at 1.12 kg/ha at the Hyslop Research Farm during the winter, 1984. The percent initial activity was determined in the laboratory using Jubilee sweet corn as a plant indicator.

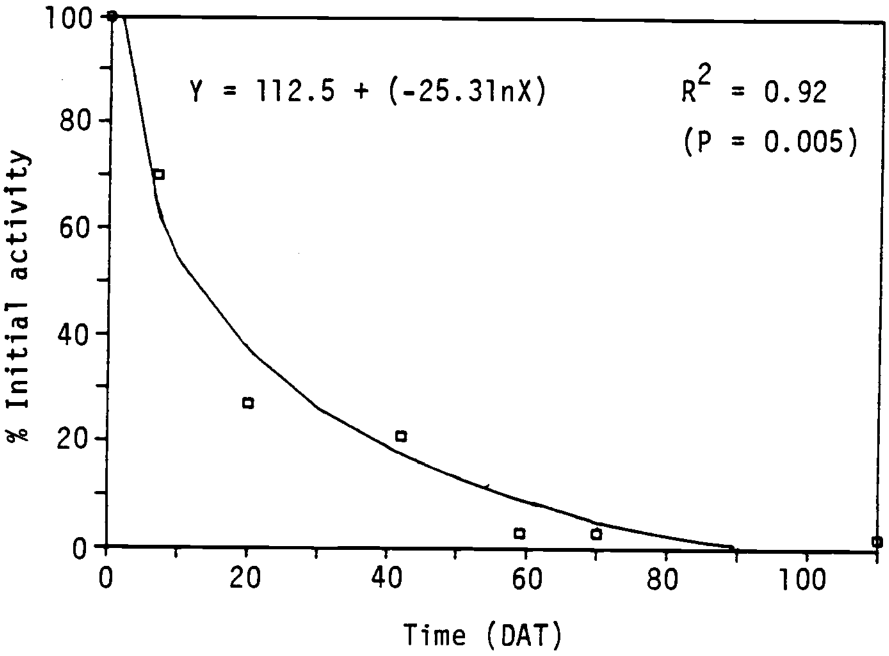


Figure 16. The reduction of residual activity, with time, of sethoxydim applied preemergence at 1.12 kg/ha at the Hyslop Research Farm during the winter, 1984. The percent initial activity was determined in the laboratory using Jubilee sweet corn as a plant indicator.

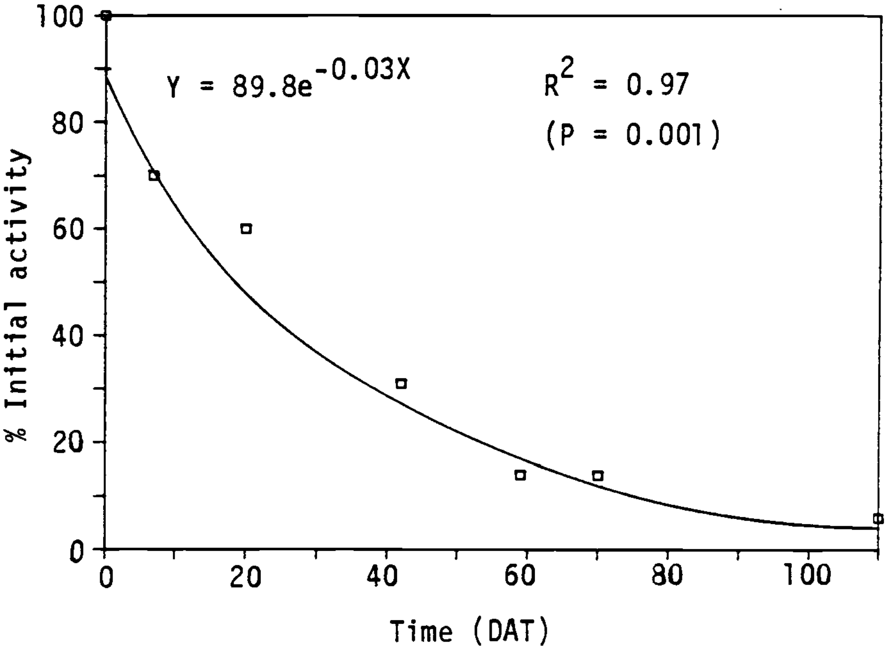


Figure 17. The reduction of residual activity, with time, of clopropoxydim applied preemergence at 1.12 kg/ha at the Hyslop Research Farm during the winter, 1984. The percent initial activity was determined in the laboratory using Jubilee sweet corn as a plant indicator.

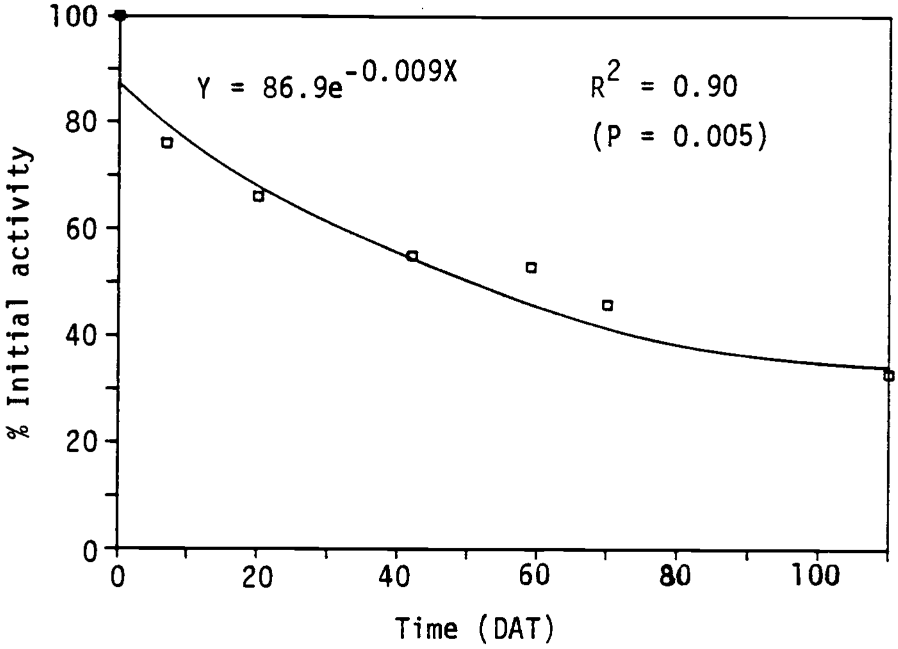


Figure 18. The reduction of residual activity, with time, of haloxyfop-methyl applied preemergence at 1.12 kg/ha at the Hyslop Research Farm during the winter, 1984. The percent initial activity was determined in the laboratory using Jubilee sweet corn as a plant indicator.

CONCLUSION

DPX-Y6202, fluazifop-butyl, sethoxydim, clopropoxydim, and haloxyfop-methyl exhibited herbicidal activity in a Woodburn silty loam soil of the Hyslop and Schmidt Research Farms. During the summer, DPX-Y6202 was the most persistent followed in turn by fluazifop-butyl, sethoxydim, and clopropoxydim. In the winter, haloxyfop-butyl was the most persistent followed in turn by fluazifop-butyl, DPX-Y6202, clopropoxydim, and sethoxydim. There was a trend towards greater persistence in the winter than in the summer. Clopropoxydim exhibited the largest increase in persistence from summer to winter. The soil activity and persistence of these postemergence grass herbicides have been reported (1, 10, 14, 28, 35, 44, 48), but there are no reports in the literature on the influence of temperatures, moisture, or season on their activity and persistence. However, the effects of temperature and season on the activity of other herbicides are well documented (36, 51, 56, 58, 66). Hurle and Walker (38) reasoned that because the rates of biological processes and non-biological reactions are increased by increasing temperature, rates of herbicide degradation should also be increased. In addition to adequate temperature, an adequate supply of water is also essential for microbial activity. Water plays an important role in non-biological reactions as well, by acting as a solvent and as a reagent in hydrolytic reactions. The effect of season on herbicidal activity and persistence also has been studied (43, 51, 53, 56, 58). These workers found that persistence generally was greater during the winter months than the summer months. In Oregon, where the winters are wet and cool, the lower temperature is likely to be the major factor limiting both microbial and non-biological reactions in the soil. This would probably account for the greater persistence of these postemergence grass herbicides in the soil during the winter.

The laboratory assay of soil activity appeared to be more sensitive than the field assay. One possible explanation for this might be that the low soil mobility of these herbicides resulted in herbicide accumulation at the surface. The samples would therefore contain higher herbicide concentrations than the soil exploited by the roots of the indicator plant in the field. Buhler and Burnside (10) found that almost complete forage sorghum control was obtained with preemergence applications of fluazifop-butyl, haloxyfop-methyl, and sethoxydim when seeds were planted on the surface. However, planting seeds 2, 4, or 6 cm deep markedly reduced control. Another possible reason for the differences in sensitivity between the field and laboratory assays might be the growing conditions during the assay. The conditions of temperature, light, and soil in the growth chamber could possibly make Jubilee corn more sensitive to the herbicides. Before laboratory assays can be used to predict activity in the field, the test needs to be calibrated with field response by weeds and susceptible crops.

Although these herbicides were developed for use primarily as postemergence grass herbicides, their soil activity can be utilized to advantage. In annual broadleaf crops, fluazifop-butyl, sethoxydim, and clopropoxydim at rates recommended for postemergence application could control grasses germinating soon after treatment without affecting subsequent susceptible crops. DPX-Y6202 and haloxyfop-methyl used at higher rates would provide good preemergence control, but could affect subsequent susceptible crops. There is one report in the literature on haloxyfop-methyl persisting 249 days in the soil (14). The effects of tillage on the persistence of the more persistent postemergence herbicides need to be examined. Where the herbicides are used in perennial crops such as peppermint, rates higher than those recommended for postemergence application might be used to obtain residual activity, provided these rates do not affect the crop.

The ability of DPX-Y6202, fluazifop-butyl, sethoxydim, clopropoxydim, and haloxyfop-butyl to reduce the growth of corn at various times after application demonstrates their soil activity and persistence. But potential preemergence and residual weed control would depend on the weed species and the depth of the weed seeds in the soil.

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APPENDICES

Appendix Table 1. Shoot and root measurements of Jubilee corn after growing 7 days in soil treated with various concentrations of DPX-Y6202.

DPX-Y6202 ppm dry soil		Shoot			Root	
		Fresh weight (g)	Dry weight (g)	Height (cm)	Fresh weight (g)	dry weight (g)
0	R1	0.7744	0.574	24.4	0.5345	0.0552
	R2	0.7426	0.0533	27.3	0.4833	0.0495
	R3	0.4892	0.0373	25.8	0.3450	0.0329
	R4	0.7319	0.0525	26.0	0.5275	0.0482
	R5	0.7748	0.0593	26.0	0.4816	0.0617
	R6	0.5827	0.0430	23.6	0.4523	0.0456
	X̄	0.6826	0.0504	25.5	0.4707	0.0489
0.0625	R1	0.5250	0.0439	20.3	0.3302	0.0358
	R2	0.4967	0.0451	22.1	0.3842	0.0525
	R3	0.3910	0.0328	20.1	0.2619	0.0238
	R4	0.5022	0.0458	19.2	0.3121	0.0317
	X̄	0.4787	0.0419	20.4	0.3221	0.0360
0.125	R1	0.6503	0.0557	19.9	0.4451	0.0433
	R2	0.3546	0.0296	17.6	0.2533	0.0309
	R3	0.5096	0.0428	19.5	0.3612	0.0390
	R4	0.5240	0.0432	21.0	0.3851	0.0429
	X̄	0.5096	0.0428	19.5	0.3612	0.0390

Appendix Table 1. (continued).

DPX-Y6202 ppm dry soil		Shoot			Root	
		Fresh weight (g)	Dry weight (g)	Height (cm)	Fresh weight (g)	Dry weight (g)
0.25	R1	0.5656	0.0529	22.2	0.3093	0.0371
	R2	0.5119	0.0487	20.3	0.3307	0.0352
	R3	0.3753	0.0323	18.3	0.2405	0.0219
	R4	0.5257	0.0467	21.7	0.3227	0.0328
	X̄	0.4946	0.0452	20.6	0.3008	0.0318
0.5	R1	0.3460	0.0440	11.8	0.2182	0.0332
	R2	0.4303	0.0486	15.5	0.3186	0.0426
	R3	0.5322	0.0506	18.3	0.4242	0.0496
	R4	0.4479	0.0460	14.7	0.3238	0.0402
	X̄	0.4391	0.0473	15.1	0.3212	0.0414
1.0	R1	0.2612	0.0280	38.3	0.1668	0.0219
	R2	0.2633	0.0282	38.6	0.1681	0.0221
	R3	0.2665	0.0285	39.1	0.1701	0.0224
	R4	0.2622	0.0281	38.4	0.1674	0.0220
	X̄	0.2633	0.0282	38.6	0.1681	0.0221
2.0	R1	0.1709	0.0304	25.0	0.2312	0.0323
	R2	0.1723	0.0306	25.2	0.2331	0.0326
	R3	0.1744	0.0310	25.5	0.2360	0.0330
	R4	0.1716	0.0305	25.1	0.2321	0.0325
	X̄	0.1723	0.0306	25.2	0.2331	0.0326

Appendix Table 2. Shoot and root measurements of Jubilee corn after growing 7 days in soil treated with various concentrations of fluazifop-butyl.

Fluazifop-butyl ppm dry soil		Shoot			Root	
		Fresh weight (g)	Dry weight (g)	Height (cm)	Fresh weight (g)	Dry weight (g)
0	R1	0.6667	0.0452	22.9	0.4696	0.0383
	R2	0.7028	0.0494	29.0	0.5003	0.0560
	R3	0.5851	0.0393	24.0	0.4884	0.0635
	R4	0.6860	0.0465	25.6	0.5050	0.0610
	R5	0.6347	0.0449	24.6	0.5258	0.0555
	R6	0.8555	0.0658	28.3	0.6476	0.0822
	$\bar{X}$	0.6884	0.0485	25.73	0.5228	0.0594
0.0625	R1	0.3045	0.0241	12.2	0.2422	0.0290
	R2	0.4602	0.0413	19.8	0.2836	0.0366
	R3	0.3802	0.0350	16.9	0.2865	0.0356
	R4	0.3780	0.0336	16.3	0.2527	0.0321
	$\bar{X}$	0.3807	0.0335	16.3	0.2663	0.333
0.125	R1	0.3599	0.0312	14.3	0.2504	0.0346
	R2	0.3356	0.0319	12.7	0.2555	0.0305
	R3	0.4566	0.0424	16.7	0.3052	0.0437
	R4	0.3871	0.0384	16.7	0.2345	0.0341
	$\bar{X}$	0.3848	0.0360	15.1	0.2614	0.0357
0.25	R1	0.1374	0.0124	6.8	0.1975	0.0287
	R2	0.3502	0.0370	10.8	0.2588	0.0381

Appendix Table 2. (continued).

Fluazifop-butyl ppm dry soil		Shoot Fresh weight (g)	Shoot Dry weight (g)	Shoot Height (cm)	Root Fresh weight (g)	Root Dry weight (g)
0.25	R3	0.3495	0.0368	15.0	0.2759	0.0389
	R4	0.3305	0.0312	12.0	0.2740	0.0359
	$\bar{X}$	0.2919	0.0294	11.2	0.2516	0.0354
0.5	R1	0.1252	0.0146	5.1	0.2425	0.0377
	R2	0.1853	0.0209	7.5	0.2460	0.0427
	R3	0.3064	0.0328	9.9	0.2449	0.0428
	R4	0.2536	0.0266	13.6	0.2248	0.0317
	$\bar{X}$	0.2176	0.0237	9.0	0.2396	0.0387
1.0	R1	0.0445	0.0039	2.5	0.2081	0.0395
	R2	0.2012	0.0248	7.2	0.2526	0.0476
	R3	0.0391	0.0148	2.4	0.2782	0.0600
	R4	0.0568	0.0139	2.9	0.2167	0.0502
	$\bar{X}$	0.0854	0.0143	3.8	0.2389	0.0493
2.0	R1	0.1218	0.0127	5.0	0.1710	0.0255
	R2	0.0184	0.0018	1.8	0.1683	0.0358
	R3	0.0593	0.0072	3.3	0.1878	0.0404
	R4	0.1061	0.0109	3.7	0.2143	0.0385
	$\bar{X}$	0.0764	0.0082	3.5	0.1854	0.0351

Appendix Table 3. Shoot and root measurements of Jubilee corn after growing 7 days in soil treated with various concentrations of sethoxydim.

Sethoxydim ppm dry soil		Shoot Fresh weight (g)	Shoot Dry weight (g)	Shoot Height (cm)	Root Fresh weight (g)	Root Dry weight (g)
0	R1	0.8090	0.0545	27.0	0.5618	0.0625
	R2	0.7040	0.0488	27.5	0.4660	0.0455
	R3	0.8176	0.0602	28.2	0.5922	0.0678
	R4	0.7953	0.0542	25.1	0.6055	0.0545
	R5	0.9022	0.0623	27.2	0.5804	0.0728
	R6	0.6340	0.0442	26.7	0.6166	0.1027
	$\bar{X}$	0.7770	0.0540	27.0	0.5704	0.0676
0.0625	R1	0.4356	0.0433	18.2	0.2970	0.0420
	R2	0.4239	0.0457	17.9	0.2651	0.0368
	R3	0.4161	0.0386	20.2	0.3207	0.0482
	R4	0.3933	0.396	19.3	0.2964	0.0372
	$\bar{X}$	0.4172	0.0418	18.9	0.2948	0.0411
0.125	R1	0.4500	0.0273	22.7	0.2772	0.0330
	R2	0.4606	0.0258	23.7	0.2620	0.0333
	R3	0.5067	0.0269	24.0	0.2739	0.0315
	R4	0.4251	0.0265	23.3	0.2696	0.0324
	$\bar{X}$	0.4606	0.0266	23.4	0.2707	0.0325
0.25	R1	0.4094	0.0334	12.4	0.2794	0.0256
	R2	0.3739	0.0321	14.6	0.3161	0.0331

Appendix Table 3. (continued).

Sethoxydim ppm dry soil		Shoot			Root	
		Fresh weight (g)	Dry weight (g)	Height (cm)	Fresh weight (g)	Dry weight (g)
0.25	R3	0.5967	0.0531	23.3	0.3376	0.0402
	R4	0.3765	0.0331	16.2	0.2702	0.0356
	X̄	0.4391	0.0379	16.6	0.3008	0.0336
0.5	R1	0.2783	0.0228	10.0	0.2901	0.0350
	R2	0.3573	0.0368	12.3	0.3012	0.0465
	R3	0.3351	0.0313	11.5	0.3056	0.0413
	R4	0.3916	0.0351	14.5	0.3059	0.0376
	X̄	0.3406	0.0315	12.1	0.3007	0.0401
1.0	R1	0.2749	0.0241	9.2	0.2026	0.0336
	R2	0.0666	0.0228	2.5	0.3372	0.0528
	R3	0.0920	0.0238	4.3	0.2343	0.0415
	R4	0.2633	0.0235	7.9	0.1995	0.0266
	X̄	0.1742	0.0236	6.0	0.2434	0.0386
2.0	R1	0.0845	0.0063	2.6	0.2736	0.0390
	R2	0.0909	0.0104	4.0	0.2731	0.0467
	R3	0.1971	0.0255	7.4	0.2334	0.0384
	R4	0.0466	0.0184	5.6	0.1158	0.0478
	X̄	0.1048	0.0152	4.9	0.2240	0.0430

Appendix Table 4. Shoot and root measurements of Jubilee corn after growing 7 days in soil treated with various concentrations of clopropoxydim.

Clopropoxydim ppm dry soil		Shoot			Root	
		Fresh weight (g)	Dry weight (g)	Height (cm)	Fresh weight (g)	Dry weight (g)
0	R1	0.8392	0.0532	28.5	0.5183	0.0525
	R2	0.8014	0.0555	29.1	0.5590	0.6713
	R3	0.7907	0.0523	28.1	0.4875	0.0557
	R4	0.7837	0.0564	27.9	0.5269	0.0606
	R5	0.7325	0.0510	27.4	0.5050	0.0607
	R6	0.7546	0.0508	26.3	0.5649	0.0628
	$\bar{X}$	0.7838	0.0532	27.9	0.5269	0.0606
0.0625	R1	0.6324	0.0468	26.7	0.4411	0.0454
	R2	0.6049	0.0450	28.9	0.3795	0.0515
	R3	0.6224	0.0505	27.3	0.4192	0.0476
	R4	0.6399	0.462	27.5	0.3777	0.0391
	$\bar{X}$	0.6249	0.0471	27.6	0.4044	0.0459
0.125	R1	0.4228	0.0357	20.1	0.3222	0.0388
	R2	0.5352	0.0474	22.9	0.3288	0.0405
	R3	0.4477	0.0354	23.0	0.3208	0.0372
	R4	0.5393	0.0416	24.7	0.3667	0.0373
	$\bar{X}$	0.4863	0.0400	22.7	0.3346	0.0385
0.25	R1	0.3627	0.0331	17.4	0.2739	0.0316
	R2	0.4185	0.0337	19.4	0.3266	0.0308

Appendix Table 4. (continued).

Clopropoxydim ppm dry soil		Shoot			Root	
		Fresh weight (g)	Dry weight (g)	Height (cm)	Fresh weight (g)	Dry weight (g)
0.25	R3	0.3456	0.0292	19.0	0.2837	0.0327
	R4	0.5175	0.0409	23.0	0.3218	0.0368
	$\bar{X}$	0.4111	0.0342	19.7	0.3015	0.0330
0.5	R1	0.3651	0.0256	12.6	0.3120	0.0419
	R2	0.3548	0.0331	13.3	0.3262	0.0400
	R3	0.3754	0.0336	13.2	0.3301	0.4120
	R4	0.3710	0.0321	12.9	0.3211	0.0424
	$\bar{X}$	0.3666	0.0332	13.0	0.3224	0.0414
1.0	R1	0.1711	0.0169	5.8	0.2737	0.0411
	R2	0.2035	0.0235	6.3	0.2517	0.0432
	R3	0.2340	0.0287	7.0	0.2749	0.0433
	R4	0.3146	0.0316	8.7	0.2953	0.0407
	$\bar{X}$	0.2308	0.0252	7.0	0.2739	0.0421
2.0	R1	0.0839	0.0115	4.0	0.2005	0.0385
	R2	0.0549	0.0063	3.9	0.2126	0.0365
	R3	0.1440	0.0168	5.1	0.2158	0.0386
	R4	0.0926	0.0125	5.0	0.2275	0.0394
	$\bar{X}$	0.0939	0.0118	4.5	0.2141	0,0383

Appendix Table 5. Shoot and root measurements of Jubilee corn after growing 7 days in soil treated with various concentrations of haloxyfop-methyl.

Haloxyfop-methyl ppm dry soil		Shoot			Root	
		Fresh weight (g)	Dry weight (g)	Height (cm)	Fresh weight (g)	Dry weight (g)
0	R1	0.6767	0.0463	27.7	0.4796	0.0501
	R2	0.7128	0.0502	29.0	0.4755	0.0469
	R3	0.6051	0.0473	24.8	0.5008	0.0511
	R4	0.6960	0.0471	28.4	0.5012	0.0498
	R5	0.6447	0.0466	26.8	0.4780	0.0390
	R6	0.6565	0.0461	26.9	0.5058	0.0388
	$\bar{X}$	0.6653	0.0473	27.3	0.4902	0.0460
0.0625	R1	0.3155	0.0274	17.4	0.2522	0.0291
	R2	0.4702	0.0417	16.7	0.2935	0.0288
	R3	0.3891	0.0396	15.9	0.2870	0.0285
	R4	0.3980	0.0388	18.0	0.2730	0.0269
	$\bar{X}$	0.3932	0.0369	17.0	0.2764	0.0283
0.125	R1	0.3500	0.0338	16.0	0.2486	0.0250
	R2	0.3562	0.0300	18.1	0.2500	0.0248
	R3	0.3611	0.0363	16.9	0.2600	0.0264
	R4	0.3600	0.0400	15.8	0.2581	0.0261
	$\bar{X}$	0.3568	0.0350	16.7	0.2542	0.0256
0.25	R1	0.3484	0.0311	12.1	0.3331	0.0297
	R2	0.3502	0.0336	11.6	0.3398	0.0342

Appendix Table 5. (continued).

Haloxyfop-methyl ppm dry soil		Shoot			Root	
		Fresh weight (g)	Dry weight (g)	Height (cm)	Fresh weight (g)	Dry weight (g)
0.25	R3	0.3595	0.0386	11.9	0.3446	0.0341
	R4	0.3405	0.0368	12.5	0.3341	0.0335
	$\bar{X}$	0.3497	0.0350	12.0	0.3397	0.0329
0.5	R1	0.1352	0.0153	10.1	0.2425	0.0243
	R2	0.1953	0.0207	9.8	0.2562	0.0249
	R3	0.3164	0.0326	11.2	0.2496	0.0251
	R4	0.2636	0.0267	9.8	0.2463	0.0240
	$\bar{X}$	0.2276	0.0238	10.2	0.2487	0.0246
1.0	R1	0.1563	0.0159	9.5	0.1400	0.0137
	R2	0.1492	0.0152	9.2	0.1360	0.0129
	R3	0.1399	0.0142	7.8	0.1270	0.0129
	R4	0.1389	0.0137	9.8	0.1240	0.0123
	$\bar{X}$	0.1461	0.0148	9.1	0.1318	0.0130
2.0	R1	0.0196	0.0019	3.2	0.0099	0.0009
	R2	0.0185	0.0019	2.8	0.0141	0.0015
	R3	0.0096	0.0009	3.1	0.0066	0.0010
	R4	0.1061	0.0015	2.7	0.0911	0.0010
	$\bar{X}$	0.0384	0.0016	3.0	0.0304	0.0011

Appendix Table 6. Shoot height of Jubilee sweet corn after growing 7 days in soil sampled, at various D.A.T., from plots treated with 1.12 kg/ha of postemergence grass herbicides in summer, 1984.

		Shoot height (cm)^a						
		Days After Treatment						
Treatment		0	7	13	15	21	42	82
DPX-Y6202	R1	0	0	7.0	8.8	7.0	15.3	17.1
	R2	0	7.2	9.1	9.4	11.4	14.3	18.0
	R3	0	8.5	10.3	10.9	8.4	13.6	18.8
	R4	0	9.7	9.6	10.3	8.5	10.4	18.6
	$\bar{X}$	0	6.4	9.0	9.9	8.8	13.4	18.1
Fluazifop-butyl	R1	0	0	6.3	8.5	7.7	10.3	21.8
	R2	0	7.8	4.6	5.4	5.9	16.4	23.5
	R3	0	11.0	4.0	6.6	5.2	12.4	22.4
	R4	0	4.4	6.2	7.0	6.2	10.8	21.7
	$\bar{X}$	0	5.8	5.3	6.9	6.2	12.5	22.4
Sethoxydim	R1	0	11.7	9.3	11.6	21.2	27.8	25.7
	R2	0	5.6	14.4	16.3	21.7	25.0	24.6
	R3	0	6.2	15.3	19.2	21.5	27.7	24.9
	R4	0	12.1	10.6	17.3	24.0	28.7	27.5
	$\bar{X}$		8.9	12.4	16.1	22.1	27.3	25.7
Clopropoxydim	R1	0	11.1	15.8	17.4	20.1	26.3	27.6
	R2	0	7.1	13.6	18.4	20.0	27.5	24.2
	R3	0	7.6	15.4	19.8	22.8	26.6	24.6
	R4	0	8.0	17.7	21.2	17.9	27.6	28.8
	$\bar{X}$	0	8.5	15.6	19.2	20.2	27.0	26.3
Check	R1	21.4	23.2	23.5	25.0	23.5	26.4	25.5
	R2	21.3	17.9	23.2	25.6	18.9	25.3	26.3
	R3	23.4	22.8	22.4	26.8	21.9	28.0	23.6
	R4	23.7	23.3	23.6	26.1	22.4	26.0	27.6
	$\bar{X}$		21.8	23.2	25.9	21.7	26.4	25.8

Appendix Table 7. Shoot height of Jubilee sweet corn after growing 7 days in soil sampled, at various D.A.T., from plots treated with 1.12 kg/ha of postemergence grass herbicides in winter, 1984.

		Shoot height (cm)[a]						
		Days After Treatment						
Treatment		0	7	20	42	59	70	110
DPX-Y6202	R1	0	5.4	9.7	10.6	10.9	12.3	10.5
	R2	0	5.6	10.8	11.1	11.0	10.5	17.8
	R3	0	5.0	9.8	11.6	10.4	11.5	14.5
	R4	0	5.6	11.2	10.1	11.0	10.9	16.0
	$\bar{X}$	0	5.4	10.4	10.7	10.8	11.3	14.7
Fluazifop-butyl	R1	0	5.9	8.2	10.2	11.2	12.1	20.1
	R2	0	5.5	8.9	8.1	11.0	15.4	21.6
	R3	0	5.1	7.8	13.7	13.2	17.1	16.7
	R4	0	5.9	7.3	11.4	13.2	13.7	21.1
	$\bar{X}$	0	5.5	8.1	10.9	12.2	14.6	19.9
Sethoxydim	R1	0	8.0	17.7	20.6	17.6	21.3	26.0
	R2	0	5.8	15.1	18.6	18.1	21.3	25.5
	R3	0	3.8	13.0	18.3	19.2	19.9	27.3
	R4	0	5.0	17.4	12.8	19.4	22.2	25.7
	$\bar{X}$	0	5.7	15.8	17.6	18.6	21.2	26.1
Clopropoxydim	R1	0	6.2	9.6	17.5	18.1	19.4	24.0
	R2	0	6.1	8.8	11.1	14.9	10.4	23.3
	R3	0	6.2	7.7	11.8	17.9	18.6	23.7
	R4	0	5.1	7.7	17.6	15.1	15.5	26.4
	$\bar{X}$	0	5.9	8.5	14.5	16.5	16.0	24.4
Haloxyfop-methyl	R1	0	5.4	7.2	9.7	10.0	11.2	8.3
	R2	0	4.6	6.2	10.9	7.7	10.2	11.7
	R3	0	4.3	7.7	9.2	9.5	11.4	9.7
	R4	0	4.5	8.3	8.2	9.5	11.5	7.2
	$\bar{X}$	0	4.7	7.4	9.5	9.2	11.1	9.2

Appendix Table 7. (continued).

Treatment		Shoot height (cm)[a] Days After Treatment 0	7	20	42	59	70	110
Check	R1	17.7	20.0	21.7	20.2	17.9	21.2	24.7
	R2	16.2	17.8	20.9	22.7	21.5	20.3	26.4
	R3	17.3	20.4	22.0	20.6	19.4	19.8	26.0
	R4	16.6	19.2	21.7	20.6	18.0	20.5	24.4
	$\bar{X}$	17.0	19.4	21.6	21.0	19.2	20.5	25.4

Appendix Table 8. Visual evaluation of injury to Jubilee sweet corn from preemergence applications of 0.14, 0.28, 0.56, and 1.12 kg/ha DPX-Y6202.

		% Growth Reduction From Check				
		Days After Treatment				
Rate kg/ha		0	7	14	21	77
0.14	R1	70	70	50	20	0
	R2	80	40	0	40	0
	R3	80	50	40	0	0
	R4	90	90	30	10	0
	X̄	80 ± 4	62 ± 11	30 ± 11	17 ± 9	0
0.28	R1	100	100	20	0	0
	R2	70	90	80	20	0
	R3	100	50	80	20	0
	R4	90	80	60	0	0
	X̄	90 ± 7	80 ± 18	60 ± 17	10 ± 6	0
0.56	R1	100	90	30	60	0
	R2	100	100	40	40	0
	R3	100	80	70	40	0
	R4	100	100	60	50	0
	X̄	100 ± 0	93 ± 5	50 ± 9	47 ± 5	0
1.12	R1	100	100	60	0	0
	R2	100	80	100	20	0
	R3	100	100	70	20	0
	R4	100	60	90	30	0
	X̄	100 ± 0	85 ± 10	80 ± 9	17 ± 6	0

Appendix Table 9. Visual evaluation of injury to Jubilee sweet corn from preemergence applications of 0.14, 0.28, 0.56, and 1.12 kg/ha fluazifop-butyl.

		% Growth Reduction From Check				
		Days After Treatment				
Rate kg/ha		0	7	14	21	77
0.14	R1	80	60	10	30	0
	R2	80	40	70	20	0
	R3	100	70	30	10	0
	R4	100	90	20	0	0
	$\bar{X}$	90 ± 6	65 ± 10	33 ± 13	15 ± 6	0
0.28	R1	100	90	80	100	0
	R2	100	60	80	0	0
	R3	100	80	80	40	0
	R4	100	80	80	60	0
	$\bar{X}$	100 ± 0	78 ± 6	80 ± 13	50 ± 21	0
0.56	R1	100	100	0	80	0
	R2	100	100	20	80	0
	R3	100	90	30	70	0
	R4	100	100	30	30	0
	$\bar{X}$	100 ± 0	98 ± 3	20 ± 7	62 ± 14	0
1.12	R1	100	80	30	20	0
	R2	100	80	20	70	0
	R3	100	100	0	20	0
	R4	100	90	40	30	0
	$\bar{X}$	100 ± 0	88 ± 5	22 ± 9	35 ± 12	0

Appendix Table 10. Visual evaluation of injury to Jubilee sweet corn from preemergence application of 0.14, 0.28, 0.56, and 1.12 kg/ha sethoxydim.

		% Growth Reduction From Check				
		Days After Treatment				
Rate kg/ha		0	7	14	21	77
0.14	R1	10	10	10	0	0
	R2	30	10	10	30	0
	R3	30	10	10	30	0
	R4	10	30	10	40	0
	$\bar{X}$	20 ± 5	15 ± 5	10	25 ± 9	0
0.28	R1	60	30	20	0	0
	R2	70	60	60	40	0
	R3	100	20	0	30	0
	R4	90	20	0	30	0
	$\bar{X}$	80 ± 9	33 ± 9	20 ± 14	25 ± 15	0
0.56	R1	50	20	0	10	0
	R2	90	70	20	30	0
	R3	80	40	30	40	0
	R4	100	40	20	0	0
	$\bar{X}$	80 ± 11	43 ± 10	20 ± 7	20 ± 9	0
1.12	R1	90	70	30	30	0
	R2	100	60	20	10	0
	R3	100	70	0	20	0
	R4	70	60	40	30	0
	$\bar{X}$	90 ± 7	65 ± 3	22 ± 9	22 ± 5	0

Appendix Table 11. Visual evaluation of injury to Jubilee sweet corn from preemergence applications of 0.14, 0.28, 0.56, and 1.12 kg/ha clopropoxydim.

		% Growth Reduction From Check				
		Days After Treatment				
Rate kg/ha		0	7	14	21	77
0.14	R1	10	10	0	40	0
	R2	10	20	0	20	0
	R3	30	0	0	0	0
	R4	30	0	0	0	0
	$\bar{X}$	20 ± 6	8 ± 5	0	15 ± 9	0
0.28	R1	60	10	10	30	0
	R2	40	0	20	30	0
	R3	80	0	10	40	0
	R4	60	30	0	0	0
	$\bar{X}$	60 ± 8	10 ± 7	10 ± 4	25 ± 9	0
0.56	R1	90	30	0	20	0
	R2	60	0	0	20	0
	R3	70	20	0	0	0
	R4	60	30	20	0	0
	$\bar{X}$	70 ± 7	20 ± 7	5 ± 5	10 ± 6	0
1.12	R1	10	40	20	30	0
	R2	30	30	0	0	0
	R3	60	0	20	0	0
	R4	20	20	0	0	0
	$\bar{X}$	30 ± 11	23 ± 9	10 ± 6	8 ± 4	0

Appendix Table 12. Daily minimum and maximum surface temperature (^{o}C) for the period July, 1984 to March, 1985. Observations taken from Hyslop Research Farm for the 24-hour period ending at 8.00 a.m.

Date	July		August		September	
	Min	Max	Min	Max	Min	Max
1	8.89	24.44	14.44	31.11	12.22	25.56
2	11.67	29.44	13.33	27.22	7.22	28.89
3	12.22	27.78	10.00	30.00	4.44	36.11
4	13.33	30.56	6.67	27.78	7.78	32.78
5	11.11	31.67	9.44	30.56	8.89	32.22
6	7.78	28.33	6.67	29.44	7.22	25.56
7	8.33	25.56	7.78	29.44	11.67	21.11
8	8.33	27.78	11.67	33.89	15.56	25.56
9	6.11	29.44	11.67	37.22	13.89	26.67
10	9.44	27.78	10.56	36.11	8.89	25.00
11	6.67	28.89	8.33	33.33	8.89	24.44
12	12.22	25.00	10.56	27.78	6.67	23.89
13	9.44	26.11	5.56	27.22	7.78	25.00
14	10.56	28.33	6.11	28.33	12.22	28.33
15	12.78	31.11	6.67	30.56	8.33	30.00
16	13.33	34.44	10.00	32.78	8.33	30.00
17	11.67	36.11	9.44	31.11	7.78	31.11
18	7.78	33.89	7.78	32.22	9.44	33.33
19	7.22	31.11	9.44	30.56	14.44	32.78
20	10.56	29.44	7.22	28.89	12.22	18.89
21	8.33	29.44	6.67	32.22	7.22	23.89
22	13.33	27.78	7.78	32.22	7.78	23.33
23	11.11	34.44	11.11	29.44	1.67	20.56
24	13.89	31.11	8.33	28.33	1.11	21.67
25	14.44	36.67	8.89	30.00	3.33	22.78
26	7.78	22.78	10.00	32.22	2.78	25.56
27	8.33	30.56	7.78	36.11	7.22	26.11
28	10.56	29.44	12.22	28.89	10.00	26.67
29	9.44	28.33	8.89	28.33	3.33	28.33
30	11.11	30.56	8.33	32.22	8.33	28.33
31	11.67	35.00	14.44	27.22		

Appendix Table 12. (continued).

Date	October		November		December	
	Min	Max	Min	Max	Min	Max
1	5.00	19.44	2.78	13.89	0.00	11.11
2	6.11	24.44	4.44	11.67	0.00	5.00
3	5.56	25.00	7.22	15.00	0.56	7.22
4	8.33	23.33	4.44	16.11	-0.56	8.33
5	5.00	19.44	4.44	17.22	-1.11	7.78
6	6.11	19.44	6.11	11.67	-5.00	7.78
7	8.89	26.67	5.00	12.78	-3.89	8.89
8	9.44	31.67	1.67	15.00	-1.11	7.78
9	7.78	22.78	4.44	8.33	2.78	7.78
10	9.44	21.67	5.56	10.56	3.33	7.78
11	8.89	13.33	7.78	14.44	-1.67	10.00
12	6.67	17.22	8.89	11.67	1.11	7.22
13	8.89	16.67	7.78	15.00	1.11	10.56
14	5.56	17.78	0.00	10.56	1.11	10.56
15	1.67	13.33	2.78	11.67	-0.56	7.78
16	3.89	12.22	1.67	8.89	0.00	5.56
17	0.00	13.89	0.56	15.56	0.56	8.89
18	3.33	15.56	2.78	10.00	-4.44	6.11
19	6.11	9.44	3.89	13.33	-6.67	1.67
20	6.67	12.78	6.11	11.67	-8.89	1.11
21	1.67	10.00	0.56	12.78	-5.00	2.22
22	2.22	11.67	2.22	6.67	1.11	9.44
23	0.56	12.22	1.11	11.11	2.78	9.44
24	3.89	10.56	0.00	9.44	1.67	10.00
25	7.22	16.11	1.67	6.67	-1.11	10.56
26	6.67	17.78	-2.22	8.33	1.67	3.89
27	5.00	12.78	0.00	7.78	2.78	10.56
28	3.89	11.67	6.67	8.33	-0.56	9.44
29	1.67	15.00	2.78	11.11	1.11	9.44
30	1.67	15.56	3.89	7.22	3.33	6.11
31	1.67	12.22			0.56	10.56

Appendix Table 12. (continued).

Date	January		February		March	
	Min	Max	Min	Max	Min	Max
1	-2.22	4.44	-1.67	6.11	1.11	17.22
2	-2.22	5.00	0.56	9.44	-1.67	13.33
3	-5.00	7.22	-4.44	2.78	-1.67	13.33
4	-5.00	6.67	-8.33	4.44	1.67	8.89
5	-3.33	3.89	-6.67	3.89	2.22	10.00
6	-2.22	5.00	0.00	6.67	-1.67	11.67
7	-1.11	6.11	1.67	10.00	-2.22	14.44
8	-3.33	8.33	0.00	5.00	-2.22	13.33
9	-3.89	7.22	0.00	6.67	-2.78	15.00
10	-3.89	9.44	0.00	7.78	-0.56	17.78
11	-3.89	1.67	2.22	9.44	-3.33	18.89
12	-3.33	6.11	0.00	10.00	-0.56	17.78
13	-5.56	7.78	-2.22	11.67	-0.56	15.00
14	-5.00	6.11	-1.11	12.22	-2.22	16.11
15	0.00	11.67	0.00	12.22	0.56	17.22
16	0.56	6.67	0.00	15.56	-1.11	17.78
17	-0.56	12.22	-0.56	11.67	0.00	16.67
18	-0.56	5.00	-3.89	12.78	1.11	17.22
19	-0.56	10.56	-1.11	13.33	1.11	18.33
20	2.22	5.56	1.11	8.33	6.11	15.56
21	1.67	12.78	2.22	11.11	2.22	15.56
22	-2.78	13.33	5.00	11.67	1.67	11.11
23	-3.89	12.22	1.67	16.67	3.89	10.00
24	-3.89	11.11	3.89	18.89	1.67	10.00
25	-2.22	10.00	-2.78	16.67	1.67	12.22
26	-5.00	9.44	0.56	13.89	0.56	12.22
27	-5.56	9.44	0.00	13.33	0.00	8.33
28	-3.33	1.67	-0.56	16.67	1.11	10.56
29	-4.44	8.89			-1.67	14.44
30	-5.00	8.33			2.22	10.00
31	-1.67	2.78			7.78	12.78

Appendix Table 13. Daily precipitation (mm) and monthly totals for the period July, 1984 to March, 1985. Observations taken from Hyslop Research Farm for the 24-hour period ending at 8.00 a.m.

Date	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
1	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.51	0.00
2	0.00	0.00	0.00	0.00	68.07	0.00	0.00	4.06	1.27
3	0.00	0.00	0.00	0.00	23.37	78.49	0.00	1.52	0.00
4	0.00	0.00	0.00	4.57	10.16	0.00	0.00	0.00	5.33
5	0.00	0.00	0.00	3.81	0.00	0.00	0.00	0.00	0.51
6	0.00	0.00	13.97	0.25	4.57	0.00	0.00	0.25	5.59
7	0.00	0.00	0.51	0.00	5.33	0.00	0.00	6.10	0.00
8	0.00	0.00	0.00	0.25	1.27	0.00	0.76	30.48	0.00
9	0.00	0.00	0.00	5.84	17.02	5.59	0.00	13.21	0.00
10	0.00	0.00	0.00	12.70	30.99	20.32	0.00	14.73	0.00
11	0.00	0.00	0.00	12.95	6.86	0.25	0.00	5.33	0.00
12	0.00	0.00	0.25	4.83	25.15	10.16	0.00	5.59	0.00
13	0.00	0.00	0.00	5.59	8.89	2.54	0.00	0.00	0.00
14	0.00	0.00	0.00	3.05	0.76	0.00	0.25	0.00	0.00
15	0.00	0.00	0.00	5.08	0.00	1.27	0.00	2.54	0.00
16	0.00	0.00	0.00	0.00	0.00	1.02	0.00	0.00	0.00
17	0.00	0.00	0.00	0.25	0.00	0.25	0.00	0.00	0.00
18	0.00	0.00	0.00	8.38	19.30	1.78	0.25	0.00	0.00
19	0.00	0.00	0.25	16.26	1.27	0.00	0.00	1.02	0.00
20	0.00	0.00	3.05	9.91	20.83	0.00	0.76	7.11	2.29
21	0.00	0.00	0.00	0.51	2.29	3.81	0.00	0.00	8.64
22	0.00	0.00	0.51	0.00	0.00	0.51	0.00	0.25	10.92
23	0.00	0.00	0.25	0.00	0.25	3.05	0.00	0.00	21.59
24	0.00	0.00	0.00	1.52	11.43	0.00	0.00	0.00	17.78

Appendix Table 13. (continued)

Date	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
25	5.08	0.00	0.00	0.25	16.67	0.25	0.00	0.00	6.60
26	0.00	0.00	0.00	6.35	3.81	3.30	0.00	0.00	15.24
27	0.00	0.00	0.00	8.89	19.56	8.64	0.00	0.00	17.53
28	0.00	0.00	0.00	5.84	27.43	9.65	1.02	0.00	2.03
29	0.00	0.00	0.00	0.51	5.08	3.05	1.52	0.00	0.25
30	0.00	0.00	0.00	0.00	13.72	21.34	0.00		2.29
31	0.00	0.00		0.51		2.54	1.78		7.62
Total	5.08	0.00	18.80	118.11	344.17	178.05	6.35	92.71	125.48

Appendix Table 14. Daily solar radiation (KJ/m^2) and monthly totals for the period July, 1984 to March, 1985. Observations taken from Hyslop Research Farm for the 24-hour period ending at 8.00 a.m.

Date	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
1	31642	25113	10296	9292	8664	M	5148	5818	11552
2	32396	15068	19211	15068	1507	M	5525	4018	7911
3	32145	23104	24108	13352	3767	3893	5441	2595	14817
4	31642	22476	22351	13435	11050	M	5776	9794	5399
5	31266	27624	19128	9417	10045	M	4520	9083	8538
6	26494	20090	6529	9543	4520	M	4771	4604	8790
7	33526	26620	9124	11803	3767	M	4060	4520	12180
8	32145	25992	11678	15068	5776	M	5399	1381	12598
9	30889	25113	10171	5399	1256	M	5399	3893	12933
10	31015	25113	11050	8790	2260	M	5734	3893	14817
11	28754	25239	14566	2386	3014	M	3558	6529	16072
12	19211	23355	15319	9794	1088	3516	5902	3516	16072
13	31140	17328	20969	3139	4646	2009	6362	9543	13310
14	31266	26118	21597	9417	3893	3767	6195	8413	16198
15	30889	24736	12389	6153	6153	4395	4604	3893	16575
16	31140	24360	20090	8413	3014	M	2888	9041	17454
17	30136	24485	19839	8580	7157	3767	6739	9669	17202
18	28754	21597	18960	7534	2009	1256	3516	12305	17830
19	27624	25615	17202	2762	5902	4771	6069	11301	17328
20	30261	26620	4520	3390	4646	4771	2511	3893	12808
21	29131	26494	8790	2888	3893	1549	7073	5525	10882
22	31140	23606	11552	4269	2009	3014	7492	3390	10924
23	30010	19086	10547	7534	5776	2511	6781	8413	7408
24	20969	16072	16072	4771	251	3265	6781	13435	4269

Appendix Table 14. (continued).

Date	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
25	25741	22476	17830	6655	2260	4395	8622	6906	14649
26	9543	24485	11301	4646	M	753	7785	12054	11929
27	27875	22853	16449	6655	3390	3641	8287	M	6529
28	27875	17705	18081	5525	879	2511	1883	13687	10045
29	29131	24485	18485	7911	3767	5525	6163		11301
30	29508	19463	16951	8287	1381	921	4897		9669
31	28127	17454		5776		2762	1590		7994
Mean		22895	15152	7659	4060	3139	5399	7073	12138

Appendix Table 15. Daily minimum and maximum soil temperature (^{o}C) at 10 cm for the period July, 1984 to March, 1985. Observations taken from Hyslop Research Farm for the 24-hour period ending at 8.00 a.m.

Date	July		August		September	
	Min	Max	Min	Max	Min	Max
1	14.44	22.22	21.11	28.89	20.00	22.78
2	15.00	25.00	21.67	26.11	18.33	25.00
3	16.67	26.11	20.56	27.22	17.78	25.56
4	18.33	27.22	19.44	26.11	17.78	26.11
5	19.44	28.89	18.89	27.78	18.89	26.11
6	18.89	27.78	18.89	25.00	15.00	20.56
7	17.78	26.11	18.33	27.22	14.44	17.78
8	18.33	26.67	18.89	27.78	16.67	20.00
9	17.78	27.22	21.11	30.00	18.89	21.67
10	17.78	27.78	21.67	30.56	15.56	20.00
11	18.33	27.78	22.22	31.11	14.44	20.56
12	18.33	23.89	21.67	27.78	15.00	19.44
13	17.78	26.67	18.89	24.44	13.89	21.67
14	18.89	28.33	18.33	27.22	15.00	22.22
15	20.00	28.89	20.00	28.89	16.67	22.22
16	20.56	30.00	20.00	28.89	16.11	23.89
17	21.67	30.56	21.11	28.33	16.67	24.44
18	21.67	30.56	21.11	27.78	17.22	25.56
19	20.56	28.89	20.56	28.33	17.78	24.44
20	19.44	28.33	20.00	26.67	18.33	20.00
21	20.00	28.89	19.44	27.78	15.00	18.89
22	19.44	26.67	19.44	27.78	13.89	18.89
23		28.89	20.00	26.11	12.78	17.78
24	20.56	26.67	20.00	25.00	11.67	18.33
25	21.11	31.11	19.44	26.67	11.11	18.89
26	17.78	22.22	19.44	27.22	12.22	18.89
27	16.67	26.67	20.56	28.33	12.22	20.56
28	18.33	26.11	20.56	25.00	13.89	20.56
29	18.33	27.22	20.00	26.67	14.44	20.56
30	18.33	27.22	19.44	27.22	14.44	21.11
31	20.00	30.00	19.44	24.44		

Appendix Table 15. (continued).

Date	October		November		December	
	Min	Max	Min	Max	Min	Max
1	14.44	17.78	6.67	9.44	5.56	7.78
2.	13.89	20.00	6.67	9.44	5.00	6.11
3	13.89	19.44	8.89	10.56	3.89	5.00
4	13.89	18.89	8.89	11.11	3.89	5.56
5	12.78	16.67	8.33	11.67	2.78	4.44
6	11.67	15.00	8.33	10.00	2.22	2.78
7	13.89	18.33	8.33	10.00	2.22	2.22
8	14.44	20.56	8.33	10.56	2.22	2.78
9	13.89	16.67	7.22	8.33	2.22	4.44
10	12.78	15.56	7.22	8.33	4.44	5.00
11	12.78	14.44	8.33	9.44	5.00	6.11
12	11.67	14.44	9.44	10.00	3.33	5.00
13	11.11	12.78	10.00	10.56	4.44	5.56
14	10.56	13.89	6.67	10.00	3.89	6.11
15	8.89	11.67	5.56	8.33	4.44	5.00
16	8.33	11.11	6.11	7.78	3.89	4.44
17	8.33	11.11	5.56	9.44	3.89	4.44
18	7.78	10.00	6.11	7.78	3.33	4.44
19	8.33	9.44	7.78	9.44	2.22	3.33
20	8.89	11.11	7.78	8.33	1.11	2.22
21	8.33	10.00	6.67	8.89	1.11	1.11
22	8.33	10.00	5.56	6.67	1.11	1.11
23	7.78	10.00	6.67	8.33	1.11	3.33
24	7.22	9.44	5.56	6.67	3.33	5.00
25	9.44	11.67	4.44	5.56	4.44	5.56
26	10.56	12.22	3.89	5.56	3.89	4.44
27	9.44	11.11	3.33	5.00	3.33	5.00
28	8.89	10.00	5.00	6.67	3.33	5.00
29	8.33	10.56	6.11	7.78	2.78	4.44
30	7.78	10.00	5.56	6.67	4.44	4.44
31	6.67	8.89			3.89	5.56

Appendix Table 15. (continued).

Date	January		February		March	
	Min	Max	Min	Max	Min	Max
1	3.33	5.00	2.78	3.89	3.89	9.44
2	2.22	2.22	1.67	2.78	5.00	8.89
3	1.67	2.22	2.22	3.33	3.89	8.33
4	1.67	2.22	1.67	2.78	5.00	6.11
5	1.67	2.22	1.11	1.67	5.00	6.67
6	1.11	1.67	1.11	1.67	3.89	6.67
7	1.11	2.22	1.11	3.89	2.22	8.89
8	1.11	3.33	2.22	3.89	3.33	8.89
9	1.67	2.78	1.11	2.78	3.33	8.89
10	1.11	2.78	1.67	2.22	3.89	10.00
11	1.11	1.67	2.22	3.89	5.00	11.11
12	1.11	1.67	3.89	6.11	3.89	11.11
13	1.11	1.67	3.89	7.22	6.11	10.56
14	1.11	1.67	2.78	6.11	5.00	10.00
15	1.67	3.89	2.78	5.56	3.89	11.11
16	3.33	3.89	4.44	8.33	5.56	11.11
17	3.33	5.56	3.33	6.11	6.11	11.11
18	3.33	5.00	2.78	6.67	6.67	11.67
19	3.33	5.00	2.78	6.11	5.56	12.22
20	3.33	3.89	3.89	5.00	7.78	11.11
21	3.89	6.67	3.33	6.11	7.78	11.11
22	3.33	6.11	5.56	7.22	6.67	8.89
23	2.78	5.56	6.11	10.00	6.11	7.78
24	2.78	4.44	7.22	11.67	6.11	8.33
25	1.67	3.89	5.56	10.00	5.56	10.00
26	2.22	3.33	3.89	8.89	5.56	9.44
27	1.67	2.78	5.00	8.89	4.44	5.56
28	1.11	1.67	2.78	9.44	3.89	7.22
29	1.11	2.22			5.56	10.56
30	2.22	4.44			6.67	7.78
31	2.78	2.78			6.67	9.44

Appendix Table 16. Daily evaporation (mm) and monthly totals for the period July, 1984 to March, 1985. Observations taken from Hyslop Research Farm for the 24-hour period ending at 8.00 a.m.

Date	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
1	5.33	6.10	3.05	1.27	0.00	0.00	0.00	0.00	0.00
2	7.11	4.57	5.33	3.56	0.00	0.00	0.00	0.00	0.00
3	6.35	5.84	6.10	2.79	0.00	0.00	0.00	0.00	0.00
4	7.37	5.33	5.84	2.79	0.00	0.00	0.00	0.00	0.00
5	7.62	6.35	4.32	1.52	0.00	0.00	0.00	0.00	0.00
6	6.86	5.08	1.78	0.76	0.00	0.00	0.00	0.00	0.00
7	7.37	5.84	1.02	1.78	0.00	0.00	0.00	0.00	0.00
8	6.86	8.38	2.03	3.05	0.00	0.00	0.00	0.00	0.00
9	5.84	6.86	3.05	1.02	0.00	0.00	0.00	0.00	0.00
10	7.11	7.87	3.56	3.05	0.00	0.00	0.00	0.00	0.00
11	6.60	6.86	3.81	0.76	0.00	0.00	0.00	0.00	0.00
12	4.06	5.59	2.54	1.27	0.00	0.00	0.00	0.00	0.00
13	6.86	4.57	5.33	0.51	0.00	0.00	0.00	0.00	0.00
14	7.11	6.60	7.87	1.27	0.00	0.00	0.00	0.00	0.00
15	7.37	6.10	4.06	0.76	0.00	0.00	0.00	0.00	0.00
16	7.87	6.10	4.32	0.76	0.00	0.00	0.00	0.00	0.00
17	9.91	6.35	4.57	1.27	0.00	0.00	0.00	0.00	0.00
18	9.40	6.10	4.83	1.27	0.00	0.00	0.00	0.00	0.00
19	7.37	6.35	6.10	0.25	0.00	0.00	0.00	0.00	0.00
20	7.87	7.62	0.00	0.25	0.00	0.00	0.00	0.00	0.00
21	6.86	7.11	2.79	0.25	0.00	0.00	0.00	0.00	0.00
22	8.71	6.60	2.54	0.51	0.00	0.00	0.00	0.00	2.03
23	9.91	5.08	2.29	0.76	0.00	0.00	0.00	0.00	3.30
24	4.32	4.32	3.05	0.00	0.00	0.00	0.00	0.00	3.56

Appendix Table 16. (continued).

Date	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
25	7.62	4.57	3.30	0.51	0.00	0.00	0.00	0.00	1.52
26	2.29	7.87	2.54	0.25	0.00	0.00	0.00	0.00	1.27
27	6.35	7.37	4.06	0.76	0.00	0.00	0.00	0.00	3.05
28	5.84	5.84	7.37	0.76	0.00	0.00	0.00	0.00	0.51
29	6.10	6.86	6.60	0.76	0.00	0.00	0.00	0.00	1.52
30	6.60	5.84	3.81	1.02	0.00	0.00	0.00		1.02
31	7.37	4.83		0.51		0.00	0.00		0.51
Total	214.20	190.75	117.86	36.07	0.00	0.00	0.00	0.00	18.29

Appendix Table 17. Daily percent minimum humidity for the period July, 1984 to March, 1985. Observations taken from Hyslop Research Farm for the 24-hour period ending at 8.00 a.m.

Date	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
1	30	43	60	56	45	64	81	66	56
2	39	50	45	48	55	81	64	61	45
3	37	47	30	46	65	61	59	62	37
4	32	43	34	51	50	57	55	48	65
5	31	45	34	71	53	60	62	45	67
6	42	47	51	70	70	54	64	74	54
7	31	34	58	46	70	56	60	62	44
8	29	31	62	34	60	74	62	87	50
9	28	36	60	62	78	80	74	74	46
10	34	33	50	51	81	78	61	58	40
11	28	40	48	62	77	71	94	54	36
12	50	51	47	63	75	66	59	77	48
13	44	45	36	68	68	67	56	56	50
14	35	38	36	51	68	70	60	60	46
15	41	37	28	66	74	67	78	69	47
16	M	35	30	69	66	79	90	53	46
17	19	43	40	64	57	69	62	52	54
18	26	47	32	62	83	60	92	59	50
19	37	37	34	86	63	47	74	49	52
20	25	32	83	83	72	57	88	69	40
21	41	29	47	83	70	85	62	61	79
22	40	23	48	76	85	81	59	72	79
23	31	49	48	78	62	80	52	56	79
24	49	45	48	81	65	74	56	48	77
25	36	41	32	83	87	73	56	57	58
26	63	31	39	69	75	89	55	51	56
27	39	34	42	67	M	62	53	55	36
28	45	48	34	77	81	75	80	48	62
29	42	35	30	57	78	67	66		52
30	46	43	30	52	76	78	62		57
31	37	58		65		80	88		78