Characterization of Runoff and Infiltration from No-till Soybeans with Selected Winter Cover Crops

Dr. Clark J. Gantzer
University of Missouri - Columbia

Grant Number: 14-08-0001-G 1235-03
U.S. Geological Survey
U.S. Department of the Interior

Missouri Water Resources Research Center
University of Missouri
Sinclair Road - Route 3
Columbia, Missouri
65203

The research on which this report is based was financed in part by the Department of the Interior, U.S. Geological Survey, through the Missouri Water Resources Research Center.

SYNOPSIS

Project: 03 Start: 5-1-86

End: 4-30-87

Title: Characterization of Runoff and Infiltration from No-Till Soybeans with Selected Winter Cover Crops.

Investigators: C.J. Gantzer
S.H. Anderson
E.E. Alberts
P.R. Beuselinck

COWRR: 02-J Congressional District: Ninth

Keywords: runoff, soil erosion, nonpoint pollution, no-tillage, living mulch, cover crop.

SUMMARY OF RESEARCH PROJECT:

Problems and research objectives:

Different crops and cropping management systems have variable effects on soil erosion. Conventional soybean (Glycine max (L) Merr.) monoculture often is subject to excessive erosion. No-tillage soybean cropping greatly reduces soil erosion relative to conventional methods. However, rates of erosion are still two times higher than for similar culture of corn (Zea mays L.) because of the different quantity and quality of plant material produced. Missouri currently has the second highest rate of soil erosion in the United States owing in parts to cropping of soybeans on erodible soils. Development of a living cover crop to be used in association with no-tilled soybeans would produce greater amounts of plant material, thus significantly reducing the amount of soil erosion. However, there is no practical system of management available for a no-till soybean and winter cover crop system. The objectives of this study were to evaluate the effects of winter cover crops on runoff, soil loss, dissolved nutrient losses, and plant growth under field conditions and to begin to develop a practical operating system for the management of no-till soybeans with winter cover crops.

Methodology:

Research was conducted on a Mexico claypan soil at the Midwest McCredie Claypan Research Station (near Kingdom City, Mo). Four treatments with two replicates of each were used in this study. Treatments consisted of 1) no-till soybeans with canada bluegrass (Poa compressa L.), 2) no-till soybeans with chickweed (Stellaria media L.), 3) no-till soybeans with downy brome (Bromus tectorum L.) and 4) no-till soybeans without a cover crop was included as a check. Natural rainfall runoff plots, 3.2 m in width by 27.4 m in length, were fitted with tanks for collection of runoff and sediment. Before planting soybeans in May, the growth of the physiologically mature winter crops were suppressed by herbicides. After physiological maturity, the living mulches were allowed to reseed themselves for growth next year. Soybeans were managed using no-tillage methods. Mature soybeans were harvested with a combine and yield data was measured. The residues were spread by hand after harvesting to provide a uniform residue cover on the soil surface. Throughout the growing season, soil water content changes were observed using the neutron probe. Eight six inch increments within the soil profile were measured for all treatments at two positions (in the row and interrow). Soil water potential was measured using gypsum blocks and tensiometers. Rain water was collected and total runoff, soil loss, and dissolved nutrients were determined using regular laboratory methods. Crop height and growth stage were observed weekly.

Principal findings and significance:

General review of results indicate that soil erosion from no-till soybeans can be effectively controlled by using winter cover crops. The amount of runoff was reduced 2 to 4 times and soil loss was almost completely controlled. Competition of available soil water, and plant nutrients existed between soybeans and winter cover crops. In the first two months of soybean growth, water content in the control plots was higher than any of the other treatments. The living mulch is the main consumer of soil water at this early growth stage of soybeans. The competition of soil water between soybean and cover crops is most severe at those stages. Two months later, soybeans enter a rapid growth stage and soybean roots penetrate deeper into the profile. Available water content drops rapidly and water content in the control treatment begins to be lower than the water content in the living mulch treatments. Soybean growth is influenced by this competition as evidenced by the later development stage and lower soybean yields found in the living mulch treatment plots than the control plots. Studies are needed on the timely management of these cropping systems to minimize yield reduction while reducing the potential of soil erosion.

Publications and professional presentations:

Zhu, J.C., C.J. Gantzer, S.H. Anderson, and E.E. Alberts. 1987. Influence of Winter Cover Crops on Soil Loss and Plant Growth in No-till Soybeans. Agron. Abst. p.249. Am. Soc. of Agron. Madison, WI 53711.

M. S. theses:

Zhu, J.C. 1987. Effects of living mulch winter cover crops on soil erosion and plant growth in no-till soybeans. In Review.

Ph.D. dissertations: None

Characterization of Runoff and Infiltration from No-till Soybeans with Selected Winter Cover Crops 1/

J.C. Zhu, C.J. Gantzer, S.H. Anderson, E.E. Alberts, and P.R. Beuselinck. 2/

1/ This work was financed in part by the Department of the Interior, U.S. Geological Survey, through the Missouri Water Resources Research Center.

2/ Graduate Research Assistant; Assistant Professors of Agronomy, Univ. of Missouri; Adjunct Assistant Professor of Agronomy, Soil Scientist, USDA-ARS Watershed Research Unit; and Assistant Professor of Agronomy, Geneticist, USDA-ARS Crop Production Unit. Columbia, MO 65211

Additional Index Words: runoff, soil erosion, nonpoint pollution, no-tillage, living mulch, cover crop.

ABSTRACT

The influence of "living mulch" winter cover crops on soil loss, runoff amount and quality and soybean growth was studied at the Midwest Claypan Experimental runoff plots located on Mexico silt loam (Udollic Ochraqualf). Experimental treatments consisted of no-till soybeans with: 1) canada bluegrass (Poa compressa L.), 2) chickweed (Stellaria media L.), 3) downy brome (Bromus tectorum L.), and 4) no cover crop (CK). Runoff, sediment, dissolved nutrients, soil water content, and plant growth characteristics were measured. For chickweed (CW), canada bluegrass (CB) and downy brome (DB) treatments, runoff was reduced 66, 56, and 80% ($P < 0.01$), and soil loss was decreased 61, 97, and 95% ($P < 0.01$), respectively, vs. the CK treatment. Concentrations of dissolved NH_4^+-N and PO_4^{-3}-P in runoff water from cover crop plots were 2 to 2.8 times higher than the CK ($P < 0.05$). Runoff from the CK had a higher concentration of dissolved NO_3^--N. Total amounts of dissolved NO_3^--N losses were significantly decreased by 71, 73, and 76% ($P < 0.01$) and NH_4^+-N losses reduced by 40, 36, and 46% ($P < 0.10$) for treatments of CW, CB, and DB vs. the CK, respectively. PO_4^{-3}-P losses also were decreased by 50, 21, and 39% for CW, CB, and DB vs. CK, but differences were not significant ($P > 0.10$). Lower plant populations and delayed plant development decreased soybean yield in cover crop treatments from 18 to 62% ($P < 0.01$) vs. the CK.

INTRODUCTION

Soil erosion from cropland affects environmental quality of surface waters. Soil and water runoff from cropland may carry along fertilizer residues, insecticides, herbicides, fungicides, and dissolved minerals into lakes and rivers, damaging water quality (SCS, USDA, 1980). Sedimentation from excessive cropland erosion is also responsible for reduced water storage capacities of reservoirs and increased maintenance of navigation corridors in waterways. Clark et al. (1985) estimated that cropland erosion related pollutants were responsible for damage to in-stream and off-stream resources of about $2.2 billion per year (in 1980 dollars) in the United States.

Recent studies show that different crops and crop management systems have variable effects on soil erosion (Alberts et al., 1985; Gantzer et al., 1984; and Laflen et al., 1979). Conventional soybean monoculture is often subject to excessive erosion (Elkins et al., 1983). No-tillage soybean cropping greatly reduces soil erosion relative to conventional methods; however, rates are still two times higher than for similar culture of corn (Alberts et al., 1985). A study on the effect of corn and soybean rotations on soil and water losses by Laflen and Moldenhauer (1979) indicates that soil losses were 40% greater following soybeans vs. corn. One reason for the difference in soil loss between these treatments can be explained by the reduced quantity and quality of post-harvest residues produced by soybeans vs. corn (Buyanovsky and Wagner, 1986). Lower amounts of plant materials produced by soybeans reduce the protective soil cover, making soybean fields more susceptible to raindrop splash and reducing soil stability (Alberts et al., 1983; Gantzer et al., 1984; Gantzer 1985 and Gantzer et al., 1987).

The 1982 NRI revealed that the average soil loss on cultivated cropland in Missouri was 27.17 Mg/ha. This is more than two times the tolerable soil loss for the average Missouri soil (SCS, USDA, 1985). Greater amounts of soil loss are partly related to an increase in the amount of land under soybean cultivation in this area.

About 60 to 70% of the total soil and water runoff is concentrated from February to May or 70 to 80% from December to May due to Missouri rainfall patterns (Scrivner et al., 1972). Generally, no crop canopy is available to protect the soil at this period, and thus soil erosion during this time can be very serious. It would be beneficial to find a winter cover crop to be used as a living mulch in association with no-tillage soybeans so as to reduce soil erosion (Hall et al., 1984).

Winter legumes rather than grasses have been used as living mulches for corn, since legumes supply nitrogen. Meyer et al., (1970) found that as little as one Mg/ha of residue had been shown to greatly reduce erosion potential. Even cover crop residues plowed under provided soil conditions less favorable for runoff and sediment transport than no cover crop plowed under (Beale et al., 1955).

Currently winter annual cover crops are beginning to be used in no-till soybeans (Elkins et al., 1983). However, problems such as difficult timing constraints for planting of winter cover crops, competition for light, water, and nutrients by the winter cover crops, and timing of herbicide application, herbicide type, and method of herbicide application have not yet allowed development of a practical system of management for a no-till soybean and living mulch winter cover crop system. The objectives of this research are: 1) to study the effects of winter cover crops on runoff and soil loss; 2) to estimate the dissolved nutrient losses in runoff water; and 3) to investigate the influence of living mulch on plant growth and develop a manageable system which has potential for reducing soil erosion from no-till soybean cropping.

MATERIALS AND METHODS

The research was performed on a Mexico silt loam claypan soil (fine, montmorillinitic, mesic, Udollic Ochraqualf) at the Midwest Claypan Experiment Station (near Kingdom City, Mo). Four treatments with two replicates each were used. Treatments consisted of no-till soybeans with living mulch winter cover crops of: 1) canada bluegrass (Poa compressa L.); 2) chickweed (Stellaria media L.); 3) downy brome, (Bromus tectorum L.); and 4) no-till soybeans without a cover crop was included as a check. Abbreviations used in this manuscript are CB, CW, DB, and CK for the treatments 1 to 4, respectively. Natural rainfall runoff plots were 3.2 m in width by 27.4 m in length and on a 3% slope. These plots were fitted with two volumetrically calibrated, covered tanks for collection of runoff and sediment.

Soybeans were planted in 0.76 m rows in early May. Fertilizer 6-24-24 was applied at the rate of 246 kg/ha (5.9 kg N, 10.4 kg P, 20 kg K) at the time of planting. Two border rows were planted adjacent to the plot borders. Paraquat (1,1'-dimethyl-4,4'-bipyridinium ion) was applied at the rate of 2.34 L/ha and X-77 surfactant spreader at the rate of 1.17 L/ha with 2.8 kg/ha alachlor (2-chloro-N-(2,6-diethyphenyl)-N-(methoxymethyl)acetamide), 0.56 kg/ha metribuzin (4-amino-6-(1,1-dimethyllethyl)-3- (methylthio)-1,2,4- triazin-5(4H)-one). Herbicide application and soybean planting were both done on the same day. Downy brome was shredded using a rotary mower. The residue of the downy brome and canada bluegrass plants were removed with a power "weed whip" when soybean plants started to emerge. Soybeans were managed using a no-tillage method. Mature soybeans were harvested with a combine and yield data were recorded. Remaining residues were hand spread uniformly over the plots.

Soil water content was measured using a neutron probe to determine water content changes and water use depletion (Gardner 1986). Eight 0.15 m increment soil profile depths were measured for all treatments at two positions, one in the row and one between soybean rows. Soil water potential was measured using tensiometers and gypsum blocks at two positions and depths of 0.15, 0.30, and 0.45 m (Campbell and Gee, 1986; Cassel and Klute, 1986). The gypsum blocks were calibrated with pressure plates before they were buried into the soil.

To quantitatively rank the living mulch winter cover crops for their ability to reduce soil erosion, the growth characteristics of the cover crops and soybeans, such as height and development stage were measured (Hanway et al., 1971). Throughout the paper "V" means the vegetative growth and "R" means the reproductive growth. Ground cover by living mulch, soybeans, and residues were measured using the meter stick method (Hartwig and Laflen, 1978). The runoff water was collected in the tank and the amounts of runoff and soil loss were determined immediately after each natural rainfall event. The dissolved NO_3^--N, NH_4^+-N, and PO_4^{-3}-P in runoff water were determined by direct collection of samples in the runoff water. All measurements were taken on weekly basis during growing season.

RESULTS

Plant Vegetative and Residue Cover

Results of plant vegetative and residue cover measurements for different treatments are presented in Fig. 1. Vegetative and residue cover for all cover crop treatments was significantly increased ($P < 0.001$) as compared to the CK plots. The weighted average annual surface coverage were 71, 92, 99, and 99% for CK, CW, CB, and DB, respectively. Although average annual vegetative and residue cover in CW was significantly less than CB and DB ($P < 0.01$), it still provided more ground cover than the CK. No difference was found between CB and DB.

Runoff and Soil Loss

Significant reductions were found in runoff and soil loss between the control and cover crop treatments in 1985 and 1986 (Fig. 2 and Fig. 3). Runoff was decreased in cover crop treatment plots from 30 to 36% in 1985 as compared to the CK ($P < 0.05$). The effects of living mulch winter cover crops on runoff become greater in the following year. In 1986, runoff was reduced 66, 56, and 80% for treatments of CW, CB, and DB, respectively vs. CK ($P < 0.01$). Downy brome had the largest effect on reducing the amount of runoff. Living mulch winter cover crops also played a great role in decreasing soil loss. The results of 1985 showed that soil losses from treatments of CW, CB, and DB were 17, 7, and 9% of that from CK ($P < 0.001$). Soil loss from CW was only 8% of that from the CK and completely controlled in the treatments of CB and DB in 1986.

Higher runoff amounts usually result in greater soil erosion. The study indicated that average annual soil loss correlated very well ($r = 0.96$) with mean annual runoff for the same periods. The following linear relationship was found between average annual runoff and soil loss:

$$A = - 1330 + 16.6 R$$

$$r^2 = 0.93$$

where

A -- Predicted average annual soil loss, kg/ha;

R -- Average annual runoff, mm.

Results of analysis indicated that runoff and soil loss were significantly correlated with the weighted average annual vegetative and residue cover ($r = 0.96$, 0.99, respectively; Figs. 4 and 5).

Dissolved Nutrient Loss

The dissolved nutrient concentrations and total amounts of nutrient loss by runoff water for the two-year average of 1985 and 1986 were shown in Figs. 6 and 7., respectively. The concentrations of dissolved NH_4^+-N and PO_4^{-3}-P were higher than those from the CK while runoff from the CK treatment had a higher concentration of NO_3^--N than winter cover crop treatments. Concentrations of PO_4^{-3} were 1.67, 1.92, and 2.26 times that of control plots ($P < 0.01$) for cover crop treatments of CW, DB, and CB, respectively. Although the differences were not significant, NH_4^+-N concentration was increased by 39, 65, and 113% with CW, CB, and DB ($P > 0.10$), respectively. The NO_3^--N concentration, however, was reduced 61, 48, and 37% by CW, CB, and DB vs. CK ($P < 0.05$). No significant differences were found among cover crop treatments.

The total loss of NO_3^--N per unit area was discovered to be closely associated with its concentration in runoff water ($r = 0.95$) for the average two-year data, but was not correlated well for NH_4^+-N and PO_4^{-3}-P ($r = 0.54$, and 0.47). Total amount of NO_3^- losses were significantly decreased by 71, 73, and 76% ($P < 0.01$) and NH_4^+-N losses were reduced by 40, 36, and 46% for treatments of CW, CB, and DB vs. the CK ($P < 0.10$), respectively. PO_4^{-3}-P losses were decreased by 50, 21, and 39% for CW, CB, and DB vs. CK, respectively. The difference, however, was not significant ($P > 0.10$). Like dissolved nutrient concentration, no significant differences were found among living mulch treatments ($P > 0.10$).

Plant Growth

The results indicated that for both V and R growth, soybeans with CK and CW developed more rapidly than soybeans with CB and DB (Table 1). Soybeans with CK and CW developed about 7-10 days earlier or faster than soybeans with CB and DB. Significant differences ($P < 0.01$) were also found on soybean growth height (Fig. 8). Soybean heights between CK and CW were not different but were significantly greater than for soybeans with CB and DB.

Soybean Yield

Soybean yields were correlated with the rate of growth. Soybean yields with CK and CW were about 2 to 3 times higher (1979 and 1925 kg/ha) than those with CB and DB (646 and 915 kg/ha) in 1986 ($P < 0.01$). In 1985, CK plots got the highest yields (2948 kg/ha) and CB had the lowest amount of yield (713 kg/ha). Treatments of CW and DB had similar yields (2107 and 2013 kg /ha) in 1985. CB decreased soybean yield from 66 to 67% (Fig. 9).

Water Content and Soil Water Depletion

Soil water content changes measured with a neutron probe for the period from soybean planting to harvesting are shown in Fig. 10. Average soil water contents during the entire growing season were 35, 34, 34, and 34% for treatments of CB, CK, CW, and DB, respectively. The contrast for average soil water content was not significant among treatments ($P > 0.10$). However, differences did exist among cover crop treatments at certain periods.

Soil water contents in CB and DB were significantly lower than CK during the first period (early vegetative growth stage V0-V1) ($P < 0.001$). Water contents in cover crop treatments of CW, CB, and DB were 1, 4, and 7% lower than CK plots. DB had the lowest water content. The difference between CK and CW was not significant ($P > 0.10$). The second period is for the V growth stages V0-V2 (day 149-184). Water content in DB was significantly decreased compared to the CK and other cover crop treatments. Water content of DB was about 7% lower than in the CK plots. Differences between CK, CW, and CB were not significant. During the period of rapid V growth, soybean flowering, pod formation, and bean development, water contents with CK and CW were significantly lower than CB and DB ($P < 0.01$). No differences were found between CK and CW, and between CB and DB. Cover crops were dead or dormant at this period and soybeans became the main soil water consumer. Soybeans in CK and CW were about 0.2 m higher than for soybeans in CB and DB. Thus, soil water in CK and CW was depleted quickly. In contrast, soybean growth in CB and DB were retarded by competition for soil water between soybeans and living mulch or because of animal damage during the early growth period. Therefore, soil water contents in CB and DB were 2 to 3% higher than CK. The lowest soil water content was found on CW plots. During the period of maturing (day 245-270), most soybeans were senescencing. Water depletion stopped and the soil profile began to recharge. Differences in soil water content were nonexistent and were not significantly different between the cover crop treatments and the control ($P > 0.10$).

The same tendencies exist both in the lower part of the profile (below 0.3 m) and in the upper 0.3 m of the profile.

However, surface water contents before harvesting were similar for all treatments.

The results of the cumulative water use by different treatments are shown in Fig. 11. Water use by each treatment was 531, 590, 517, and 486 mm for CK, CW, CB, and DB, respectively. The total amount of water use by CW was significantly greater than for CB and DB ($P < 0.05$). Soybeans with CW used the largest amount of water and those with DB used the least amount of soil water. Soil water depletion in CK was close to that of CW and soil water use in CB was close to that of DB ($P > 0.10$). The ratios of soybean grain yields and amounts of soil water used are 3.73, 3.26, 1.25, and 1.88 kg/ha/mm for CK, CW, CB, and DB, respectively. More water use in CK and CW may indicate that soil water was used more efficiently in these treatments vs. CB and DB in terms of soybean yields.

DISCUSSION

A cropping system is a principal determinant of cropland erosion (Wischmeier and Smith, 1978). Under the same soil conditions, different amounts of soil erosion may be produced by different cropping systems and crops (Alberts et al., 1985). This is because various cropping systems have different canopy and residue coverage over the soil and affect the erosion-related soil physical and chemical properties. These factors will influence on the resistance of the soil to erosion. Thus varied amounts of soil erosion occurred when different kinds of crops were planted and different tillage methods were used. Conventional tilled cropland is more vulnerable to erosion than conservation tillage systems, such as no-till. Principally because conservation tillage systems leave more residues on the soil surface than conventional tillage methods. Since post-harvest residue after corn is about two times greater than that after soybeans (Buyanovsky and Wagner, 1986) and soybeans may produce poorer quality of plant material than corn (Gantzer et al., 1987), soil erosion from land cropped to soybeans is as much as 2 times higher than that from corn under the same soil conditions and the same cropping management practice (Laflen and Moldenhauer, 1979 and Alberts et al., 1985).

Although soybeans are often related to increased soil erosion compared to corn, soybeans are the primary economic crop in parts of the Midwest. Therefore, to develop a crop management system for soybeans which controls erosion, greater amounts of plant residues will be necessary when soybeans are grown.

No-till soybeans with a living mulch winter cover crop has potential as such a system. Soybeans are cultivated using a no-tillage method. A living mulch is maintained after soybean harvesting and before soybean planting. The mulch can provide additional 30 to 50% plant vegetation and residue cover on the soil surface during seedbed stage of soybeans. The soil surface is protected either by soybean canopy or by soybean residues or by vegetative mulch year round (Fig. 1). Soil erosion can be reduced to very low level (less than 10% of that from CK). Living mulches can be annual or perennial, both should have the least competition for soil water and nutrients with soybeans. Annuals of chickweed and downy brome and perennial of canada bluegrass were used in this study. Other studies have been reported using legumes as living mulches for corn (Corak et al., 1987 and Vrabel et al., 1981).

The vegetative and residue cover was significantly increased in CW, CB, and DB vs. the CK. Cover crop treatments increased the weighted average annual vegetative and residue cover by 31, 40, and 40% for CW, CB, and DB, respectively. The coverage of soil in living mulch treatments were 2 times higher than the CK especially at the time of soybean planting (Fig. 1). Increased coverage reduced 50% of runoff, 93% of soil loss, and 50% of dissolved nutrient losses.

Runoff and soil loss from no-till cover crop treatments were much less than those from no-till soybeans without cover crop for the 2-yr study period. Runoff in the cover crop treatment plots was decreased by 30 to 36% in 1985, 56 to 80% in 1986 vs. the CK plots (Fig. 2). Total amounts of soil losses from cover crop treatments were reduced by 83 to 91% vs. the CK for the first year study. Soil loss in CW was only 8% of the CK in 1986. Erosion was completely controlled in the treatments of CB and DB during the second year of study (Fig. 3). Soil loss was a function of runoff. Since runoff decreased with cover crop treatments, little soil was eroded from cover crop plots. Both runoff and soil loss were significantly correlated with vegetative and residue cover (r = = 0.96 and 0.99, respectively; Figs. 4 and 5).

McDowell and McGregor (1980), who studied nutrient losses in runoff from no-till soybeans in northern Mississippi on a Providence silt loam (Typic Fragiudalf), reported that both concentration and net loss of soluble nitrogen and phosphorus in runoff water from no-till soybeans were significantly greater than from conventional tilled soybeans. Our results showed that only dissolved PO_4^{-3}-P concentrations from cover crop treatments were significantly higher than that from the CK ($P < 0.01$). Because residues over the soil surface are a kind of "buffer pool" and some PO_4 can be leached out from residues, PO_4-P concentrations from cover crop treatments were higher than from CK plots. However, the CK plots had a greater concentration of NO_3^--N than cover crop treatments ($P < 0.05$) (Fig. 6). The CK had the largest amount of nutrient losses of NO_3^-, NH_4^+, and PO_4^{-3} (Fig. 7). Total amount of NO_3^- losses were significantly decreased by 71, 73, and 76% ($P < 0.01$) and NH_4^+-N losses were reduced by 40, 36, and 46% for treatments of CW, CB, and DB vs. the CK ($P < 0.10$), respectively. PO_4^{-3}-P losses were also decreased by 50, 21, and 39% for CW, CB, and DB vs. CK, respectively.

Barisas et al. (1978) observed that nutrient losses in the runoff were relatively small and sediment was the major carrier of nutrients. The study in Mississippi also supports this conclusion (McDowell and McGregor, 1980). Since soil erosion was reduced in cover crop treatments and the net dissolved nutrient losses with runoff water were greatly reduced by the use of living mulch winter cover crops (due to runoff reduction), therefore, total (solution plus sediment) plant nutrient losses would be decreased and surface water quality would be expected to improve by using any of the winter cover crops with no-till soybeans.

Soil water measurements showed that soil water content was similar among all treatments in spring before rapid growth of living mulch (late of March or early April). Water use in this period was not different ($P > 0.10$). As soon as winter cover crops began to grow rapidly, soil water content in cover crop treatments decreased to 8, 13, and 14% lower than the CK for CW, CB, and DB, respectively (Fig. 10). More water was used by the cover crop treatments than the CK during this period (Fig. 11). Competition for soil water between cover crops and soybeans delayed soybean development at this period (Table 1, Fig. 8) and the residual effect of retarded growth continued through the growing season and ultimately reduced soybean yields (Fig. 9).

When winter cover crops were dead or suppressed, water contents in CB and DB was about 4 to 5% higher than CK and CW. This is because the CB and DB had poor soybean development and could not extract as much water as soybeans in CK and CW.

Box et al. (1980) conducted a study on Cecil sandy loam (Typic Hapludulf) in Georgia and found that corn grown on completely killed mulch had a higher yield than corn grown in fields where only strips were killed. A study in Illinois by Elkins et al. (1982) indicated that when rainfall was adequate, good soybean yield can be obtained in forage grasses where most or all of the sod was killed. When the grass sod was not killed completely, the system could be successful only if supplemental water could be supplied in drought periods. Their findings showed competition for soil water between living mulch and main crops.

Different results were reported by Corak et al. (1987). They studied water release by alfalfa in an alfalfa and maize association and found a favorable soil water effect where a living mulch was used. The deep-rooted alfalfa could transfer water located lower in the profile to shallow-rooted maize during severe drought. However, Dirksen and Raats in a similar experiment (1985) could not detect water release to the dry upper soil depth by alfalfa roots. They concluded that water release by roots would not have much "practical" significance. Our results indicated that competition existed at the early soybean growth stages (V0-V2), and no competition for soil water between soybeans and cover crops was found in term of total water depletion (Fig. 11). This suggests that early plant water stress may have an important effect on later plant development.

The mulch management designed for this study included spraying herbicides on cover crops in spring when they were physiologically matured and then planting soybeans. The advantage of this management is that annual cover crops can reseed themselves naturally and thus reseeding expenses for the cover crop are not required after soybean harvesting.

Several disadvantages are also apparent with this management. First, time of soybean planting would have to be postponed to allow for cover crop maturity. For example, downy brome matures from early to mid-June, and planting soybeans after downy brome maturity may be delayed by as much as one month compared to normal soybean planting at this area. Full-season varieties decrease yield from planting in mid-May to early June at the rate of 68 kg/week/ha, and then decrease at a rate of slightly more than 70 kg/week/ha until late of June (Helsel and Scott, 1987). Yield potential could be reduced for this reason. Secondly, lower populations of soybeans may also occur because of smother, poorly covered seed and poor seed-soil contact (Mitchell and Teel, 1977). This was qualitatively observed in our CB and DB plots which had heavy mulches. Rodent damage was a problem in the CB plots, which decreased soybean population and yields. Soybean populations in CB and DB treatments were decreased by 50 to 30% as compared to the CK. Mulch could be removed but this might also remove seeds needed for next years's cover crops. Third, growth of living mulches in April and May extracted soil water and resulted in plant water stress (Fig. 10). In 1985 soybean yields were reduced 28, 76, and 32% by CW, CB, and DB vs. the CK. Soybean yields were decreased 3, 67, and 54% vs. the CK for CW, CB, and DB, respectively, in 1986.

Chickweed often matures in late April and may have less interference with soybeaan growth. A good chickweed stand was achieved in 1985. However, the chickweed did not come up in 1986. A very good stand of chickweed developed again in spring of 1987. The CW treatment appears to have the best potential to be used as a living mulch winter cover crop with no-till soybeans (ie. the least apparent interference with soybean growth) but reliability in stand maintenance needs further improving. CB may be not as suitable for use with no-till soybeans. Since DB greatly reduced soil erosion and interfered with soybean growth less than CB in our study, continued improvement of its mulch management system is needed on timing, type, and method of herbicides application.

SUMMARY AND CONCLUSIONS

Effects of selected winter cover crops on soil erosion, dissolved nutrient loss, and plant growth were studied on natural rainfall runoff plots. For treatments of CW, CB and DB, runoff was decreased 66, 56, and 80% ($P < 0.01$), soil loss was decreased 61, 97, and 95% ($P < 0.01$), respectively, vs. the CK. Dissolved nutrients losses also were reduced on cover crop plots. Soybean grain yields, however, were decreased 18, 62, and 41% in CW, CB, and DB treatments. With improved management system, no-till soybeans with winter cover crops would have the ability to reduce soil erosion with no or minimal decrease soybean yields.

The following conclusions can be drawn from this study:

1. The use of living mulch winter cover crops with no-till soybeans increased vegetative and residue cover from 31 to 40% through the year, and was 2 times greater than the control at the time of soybean planting;

2. Runoff and soil loss were functions of vegetative and residue cover. Soil loss from cover crop treatments was only 3 to 12% of that from the control;

3. Dissolved nutrient losses in cover crop treatments were significantly decreased from 21 to 76% vs. the control due to runoff reduction, even though concentrations of NH_4-N and PO_4-P were higher than control plots;

4. Competition for soil water existed during the early soybean growth stages. Delayed soybean development and lower population reduced soybean yield. No significant difference was found on total water use over all treatments;

5. Chickweed and downy brome have potentials of being used as winter cover crops for erosion control with no-till soybeans. Continued work is needed to improve the mulch management system and enhance the reliability of no-till soybeans with living mulch winter cover crops.

REFERENCES

Alberts, E.E., R.C. Wendt, and R.E. Burwell. 1985. Corn and soybean cropping effects on soil losses and C factors. Soil Sci. Soc. Am. J. 49:721-728.

Alberts, E.E., R.C. Wendt, and R.F. Piest. 1983. Physical and chemical properties of eroded soil aggregates. TRANS. ASAE. 26:465-471.

Barisas, S.G., J.L. Baker, H.P. Johnson, and J.M. Laflen. 1978. Effects of tillage systems on runoff losses of nutrients, a rainfall simulation study. Trans. of the ASAE. 21:893-897.

Beale, O.W., G.B. Nutt, and T.G. Peele. 1955. The effects of mulch tillage on runoff, erosion, soil properties, and crop yields. Soil Sci. Soc. Am. J. 19:244-247.

Box, J.E., S.R. Wilkinson, R.N. Dawson, and J. Kozachyn. 1980. Soil water effects on no-till corn production in strip and completely killed mulches. Agronomy J. 72:797-802.

Buyanovsky, G.A., and G.H. Wagner. 1986. Post-harvest residue input to cropland. Plant Soil 93:57-65.

Campbell, G.S. and G.W. Gee. 1986. Water Potential: Miscellaneous methods. p.619-634. In: A. Klute (ed.) Methods of soil analysis, Part 1. Physical and mineralogical properties. 2nd. ed. Agronomy 9, ASA, SSSA, Madison, WI.

Cassel, D.K. and A. Klute. 1986. Water Potential: Tensiometry. p.563-596. In: A. Klute (ed.) Methods of soil analysis, Part 1. Physical and mineralogical properties. 2nd. ed. Agronomy 9, ASA, SSSA, Madison, WI.

Clark, E.H., J.A. Haverkamp, and W. Chapman. 1985. Eroding Soils: the off-farm impacts. The Conservation Foundation, Washington, D. C.

Corak, S.J., D.G. Blevins and S.G. Pallardy. 1987. Water transfer in an alfalfa/maize association. Plant Physiol. 84:582-586.

Dirksen, C. and P.A.C. Raats. 1985. Water uptake and release by alfalfa roots. Agron. J. 77:621-626.

Elkins, D., D. Frederking, R. Marashi, and B. McVay. 1983 Living mulch for no-till corn and soybean. Journal of Soil and Water Conservation. 38:431-433.

Elkins, D.M., J.D. George, and G.E. Birchett. 1982. No-till soybeans in forage grass sod. Agrono. J. 74:359-363.

Gantzer, C.J. and E.E. Alberts. 1984. Effects of corn and soybean cropping on splash detachment and soil strength. Agron. Abstract. P.248.

Gantzer, C.J. 1985. Study of cropping effects on soil properties related to water infiltration, runoff and soil loss using simple laboratory methods. Missouri Water Resource Research Center. Report No. G-916-02.

Gantzer, C.J., G.A. Buyanovsky, E.E. Alberts, and P.A. Remley. 1987. Effects of Soybean and Corn Residue Decomposition on Soil Strength and Splash Detachment. Soil Sci. Soc. Am. J. 51:202-206.

Gardner, W.H. 1986. Water Content. p.493-544. In: A. Klute (ed.) Methods of soil analysis, Part 1. Physical and mineralogical properties. 2nd. ed. Agronomy 9, ASA, SSSA, Madison, WI.

Hall, J.K., N.L. Hartwig, and L.D. Hoffman. 1984. Cyanazine losses in runoff from no-tillage corn in "living" and dead mulches vs. unmulched conventional tillage. Journal of Environ. Qual. 13:105-110.

Hanway, J.J. and Thompson, H.E. 1971. How a Soybean plant develops. Special Report 53 (Rev.) Iowa State Univ. of Sci. & Technology Cooperative Extension Service. Ames Iowa.

Hartwig, R.O. and J.M. Laflen. 1978. A meterstick method for measuring crop residue cover. J. of Soil and Water Conserv. 33:90-91.

Helsel, Z.R. and J.H. Scott. 1987. Planting practices. p.23-28. In: Missouri soybean handbook. Univ. of MO-Columbia, College of Agric. & Extension Div. Manual 123.

Laflen, J.M. and W.C. Moldenhauer. 1979. Soil and water losses from corn-soybean rotations. Soil Sci. Soc. Am. J. 43:1213-1215.

McDowell, L.L. and K.C. McGregor. 1980. Nitrogen and phosphorus losses in runoff from no-till soybeans. Trans. of the ASAE. 23:643-648.

Meyer, L.D., W.H. Wischmeier, and G.R. Foster. 1970. Mulch rates required for erosion control on steep slopes. Soil Sci. Soc. Am. J. 34:928-931.

Mitchell, W.H. and M.R. Teel. 1977. Winter-annual cover crops for no-tillage corn production. Agron. J. 69:569-573.

Scrivner, C.L., J.D. McQuigg, and D.R. Bress. 1972. A study of temperature, precipitation, and evapotranspiration characteristic areas of Missouri. Res. in Agronomy, UMC. Miscellaneous Publication. 72-5.

Soil Conservation Service, USDA. 1980. America's soil and after conditions and trends. Washington D.C.

Soil Conservation Service, USDA. 1985. Missouri's Land: its use and condition -- Summary of 1982 National Resources Inventory. Columbia, MO.

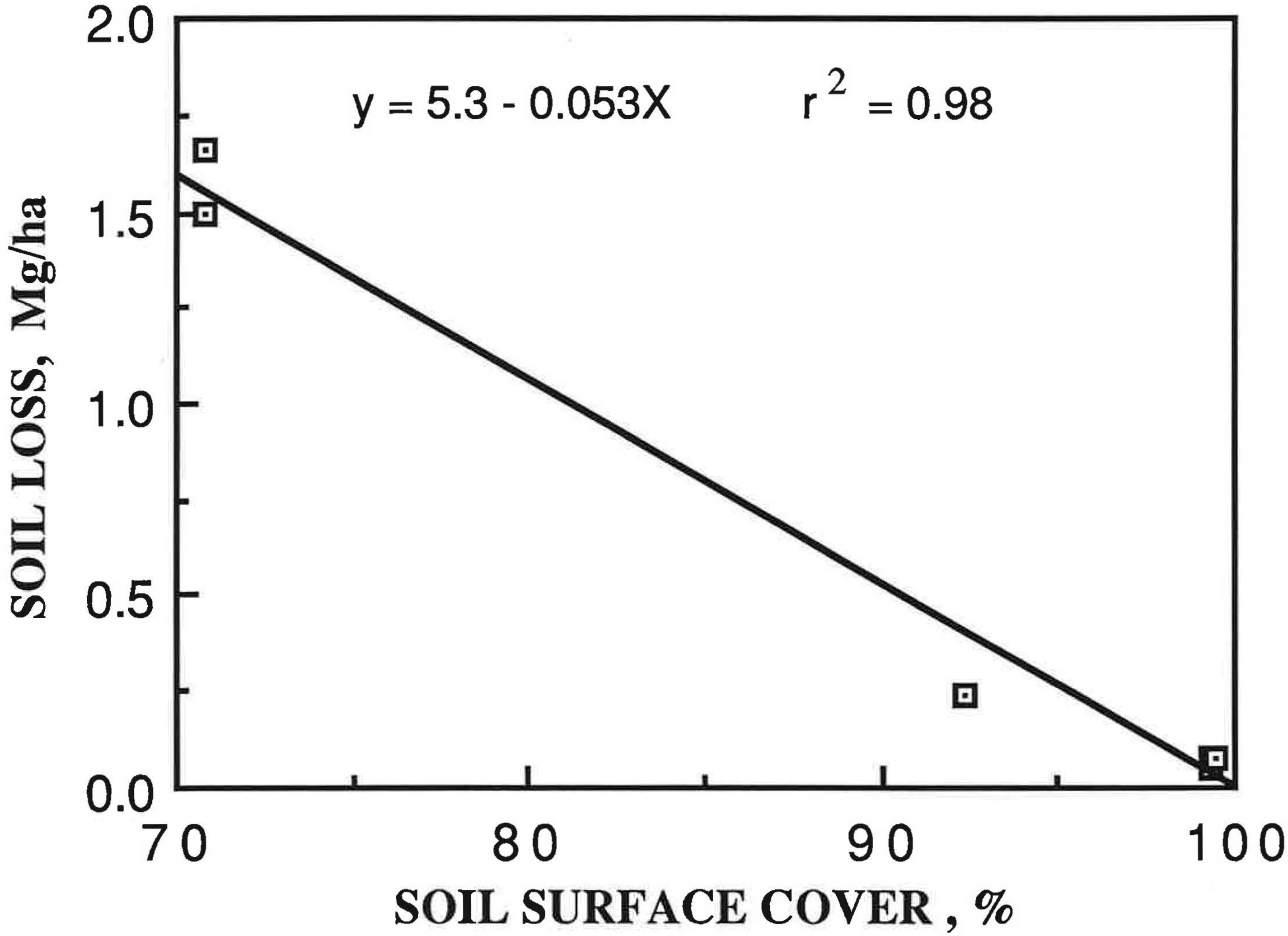
Vrabel, T.E., P.L. Minotti, and R.D. Sweet. 1981. Legume sods mulches in sweet corn. Proc. Northeast Weed Sci. Soc. 35:158-159.

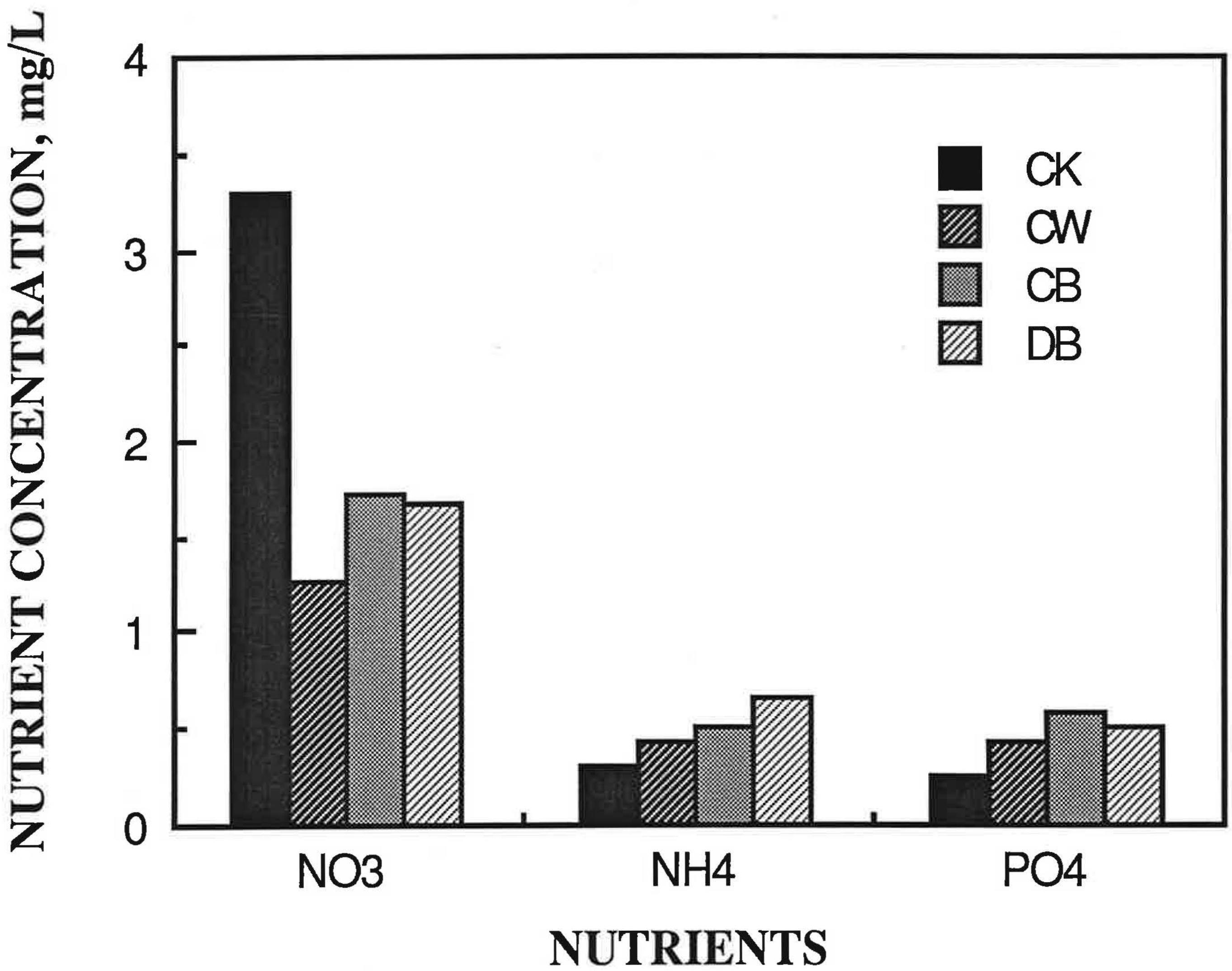
Wischmeier, W.H. and D.D. Smith. 1978. Predicting rainfall erosion losses - a guide to conservation planning. Agric. Handb. No. 537. USDA, SEA. U.S. Government Printing Office, Washington, D.C.

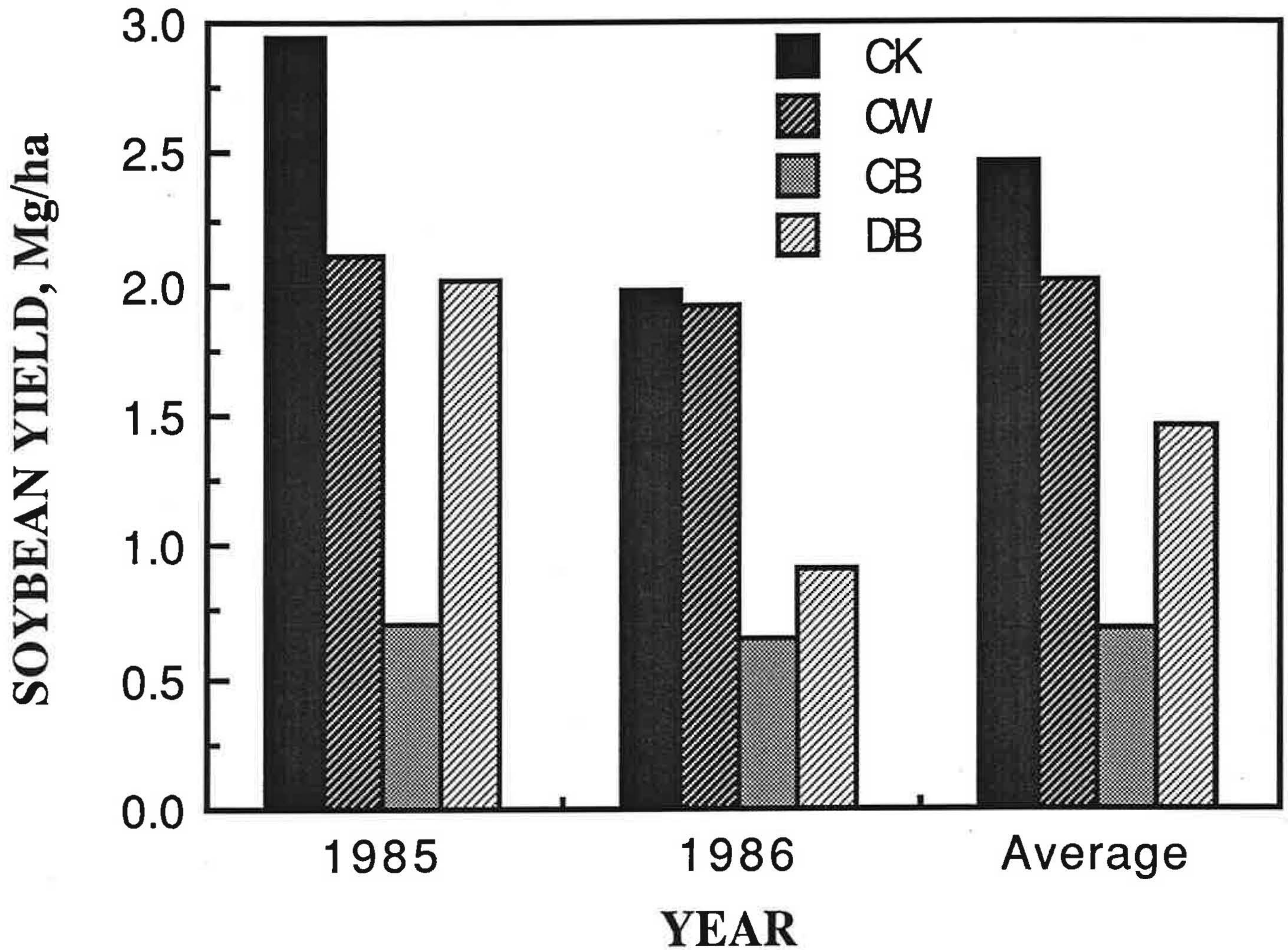
LIST OF FIGURES AND TABLES

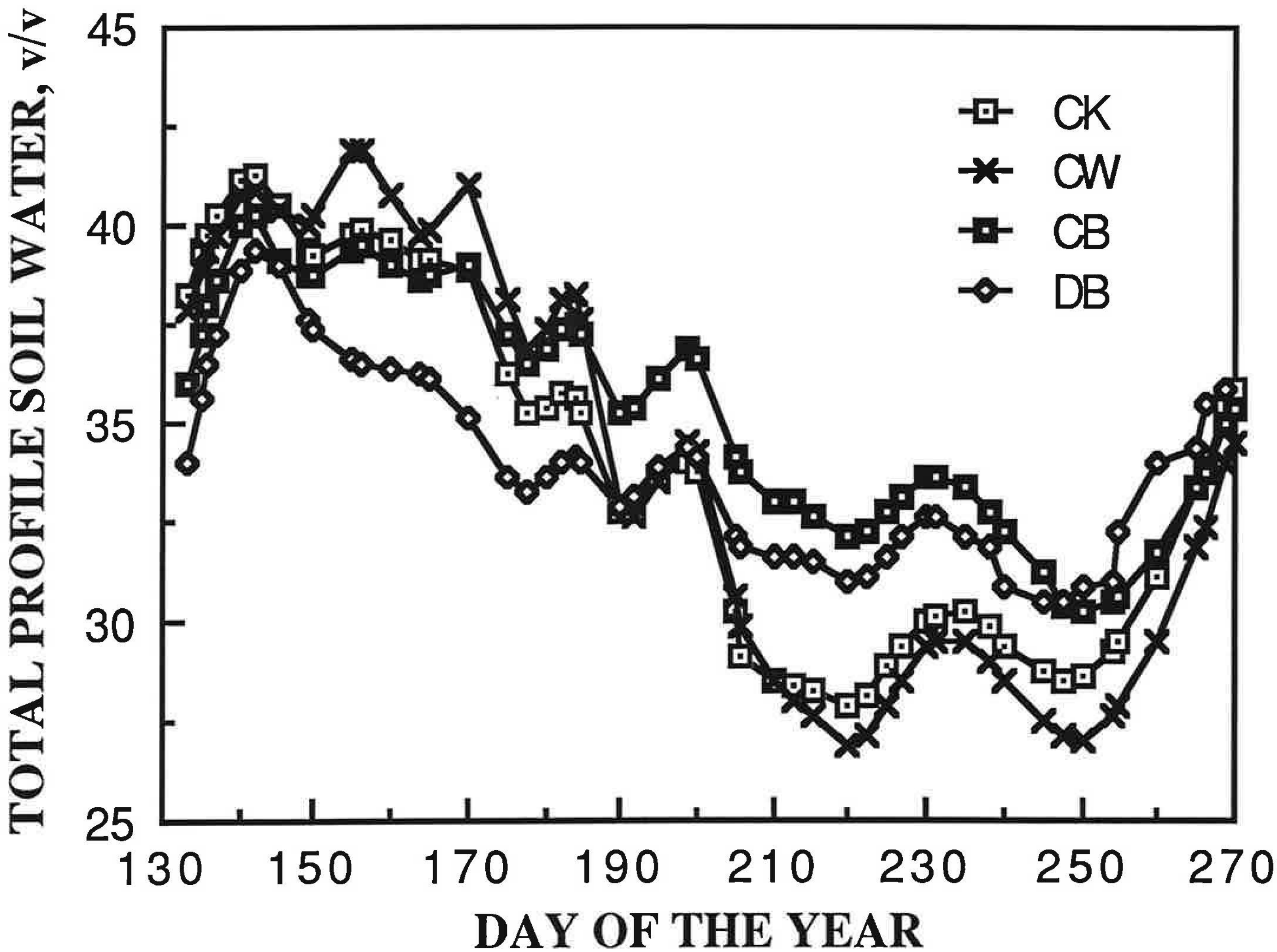
Table 1. Soybean Growth Stage Observations in 1986

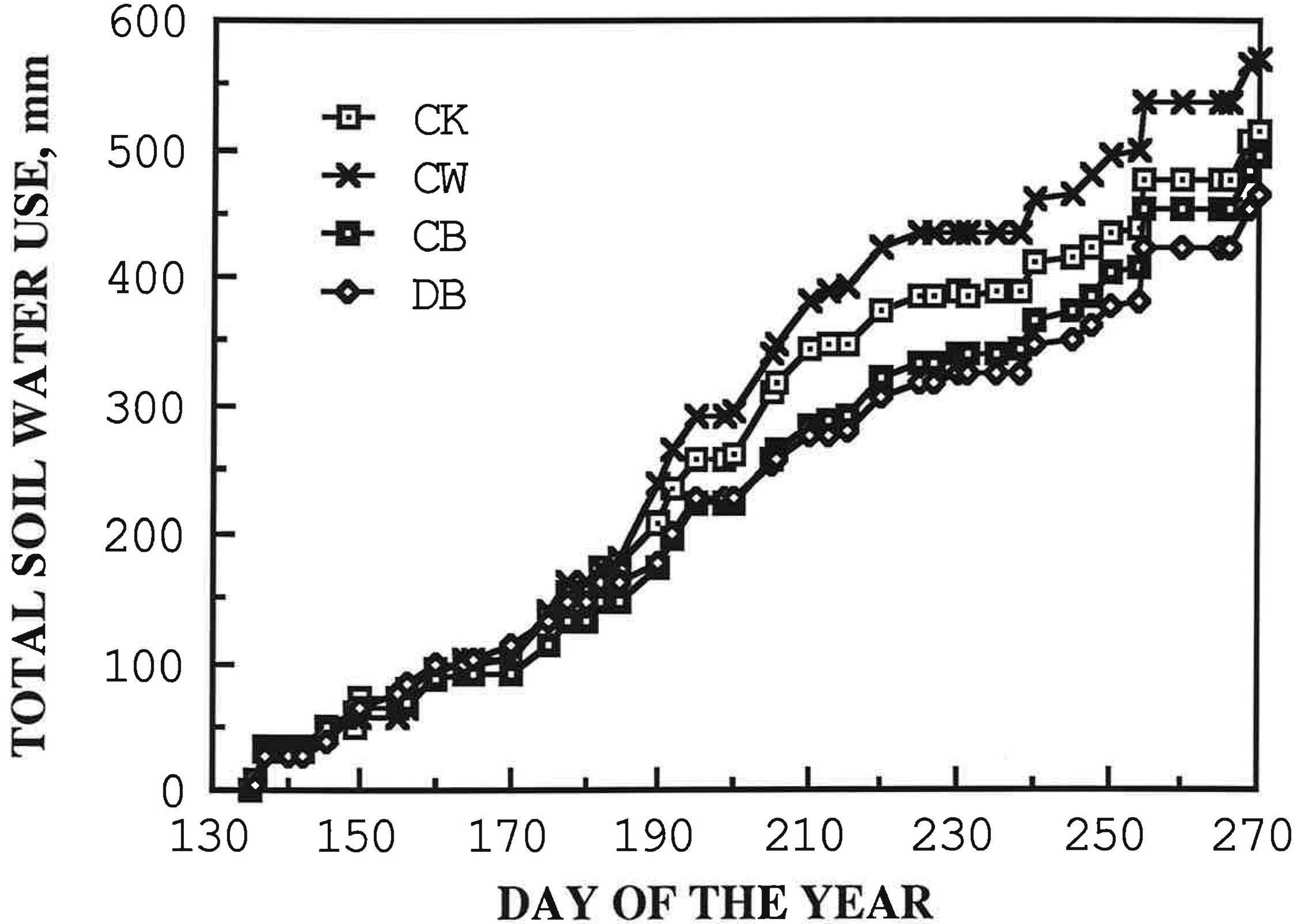
Growth Stage	Treatments			
	CK	CW	CB	DB
	day of the year			
V0	143	143	143	143
V1	150	150	153	150
V2	157	157	157	157
V3	164	165	171	171
R4	175	175	184	184
R5	184	184	190	190
R5.5	199	199	203	203
R6	203	203	206	206
R7	206	206	210	210
R9	231	231	235	235
R10	240	240	245	245
R11	270	270	270	270

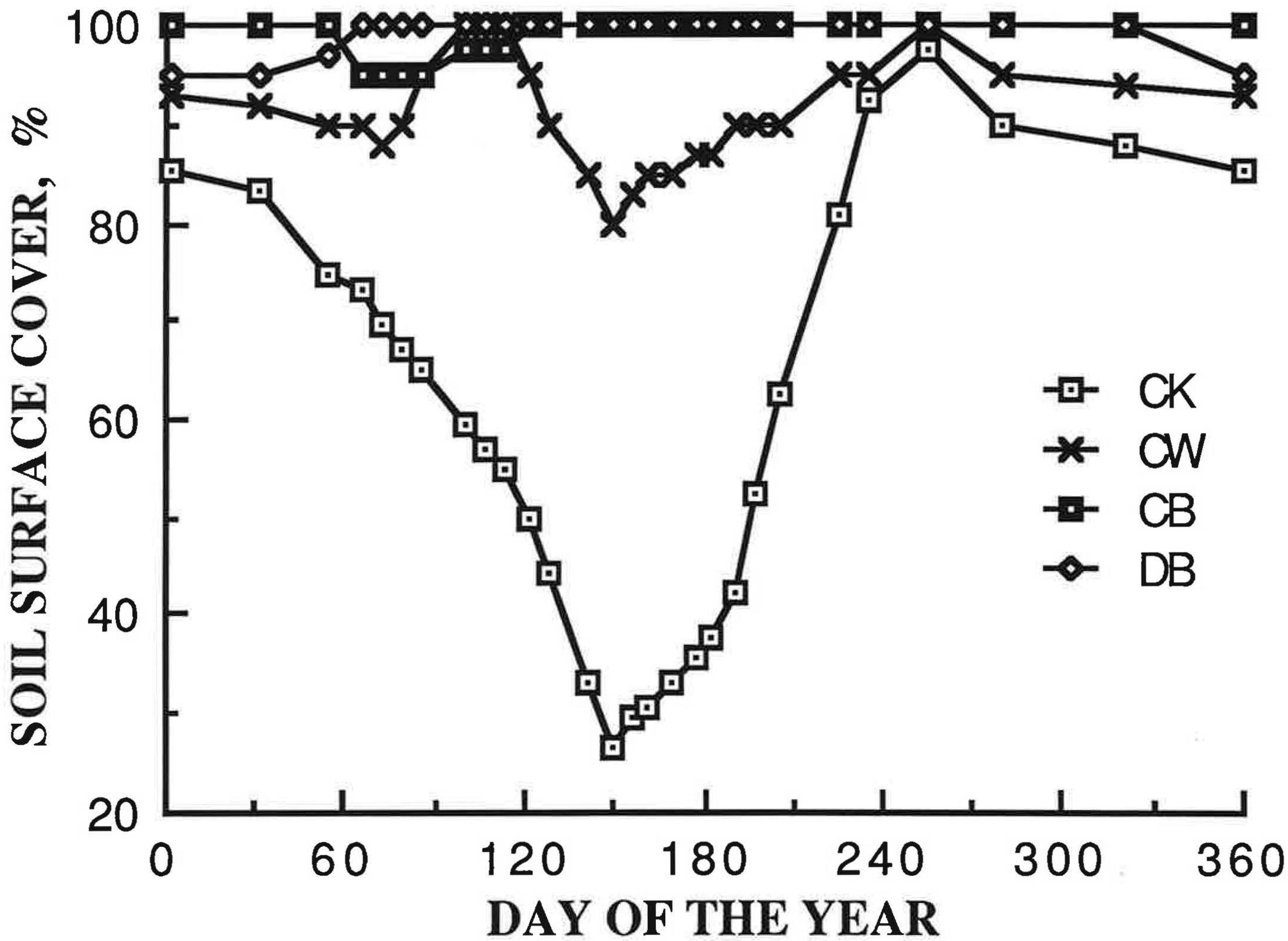

y = 5.3 - 0.053X
r 2 = 0.98
2.0
1.5
1.0
0.5
0.0
SOIL LOSS, Mg/ha
70
80
90
100
SOIL SURFACE COVER , %

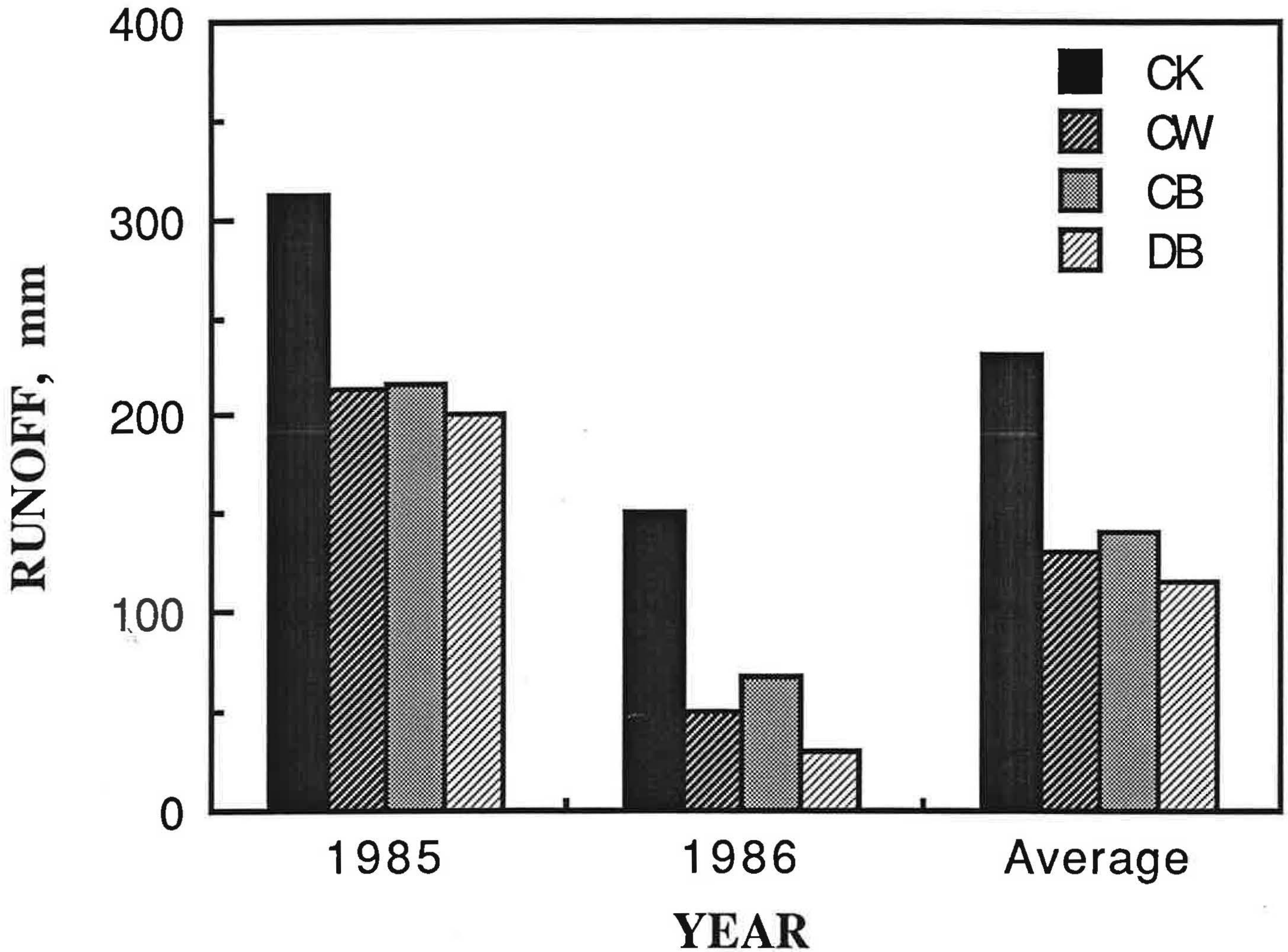

NUTRIENT CONCENTRATION, mg/L
4
3
2
1
0
CK
CW
CB
DB
NO3
NH4
PO4
NUTRIENTS

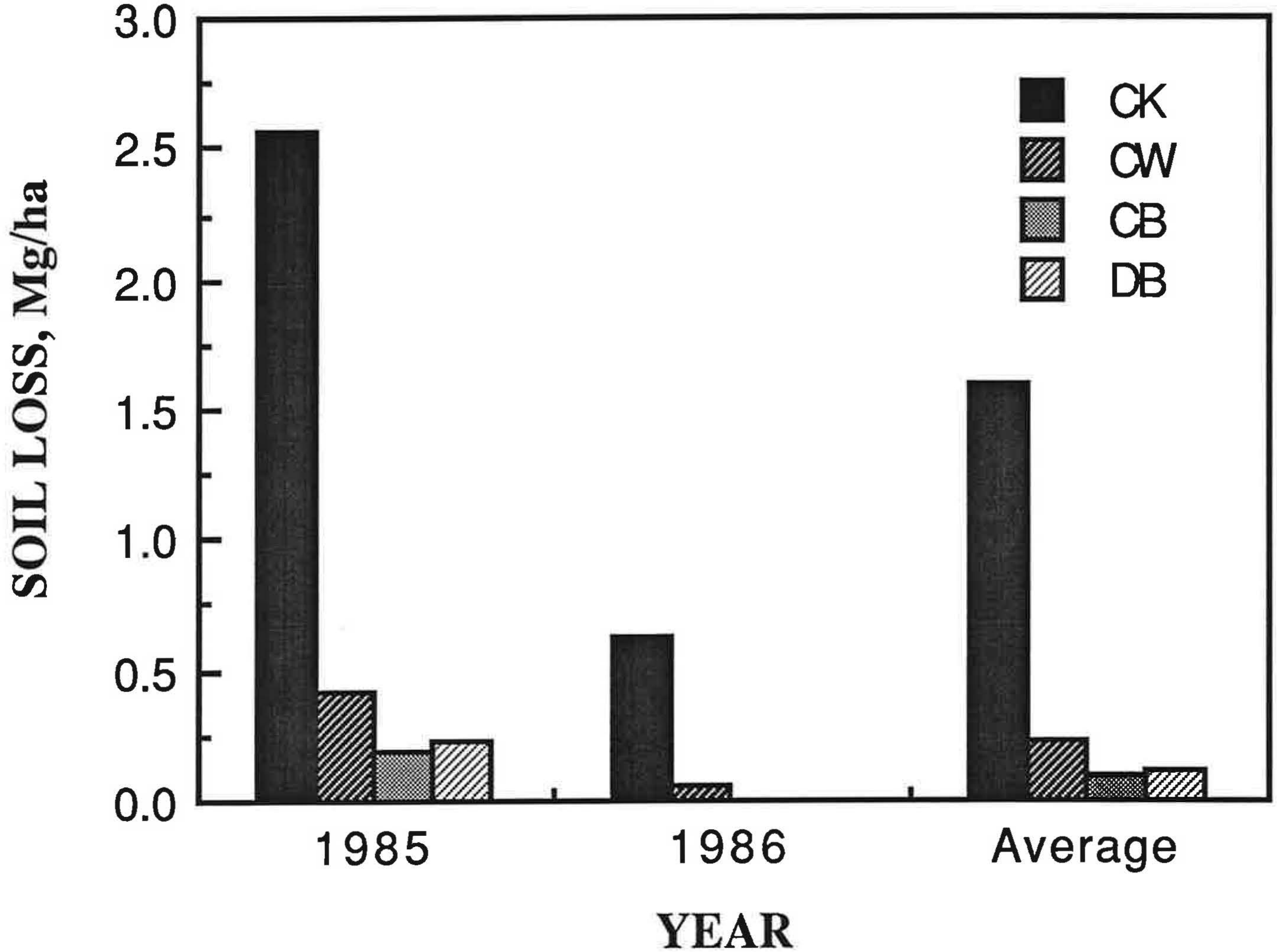

SOYBEAN YIELD, Mg/ha
3.0
2.5
2.0
1.5
1.0
0.5
0.0
CK
CW
CB
DB
1985
1986
Average
YEAR

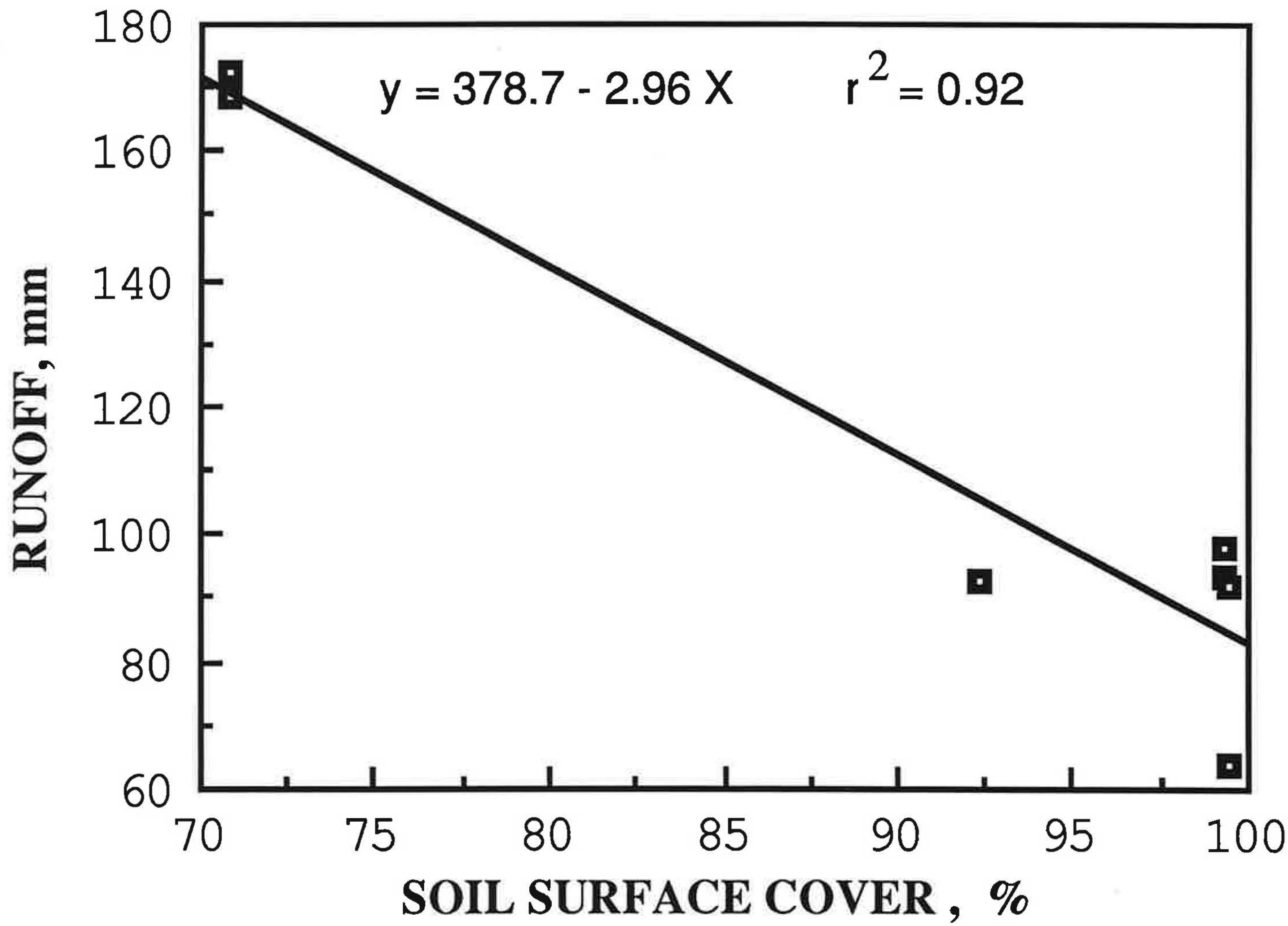

TOTAL PROFILE SOIL WATER, v/v
45
40
35
30
25
130
150
170
190
210
230
250
270
DAY OF THE YEAR
CK
CW
CB
DB

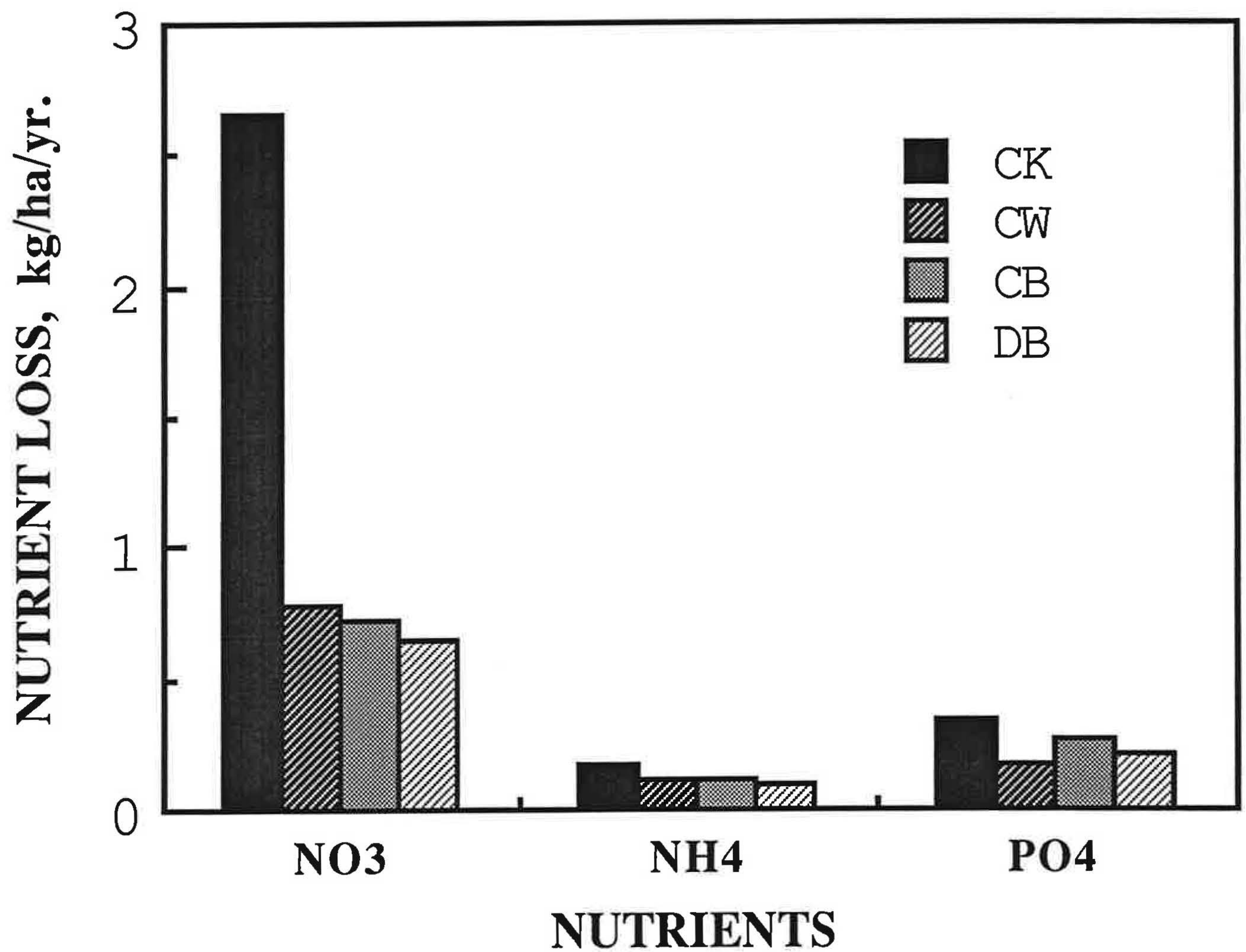

TOTAL SOIL WATER USE, mm
600
500
400
300
200
100
0
130
150
170
190
210
230
250
270
DAY OF THE YEAR
CK
CW
CB
DB

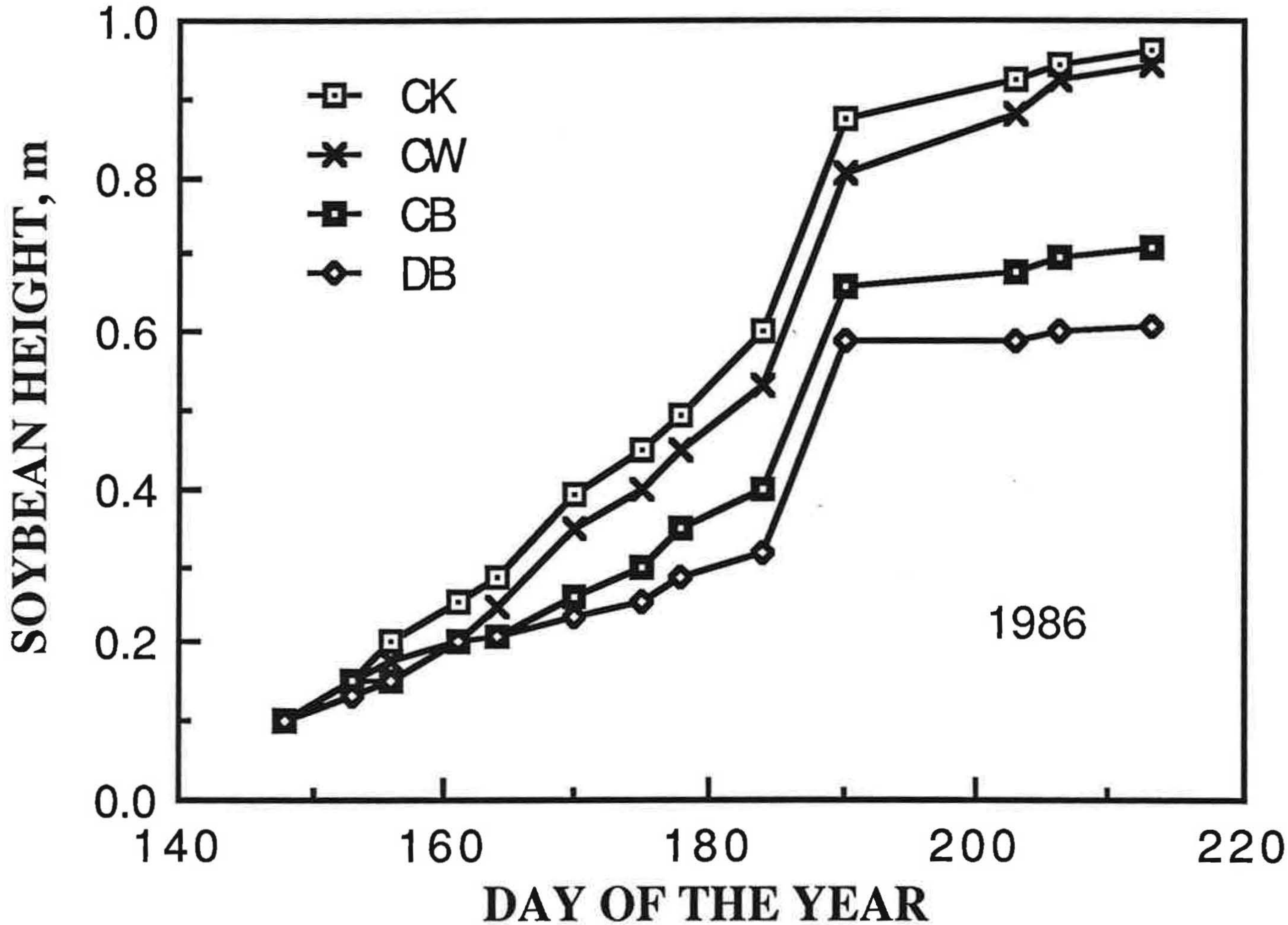

SOIL SURFACE COVER, %
100
80
60
40
20
0
60
120
180
240
300
360
DAY OF THE YEAR
CK
CW
CB
DB


400
300
200
100
0
RUNOFF, mm
CK
CW
CB
DB
1985
1986
Average
YEAR


SOIL LOSS, Mg/ha
3.0
2.5
2.0
1.5
1.0
0.5
0.0
CK
CW
CB
DB
1985
1986
Average
YEAR


y = 378.7 - 2.96 X
$r^2 = 0.92$
RUNOFF, mm
180
160
140
120
100
80
60
70
75
80
85
90
95
100
SOIL SURFACE COVER , %


NUTRIENT LOSS, kg/ha/yr.
0
1
2
3
CK
CW
CB
DB
NO3
NH4
PO4
NUTRIENTS


1.0
0.8
0.6
0.4
0.2
0.0
140
160
180
200
220
SOYBEAN HEIGHT, m
DAY OF THE YEAR
CK
CW
CB
DB
1986