



The colonization of Montana roadsides by native and exotic plants
by Gretchen Ann Meier

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in
Biological Sciences
Montana State University
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Abstract:

Roadside communities throughout Montana were sampled to identify native species suitable for roadside vegetation management and to determine exotic species needing control. Information was gathered by sampling roadside communities within broad environmental zones, with the assumption that plants growing well on sites representative of a major environmental type will grow well on other sites within that zone. I found 211 plants in the 370 sites established along Interstate and primary highways. Of these species only 50, 28 native and 22 exotic species, were common (constancy greater than 10%) in at least one of Montana's five major environmental zones (Kuchler, 1964).

The results are presented in two ways. The first presentation lists species occupying typical and uncommon roadside environments. A list of species with highest occurrence in each environmental zone is presented first, followed by lists of species adapted to extremes of climate (temperature and precipitation). Additional lists highlight plants adapted to atypical environmental conditions including soil water balance (water holding capacity, clay, sand), soil fertility (organic carbon, pH) salinity (conductivity) and topographic features (plot position and aspect).

The second presentation focuses on species rather than environments. In Appendix A, 50 species profiles illustrate the response of a species to each of the eleven environmental variables listed above. Each profile compares the distribution of that species with the distribution of all study sites across eleven environmental conditions to identify species adapted to specific conditions.

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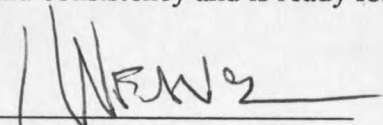
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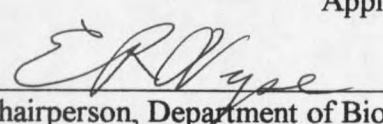
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ABSTRACT

Roadside communities throughout Montana were sampled to identify native species suitable for roadside vegetation management and to determine exotic species needing control. Information was gathered by sampling roadside communities within broad environmental zones, with the assumption that plants growing well on sites representative of a major environmental type will grow well on other sites within that zone. I found 211 plants in the 370 sites established along Interstate and primary highways. Of these species only 50, 28 native and 22 exotic species, were common (constancy greater than 10%) in at least one of Montana's five major environmental zones (Kuchler, 1964).

The results are presented in two ways. The first presentation lists species occupying typical and uncommon roadside environments. A list of species with highest occurrence in each environmental zone is presented first, followed by lists of species adapted to extremes of climate (temperature and precipitation). Additional lists highlight plants adapted to atypical environmental conditions including soil water balance (water holding capacity, clay, sand), soil fertility (organic carbon, pH) salinity (conductivity) and topographic features (plot position and aspect).

The second presentation focuses on species rather than environments. In Appendix A, 50 species profiles illustrate the response of a species to each of the eleven environmental variables listed above. Each profile compares the distribution of that species with the distribution of all study sites across eleven environmental conditions to identify species adapted to specific conditions.

INTRODUCTION

Montana Department of Transportation (MDT) manages over 6,600 miles of road throughout the state. Adjacent roadsides are managed for driver safety, to provide effective maintenance, and for emergency parking. Roadside managers seek to stabilize soil, exclude weeds, minimize maintenance and provide an aesthetic view.

The MDT plants aggressive species intended to establish vegetation and to permanently protect the sites from erosion. The primary objective for this study was to identify native plants suitable for roadside reclamation. A secondary objective was to identify especially troublesome weeds. We approached these objectives by identifying native and exotic plants which have colonized roadsides in major environmental zones. To determine optimal conditions of these plants we related their performance to environmental zones and to important environmental conditions within each zone. Specifically we correlated plant performance with mean July temperature, mean annual precipitation, soil water-holding capacity, soil texture, soil fertility, plot position and aspect. The results of this work should be applicable to low elevation forest and grassland types throughout the Northern Rocky Mountains and Great Plains.

LITERATURE REVIEW

Composition of Roadside Communities

Historically, roadside communities have been studied on several continents. Clements (1897) first identified roadside vegetation as a unique community in Nebraska. He described the plant associations occurring in waste areas as a product of "tensions existing between invading weeds and the adjacent undisturbed vegetation." Since then roadside communities have been extensively studied in Europe, where road systems have been established for centuries (Heidl and Ullmann, 1991). These studies focused on defining specific plant associations growing in disturbed areas, environmental influences to roadside plant communities, propagule dispersal, and the threat of noxious weeds.

Roadside communities are influenced by climate (Wein et al., 1992; Ullmann, 1989; Ullmann and Hendl, 1991; Wilson et al., 1992) especially precipitation (Lausi and Nimbis, 1985), latitude (MacClellan and Stewart, 1986), adjacent vegetation (Lausi and Nimbis, 1985) and deicing salts (Scott and Davidson, 1985).

Roadways and motor vehicles aid the dispersal of roadside weeds (Ridley, 1930; Clifford, 1959). Nearly all seeds regardless of size are transported by vehicles (Schmidt, 1989). Thus, the absence of roadside species is not limited by dispersal (Wilson et al., 1992). Roads aid dispersal by acting as corridors and disturbance of the roadside area

may favor the maintenance of weedy vegetation (Nip van der Voot et al., 1979; Tyson and Worley, 1992). Many exotic species have spread northward along highways and railroads, though alien species richness declines from roadways to adjacent undisturbed vegetation (Wester and Juvik, 1983; Weaver et al., 1989; Wein et al., 1992)).

Roadside Vegetation Management

Native species are useful in roadside reclamation. Some species may reduce the cost of vegetation maintenance, weed infestation and fire hazard, while encouraging desirable wildlife and discouraging pests (Brown et al., 1994). Native perennial grasses may decrease the cost of vegetation management by reducing the need for herbicides, and prevent weed invasion either by competition or by releasing allelopathic compounds (Brown et al., 1994). Conservationists may view roadside right-of-ways as a public area to be managed as a refuge for native species (Daar, 1994). Extensive work has been conducted to recommend native species suitable for specific areas (Weaver, 1989; Daar, 1994; Brown, Bugg and Anderson, 1994).

Roadside reclamation has been a MDT policy since the early 1960's (MDT, 1974). Three laws, the Highway Seeding Act, the County Noxious Weed control Act, and the Water Quality Act, mandate the establishment and maintenance of vegetation on highway right-of ways. (MOCC, 1978). Traditionally, reclamation science focused on establishing single species stands of exotic grasses. As native seed became commercially available, managers began to design multi-species 'communities' using a mixture of native species.

In 1994, President Clinton issued a Presidential Directive instructing Federal agencies to use regionally native plants for landscaping to minimize adverse effects on natural habitats (Clinton, 1994). This study addresses species particularly useful for the reclamation of Montana roadsides.

While the exotic grass species used for roadside reclamation establish quickly and provide adequate and attractive cover, they may have drawbacks. Because they are highly competitive, these species exclude native species from grassland sites (Wilson, 1989).

Agropyron cristatum, *Bromus inermis* and *Poa pratensis* are useful species though their aggressive nature makes their use in roadside revegetation undesirable. Uniform stands of *Agropyron cristatum* have more exposed soil and are more susceptible to erosion than stands of native grasses (Wilson, 1989). *Bromus inermis* and *Poa pratensis* are capable of colonizing and spreading in fine texture soils along roadsides. *Bromus inermis* has invaded some grassland and shrubland ecotones in Canada (Wein et al., 1992) and *Poa pratensis* invades native vegetation in Montana (Weaver et al., 1989).

One objective for roadside reclamation is to prevent roadsides from becoming a source of noxious weeds for crop and rangeland. Noxious weeds are a serious threat to adjacent rangeland, cropland and recreation areas. In Montana, roadside exotics invade adjacent native vegetation, especially if this area is disturbed (Weaver et al., 1989). The noxious weed, *Centaurea maculosa*, is especially invasive (Tyser and Worley, 1992; Lindquist et al, 1996). The maintenance of a vigorous native vegetation may be an important strategy for minimizing the invasion of exotic species (Wein et al., 1992).

ENVIRONMENTAL SETTING

Study Area

This study applies to much of the Northern Plains and Northern Rocky Mountain Provinces. The area sampled extends from the Montana-Canada border in the north (49°N latitude) south to the Montana-Wyoming border (45°N latitude). The eastern boundary was set east of Stanley, North Dakota (102°E longitude) to adequately sample Montana's eastern-most grassland environmental type. I sampled west to the Montana-Idaho border (Figure 1).

Geology

The landscape east of the Rocky Mountains is dominated by flat sedimentary layers of Cretaceous sandstone and mudstone. These layers form the oil-rich Williston Basin in west-central North Dakota. The eastern plains of central Montana are flat and uniform. The northern half of this area is glaciated, adding to its low relief. The Yellowstone River and igneous island mountains provide rare relief from this flat landscape (Alt and Hyndman, 1986).

West of the Rocky Mountain front, the terrain is mountainous. Precambrian sedimentary rocks are folded and faulted creating mountains, hills and valleys of

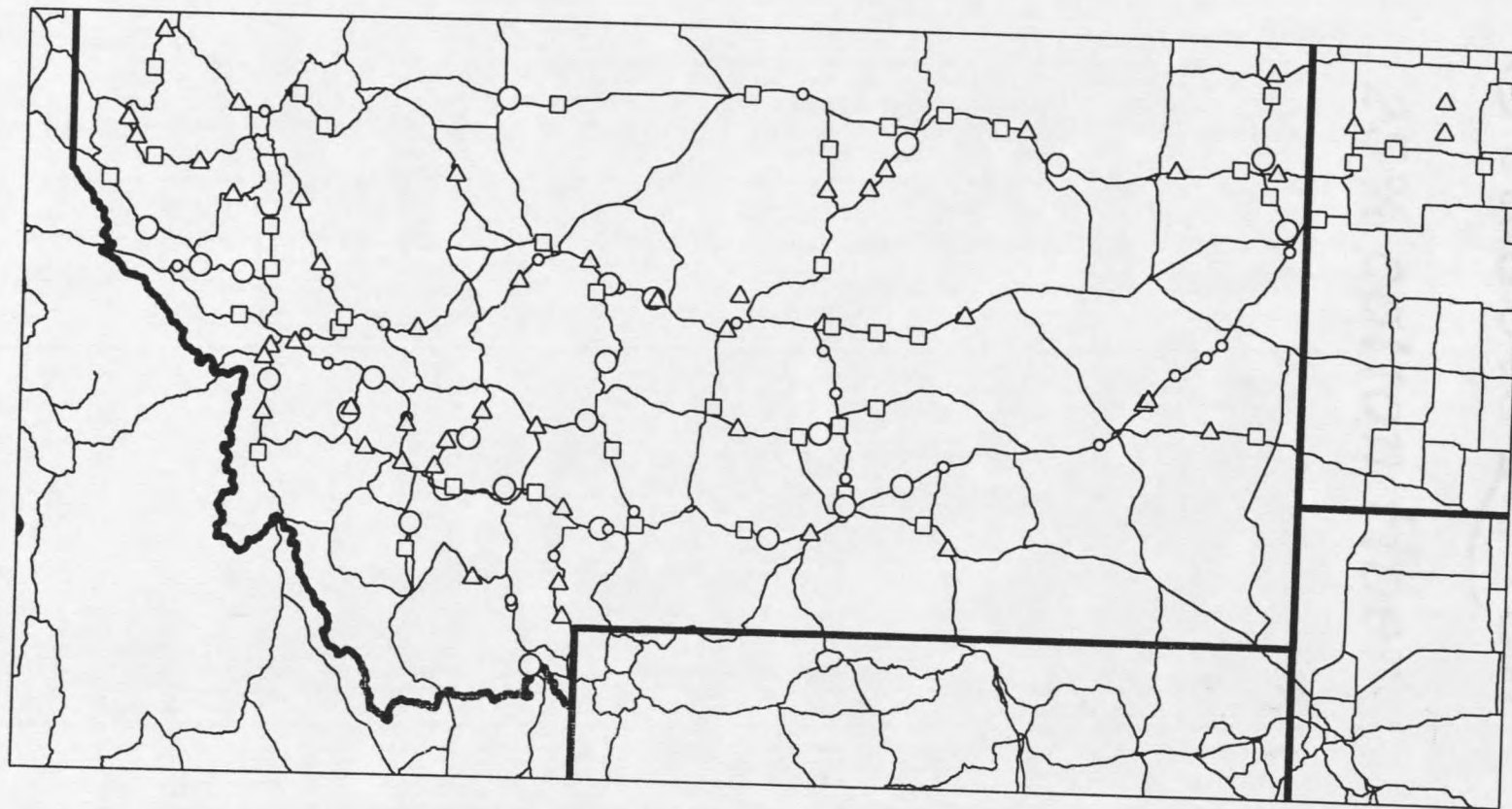


Figure 1. Location of Study Sites in Montana and North Dakota. Symbols represent plots locations. Small circles indicate locations with one plot, triangles=2 plots, squares=3 plots, and large circles=4 plots.

Northwestern Montana. The Rocky Mountain trench extends from Eureka to St. Ignatius and separates the Precambrian beds of northwestern Montana from the Cretaceous beds of the Rocky Mountains and eastern plains. The layered beds that form the northern Rocky Mountains contain sedimentary layers varying in age from Precambrian in the west to Paleozoic in the east and Mesozoic at the eastern margin of the Rocky Mountains. Western Montana was heavily glaciated. These glaciers carved broad valleys leaving piles of rubble behind. In contrast, the landscape of south-central Montana, is dominated by wide valleys and occasional igneous batholiths (Alt and Hyndman, 1986).

Soils

The soils along roadsides are those common to grasslands and forests of the region. In northwestern North Dakota, eastern Montana, and the grassland areas of south central Montana, the soils are primarily Mollisols (dark colored base rich grassland soils) and Vertisols (extremely clay rich grassland soils characterized by wide deep cracks opening under dry conditions). In contrast, soils occurring in wooded areas of northwestern and south-central Montana are light colored Inceptisols and Alfisols, slightly to moderately acidic with a brownish subsoil horizon of clay accumulation (Montagne et al., 1982).

Environmental Types

Regions within this area have different environmental types indicated by the vegetation that covers them (Kuchler, 1964; Daubenmire, 1968). The most widespread environmental types in the area are three grassland and two forest types (Figure 2). Each environmental type is occupied by a different group of plants, though some species overlap. Each environmental type is characterized by at least one dominant and distinctive species (Kuchler, 1964). The name of this distinctive species is used as a name for the environmental type. The study of these broad environmental types permitted adequate sampling of representative segments of roadside in each type. I eliminated two types, the *Artemisia - Agropyron* type and the eastern *Pinus ponderosa*, because roads pass through too few suitable sites.

The three grassland types are the *Andropogon scoparium* (ANSC) type, the *Bouteloua gracilis* (BOGR) type, and the *Agropyron spicatum* (AGSP) type. The ANSC environmental type is relatively moist and is covered by a moderately dense stand of medium stature grasses. This type occupies the northeastern and southeastern corners of Montana, and the western Dakotas south to the Nebraska border (Figure 2). Dominant plant species are *Andropogon scoparium*, *Agropyron smithii*, *Stipa viridula*, *Stipa comata* and *Bouteloua gracilis* (Kuchler, 1964).

The BOGR environmental type is semiarid, and occupied by a short and open grassland dominated by *Bouteloua gracilis*, *Agropyron smithii* and *Stipa comata*. This type occupies most of Montana extending eastward from the Rocky Mountains to the

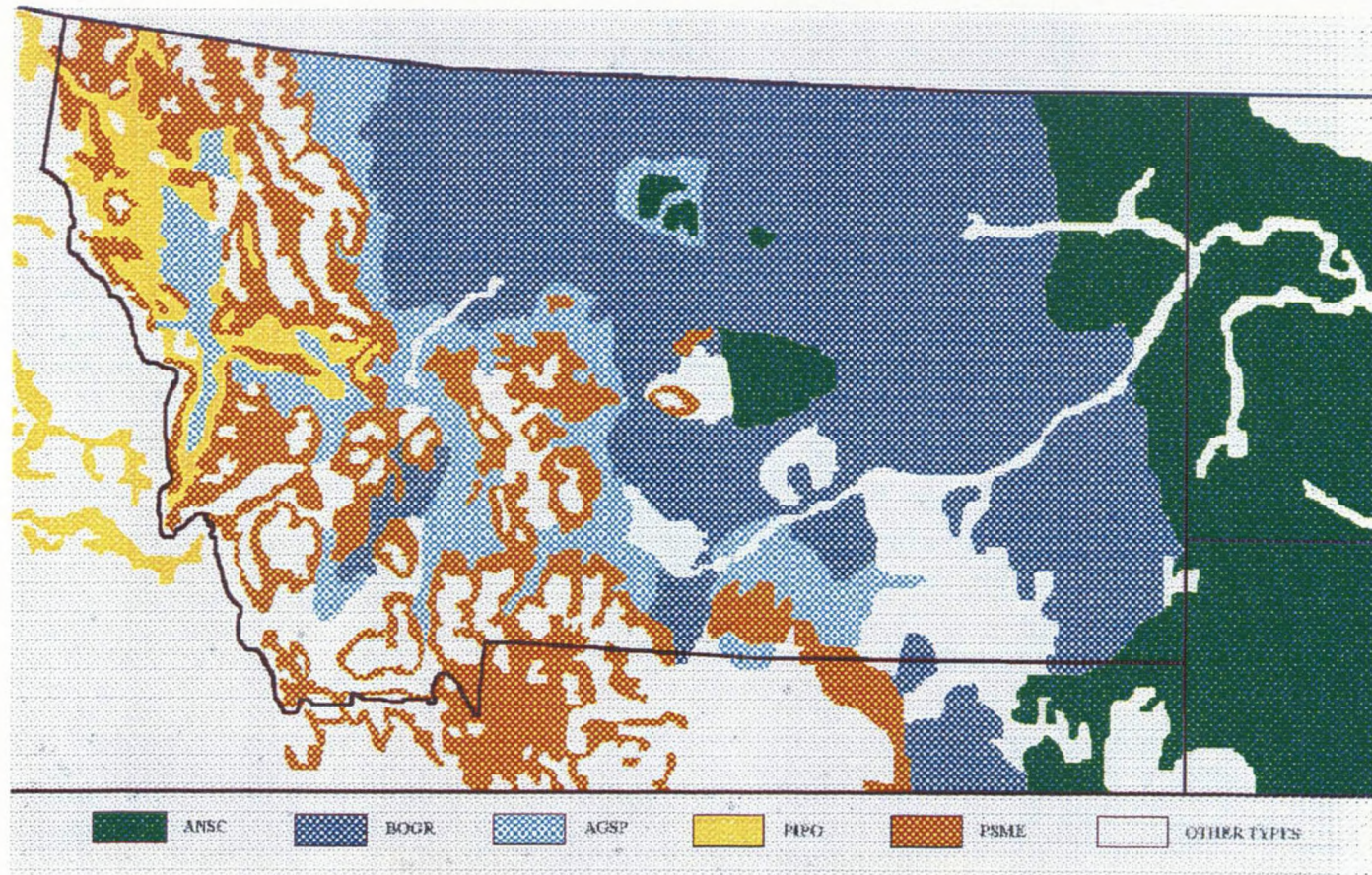


Figure 2. Environmental Types across the Northern Rocky Mountain Provinces.

western edge of the ANSC prairie and southward through Wyoming to Texas (Kuchler, 1964; Weaver 1996).

The AGSP environmental type is more moist and occupies gravel rich soils. It is occupied by an open stand of short bunch grasses, dominated by *Agropyron spicatum*, *Festuca idahoensis*, *Festuca scabrella*, and *Stipa comata* (Kuchler, 1964). This type occupies the foothills between the BOGR type of eastern Montana and the forest types of the Rocky Mountains (Figure 2).

The two forest environmental types studied were the low elevation western *Pinus ponderosa* (PIPO) and the higher elevation *Pseudotsuga menziesii* (PSME) types (Kuchler, 1964). The PIPO type is occupied by moderately dense stands of *Pinus ponderosa* with grassy or shrubby understories of *Agropyron spicatum*, *Festuca idahoensis*, *Festuca scabrella*, *Symphoricarpos albus* and/or *Physocarpus malvaceus* (Figure 2). Forests of *P. ponderosa* extend from central British Columbia south to Mexico (Daubenmire, 1978). *P. ponderosa* occurs in the drier portions of western and eastern Montana. The western *P. ponderosa* type extends from central Washington to the east slope of the Rocky Mountains and to south central Idaho (Kuchler, 1964). The eastern *P. ponderosa* forest occurs in southeastern Montana though infrequently adjacent roads. I was unable to sample enough locations of the eastern type therefore data for this type was not analyzed.

The PSME type is a relatively moist forest environmental type and is occupied by stands of *Pseudotsuga menziesii* of medium height and density (Kuchler, 1964). This forest type covers extensive portions of western North America (Figure 2). Variations of

the PSME type are common throughout the Rocky Mountains and in the wetter portions of north-western Montana.

Road Construction and Road Morphology

Roadsides are engineered to facilitate drainage, to retain topsoil, and to provide an area for maintenance and emergency use. Gravel and selected local parent material are mixed, layered and compacted to create a raised roadbed. The platform is topped with an impermeable layer and covered with gravel. The last layer, called the base course, is designed to promote water drainage from underneath the roadbed (Figure 3). The road is laid on top of the base course. The inslope is the side of the raised roadbed extending from the pavement edge down into the ditch bottom. Exposed base course extends from the edge of the pavement partially down the inslope, depending on its thickness (Figure 3). Until recently, only the inslope from the edge of base course to the ditch bottom was covered with topsoil. The backslope or roadcut extends from the edge of the ditch to the furthest edge of the right-of-way and consists of exposed substrate and covered with a thin layer of topsoil if the slope is less than 33% (MDT, 1995; Figure 3).

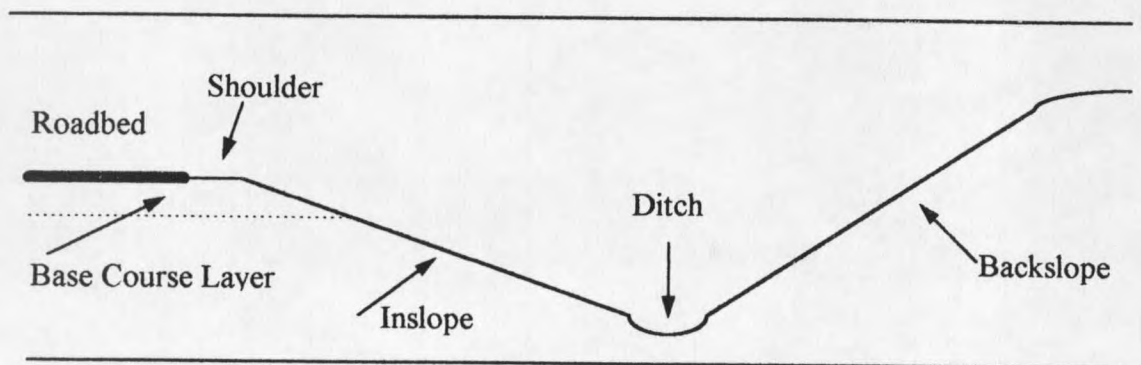


Figure 3. Diagram of a Typical Roadside Section.

MDT used construction and vegetation techniques to stabilize the soil on recently constructed sites. Techniques used to minimize soil erosion include 1) minimizing of slope angles, 2) slope roughening and terracing, 3) temporarily seeding with cover crops, and 4) sediment traps or barriers or other appropriate measures (MDT, 1995).

MDT uses mixtures of seed applied to roadside surfaces to establish vegetation. Seeds are planted in three zones adjacent the roadbed. All areas with slopes less than 3:1 and the exposed base coarse are drill seeded with fertilizer. Areas with slopes greater than 3:1 are broadcast seeded with mulch (either straw or recycled paper fiber) and a tackifier in a water propellant. The tackifier binds the mulch and protects the applied seed mixture from wind and rain erosion (MDT, 1995).

Environmental Characteristics of Study Area

The principle variables that determine differences in vegetation between environmental zones are precipitation and temperature regimes. Both variables are influenced by elevation. Large scale trends of these variables are shown in Table 1. Mean annual precipitation and mean July temperature were chosen as indices of water availability and growing season temperature.

Table 1. Comparison of environmental variables across five environmental types.

variable	Environmental Types ¹				
	ANSC	BOGR	AGSP	PIPO	PSME
Elevation (m) ^A	2200	3000	4000	5000	5000
Mean July Temperature (°C) ^B	22	21	20	20	17
Mean Annual Precipitation (cm) ^B	53	35	38	55	58
Sand (%) ^C	*	33±3	36±4	36±14	36±5
Clay (%) ^C	*	28±2	27±3	28±8	12±2
Organic Carbon (%) ^C	*	1.5±0.1	2.8±0.7	2.9±0.5	1.2±0.2
pH ^C	*	7.4±0.2	6.5±0.1	6.4±0.3	5.6±0.3

^A typical elevation as seen in Montana Atlas, 1994, ^B(Weaver, 1980), ^C(Weaver, 1978),

¹ Environmental types are ANSC = *Andropogon scoparium*, BOGR = *Bouteloua gracilis*, AGSP = *Agropyron spicatum*, PIPO = *Pinus ponderosa*, PSME = *Pseudotsuga mensizeii*, see text for more detailed descriptions. * information not available.

Within an environmental type, microsites are differentiated by soil characteristics including texture, fertility, salinity, and topography. The fine earth fraction of the soil contains three particle sizes, sand, silt and clay. Soils rich in the largest particle size, sand, allow water to infiltrate and drain the soil profile. Soils rich in the finest particle size, clay, retain water. Plant distributions are also affected by fertility, indexed by pH, organic matter, and salinity, indexed by electrical conductivity (Ellis and Mellor, 1995).

METHODS

Introduction

The objectives of the study were to determine which plant species have successfully established on roadsides and which environmental factors are correlated with their establishment. Successful establishment in the past should indicate future success, whether due to climatic zone or by local soil condition. Thus, native species aggressively colonizing roadside areas are considered good candidates for roadside plantings. Similarly aggressive exotic plants invading roadsides are potential threats to the stability of roadside and adjacent vegetation throughout the region. Observations were made in five environmental types (Kuchler, 1964), determined primarily by temperature and precipitation. Observations made within types show the effects of soil texture, soil organic matter, pH, salinity, aspect and plot position.

Sites Selection Criteria

I selected site locations approximately 24 km apart along Montana interstates and primary highways (Figure 1). To be eligible, sites within a location had to be uniform, relatively undisturbed, and representative of the local vegetation. Preferred locations had groups of four sites, an inslope and backslope plot on opposite sides of the road.

Especially in hilly regions of northwestern Montana ideal locations were difficult to find. Thus plots are often disjunct from one another, with inslope plots not paired with backslope plots. Sites were recorded according to highway name, milepost, plot position (backslope or inslope), and aspect (N, S, E, W).

Five environmental types (ANSC, BOGR, AGSP, PIPO and PSME) (Kuchler, 1964) were outlined on a current Montana highway map. Sites lying within an environmental type were grouped and analyzed together to determine the effect of environmental type on species distributions. Sites occupying other types (e.g. eastern *P. ponderosa*), lying on ecotones, or occupying unidentified environmental types were not analyzed.

To determine the effect of aspect on plant establishment in each environmental type four aspects (north, south, east and west) were sampled in approximately equal numbers. Sites analyzed had bearings north-south or east-west and within 10 degrees of that aspect.

Plot position within the roadside cross section was analyzed to determine the effects of slope and site preparation on roadside vegetation. Positions are defined in terms of four zones seen as one moves away from the roadbed. The first zone is an untopsoiled gravel strip, the exposed base course, approximately 1-3 m wide adjacent to the roadbed. (Figure 3). The second zone is the topsoiled inslope, extending from the exposed gravel to the top edge of the ditch. The third zone is the ditch, which is relatively wet and occupied by different vegetation. Ditches were not sampled and are not a significant

component of the vegetation cover of roadside areas. The last zone is the backslope (or road cut) and it extends from the far edge of the ditch to the top of the slope.

Plots were established in the center of the slope, to maximize the homogeneity of the vegetation by avoiding edges. The upper edge of the inslope plot was located below the exposed base course and the lower edge was located above the edge of the ditch. The top edge of the backslope was often irregular, and occupied by different vegetation. The backslope site was located in the center portion of the slope, above the ditch and below the top edge of the slope to maximize homogeneity of the vegetation.

Vegetation Measurements

I sampled 1-4 plots at each location. Each plot was 10 meters long parallel to the roadbed and as wide as the area permitted. I measured the sites with a meter tape and marked the corners with survey flags. Inslope plots were 1-2 meters wide and backslope plots ranged from 5 to 50 meters wide. Inslope and backslope plots are different sizes. The larger backslope plot is expected to have more species than the inslope plot.

In each sample plot, I listed all species covering more than 1 % of the site and estimated their cover. I used two methods, ocular and point intercept, to measure total cover and the cover of individual species (%). I chose both methods as efficient sampling techniques suitable for extensive sampling. Ocular estimates were made, as a primary measure, on all sites by viewing the vegetation covering the sites, ignoring the underlying surface characteristics and estimating total cover and species by species cover (%).

A point intercept method (Evans and Love, 1957) was used to calibrate the ocular cover estimates. On plot edges perpendicular to the roadbed, I placed two survey flags dividing the plot edge into thirds. I paced two lines parallel to the roadbed, each from one survey flag to its opposite flag. I obscured my feet with a clipboard to prevent me from selecting sampling points. At each step the species intercepted by a point on my boot tip was recorded. The number of intercepts for each plant species divided by the total number of steps (~100) established the percent cover for the individual species. The sum gave the total cover for the site.

Ocular estimates were adjusted to accommodate point intercept measurements. The discrepancy between the two measurement techniques decreased with experience. Early in the season, point counts were made daily and often at each site. With experience the need for pacing was reduced. At mid-season point estimates were done only at the beginning of the week and on any site where an ocular estimate seemed difficult. Late in the season point counts were made only at the beginning of the week.

Unknown plants were present at many sites. Individuals of these species were collected, pressed, and identified later in the MSU Herbarium. Data for these species were incorporated after the identifications were completed. I found two hundred and eleven species on the roadsides (Appendix B) and selected 50 species for analysis (Appendix C). Of the species chosen, 46 species occurred in at least 10% of the sites in one environmental type, 3 were borderline species (9% occurrence) of interest, and one, *Bouteloua gracilis*, is an important component of dry grasslands.

Environmental Correlates of Vegetation

Climate Data

Mean annual precipitation and mean July temperature were chosen as indices of growing season temperature and water availability. Climate for each location was read from MAPS ATLAS (Caprio et al., 1990) using latitude and longitude reference points. MAPS ATLAS gives an array of other soil, climate and vegetation data for three square mile polygons throughout Montana. Climate data for North Dakota were interpolated from climate maps (NOAA, 1974).

Physical Environment

Five landscape characteristics were recorded on each plot. Adjacent land use (range, crop, forest or residential) was observed. Plot position (inslope, backslope) was recorded. Aspect (north-, south-, east- and west-facing) was measured with a compass. Percent slope(0-1%, 2-5%, 5-10%, 10-25%, 25% and above) was an ocular estimate.

Erosion was indicated by the amount of hummocking, number of rills, the number of gullies, and the presence of slumps. Hummocks are the result of soil erosion between grass clumps, creating pedestals. The amount of hummocking was measured in three categories, none, slight and extreme. Rills are eroded trenches less than 30 cm across. The number of rills in each site was counted and placed in one of three categories, 0, 1-5, 6 or more. Gullies are large rills, 30 to 50 cm across. The number of gullies in each site

was counted and placed in three categories, 0, 1-5, 6 or more. A slump or backcut is large movement of soil and rock down the backslope, undercutting the top of the slope. The presence or absence of a slump or backcut was noted at each site.

Roadside vegetation may be influenced by factors not analyzed due to time and financial limitations. These include three landscape variables, adjacent land use, slope and evidence of erosion and disturbance factors, herbicide and pesticide spraying, changes in seed mixtures and pollution.

Soil surface characteristics recorded at each site are exposed parent rock (%), surface rock (%), bare ground (%), basal vegetation cover (%) and ground litter (%). Each characteristic was measured with an ocular estimate, ignoring the over-lying vegetation. Surface rock was any loose rock greater than 1 cm in diameter. Bare ground was gravel and soil with particles less than 1 cm in diameter. Basal vegetation cover was the area of ground covered by the basal rosettes of the plant alone. Litter is any remaining dead organic material on the soil surface. This information may be analyzed at another time.

Soil Measurements and Laboratory Analysis

At each site I collected a soil sample to determine soil texture, pH, organic carbon and conductivity for correlation with plant performance. I used a spade to remove at least the top six inches of soil at three to five locations in the plot. Equal portions from each shovelful were mixed in a labeled ziplock bag. Soil collection was often difficult because

sites were compact, rocky, and with little soil development. In some cases, samples were small and had a little fine earth.

The soil samples were prepared for analysis by drying at 40 degrees centigrade, grinding, and sieving to remove coarse fragments ($>2\text{mm}$). Both fine and coarse portions of the sample were weighed and labeled separately. Percent soil and percent coarse fragments were calculated from these weights.

The MSU soil testing lab analyzed the samples for texture, organic carbon, pH and electrical conductivity on the fine earth portion of the soil samples. Soil texture is determined by the sand, silt and clay contents of the fine earth fraction. Clay content (particles less than 0.002mm) strongly influence water-holding capacity, and index a soils capacity to store winter moisture for summer use. Sand (particles $>0.05\text{mm}$ and $<2. \text{mm}$) is an index of a soil's permeability and its capacity to absorb summer rain. The MSU soil testing lab analyzed soil texture (% sand, silt and clay) with a modified hydrometer method. The soil was dispersed in a mixture of calgon and water to separate soil aggregates and blended to create a slurry. The differential settling by particle size allows estimation of the proportion of particles in each size class (Bouyoucos, 1962; Tan, 1996).

Soil organic matter is material derived from living or decomposing plant or animal tissues. It contributes to soil water-holding capacity and because it is a source of plant nutrients and binds cations, it is also an index of soil fertility. The MSU soil testing lab determined organic carbon (%) with a wet dichromic acid digestion (Walkley, 1947) followed by a measure of absorbence at $600\text{m}\mu$ (Sims and Haby, 1971). Organic carbon is

estimated from a standard curve relating absorbance at 600m μ to organic carbon content(%).

Most plants grow best in slightly acid soils because nutrients are most available at this pH (Tan, 1996). The MSU soil testing lab measured the pH of each soil sample on a slurry of one part soil to two parts water. The electrode was calibrated in a 7.0 buffer solution before use (McLean, 1982).

Salinity is due to the accumulation of salts in the soil and is indexed by electrical conductivity (Ellis and Mellor, 1995). The MSU soil testing lab measured conductivity on a slurry of one part soil and two parts water. The conductivity was determined using a temperature compensating conductivity meter (Rhoades, 1982).

Statistics

Correlation's between plant distribution and environmental factors were evaluated with three statistical techniques. The data set includes 370 sites, 50 plant species and 11 variables. A multitude of univariate tests were used to determine the effect of each variable on the distribution of each species. A Kruskal-Wallis non-parametric ANOVA (Box et al., 1978) was used to relate plant performance to categorical variables (environmental type and mean annual precipitation). A randomization test (Manley, 1991) was most appropriate for relating plant performance to the continuous variables (July temperature, water-holding capacity, clay, sand, organic carbon, pH, and salinity).

Interaction plots were used to evaluate the effects of plot position and aspect. All results were interpreted at the 0.05 alpha level.

A Kruskal-Wallis non-parametric analysis of variance (ANOVA) was used to determine the relationships between the plant distributions and the categorical variables, environmental type and mean annual precipitation. This test established which plant species varied among factor levels. Kruskal-Wallis p-values are presented in Appendix C. This test ranks all measurements within a category and the ANOVA was performed on the rankings not the actual data, making this test robust for non-normal data (Box et al., 1978). Because a Kruskal-Wallis test does not identify distinct factor levels, a pairwise comparison of all possible combinations of data were performed on the data to determine which levels had significant effects (Box et al., 1978). A multiple comparisons test performs a pairwise comparison on every paired combination of data and provides a p-value for each comparison. The resulting table of p-values (Appendix E) allows one to establish which categories are significantly different and which are not.

Kruskal-Wallis rankings are reported in all environmental type and precipitation graphs in Appendix A. The rank of the cover indicate the relative performance of the species across categories. These rankings are helpful for interpreting the differences determined by the multiple comparisons tests.

A Randomization test (Manley, 1991) was used to evaluate the relationships between the continuous variables (mean July temperature, water-holding capacity, clay, sand, organic carbon, pH and conductivity), and each plant species. This test compared conditions on which each plant was growing with the conditions of all roadside sites.

The randomization test has three stages. First, from the original 370 sites, I drew, with replacement, a random sample equal to the number of sites on which the plant species occurred and calculated the mean. This process was repeated 1000 times. This stage created a distribution of 1000 randomly generated means of the variable considered. Second, I calculated the variable mean for a plant species. Then I calculated the critical values of a 95% confidence interval for the distribution of 1000 means. Third, I compared the mean of the variable where the plant species grew with the critical values to determine whether the species mean fell within the confidence interval. If the plant mean fell outside the 95% confidence interval we determined the plant's distribution to be significantly affected by the factor rather than by random variation. Appendix F gives means for all species across all randomized variables. The graphs in Appendix A compare species distributions on each factor with the overall distribution of that factor.

Plot position and aspect are highly correlated. For this reason I cannot distinguish the effect of plot position from that of aspect. These variables are discussed qualitatively using interaction plots.

My sampling procedure was designed to cover a large, variable area quickly and consequently two characteristics require comment. First, the sampling design lacks any formal randomness, thereby restricting the use of many statistical tests. Classical statistical tests, such as the Kruskal-Wallis ANOVA, are inappropriate due to the lack of an underlying probability model provided by random sampling. Second, I did a large number of comparisons to establish differences between groups. No correction factor such as a Bonferonni correction factor, was used to treat resulting probabilities more conservatively

to account for random significant results. Therefore where p-values, or other significant results appear they highlight differences but do not indicate actual probabilities.

RESULTS AND DISCUSSION

Two hundred and eleven species were found on Montana roadsides (Appendix B). These species either were planted or colonized from other sources. Colonizers can be desirable native species, noxious exotic weeds or perhaps desirable exotic species. We seek to identify strong native colonizers for use in future plantings. Correlation's between species establishment and the environments in which they establish can be used to refine recommendations for planting by indicating where that species is most likely to succeed.

Species Selected for Analysis

I selected 50 species for analysis (Appendix C). Of these, 46 species occurred in at least 10% of the sites in one environmental type, three species occurred in 9% of the sites. *Bouteloua gracilis* is infrequent but included because it is an important component of dry grasslands. Twenty nine of the species, 13 grass and 16 forb, are native. The native species may be useful for roadside reclamation. Twenty one of the species chosen, 9 grass and 13 forb species, are exotic. Exotic grass species can be useful in reclamation especially if the threat to adjacent vegetation is limited. Exotic forb species are weedy and some, such as *Centaurea maculosa*, considered noxious. Highly invasive weedy exotic species are, of course, not recommended for roadside reclamation.

Richness of Roadside Communities

We evaluated richness in roadside communities by comparing the number of constant species in an environmental type with the number of constant species in native vegetation occupying the same environmental type. Table 2 contains comparisons between roadside communities (bold) and similar native communities (indented). Roadside stands had an average of 7 constant species (constancy > 25%) whereas similar native stands had an average of 22 constant species (Table 2). Compared to native communities, roadside communities in grassland environments have fewer grass species, far fewer composite species and more legumes (Table 2). Roadside communities in forest environments lack the tree and shrub species that predominate in native forest communities. More grass species and fewer forb species occur in the understories of roadsides communities than in native forest communities growing in the same environments. Overall, roadside communities have fewer species in every category than do native communities (Table 2). Thus, roadside communities are depauperate in terms of constant species (Table 2).

Table 2. Number of Constant (constancy >25%) Species in Roadside and Native Communities across Montana.

Type	Tree	Shb ^A	Grs ^B	Cmp ^C	Cruc ^D	Forb Lgm ^E	Othr	Ttls ^F
ANSC ¹	0	1	4	1	0	2	0	8
BOGR ¹	0	2	4	1	0	2	0	9
STCO ²	0	5	8	2	0	1	3	19
STCO/AGSM ²	0	4	12	6	0	2	6	30
AGSP ¹	0	0	7	1	0	1	0	9
AGSP/BOGR ²	0	7	6	6	0	1	6	26
AGSP/BOGR/LIPU ²	0	3	10	11	0	1	7	32
AGSP/AGSM ²	0	4	9	11	0	1	7	32
AGSP/AGSM/STVI ²	0	7	12	19	0	4	15	57
AGSP/POSA ²	0	4	5	9	0	3	9	30
AGSP/POSA/STCO ²	0	6	7	11	1	2	18	45
PIPO ¹	0	0	5	1	0	1	1	8
PIPO/AGSP ³	3	3	2	1	0	0	0	9
PIPO/FEID ³	3	3	2	1	0	0	0	9
PIPO/SYAL ³	3	4	3	1	0	0	1	12
PSME ¹	0	0	7	1	0	1	0	9
PSME/AGSP ³	4	4	2	1	0	0	1	12
PSME/FEID ³	2	1	2	2	0	0	0	7
PSME/SYAL/AGSP ³	2	5	5	2	0	0	0	14
PSME/SYAL/SYAL ³	3	9	3	2	1	0	4	22
PSME/PHMA/PHMA ³	2	6	2	1	1	0	3	15
PSME/CARU/CARU ³	2	6	2	1	1	0	3	15
PSME/CAGE ³	4	4	3	2	1	0	3	17
PSME/SPBE ³	4	7	5	2	0	0	4	22

¹ Environmental types used in this document, ² from Mueggler & Stewart (1980), ³ from Pfister et al. (1977), ^A Shb=Shrub species, ^B Grs = Grass species, ^C Cmp = Composite species, ^D Crus = Crucifers, ^E Leg = Legumes, ^F Tls = Totals.

Roadside communities in Montana have very few species with high cover. In roadside communities, 3% of all species found have cover greater than 50 %, 19% of all species have cover of 10-50%, the remaining 77% of species have cover of less than 10%.

Almost identical observations were made on roadsides in Europe (Schmidt, 1989). In

both cases roadside communities are characterized by very low numbers of high presence species and high numbers of low presence species.

Response of Individual Species to Environmental Conditions

Plants likely to be successful in an environment are those which establish in that environment. Most species displayed some specialization for climate, soil or topographic factors. Exceptions are *Gaura coccinea* and *Symphoricarpos albus*. Appendix A summarizes the response of 50 species to eleven environmental variables. Appendices D and E contain p-values establishing the difference between groups and Appendix F contains means of randomized variables.

Environmental Type

Twenty-six species have significantly ($p < 0.05$) higher cover (%) in at least one environmental type (Table 3 and Appendices D and E). Individual reports for each species are summarized in Appendix A. Twenty-four species, 14 native and 10 exotic had similar ($p > 0.05$) cover in all environmental types (Appendices A and D).

Species with high ($p < 0.05$) cover in one or several types and their origin (native or exotic) are listed in Table 3. Species designated with an A have highest cover in that type. Native species abundant in the ANSC type are *Dalea purpurea*, and *Stipa viridula* (Table 3). Exotic species abundant in the ANSC type are *Avena sativa*, *Lactuca serriola*, *Bromus inermis* and *Poa pratensis* (Table 3). Five native species, *Agropyron smithii*,

Artemisia frigida, *Hordeum jubatum*, *Koeleria nitida* and *Stipa viridula*, and five exotic species, *Agropyron cristatum*, *Agrostis stolonifera*, *Bromus tectorum*, *Poa pratensis*, and *Thlaspi arvense* have high cover in the BOGR type. Five native species, *Achillea millefolium*, *Agropyron dasystachyum*, *Artemisia frigida*, *Festuca scabrella*, and *Stipa comata*, and five exotic species *Bromus tectorum*, *Dactylis glomerata*, *Kochia scoparia*, *Melilotus offincinalis*, and *Poa pratensis*, have high cover in the AGSP type. Three native species *Agropyron dasystachyum*, *Festuca idahoensis* and *Festuca ovina* and four exotic species, *Bromus tectorum*, *Dactylis glomerata*, *Poa compressa*, and *Phalaris arundinacea* have highest cover in the PIPO type. In the PSME type, two native species, *Agropyron dasystachyum* and *Stipa viridula*, and five exotic species, *Dactylis glomerata*, *Melilotus offincinalis*, *Phalaris arundinacea*, *Poa pratensis*, and *Thlaspi arvense*, are most abundant.

Many of the species mentioned above have highest cover in only one type while others perform best in several types. Species with high cover in more than one type are presumed to have broader tolerances and should allow more latitude to land managers.

Table 3. Plant Species with Significant ($p < 0.05$) Differences of Cover (%) between Environmental Types. Types sharing a letter do not significantly differ. Appendix A presents underlying data for each species and Appendix D and E establish differences between groups.

	Origin	Environmental type				
		ANSC	BOGR	AGSP	PIPO	PSME
Avsa ^A	E	A	B	B	B	B
Lase	E	A	B	B	B	B
Dapu	N	A	B	B	B	B
Brin	E	A	BC	BC	C	AB
Stvi	N	A	A	B	B	A
Popr	E	A	A	A	B	A
Thar	E	AB	A	B	AB	A
Arfr	N	B	A	A	AB	AB
Agcr	E	B	A	B	C	C
Agsm	N	B	A	B	B	B
Agst	E	B	A	B	B	B
Hoju	N	B	A	B	AB	B
Koni	N	B	A	B	B	AB
Brte	E	B	A	A	A	AB
Meof	E	B	AB	A	AB	A
Stco	N	BC	AB	A	C	BC
Kosc	E	B	B	A	B	B
Fesc	N	B	B	A	B	B
Acmi	N	C	B	A	BC	AB
Dagl	E	B	B	A	A	A
Agda	N	C	B	A	A	A
Poco	E	C	C	B	A	BC
Feov	N	D	CD	BC	A	B
Feid	N	C	C	BC	A	AB
Phar	E	B	B	B	A	AB
Phpr	E	B	B	B	AB	A

^A Refer to Appendix B for species acronym.

Temperature

Another component of environment is growing season temperature. We indexed growing season temperature with mean July temperature. Average July temperature was 18.8°C and significantly affected the distribution of 19 species. Native species thriving on sites with mean July temperature above 18.8°C are *Agropyron smithii*, *Artemisia frigida*, *Bouteloua gracilis*, *Heterotheca villosa*, *Lupinus argenteus* and *Hordeum jubatum* (Table 4). Exotic grass and forbs growing on warm sites are *Agropyron cristatum*, *Avena sativa*, and *Medicago sativa* (Table 4). Many of these species are abundant in the BOGR type. Native species thriving on sites with mean July temperature significantly ($p < 0.05$) less than 18.8°C are *Agropyron dasystachyum*, and *Festuca idahoensis* (Table 4). Exotic species growing on cool sites are *Dactylis glomerata*, *Medicago polymorpha*, *Phalaris arundinaceae*, *Phleum pratense*, *Poa pratensis*, *Trifolium hybridum*, and *Verbascum thapsus*. Many of these species are abundant in either the PIPO, PSME or both types. Thirty-one species, 19 native and 12 exotic, had similar ($p > 0.05$) cover in cool and warm sites.

Table 4. Species Thriving on Sites with Mean July Temperature Significantly Different from the Mean for all Sites (18.8°C). Appendix A presents underlying data for each species

	Origin ^A	Habit ^B	Mean J temp
Species with means greater than 18.8°C			
<i>Bouteloua gracilis</i>	N	G	20.0
<i>Artemisia frigida</i>	N	F	19.8
<i>Avena sativa</i>	E	G	19.8
<i>Medicago sativa</i>	E	F	19.8
<i>Heterotheca villosa</i>	N	F	19.6
<i>Agropyron cristatum</i>	E	G	19.6
<i>Hordeum jubatum</i>	N	G	19.4
<i>Agropyron smithii</i>	N	G	19.2
Species with means less than 18.8°C			
<i>Trifolium hybridum</i>	E	F	14.4
<i>Medicago polymorpha</i>	E	F	16.1
<i>Pinus ponderosa</i>	N	T	16.5
<i>Centaurea maculosa</i>	E	F	16.9
<i>Lupinus argenteus</i>	N	F	17.1
<i>Verbascum thapsus</i>	E	F	17.1
<i>Festuca idahoensis</i>	N	G	17.3
<i>Phalaris arundinaceae</i>	E	G	17.3
<i>Poa compressa</i>	E	G	17.5
<i>Agropyron dasystachyum</i>	N	G	17.7
<i>Dactylis glomerata</i>	E	G	17.7
<i>Phleum pratense</i>	E	G	17.7

^A Origin = exotic(E) or native (N). ^B Habit = grass (G), forb (F) or tree (T)

Precipitation

Another component of environmental condition is precipitation. I used mean annual precipitation and significantly affected the distribution of nineteen species (Table 5). Appendix A shows the distribution of each species against the precipitation in all sites. Appendices D and E give p-values establishing differences between groups. Thirty-one

species do not have cover significantly ($p > 0.05$) higher in any category (Appendices A and D)

Table 5. Distribution of Species across Precipitation Categories. Species performance does not significantly ($p < 0.05$) differ among regimes sharing a letter. * Indicates category with highest mean cover. Appendix A presents underlying data for every species. Appendices D and E give p-values establishing differences between precipitation levels.

name	Precipitation categories (cm)								
	20-25	25-30	30-35	35-40	40-45	45-50	50-75	75-100	100-150
Mepo ^A	*A	B	B	B	B	B	B	B	B
Bogr	*A	B	C	BC	C	BC	C	BC	BC
Spco	*A	B	BC	C	BC	BC	C	BC	BC
Syal	*A	C	C	C	C	AB	C	B	B
Agcr	*A	AB	CD	BC	E	E	E	E	BDE
Meof	*A	CE	CD	BDE	CE	AD	BDE	AC	AB
Cema	*A	BC	CD	CD	CD	CD	D	AC	AB
Veth	*A	C	C	BC	BC	BC	C	BC	AB
Koni	AD	AB	BCD	BD	CD	AD	CD	AD	*A
Stco	AB	AC	BD	BC	DF	CDE	EF	CDE	*A
Agsm	BC	A	A	BCD	C	AB	BC	AC	*AD
Brin	E	BDE	A	CB	ABC	AC	BDE	D	*ABC
Dagl	BD	D	D	D	*A	AB	BC	ACD	BD
Agda	ADE	BE	BE	E	A	AC	BCD	*AB	DE
Phpr	BCE	DE	DE	BCE	AC	AE	A	*ABD	BE
Feov	AD	D	D	BD	BCD	A	AC	*AB	AD
Feid	CD	CD	D	CD	CD	B	C	*A	CD
Phar	BC	C	BC	C	C	BC	B	*A	BC
Trhy	BC	C	C	C	C	BC	B	BC	*A

^A Refer to Appendix B for species names and acronyms.

Plants adapted to relatively dry or moist conditions are listed in Table 5. Native species adapted to dry (8-10cm) roadsides are *Bouteloua gracilis*, *Symphoricarpos alba*, and *Sphaeralcea coccinea*. Exotic species with cover (%) higher on dry sites are *Verbascum thapsus*, *Agropyron cristatum* and *Medicago polymorpha*. One exotic

species, *Dactylis glomerata* is adapted to sites with moderate precipitation of 40-50cm. Native species abundant on moist (75-100 cm) sites are *Festuca ovina* and *Festuca idahoensis*. Three exotic species, *Phalaris arundinaceae*, *Bromus inermis*, *Phleum pratense* and *Trifolium hybridum* are adapted to moist sites. The remaining species in Table 5 are abundant in particular categories but show no clear pattern of distribution among species.

Soil Water-Holding Capacity and Clay Content

The availability of water for growth is affected by soil water-holding capacity as well as climate because the impact of a drought period is buffered by water stored in the soil. Soil water-holding capacity is largely determined by, and may be calculated from, its clay and organic matter content.

Twelve species occupied sites with either a higher or lower than average soil water-holding capacity. Average water-holding capacity for all sites is 8.4%. One native plant, *Artemisia frigida*, is adapted to sites with high water-holding capacity (Table 6). Exotic species adapted to these sites are *Agropyron cristatum*, *Medicago sativa* and *Thlaspi arvense* (Table 6).

Similarly, *Agropyron smithii*, *Artemisia cana*, *Artemisia frigida*, and *Opuntia polycantha* are native species found on sites with significantly higher than average soil clay content (Table 7). Exotic species found on high clay sites are *Agropyron cristatum* and *Medicago sativa* (Table 7). Thirty-eight species occurred on sites with both low and high

water holding capacity (Appendices A and D). Thirty-four species occurred on sites with both low and high clay content (Appendices A and D).

Table 6. Species Occupying Sites with Mean Soil Water-Holding Capacity (WHC) Significantly Different from the Mean for all Sites (8.4%). Appendix A presents underlying data for every species.

Name	Origin ^A	Habit ^B	Mean WHC
Species with mean greater than 8.4			
<i>Thlaspi arvense</i>	E	F	11.5
<i>Medicago sativa</i>	F	E	9.7
<i>Artemisia frigida</i>	F	N	9.6
<i>Agropyron cristatum</i>	G	E	9.3
Species with means less than 8.4			
<i>Centaurea maculosa</i>	F	E	5.1
<i>Verbascum thapsus</i>	F	E	5.2
<i>Phalaris arundinaceae</i>	G	E	5.5
<i>Dactylis glomerata</i>	G	E	5.6
<i>Festuca idahoensis</i>	G	N	5.6
<i>Poa compressa</i>	G	N	5.7
<i>Medicago polymorpha</i>	F	E	5.9
<i>Agropyron dasystachyum</i>	G	N	6.5
<i>Festuca ovina</i>	G	N	6.7
<i>Phleum pratense</i>	G	E	6.9
<i>Bromus tectorum</i>	G	E	7.5

^A Origin = exotic(E) or native (N). ^B Habit = grass (G), forb (F) or tree (T)

Native species growing on sites with lower than average water-holding capacity are *Agropyron dasystachyum*, *Festuca ovina*, and *Festuca idahoensis* (Table 6). Exotic species growing on sites with low water-holding capacity are *Bromus tectorum*, *Centaurea maculosa*, *Dactylis glomerata*, *Medicago polymorpha*, *Phalaris arundinaceae*, *Poa compressa*, *Phleum pratense*, and *Verbascum thapsus* (Table 6).

Native plants growing on sites with lower than average clay content are *Agropyron dasystachyum*, *Festuca idahoensis*, *Festuca ovina*, and *Pinus ponderosa* (Table 7).

Exotic species growing on sites with lower than average clay content are *Dactylis glomerata*, *Phalaris arundinaceae*, *Centaurea maculosa*, *Medicago polymorpha* and *Poa compressa* (Table 7).

Plants occupying sites with especially high water content are expected to occupy sites with high clay content because clay content is an important determinant of water-holding capacity. Similarly plants occupying sites with lower water-holding capacity are expected to occupy sites with low clay content. However the lists presented above are not parallel. Species that occupy sites with high clay but not high water-holding capacity, *Agropyron smithii*, *Artemisia cana*, *Medicago sativa* and *Opuntia polycantha*, may tolerate drought conditions due to low summer precipitation with high run off.

Table 7. Species with Mean Soil Clay Content Significantly Different than the Mean for all Sites (23.8%). Appendix A presents underlying data for every species.

Name	Origin ^A	Habit ^B	Mean
Species with means greater than 23.8			
<i>Opuntia polycantha</i>	N	F	30.1
<i>Artemisia cana</i>	N	F	28.4
<i>Medicago sativa</i>	E	F	27.5
<i>Artemisia frigida</i>	N	F	27.2
<i>Agropyron smithii</i>	N	G	26.5
<i>Agropyron cristatum</i>	E	G	26.2
<i>Agropyron dasystachyum</i>	N	G	18.2
Species with means less than 23.8			
<i>Pinus ponderosa</i>	N	T	12.7
<i>Centaurea maculosa</i>	E	F	13.2
<i>Festuca idahoensis</i>	N	G	15.2
<i>Phalaris arundinacea</i>	E	G	15.4
<i>Poa compressa</i>	E	G	15.8
<i>Medicago polymorpha</i>	E	F	16.1
<i>Dactylis glomerata</i>	E	G	16.3
<i>Agropyron dasystachyum</i>	N	G	18.2
<i>Festuca ovina</i>	N	G	19.7

^A Origin = exotic(E) or native (N). ^B Habit = grass (G), forb (F) or tree (T)

Sites with low clay but average water-holding capacity may support species that require high infiltration of summer rains such as, *Pinus ponderosa*. Similarly sites with significantly low water-holding capacity and average clay content may support species requiring rocky sites with high run off such as *Bromus tectorum*, and *Verbascum thapsus*

Soil Permeability

Sand and coarse fragments allow summer rain to penetrate the soil surface, reducing the effects of drought. I used soil sand content as an index to permeability.

Average sand content for all sites is 45.6%. Native plants associated with sand contents higher than 45.6% are *Agropyron dasystachyum*, *Festuca idahoensis*, and *Festuca ovina* (Table 8). Exotic species associated with high sand contents are *Dactylis glomerata*, *Phalaris arundinacea*, *Phleum pratense*, *Poa compressa*, *Centaurea maculosa*, *Medicago polymorpha*, and *Verbascum thapsus* (Table 8). Native species growing on sites with average sand content lower than 45.6% are *Agropyron smithii*, *Artemisia cana*, *Artemisia frigida*, *Artemisia tridentata*, *Dalea purpurea*, *Gutierrezia sarothrae* and *Opuntia polycnatha* (Table 8). Exotic species growing where soils contain lower than 45.6 % sand are *Agropyron cristatum* and *Medicago sativa* (Table 8). Thirty-two species occurred on sites with both low and high sand content (Appendices A and D)

Table 8. Species Growing on Sites with Mean Soil Sand Content Significantly ($p < 0.05$) Different from the Mean for all Sites (45.6%). Appendix A presents underlying data for every species.

Name	Origin ^A	Habit ^B	Mean
Species with mean greater than 45.6			
<i>Phalaris arundinacea</i>	E	G	59.2
<i>Centaurea maculosa</i>	E	F	58.7
<i>Poa compressa</i>	N	G	58.3
<i>Festuca idahoensis</i>	N	G	57.8
<i>Dactylis glomerata</i>	E	G	56.5
<i>Agropyron dasystachyum</i>	E	G	54.1
<i>Medicago polymorpha</i>	E	F	53.8
<i>Verbascum thapsus</i>	E	F	53.5
<i>Festuca ovina</i>	N	G	53.2
<i>Phleum pratense</i>	E	G	51.3
Species with means less than 45.6			
<i>Dalea purpurea</i>	N	F	29.8
<i>Opuntia polyacantha</i>	N	F	34.4
<i>Gutierrezia sarothrae</i>	N	F	35.6
<i>Artemisia tridentata</i>	N	F	36.7
<i>Artemisia cana</i>	N	F	39.6
<i>Artemisia frigida</i>	N	F	40.0
<i>Medicago sativa</i>	E	F	40.5
<i>Agropyron cristatum</i>	E	G	42.0
<i>Agropyron smithii</i>	N	G	42.4

^A Origin = exotic (E) or native (N). ^B Habit = grass (G), forb (F) or tree (T)

Fertility

Organic carbon indexes fertility because organic matter contains nitrogen, sulfur and phosphorus available on decomposition. In addition organic carbon has a high cation exchange capacity and therefore retains cations against leaching. Mean organic carbon was 2.7% for all sites. No roadside plants were significantly more abundant on sites with high organic carbon. Native plants found on sites with soil organic carbon averaging less

than 2.7% were *Festuca ovina*, *Gutierrezia sarothrae*, and *Opuntia polyantha* (Table 9).

One exotic species *Melilotus officinalis* was found on sites with low organic carbon.

(Table 9). The remaining 46 species are successful on sites with average organic carbon (Appendices A and D).

Table 9. Species Occupying Sites with Mean Soil Organic Carbon (OC) Content Significantly Lower than the Mean for all Sites (2.7%). Appendix A presents underlying data for every species.

Name	Origin ^A	Habit ^B	Mean OC
<i>Festuca ovina</i>	N	G	2.09
<i>Gutierrezia sarothrae</i>	N	F	1.96
<i>Melilotus officinalis</i>	E	F	2.39
<i>Opuntia polyantha</i>	N	F	1.77

^A Origin = exotic(E) or native (N). ^B Habit = grass (G), forb (F)

Soil pH, by indicating the chemical binding of nutrients, is another indicator of soil fertility. In the pH 6-9 range Fe, Bo, Mn, Cu and Zn become increasingly unavailable while N and P become increasingly unavailable above pH 8 (Daubenmire, 1974). Mean pH for all sites is 7.5. Two native species, *Artemisia frigida* and *Dalea purpurea*, occurred on sites with pH significantly greater than 7.5 (Table 10). One native species, *Lupinus argenteus* and three exotic species, *Alyssum alyssoides*, *Trifolium hybridum* and *Centaurea maculosa* occurred on sites with pH significantly less than 7.5 (Table 10).

Table 10. Species Occurring on Sites with Mean Soil pH Significantly Different than the Mean for all Sites (7.5). Appendix A presents underlying data for every species.

Name	Origin ^A	Habit ^B	Mean pH
Species with mean pH greater than 7.5			
<i>Dalea purpurea</i>	N	F	8.2
<i>Artemisia frigida</i>	N	F	7.7
Species with mean pH less than 7.5			
<i>Trifolium hybridum</i>	E	F	6.8
<i>Lupinus argenteus</i>	N	F	6.9
<i>Centaurea maculosa</i>	E	F	7.1
<i>Alyssum alysoides</i>	E	F	7.2

^A Origin = exotic(E) or native (N). ^B Habit = grass (G), forb (F)

Salinity

High salinity may reduce plant performance either on dry plains or along winter salted roads. Electrical conductivity is an index of salinity (Ellis and Mellor, 1995) Mean conductivity for all sites was 0.27 mmhos/cm. Native plants tolerant of high salinity were *Agropyron smithii*, *Artemisia cana*, *Heterotheca villosa*, *Koeleria nitida*, *Opuntia polycantha* and *Poa sandbergii* (Table 11). Exotic plants growing on saline sites were *Agropyron cristatum*, *Agrostis stolonifera*, and *Medicago sativa*. Native plants significantly more abundant on sites with lower than average salinity were *Agropyron dasystachyum*, *Festuca idahoensis*, *Festuca ovina* and *Pinus ponderosa* (Table 11). Exotic species unable to tolerate saline areas were *Centaurea maculosa*, *Medicago polymorpha*, *Phleum pratense*, *Poa compressa*, *Trifolium hybridum* and *Verbascum thapsus* (Table 11).

Table 11. Species with Mean Soil Conductivity (EC) Significantly Different than the Mean for all Sites (0.27mmhos/cm). Appendix A presents underlying data for every species.

Name	Origin	Habit	Mean EC
Species with mean EC greater than 0.27			
<i>Opuntia polycantha</i>	N	F	0.45
<i>Artemisia cana</i>	N	F	0.40
<i>Hordeum jubatum</i>	N	G	0.39
<i>Poa sandbergii</i>	N	G	0.37
<i>Koeleria nitida</i>	N	G	0.36
<i>Agrostis stolonifera</i>	E	G	0.36
<i>Heterotheca villosa</i>	N	F	0.35
<i>Medicago sativa</i>	E	F	0.34
<i>Artemisia frigida</i>	N	F	0.33
<i>Agropyron smithii</i>	N	G	0.33
<i>Agropyron cristatum</i>	E	G	0.32
Species with mean EC less than 0.27			
<i>Medicago polymorpha</i>	N	F	0.13
<i>Festuca idahoensis</i>	N	G	0.13
<i>Trifolium hybridum</i>	E	F	0.14
<i>Pinus ponderosa</i>	N	T	0.15
<i>Poa compressa</i>	N	G	0.15
<i>Centaurea maculosa</i>	E	F	0.15
<i>Verbascum thapsus</i>	E	F	0.17
<i>Festuca ovina</i>	N	G	0.19
<i>Agropyron dasystachyum</i>	N	G	0.21
<i>Phleum pratense</i>	E	G	0.22

^A Origin = exotic(E) or native (N). ^B Habit = grass (G), forb (F) or tree (T)

Plot Position and Aspect

Plot position (backslope and inslope) and aspect (N, S, E, W) were expected to influence plant distribution along roadsides. Mean plant cover for inslopes (adjacent roadbed) and backslope (adjacent native vegetation) was compared in interaction plots presented for individual species in Appendix F. *Artemisia frigida*, *Gaura coccinea*,

Heterotheca villosa and *Stipa comata*, all native species, were more abundant on backslopes than inslopes. The exotic species, *Bromus inermis*, *Dactylis glomerata*, and *Phalaris arundinacea* and one native species, *Poa sandbergii*, were more common on inslopes than backslopes.

Effects of aspect were analyzed by comparing mean cover of opposing aspects in interaction plots. *Achillea millefolium* had highest cover south-facing slopes.

Astonishingly no other species demonstrated higher cover on any other aspect.

CONCLUSIONS

The following conclusions can be drawn from this study.

1. Roadsides support depauperate communities, containing approximately half the number of species found in native communities occupying similar environments. Roadside communities are characterized by having few high presence species and many low presence species.
2. Twenty-eight native species are common (constancy greater than 10%) along Montana roadsides (Table 19). These species colonizing roadsides are good candidates for revegetation.
3. Twenty-two exotic species are common (constancy greater than 10%) along Montana roadsides. They include species intentionally introduced and invading species. While some exotic species are useful for management they may have undesirable impacts on the stability of roadside vegetation. Exotic species should be used with care to minimize impacts on adjacent farm or range land. Especially invasive noxious weeds can never be recommended for revegetation. This survey will help managers identify environments where undesirable exotic species are likely to be problematic.
4. I list species with higher occurrence in atypical levels of eleven environmental factors (pages 23-40, Appendix A) including, climate (temperature, precipitation), soil water conditions (water-holding capacity, clay, sand), soil fertility (organic carbon and pH), and salinity. These species are good candidates for planting in extreme conditions. Species growing poorly in these areas are especially bad candidates.

5. The response of each individual species to eleven environmental conditions is presented in Appendix A.

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APPENDICES

APPENDIX A. RESPONSE OF INDIVIDUAL SPECIES TO ELEVEN
ENVIRONMENTAL CONDITIONS

Introduction to Appendix A

The environmental data presented help managers identify species likely to establish under typical and a typical conditions. Environmental conditions likely to control the distribution of roadside plants are environmental type, July temperature, mean annual precipitation, soil water-holding capacity, clay, sand, organic carbon, pH, conductivity, slope and aspect.

Environmental data is displayed in graphical form. Histograms for the categorical variables environmental type and precipitation, indicate species performance across categories. Refer to page 21 for an explanation of statistical methods used to establish differences between categories. Mean rank is the average Kruskal-Wallis ranking for that category and is used to illustrate differences between groups. Frequency diagrams for temperature, water-holding capacity, clay, sand, organic carbon, pH and conductivity display the presence of the species at each level and the distribution of that variable across all roadside sites. If the distribution of that species occurrences is significantly different from the distribution of all roadside occurrences then the means are displayed in the upper right corner of the graph. Graphs for slope and aspect show the interacting effects of slope and aspect on mean cover. Acquisition, analysis, and application of this data is discussed in the methods and results sections of the text.

1. Origin, Duration and Habit: Species are characterized by Latin name, family and origin, duration, habit and vegetative reproduction. Exotic plants that sometimes are questionable in plantings are identified under origin. Perennial plants, most useful in planting are identified under duration. Grass, forb and shrub life forms and vegetative reproduction are identified under habit.

2. Environmental type: Refer to text (Pgs 8-11, 29-30) for an explanation of methods and results.

3. Temperature: Mean July temperature ($^{\circ}\text{C}$) is presented as an index for comparing growing season temperatures among environmental types.

4. Precipitation: Mean annual precipitation (cm) is used to compare precipitation among environmental types.

5. Water-holding capacity: WHC is calculated using the Decker equation, refer to page 19 for a description of methods. Fifteen bar WHC is the weight of water stored in a dry soil, expressed as a percent of the soils dry weight. 1/3 bar WHC (twice 15 bar) is a measure of the soils total water storage capacity. 1/3 bar WHC - 15 bar WHC indexes the amount of water a moist soil can deliver to plants.

6. Clay: Contribution to total soil (%). High clay is positively correlated with water storage capacity and negatively correlated with water infiltration.
7. Sand: Contribution to total soil (%). High sand is positively correlated with infiltration and negatively correlated with water storage.
8. Organic carbon: Contribution to total soil (%). Organic matter percent in approximately $1.82 \times \%OC$. Organic matter contributes to total soil WHC. Refer to Methods (p19) for an explanation of methods. It adds to soil fertility both through nutrient released from decomposition and through a high cation exchange capacity.
9. pH: A measure of acidity and an indicator of fertility. All nutrients are most available at pH 7 and most become less available when pH deviates significantly.
10. Conductivity: Electrical conductivity of a 2:1 suspension of soil in water. Indexes salinity.
11. Position: On the inslope (between shoulder and ditch) or on the backslope (on the roadcut above the ditch).
12. Aspect: Compass direction of the slope within 5 degree of north, south, east or west.

Achillea millefolium (Acmi)

yarrow

Asteraceae

Origin, Duration and Habit¹: Native Perennial Forb, not vegetatively reproducing.

Environmental Type²: Acmi cover (%) is highest in the AGSP and PSME types, lower in PIPO and BOGR types and lowest in the ANSC type (Fig. 4).

Temperature: Temperature does not differ between Acmi sites and average sites (Fig. 5A).

Precipitation: Acmi cover (%) does not differ among categories (Fig. 4).

Water-holding capacity: WHC does not differ between Acmi and average sites (Fig. 5B).

Clay: Clay does not differ between Acmi sites and average sites (Fig. 5C).

Sand: Sand does not differ between Acmi sites and average sites (Fig. 5D).

Organic carbon: OC does not differ between Acmi sites and average sites (Fig. 5E).

pH: pH does not differ between Acmi sites and average sites (Fig. 5F).

Conductivity: Conductivity does not differ between Acmi sites and average sites (Fig. 5G).

Position and Aspect: Acmi does not occur on east, west, or north-facing inslopes or backslopes. Mean percent cover is slightly higher on south-facing inslopes than south-facing backslopes (Fig. 5H).

¹ Refer to introduction (p52) for a description of each category. ² Significant category.

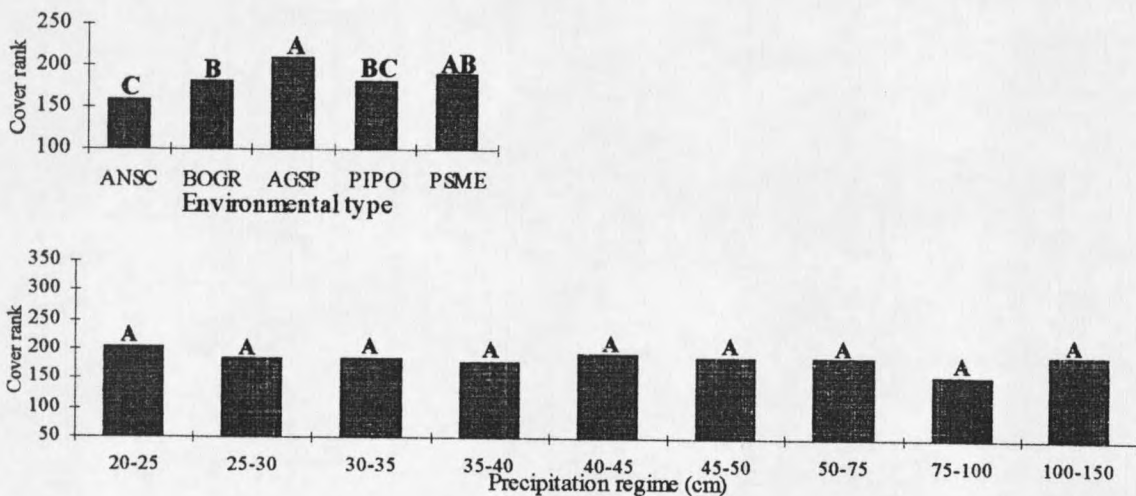


Figure 4. Effect of Environmental Type and Precipitation on Cover (%) of *Achillea millefolium*. Categories sharing a letter do not significantly ($p > 0.05$) differ.

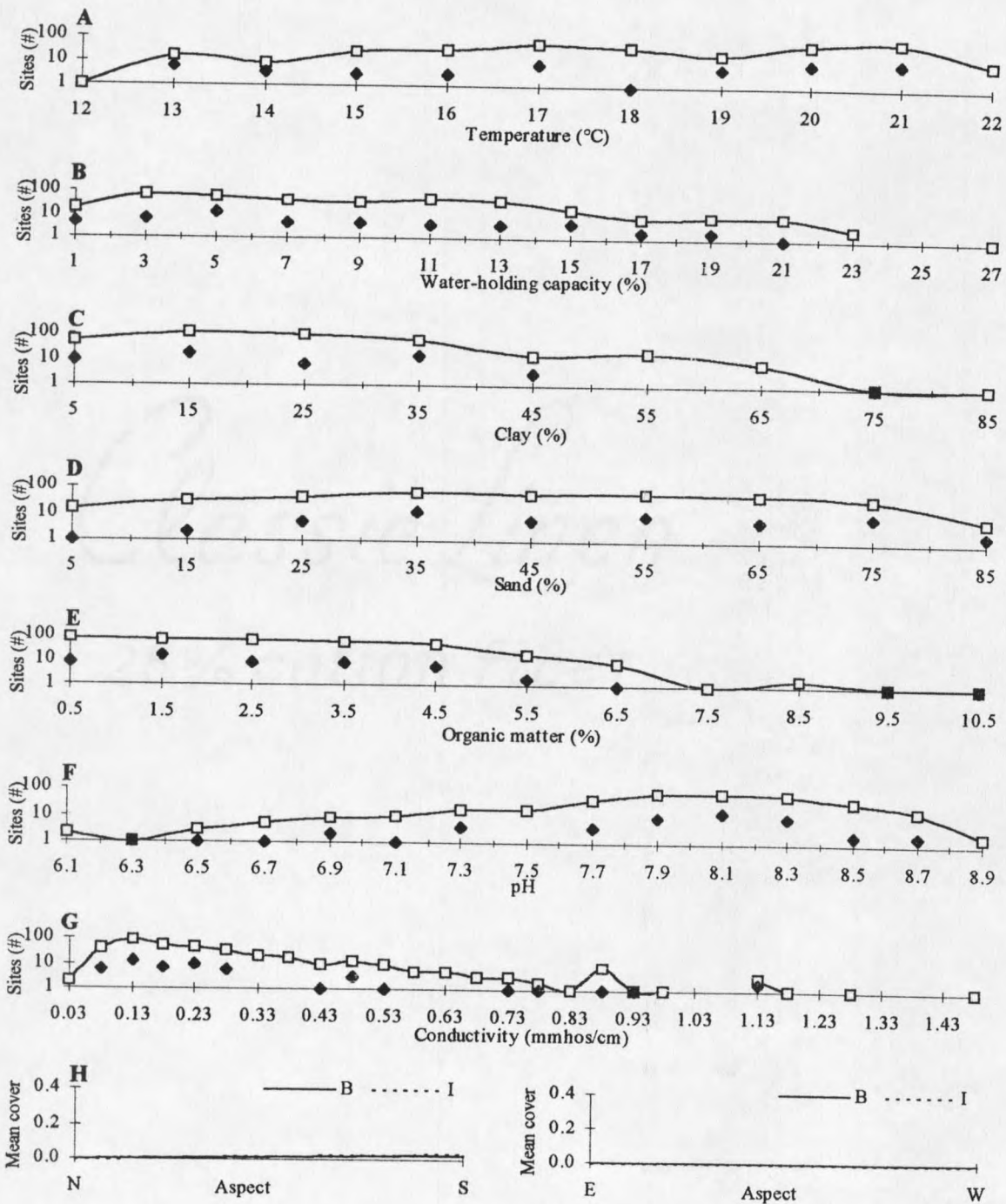


Figure 5. The Distribution of *Achillea millefolium* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Achillea millefolium* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Agropyron cristatum (Agcr)

crested wheatgrass

Poaceae

Origin, Duration and Habit¹: Exotic Perennial grass, not vegetatively reproducing.

Environmental Type²: Agcr cover (%) is highest in the BOGR type, lower in the ANSC and AGSP types, and lowest in PIPO and PSME types (Fig. 6).

Temperature²: Temperature is higher than in average sites (Fig. 7A).

Precipitation²: Agcr cover (%) tends to be higher on drier sites than in moist sites. Cover (%) is highest in 20-25cm. and 25-30cm (Fig. 6).

Water-holding capacity²: WHC in Agcr sites is higher than in average sites (Fig. 7B).

Clay²: Clay in Agcr sites is higher than in average roadside sites (Fig. 7C).

Sand²: Sand in Agcr sites is lower than in average roadside sites (Fig. 7D).

Organic carbon: OC does not differ between Agcr sites and average sites (Fig. 7E).

pH: pH does not differ between Agcr sites and average sites (Fig. 7F).

Conductivity²: Conductivity in Agcr sites is higher than average sites (Fig. 7G).

Position and Aspect: An interaction between aspect and plot position occurs for north and south-facing inslopes and backslopes. Percent cover for east-facing backslopes is higher than east-facing inslopes (Fig. 7H).

¹ Refer to introduction (p52) for a description of each category. ² Significant category.

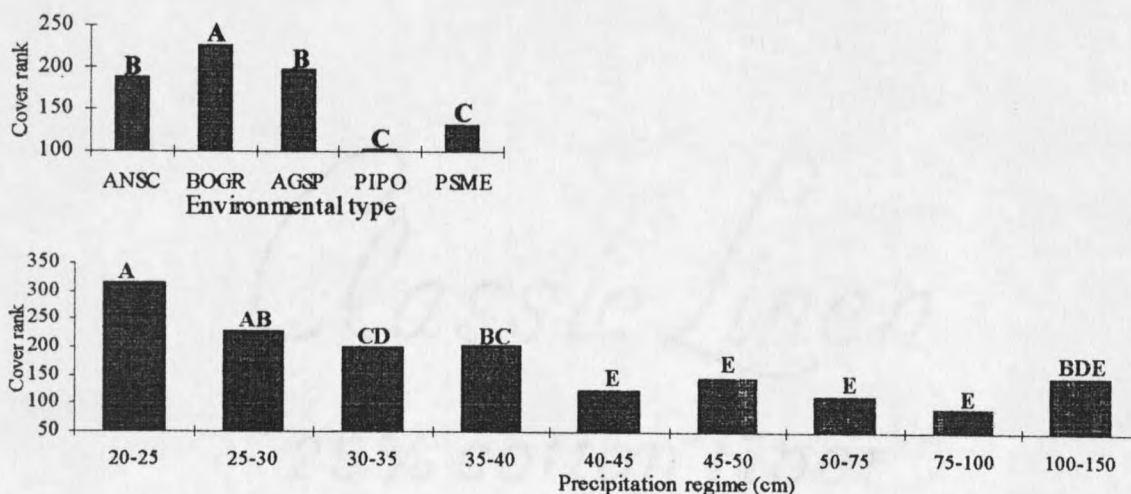


Figure 6. Effect of Environmental Type and Precipitation on Cover (%) of *Agropyron cristatum*. Categories sharing a letter do not significantly ($p > 0.05$) differ.

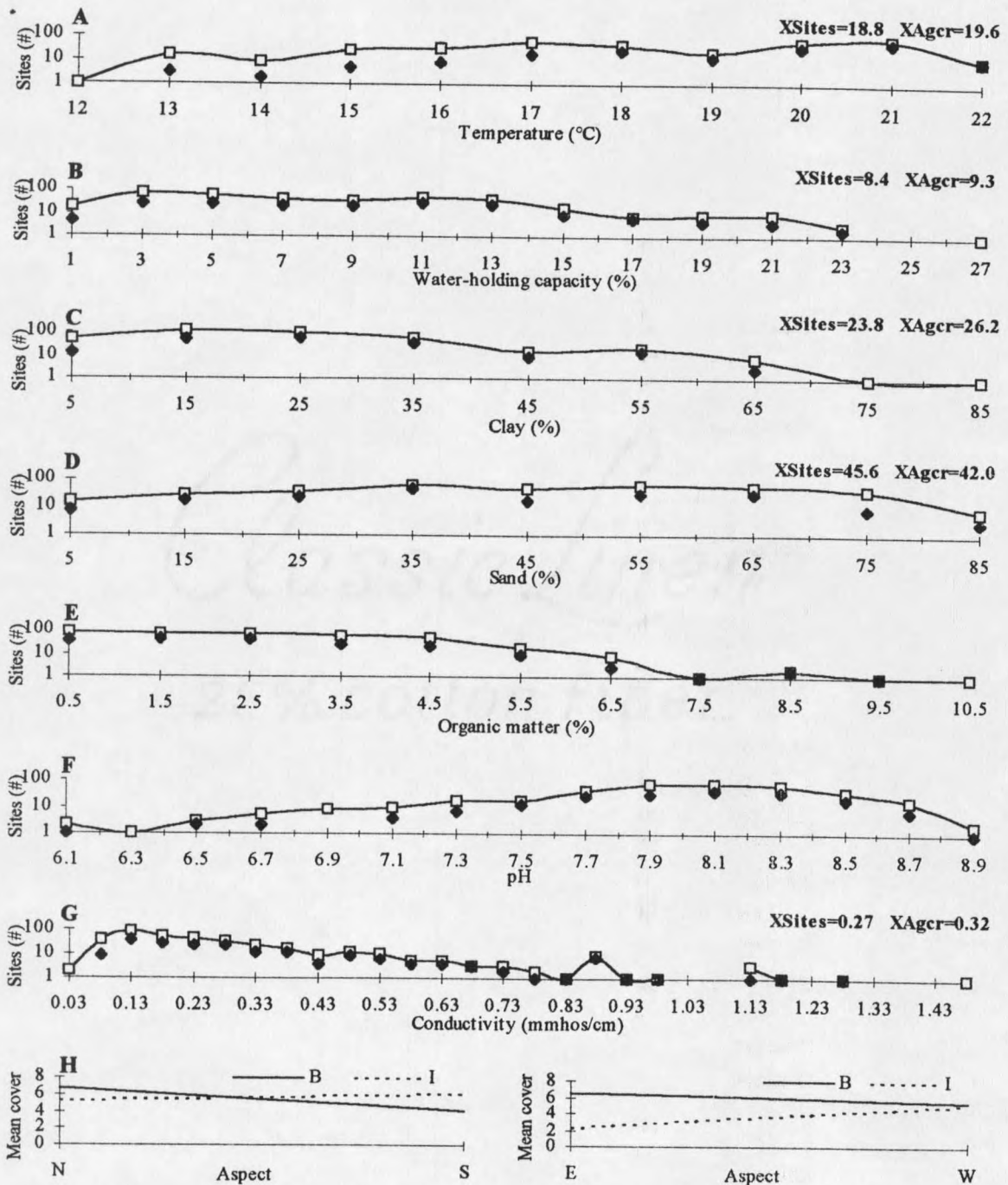


Figure 7. The Distribution of *Agropyron cristatum* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Agropyron cristatum* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Agropyron dasystachyum (Agda) thickspike wheatgrass Poaceae

Origin, Duration and Habit¹: Native Perennial Grass, vegetatively reproducing.

Environmental Type²: Agda cover (%) is highest in the PIPO, PSME and AGSP types and lowest in the BOGR and ANSC types (Fig. 8).

Temperature²: Temperature in Agda sites is higher than in average roadside sites (Fig. 9A).

Precipitation²: Agda cover is higher in moist (45-100 cm) sites than in dry sites (Fig. 8).

Water-holding capacity²: WHC of Agda sites is lower than average roadside sites (Fig. 9B).

Clay²: Clay in Agda sites is lower than average roadside sites (Fig. 9C).

Sand²: Sand in Agda sites is higher than average roadside sites (Fig. 9D).

Organic carbon: OC does not differ between Agda sites and average sites (Fig. 9E).

pH: pH does not differ between Agda sites and average sites (Fig. 9F).

Conductivity: Conductivity does not differ between Agda sites and average sites (Fig. 9G).

Position and Aspect: Mean Agda cover (%) is equal on north and west-facing inslopes and backslopes. Cover is higher on south and east-facing inslopes than backslopes (Fig. 9H).

¹ Refer to introduction (p52) for a description of each category. ² Significant category.

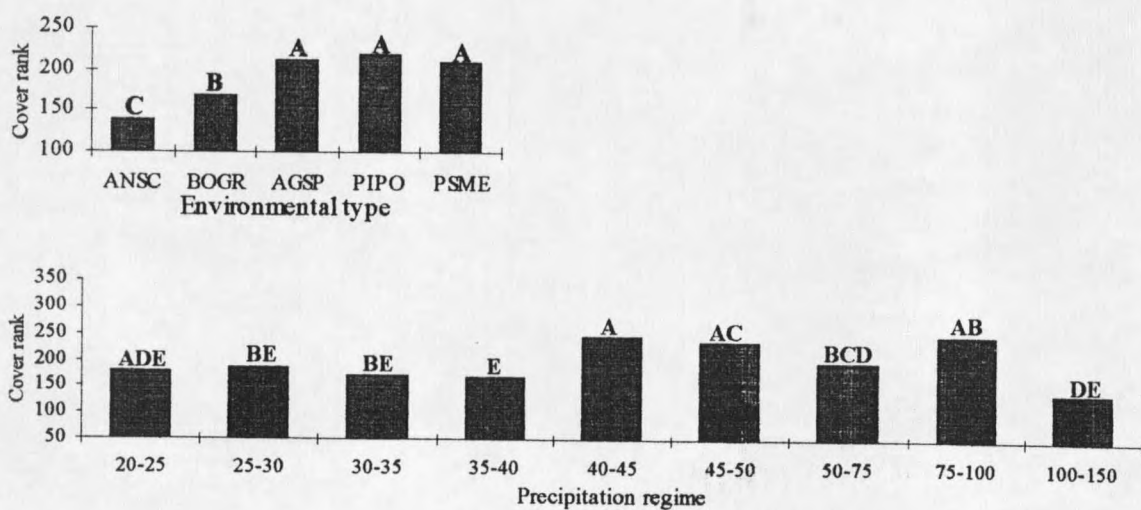


Figure 8. Effect of Environmental Type and precipitation on percent cover of *Agropyron dasystachyum*. Categories sharing a letter do not significantly ($p > 0.05$) differ.

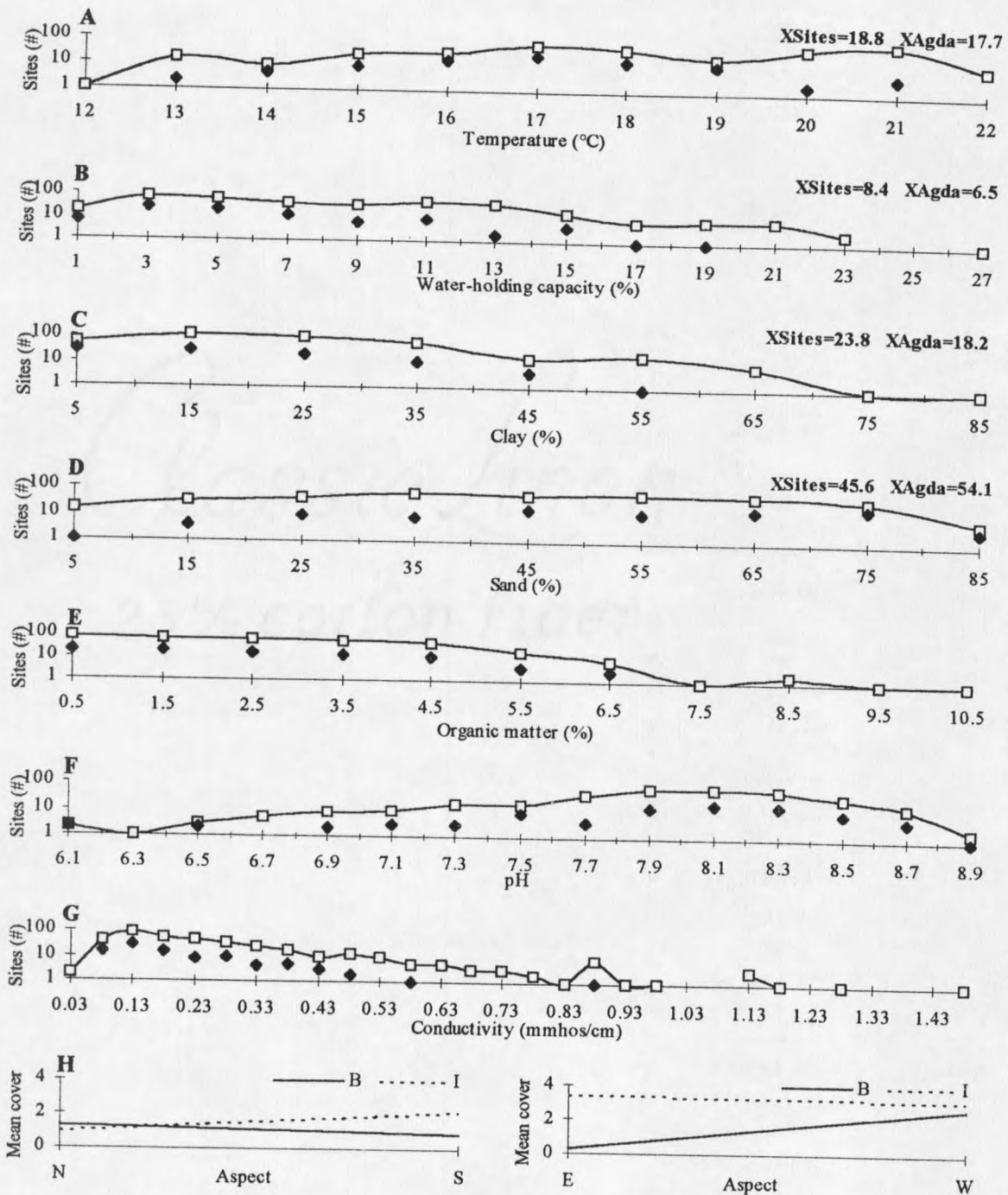


Figure 9. The Distribution of *Agropyron dasystachyum* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Agropyron dasystachyum* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Agropyron smithii* (Agsm)*western wheatgrass****Poaceae**

Origin, Duration and Habit¹: Native Perennial grass, vegetatively reproducing.

Environmental Type²: Agsm cover (%) is highest in the BOGR type than any other type (Fig. 10).

Temperature²: Temperature in Agsm sites is higher than average roadside sites (Fig. 11A).

Precipitation²: Agsm cover (%) is highest on moist sites (100-150 cm) (Fig. 10).

Water-holding capacity²: WHC does not differ between Agsm and average sites (Fig. 11B).

Clay²: Clay in Agsm sites is higher than in average roadside sites (Fig. 11C).

Sand²: Sand in Agsm sites is lower than in average roadside sites (Fig. 11D).

Organic carbon: OC does not differ between Agsm sites and average sites (Fig. 11E).

pH: pH does not differ between Agsm sites and average sites (Fig. 11F).

Conductivity: Conductivity in Agsm sites is higher than in average sites (Fig. 11G).

Position and Aspect: There is an interaction between plot position and aspect in north and south-facing inslopes and backslopes. Mean cover (%) is higher on east and west-facing backslopes than north and south-facing inslopes and backslopes (Fig. 11H).

¹ Refer to introduction (p52) for a description of each category. ² Significant category.

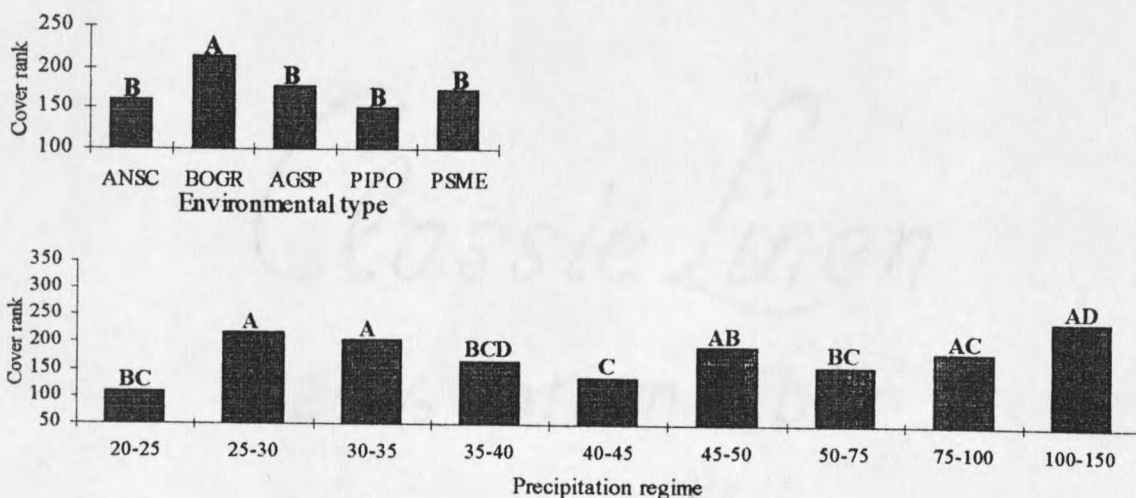


Figure 10. Effect of Environmental Type and Precipitation on Cover (%) of *Agropyron smithii*. Categories sharing a letter do not significantly differ.

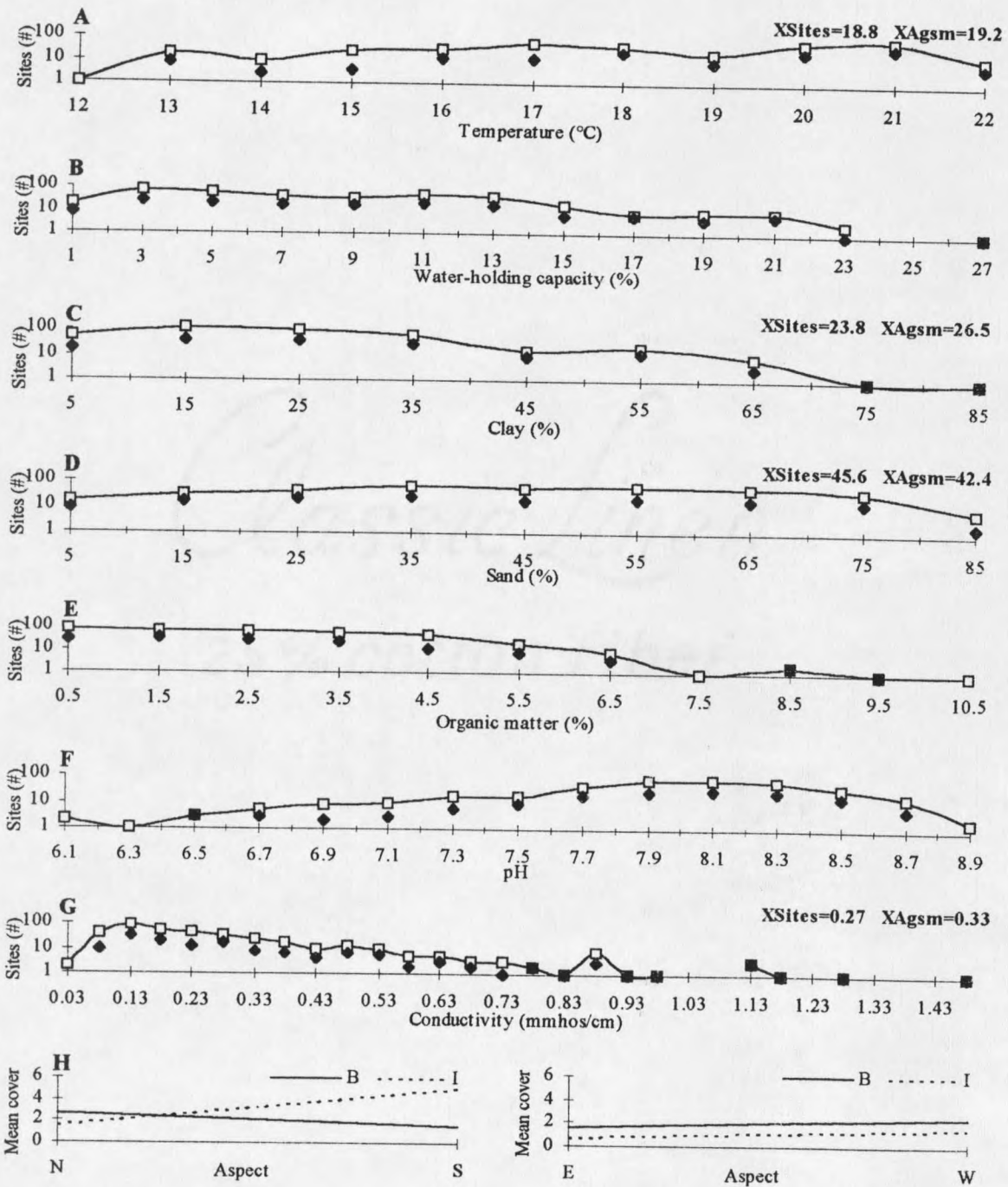


Figure 11. The Distribution of *Agropyron smithii* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Agropyron smithii* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Agropyron spicatum* (Agsp)*bluebunch wheatgrass****Poaceae**

Origin, Duration and Habit¹: Native Perennial Grass, not vegetative reproducing.

Environmental type: Agsm cover (%) does not differ among types (Fig. 12).

Temperature regime: Temperature in Agsp sites does not differ from average sites (Fig. 13A).

Precipitation: Agsp cover (%) does not differ among categories (Fig. 12).

Water-holding capacity: WHC does not differ between Agsp sites and average sites (Fig. 13B).

Clay: Clay does not differ between Agsp sites and average sites (Fig. 13C).

Sand: Sand does not differ between Agsp sites and average sites (Fig. 13D).

Organic carbon: OC does not differ between Agsp sites and average sites (Fig. 13E).

pH: pH does not differ between Agsp sites and average sites (Fig. 13F).

Conductivity: Conductivity does not differ between Agsp and average sites (Fig. 13G).

Position and Aspect: Mean cover (%) is higher on north and south-facing backslopes than inslopes. Mean cover is approximately equal on east and west-facing inslopes and backslopes (Fig. 13H).

¹ Refer to introduction (p52) for a description of each category.

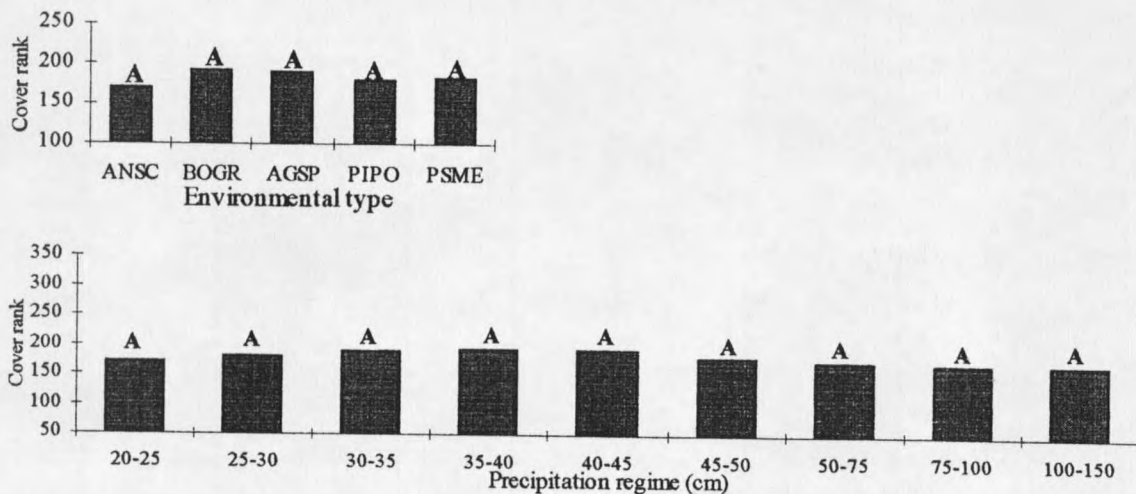


Figure. 12. Effect of Environmental Type and Precipitation on Cover (%) of *Agropyron spicatum*. Categories sharing a letter do not significantly differ.

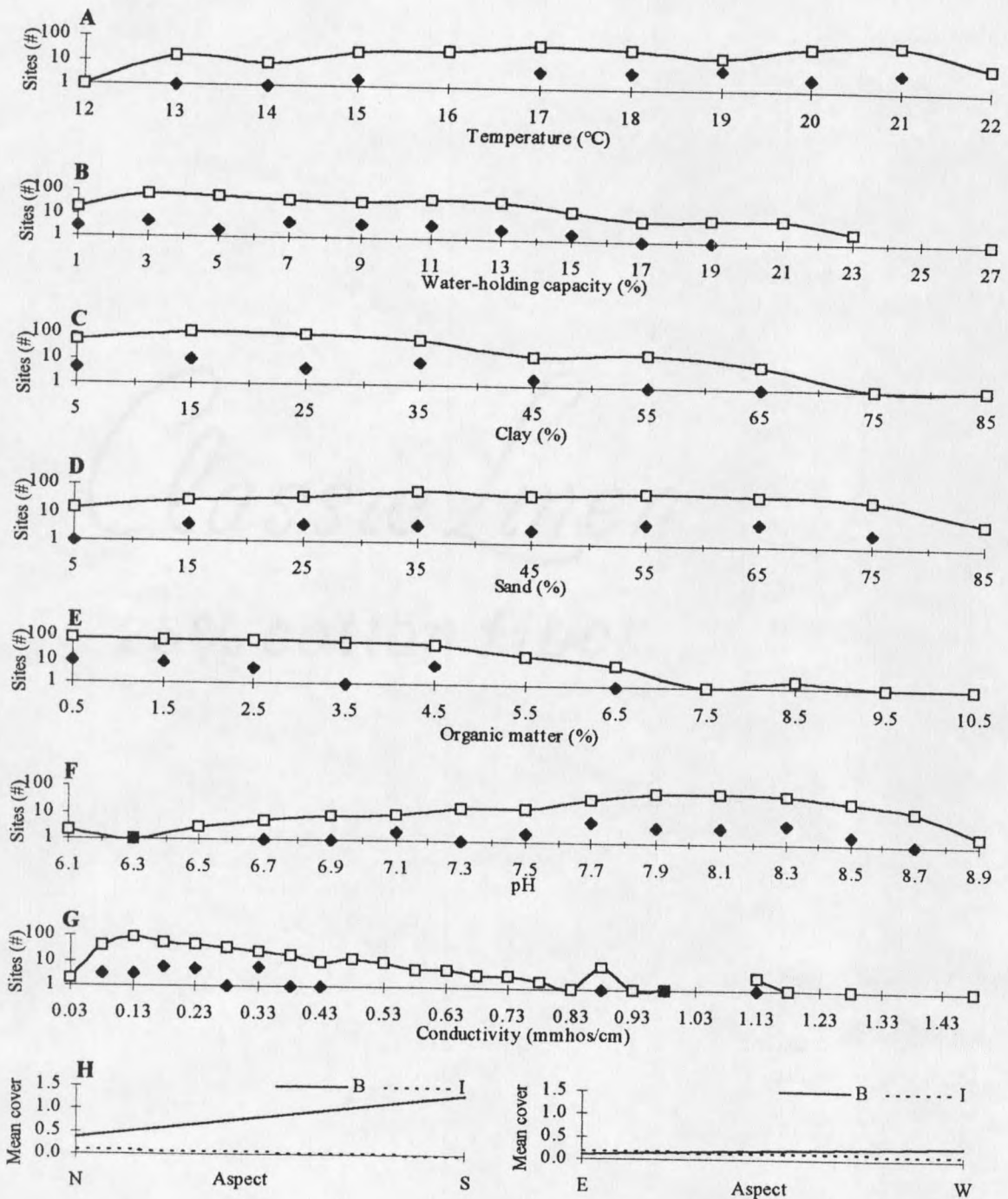


Figure 13. The Distribution of *Agropyron spicatum* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Agropyron spicatum* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Agrostis stolonifera (Agst)

redtop bent grass

Poaceae

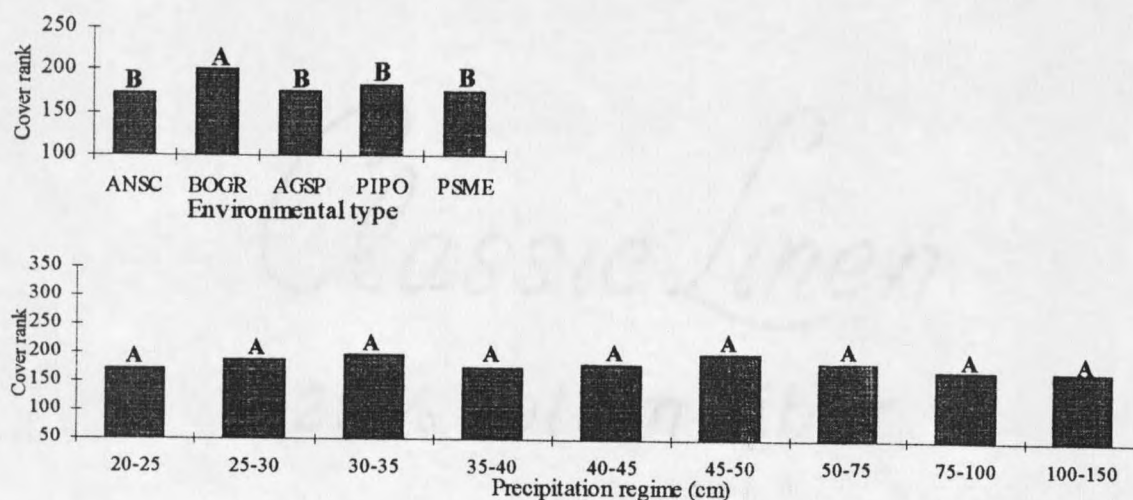
Origin, Duration and Habit¹: Exotic Perennial grass, vegetatively reproducing.Environmental Type²: Agst cover (%) is higher in the BOGR type than in any other type (Fig. 14).Temperature: Temperature does not differ between Agst sites and average sites (Fig. 15A).Precipitation: Agst cover (%) does not differ between moist and dry sites (Fig. 14).Clay: Clay does not differ between Agst sites and average sites (Fig. 15C).Sand: Sand does not differ between Agst sites and average sites (Fig. 15B).Water-holding capacity: WHC does not differ between Agst sites and average sites (Fig. 15D).Organic carbon: OC does not differ between Agst sites and average sites (Fig. 15E).pH: pH does not differ between Agst sites and average sites (Fig. 15F).Conductivity²: Conductivity is higher on Agst sites than average sites (Fig. 15G).Position and Aspect: Does not occur on south-facing backslopes or east facing inslopes. Mean cover (%) is highest on south-facing inslopes and west-facing backslopes (Fig. 15H).¹ Refer to introduction (p52) for a description of each category. ² Significant category.

Figure 14. Effect of Environmental Type and Precipitation on Cover (%) of *Agrostis stolonifera*. Categories sharing a letter do not significantly differ.

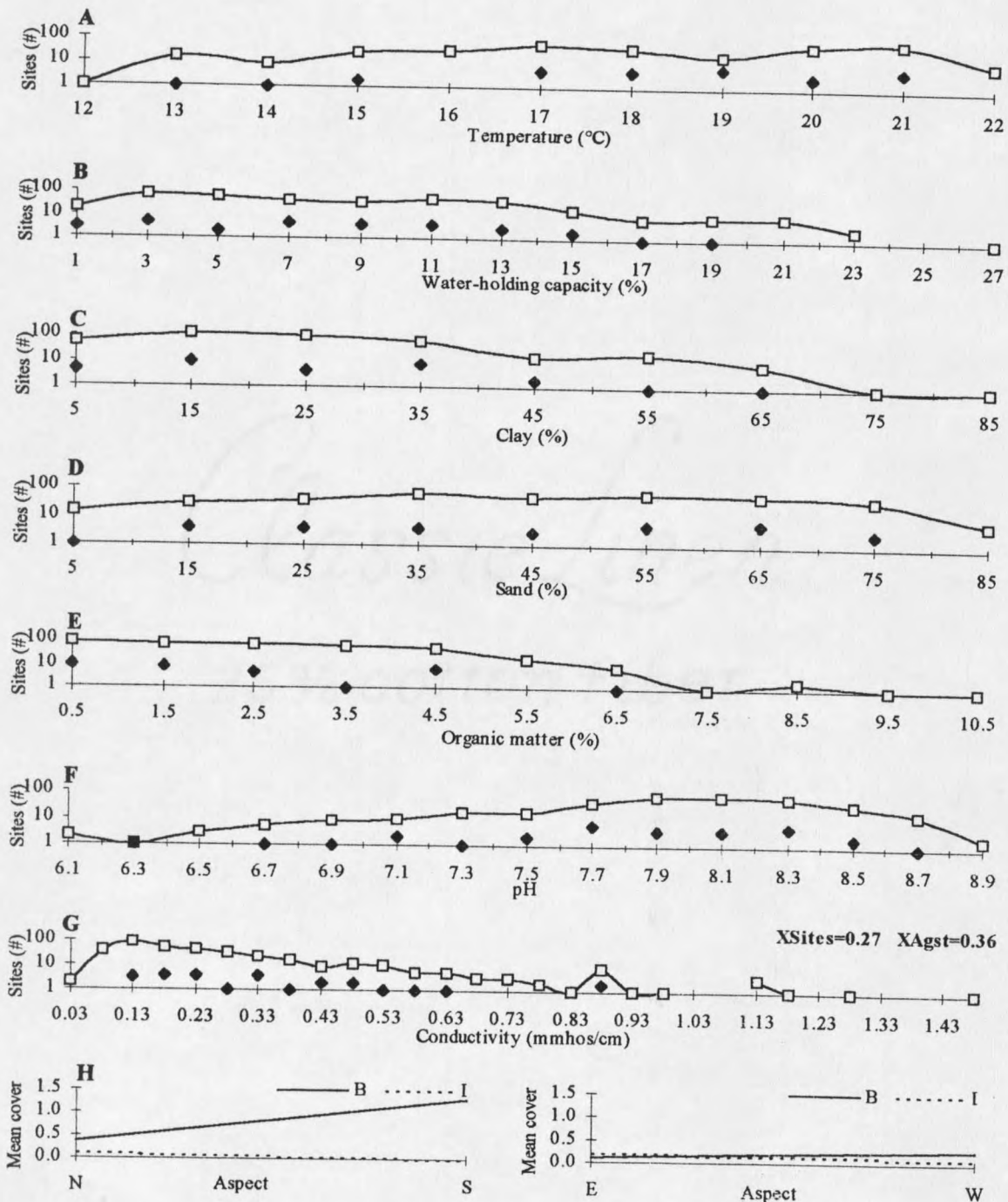


Figure 15. The Distribution of *Agrostis stolonifera* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Agrostis stolonifera* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Alyssum alyssoides (Alal)

pale alyssum

Brassicaceae

Origin, Duration and Habit¹: Exotic Annual Forb, not vegetatively reproducing.

Environmental type: Alal cover (%) does not differ between types (Fig. 16).

Temperature: Temperature does not differ between Alal sites and average sites (Fig. 17A).

Precipitation: Alal cover (%) does not differ between moist and dry sites (Fig. 16).

Water-holding capacity: WHC does not differ between Alal sites and average sites (Fig. 17B).

Clay: Clay does not differ between Alal sites and average sites (Fig. 17C).

Sand: Sand does not differ between Alal sites and average sites (Fig. 17D).

Organic carbon: OC does not differ between Alal sites and average sites (Fig. 17E).

pH²: pH in Alal sites is lower than average roadside sites (Fig. 17F).

Conductivity: Conductivity does not differ between Alal sites and average sites (Fig. 17G).

Position and Aspect: Occurs only on north-facing backslopes (Fig. 17H).

¹ Refer to introduction (p52) for a description of each category. ² Significant category.

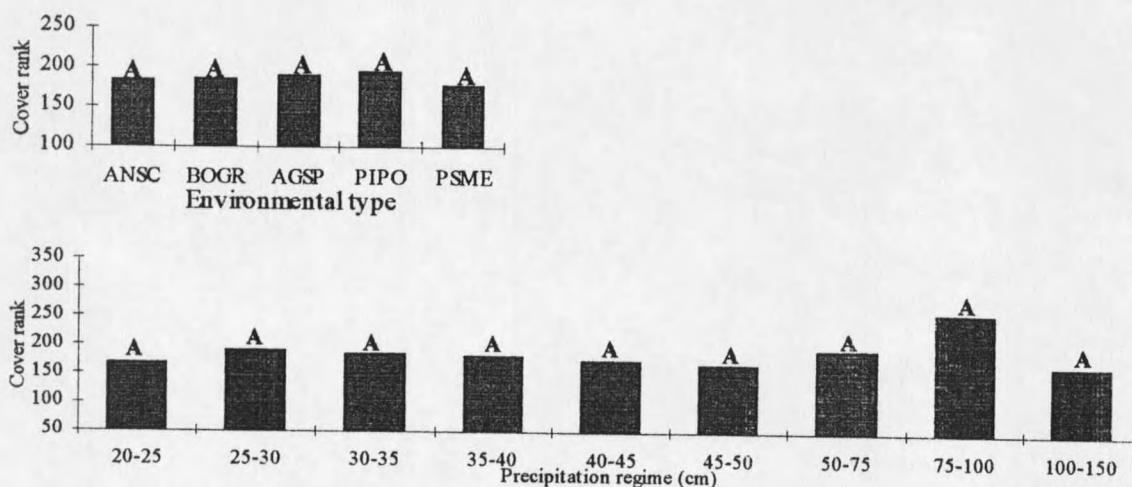


Figure 16. Effect of Environmental Type and Precipitation on Cover (%) of *Alyssum alyssoides*. Categories sharing a letter do not significantly differ.

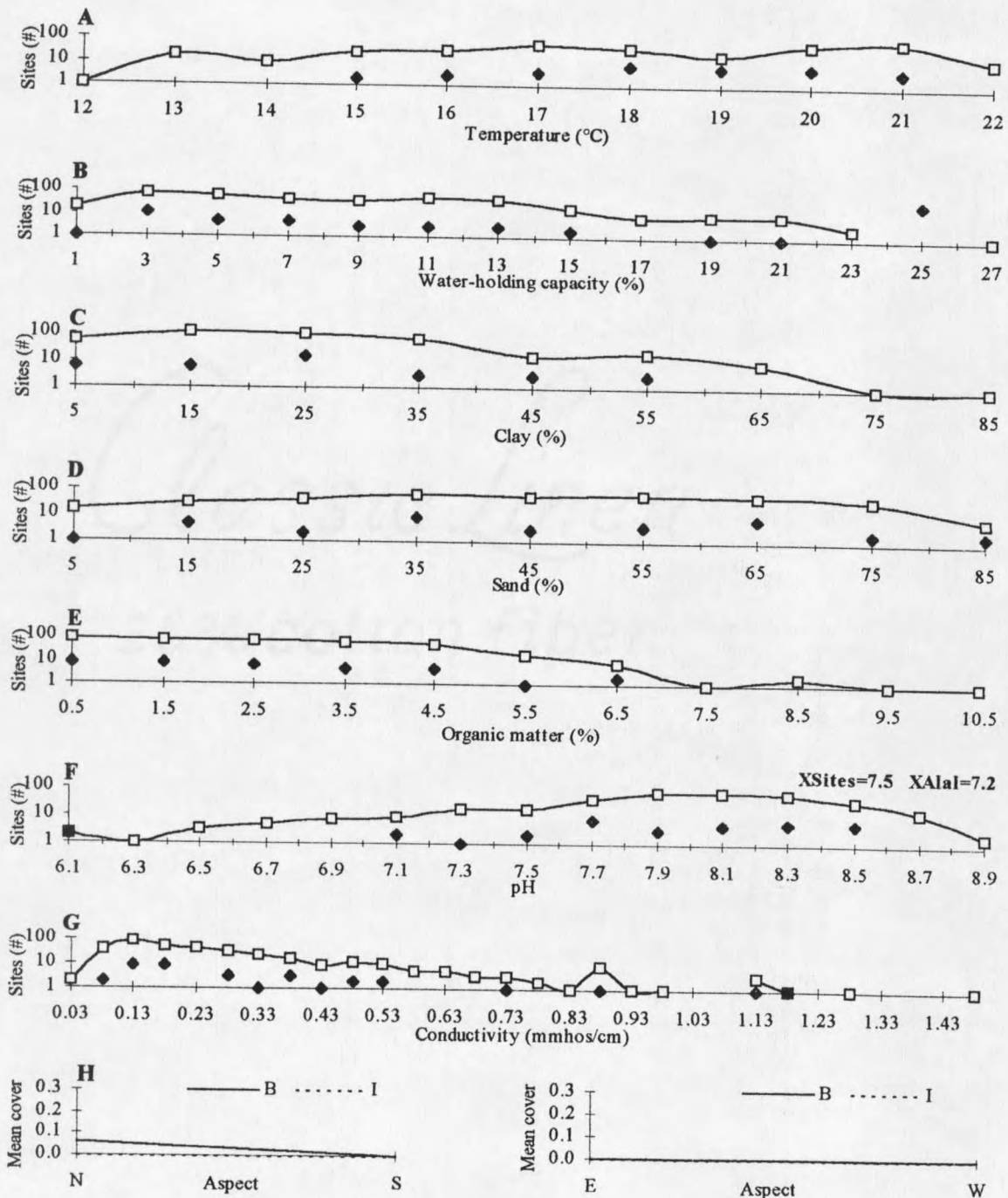


Figure 17. The Distribution of *Alyssum alyssoides* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Alyssum alyssoides* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Artemisia cana (Arca)

silver sage

Asteraceae

Origin, Duration and Habit¹: Native Perennial Shrub, not vegetatively reproducing.

Environmental type: Arca cover (%) does not differ between types (Fig. 18).

Temperature: Temperature does not differ between Arca and average sites (Fig. 19A).

Precipitation: Arca cover (%) does not differ between moist and dry sites (Fig. 18).

Water-holding capacity: WHC does not differ between Arca sites and average sites (Fig. 19B).

Clay²: Clay in Arca sites is higher than average roadside sites (Fig. 19C).

Sand²: Sand in Arca sites is lower than average roadside sites (Fig. 19D).

Organic carbon: OC does not differ between Arca sites and average sites (Fig. 19E).

pH: pH does not differ between Arca sites and average sites (Fig. 19F).

Conductivity²: Conductivity in Arca sites is higher than average sites (Fig. 19G).

Position and Aspect: Mean cover (%) is higher on backslopes than inslopes. Mean cover is highest on north-facing inslopes than, south, east or west-facing inslopes (Fig. 19H).

¹ Refer to introduction (p52) for a description of each category. ² Significant category.

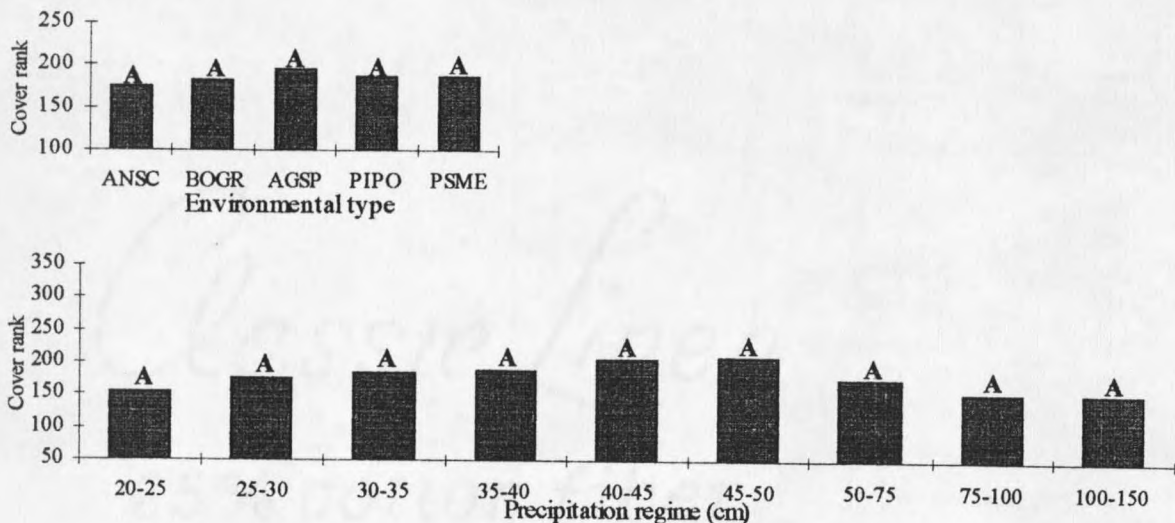


Figure 18. Effect of Environmental Type and Precipitation on Cover (%) of *Artemisia cana*. Categories sharing a letter do not significantly differ.

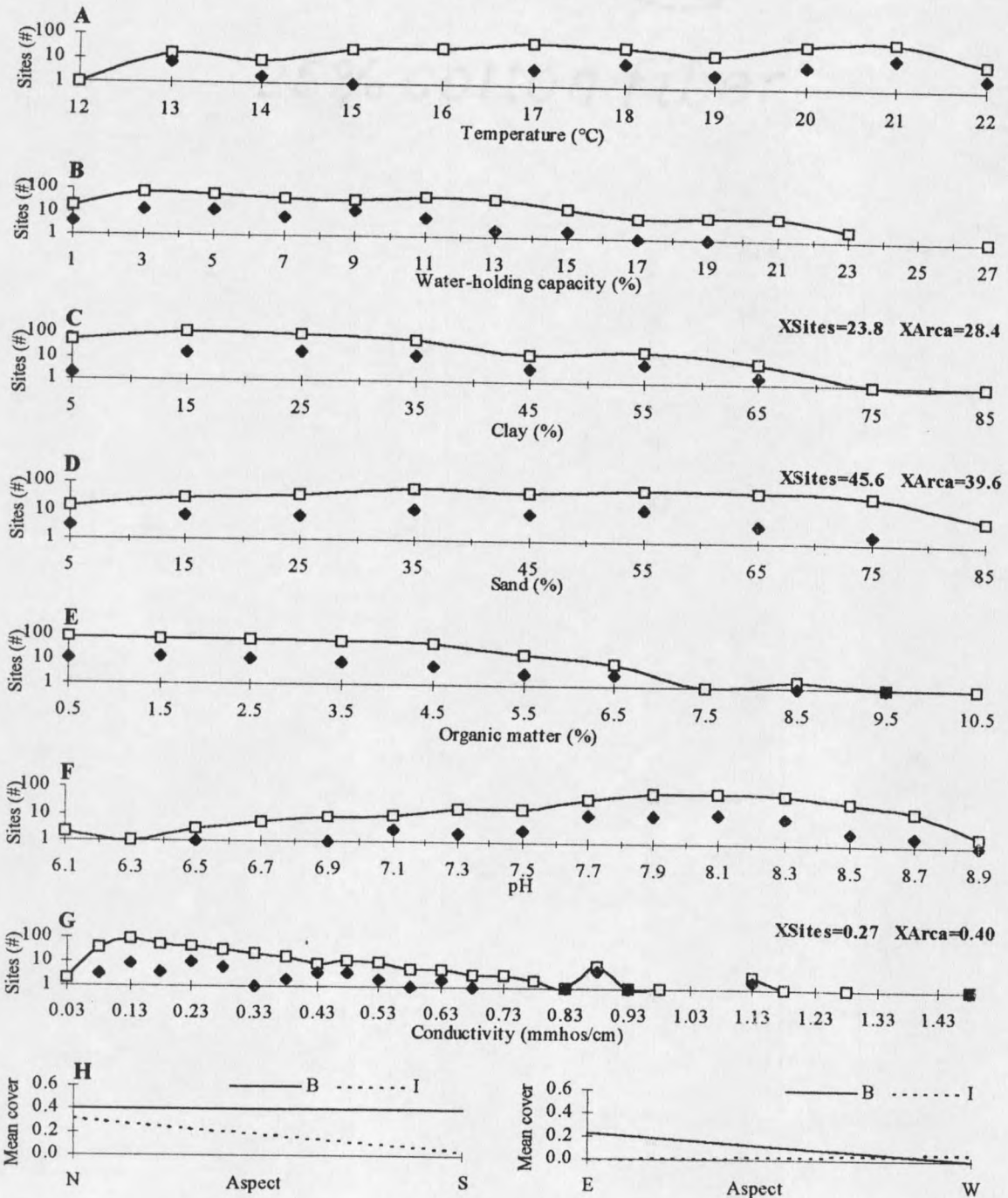


Figure 19. The Distribution of *Artemisia cana* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Artemisia cana* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Artemisia frigida (Arfr)

fringed sage

Asteraceae

Origin, Duration and Habit¹: Native Perennial Forb, vegetatively reproducing.

Environmental Type²: Arfr cover (%) is highest in AGSP and BOGR types and lowest in the ANSC type. PIPO and PSME types are intermediate (Fig. 20).

Temperature²: Temperature in Arfr sites is higher than average sites (Fig. 21A).

Precipitation: Arfr cover (%) does not differ between categories (Fig. 20).

Water-holding capacity²: WHC in Arfr sites is higher than in average roadside sites (Fig. 21B).

Clay²: Clay in Arfr sites is lower than in average roadside sites (Fig. 21C).

Sand²: Sand in Arfr sites is lower than in average roadside sites (Fig. 21D).

Organic carbon: OC does not differ between Arfr sites and average sites (Fig. 21E).

pH²: pH in Arfr sites is higher than in average roadside sites (Fig. 21F).

Conductivity²: Conductivity in Arfr sites is higher than in average roadside sites (Fig. 21G).

Position and Aspect: Mean cover (%) is highest on backslopes of all aspects and absent or sporadic on inslopes. Mean cover is highest on north-facing backslopes (Fig. 21H).

¹ Refer to introduction (p52) for a description of each category. ² Significant category.

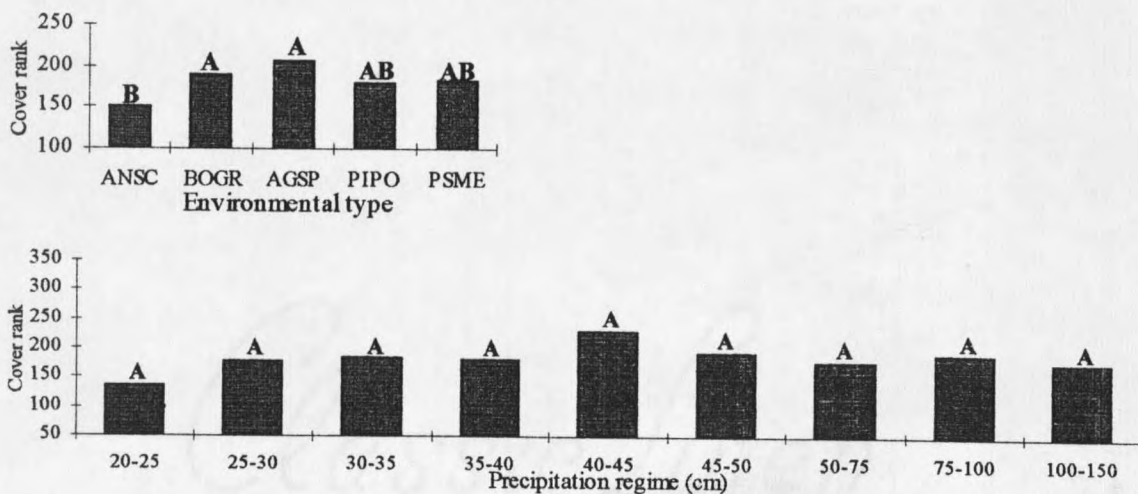


Figure 20. Effect of Environmental Type and Precipitation on Cover (%) of *Artemisia frigida*. Categories sharing a letter do not significantly differ.

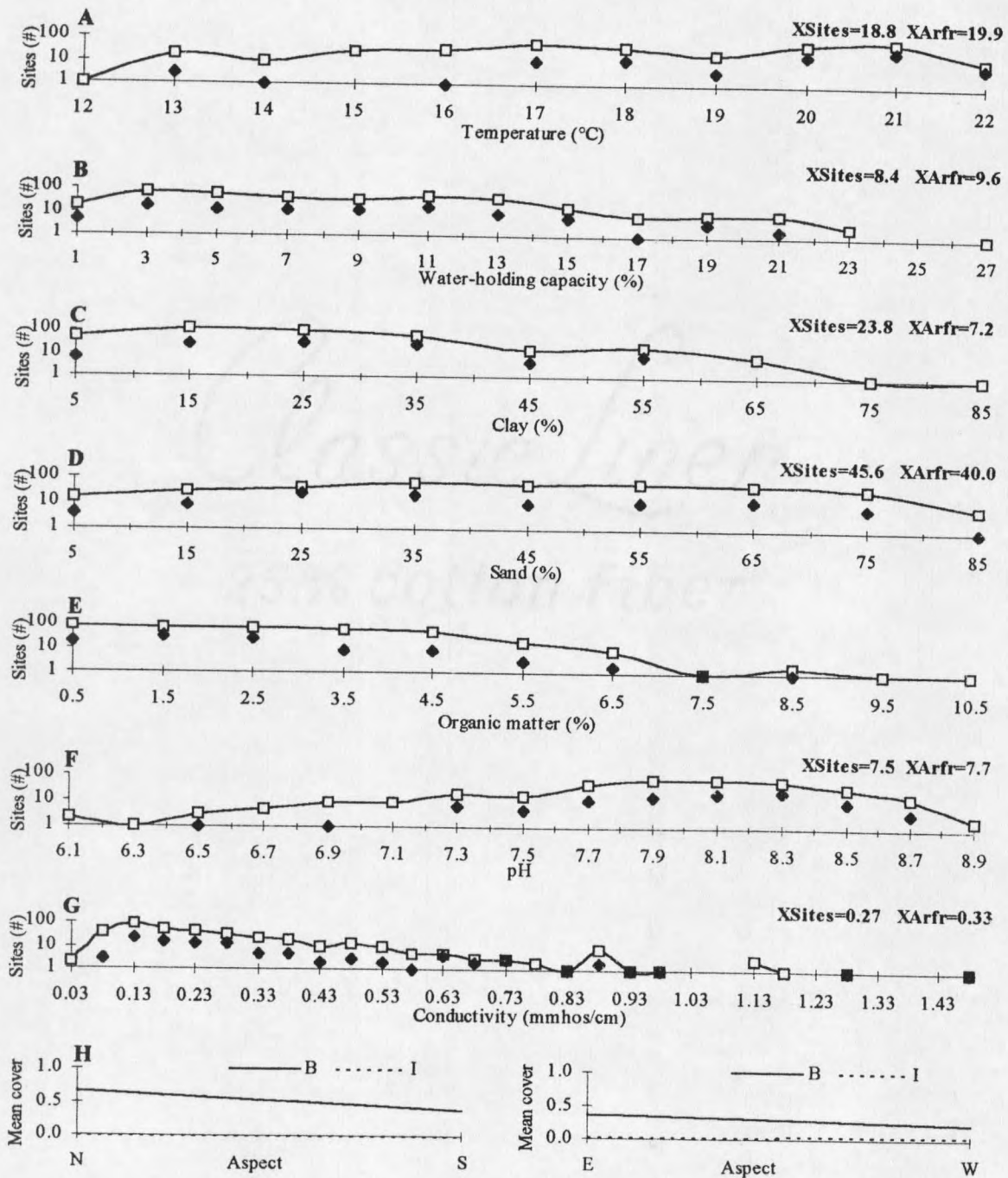


Figure 21. The Distribution of *Artemisia frigida* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Artemisia frigida* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Artemisia tridentata (Artr)

big sagebrush

Asteraceae

Origin, Duration and Habit¹: Native Perennial Shrub, not vegetatively reproducing.

Environmental type: Artr cover (%) does not differ between types (Fig. 22).

Temperature: Temperature does not differ between Artr sites and average sites (Fig. 23A).

Precipitation: Artr cover (%) does not differ between moist and dry sites (Fig. 22).

Water-holding capacity: WHC does not differ between Artr sites and average sites (Fig. 23B).

Clay: Clay does not differ between Artr sites and average sites (Fig. 23C).

Sand²: Sand in Artr sites is lower than average roadside sites (Fig. 23D).

Organic carbon: OC does not differ between Artr sites and average sites (Fig. 23E).

pH: pH does not differ between Artr sites and average sites (Fig. 23F).

Conductivity: Conductivity does not differ between Artr and average sites (Fig. 23G).

Position and Aspect: Mean cover (%) is consistently higher on backslopes than inslopes. Mean cover is highest on east and south-facing backslopes (Fig. 23H).

¹ Refer to introduction (p52) for descriptions of each category. ² Significant category.

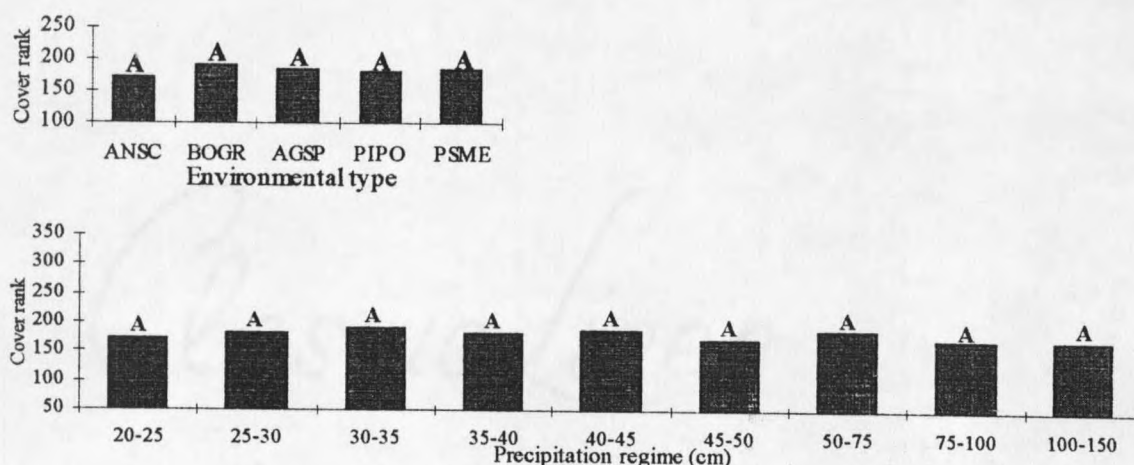


Figure 22. Effect of Environmental Type and Precipitation on Cover (%) of *Artemisia tridentata*. Categories sharing a letter do not significantly differ.

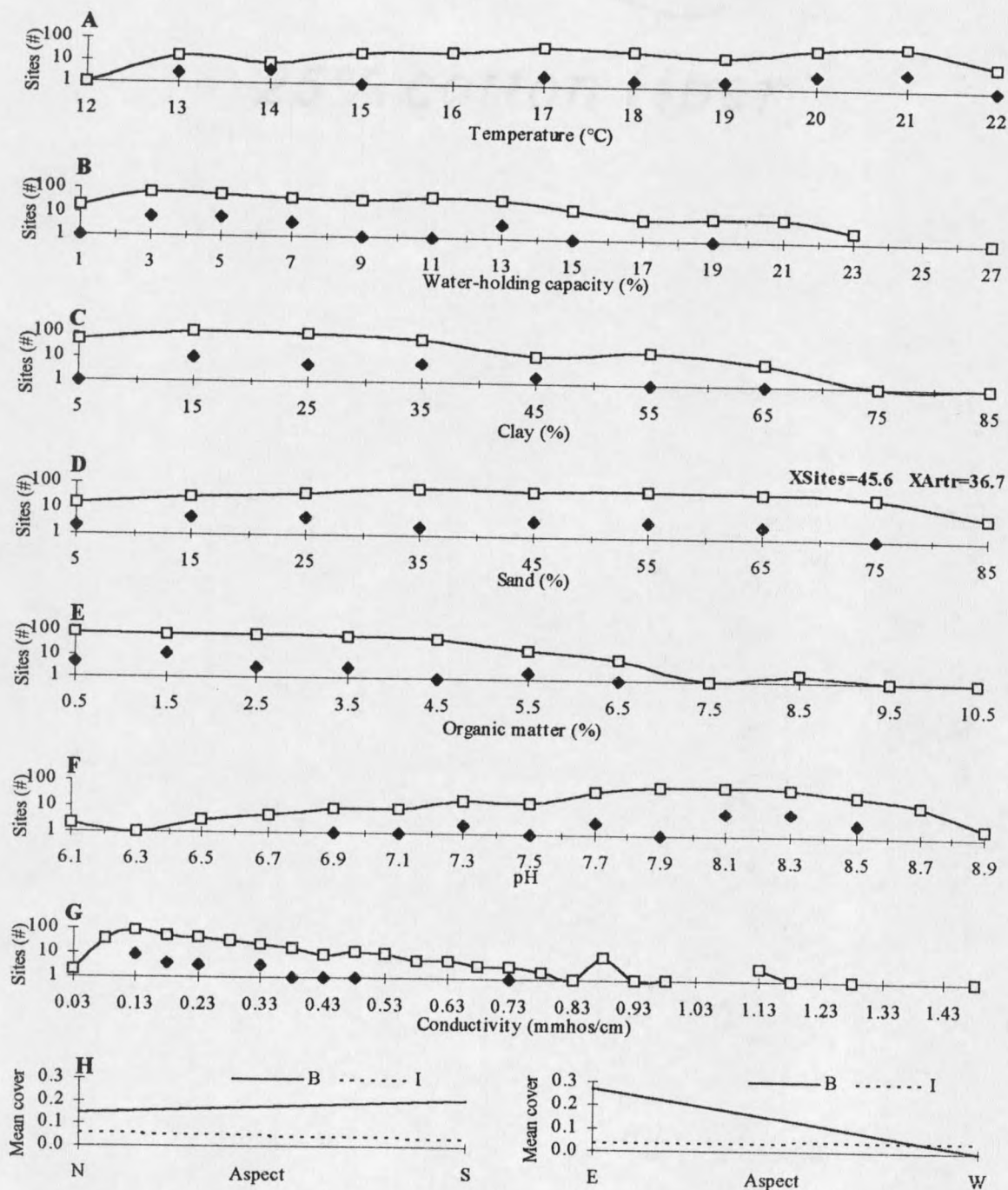


Figure 23. The Distribution of *Artemisia tridentata* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Artemisia tridentata* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Avena sativa* (Avsa)*domestic oat****Poaceae**

Origin, Duration and Habit¹: Exotic Annual Grass, not vegetatively reproducing.

Environmental Type²: Avsa cover (%) is higher in the ANSC than any other type (Fig. 24).

Temperature²: Temperature on Avsa sites is higher than average roadside sites (Fig. 25A).

Precipitation: Agcr cover (%) does not differ between moist and dry sites (Fig. 24).

Water-holding capacity: WHC does not differ between Avsa sites and average sites (Fig. 25B).

Clay: Clay does not differ between Avsa sites and average sites (Fig. 25C).

Sand: Sand does not differ between Avsa sites and average sites (Fig. 25D).

Organic carbon: OC does not differ between Avsa sites and average sites (Fig. 25E).

pH: pH does not differ between Avsa sites and average sites (Fig. 25F).

Conductivity: Conductivity does not differ between Avsa and average sites (Fig. 25G).

Position and Aspect: Did not occur on north, south or east-facing inslopes or backslopes. Mean is higher of west-facing inslopes than west-facing backslopes (Fig. 25H).

¹ Refer to introduction (p52) for a description of each category. ² Significant category.

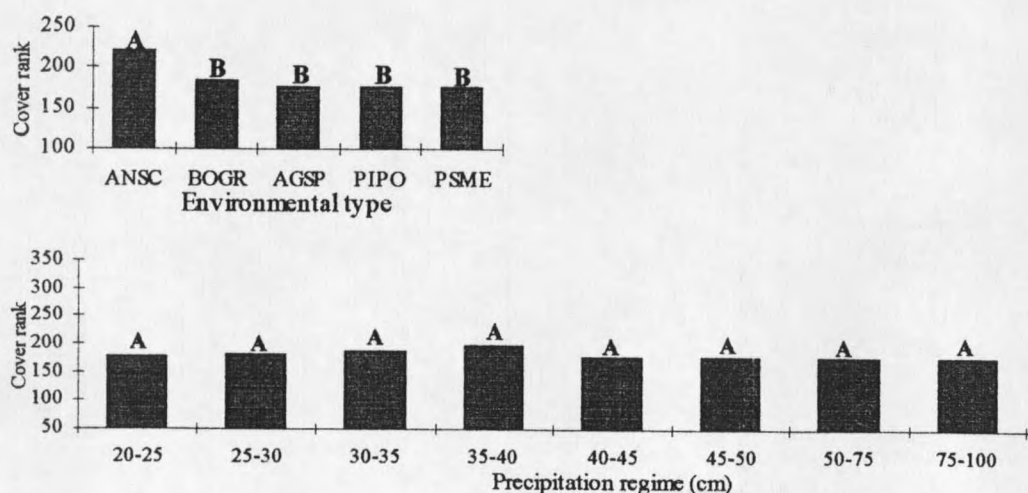


Figure 24. Effect of Environmental Type and Precipitation on Cover (%) of *Avena sativa*. Categories sharing a letter do not significantly differ.

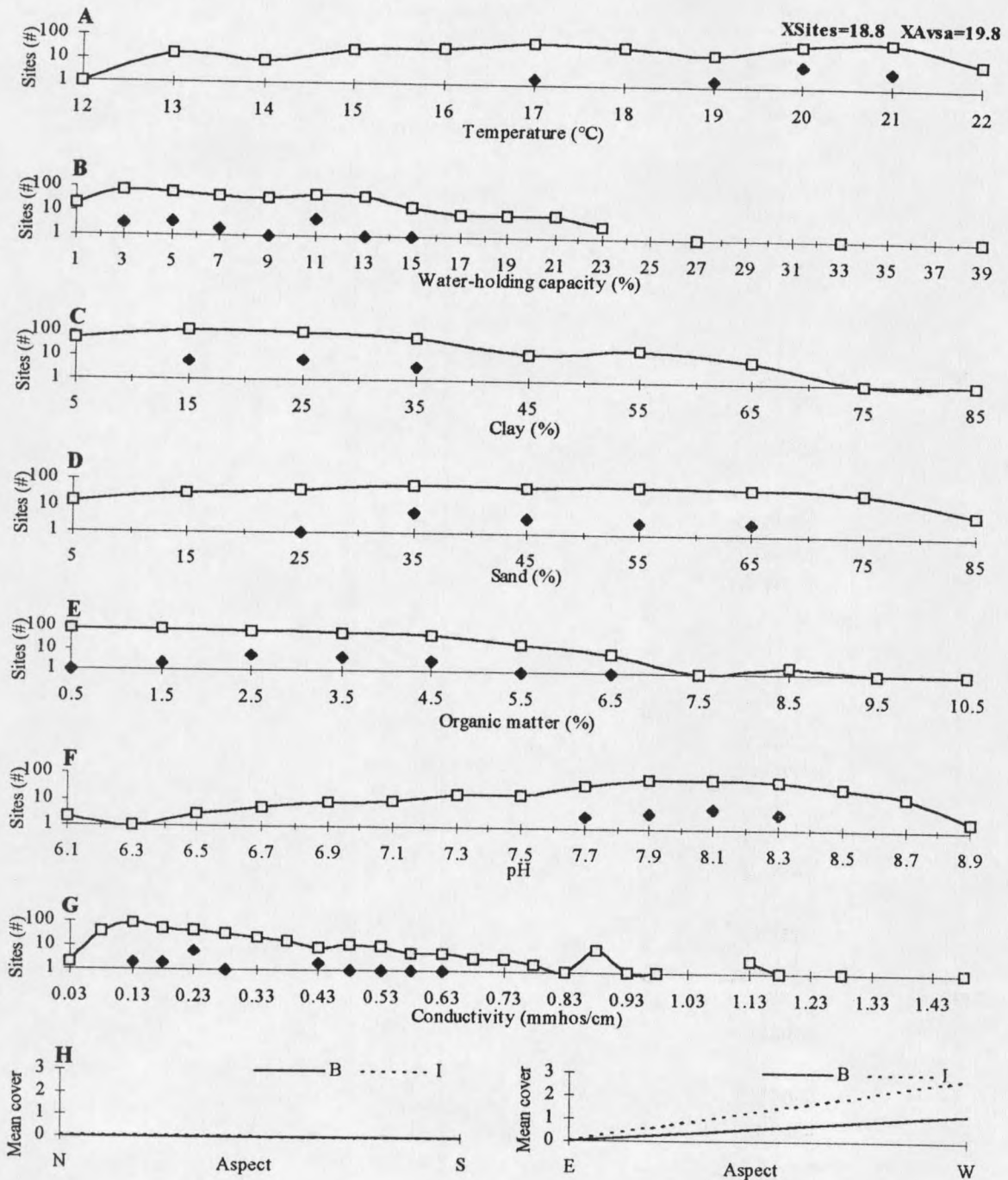


Figure 25. The Distribution of *Avena sativa* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Avena sativa* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Bouteloua gracilis* (Bogr)*blue gramma****Poaceae**

Origin, Duration and Habit¹: Native Perennial Grass, vegetatively reproducing.

Environmental type: Bogr cover (%) is the same in all types (Fig. 26).

Temperature²: Temperature in Bogr sites is higher than average sites (Fig. 27A).

Precipitation²: Bogr cover (%) is highest in the driest sites (20-25cm) (Fig. 26).

Water-holding capacity: WHC does not differ between Bogr and average sites (Fig. 27B).

Clay: Clay does not differ between Bogr sites and average sites (Fig. 27C).

Sand: Sand does not differ between Bogr sites and average sites (Fig. 27D).

Organic carbon: OC does not differ between Bogr sites and average sites (Fig. 27E).

pH: pH does not differ between Bogr sites and average sites (Fig. 27F).

Conductivity: Conductivity does not differ between Bogr and average sites (Fig. 27G).

Position and Aspect: Mean cover (%) is highest on east-facing inslopes and absent or sporadic on other sites (Fig. 27H)

¹ Refer to introduction (p52) for a description of each category. ² Significant category.

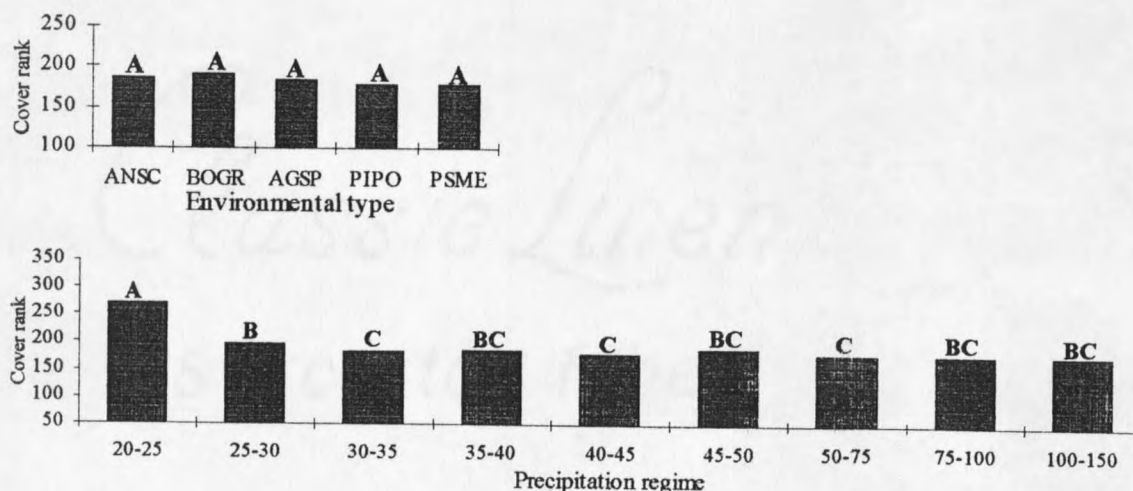


Figure 26. Effect of Environmental Type and Precipitation on Cover (%) of *Bouteloua gracilis*. Categories sharing a letter do not significantly differ.

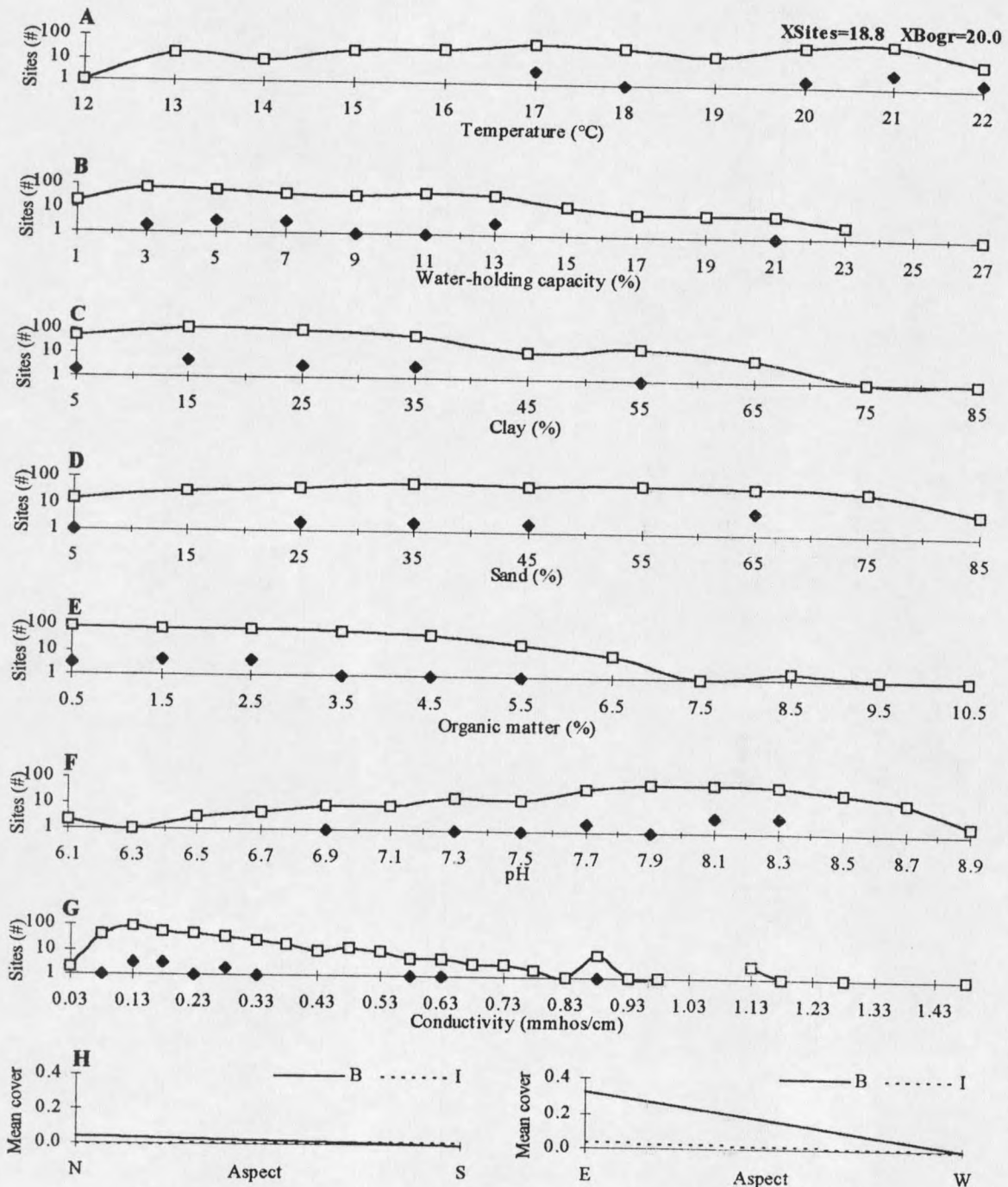


Figure 27. The Distribution of *Bouteloua gracilis* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Bouteloua gracilis* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Bromus inermis (Brin)

smooth brome

Poaceae

Origin, Duration and Habit¹ Exotic Perennial Grass, vegetative reproducing.

Environmental Type²: Brin cover (%) is highest in the ANSC and PSME types and lowest in the PIPO type (Fig. 28).

Temperature: Temperature does not differ between Brin sites and average sites (Fig. 29A).

Precipitation²: Brin cover (%) is highest in moderate (45-55cm) and moist sites (100-150 cm) (Fig. 28).

Water-holding capacity: WHC does not differ between Brin and average sites (Fig. 29B).

Clay: Clay does not differ between Brin sites and average sites (Fig. 29C).

Sand: Sand does not differ between Brin sites and average sites (Fig. 29D).

Organic carbon: OC does not differ between Brin sites and average sites (Fig. 29E).

pH: pH does not differ between Brin sites and average sites (Fig. 29F).

Conductivity: Conductivity does not differ between Brin and average sites (Fig. 29G).

Position and Aspect: Mean percent cover of north and south-facing inslopes are higher than backslopes. Mean percent cover of east-facing inslopes is higher than east-facing backslopes (Fig. 29H).

¹ Refer to introduction (p52) for a description of each category. ² Significant category.

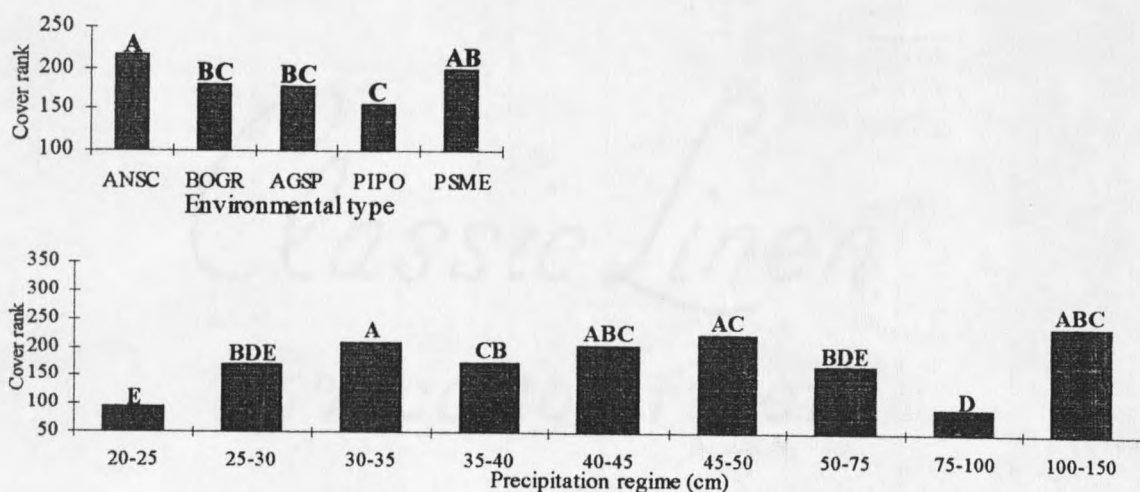


Figure 28. Effect of Environmental Type and precipitation regime on cover (%) of *Bromus inermis*. Categories sharing a letter do not significantly differ.

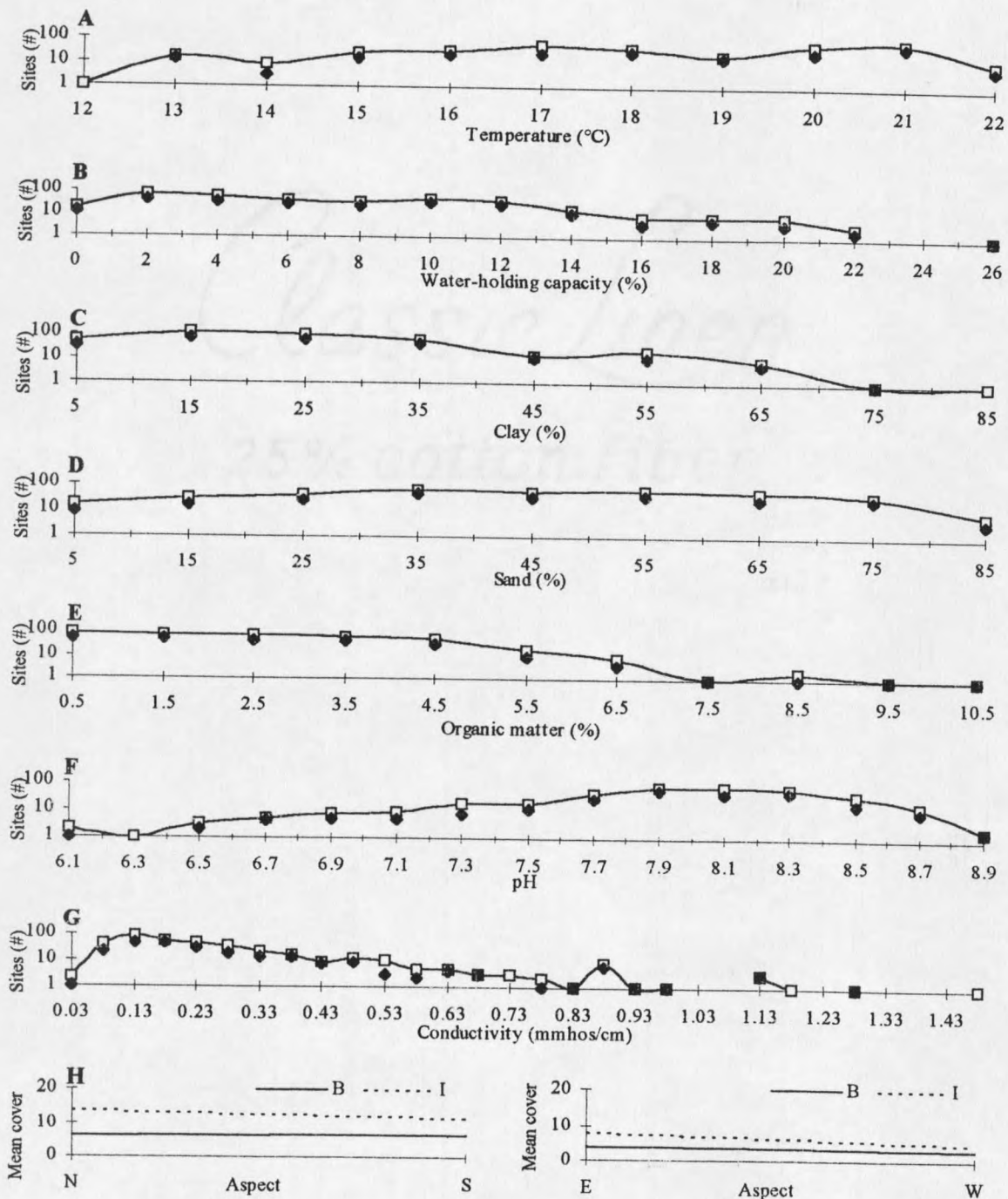


Figure 29. The Distribution of *Bromus inermis* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Bromus inermis* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Bromus tectorum* (Brte)*cheat grass****Poaceae**

Origin, Duration and Habit¹: Exotic Annual Grass, not vegetatively reproducing.

Environmental Type²: Brte cover (%) is highest in the BOGR, AGSP and PIPO types than the PSME type (Fig. 30).

Temperature: Temperature does not differ between Brte sites and average sites (Fig. 31A).

Precipitation: Brte cover (%) does not differ between categories (Fig. 30).

Water-holding capacity: WHC of Brte sites is lower than average roadside sites (Fig. 31B).

Clay: Clay does not differ between Brte sites and average sites (Fig. 31C).

Sand: Sand does not differ between Brte sites and average sites (Fig. 31D).

Organic carbon: OC does not differ between Brte sites and average sites (Fig. 31E).

pH: pH does not differ between Brte sites and average sites (Fig. 31F).

Conductivity: Conductivity does not differ between Brte and average sites (Fig. 31G).

Position and Aspect: Mean percent cover is slightly higher on north-facing inslopes than south-facing inslopes (Fig. 31H).

¹ Refer to introduction (p52) for a description of each category. ² Significant category.

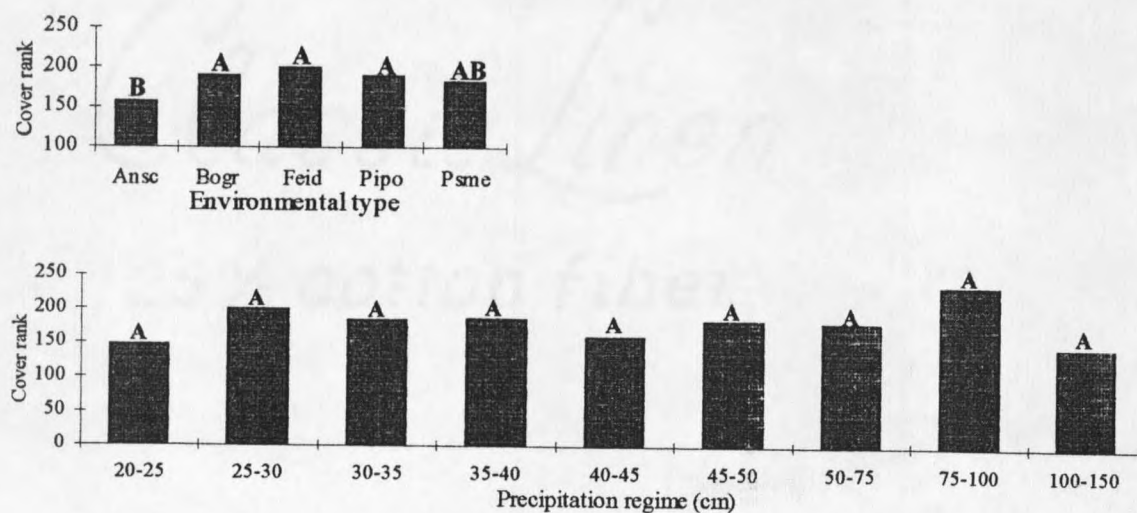


Figure 30. Effect of Environmental Type and precipitation on percent cover of *Bromus tectorum*. Categories sharing a letter do not significantly differ.

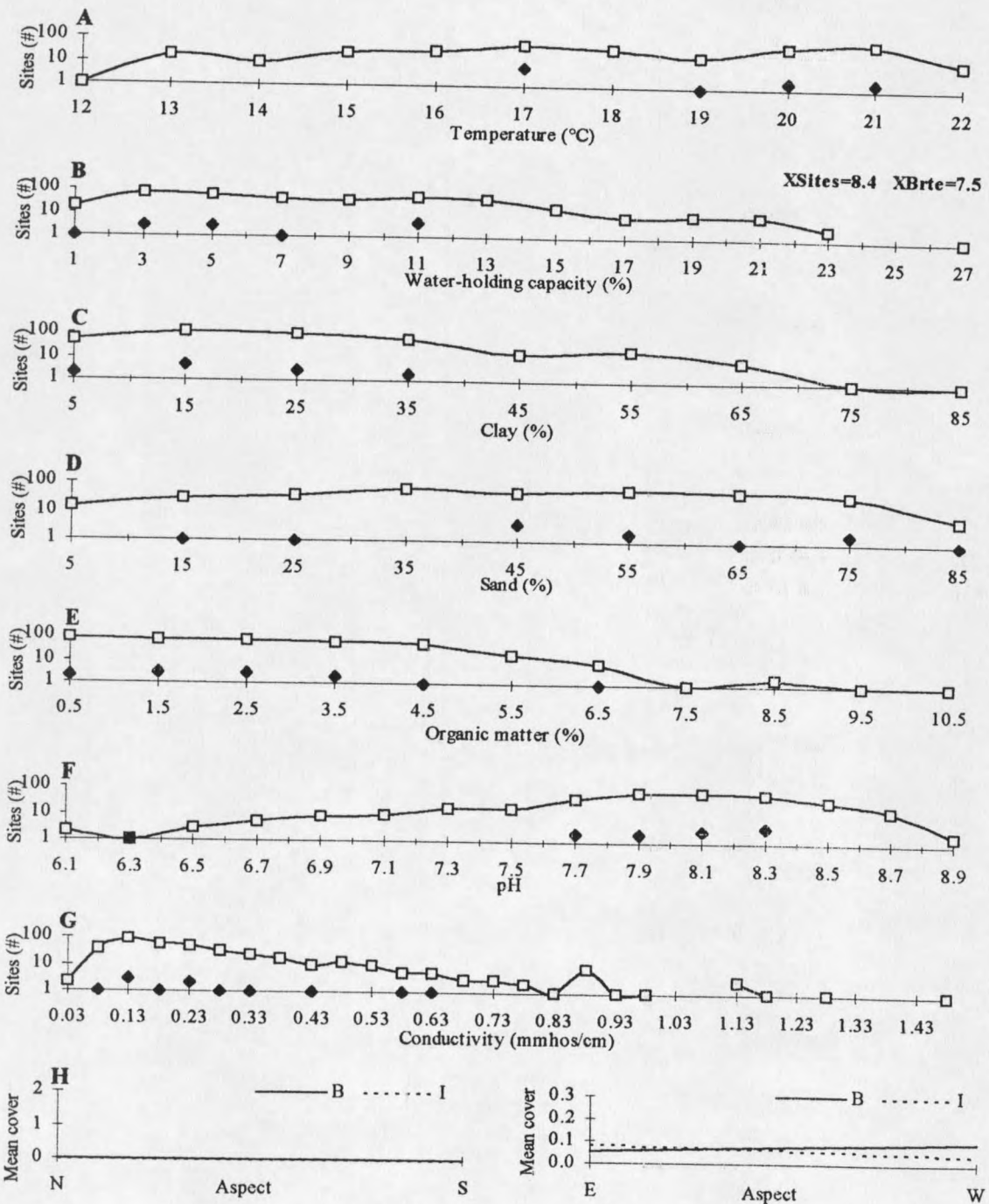


Figure 31. The Distribution of *Bromus tectorum* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Bromus tectorum* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Centaurea maculosa (Cema)

spotted knapweed

Asteraceae

Origin, Duration and Habit¹: Exotic Biennial Forb, not vegetatively reproducing.

Environmental type: Cema cover (%) does not differ between types (Fig. 34).

Temperature²: Temperature in Cema sites is lower than in average sites (Fig. 35A).

Precipitation²: Cema cover (%) is highest in the driest (20-25cm) and moist sites (75-150 cm)(Fig. 35B).

Water-holding capacity²: WHC in Cema sites is lower than average roadside sites (Fig. 35C).

Clay²: Clay in Cema sites is lower than average roadside sites (Fig. 35D).

Sand²: Sand in Cema sites is higher than average roadside sites (Fig. 35E).

Organic carbon: OC does not differ between Cema sites and average sites (Fig. 35F).

pH: pH in Cema sites is lower than average roadside sites (Fig. 35G).

Conductivity: Conductivity in Cema sites is lower than average sites (Fig. 35H).

Position and Aspect: There is an interaction between plot position and aspect on north and south-facing sites. Mean percent cover is higher on east and west-facing inslopes than north and south-facing backslopes (Fig. 35G).

¹ Refer to introduction (p52) for a description of each category. ² Significant category.

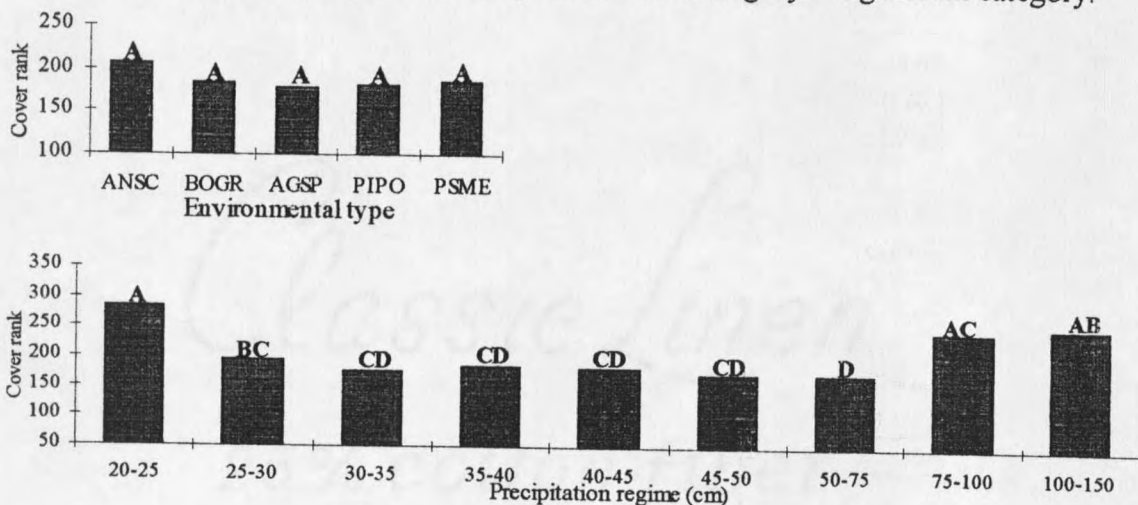


Figure 32. Effect of Environmental Type and Precipitation on Cover (%) of *Centaurea maculosa*. Categories sharing a letter do not significantly differ.

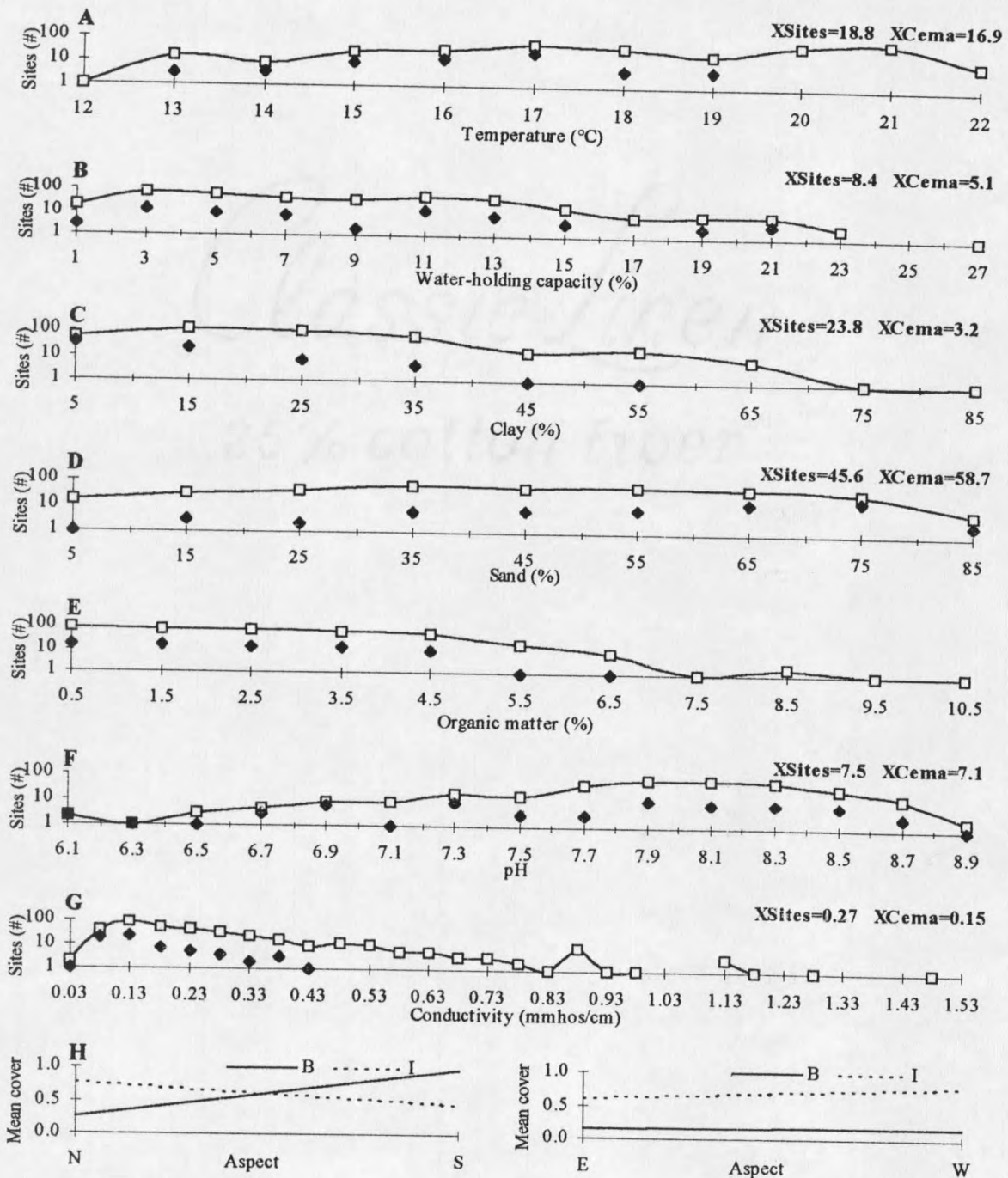


Figure 33. The Distribution of *Centaurea maculosa* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Centaurea maculosa* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Cirsium arvense (Ciar)

Canada thistle

Asteraceae

Origin, Duration and Habit¹: Exotic Perennial Forb, vegetatively reproducing.

Environmental type: Ciar cover (%) does not differ between types (Fig. 32).

Temperature: Temperature in Ciar does not differ from average roadside sites (Fig. 33A).

Precipitation: Ciar cover (%) does not differ between moist and dry sites (Fig. 32).

Water-holding capacity: WHC does not differ between Ciar sites and average sites (Fig. 33B).

Clay: Clay does not differ between Ciar sites and average sites (Fig. 33C).

Sand: Sand does not differ between Ciar sites and average sites (Fig. 33D).

Organic carbon: Organic carbon does not differ between Ciar sites and average sites (Fig. 33E).

pH: pH does not differ between Ciar sites and average sites (Fig. 33F).

Conductivity: Conductivity does not differ between Ciar sites and average sites (Fig. 33G).

Position and Aspect: Cover is higher on south facing inslopes than backslopes and higher on east-facing backslopes than backslopes (Fig. 33H).

¹ Refer to introduction (p52) for a description of each category.

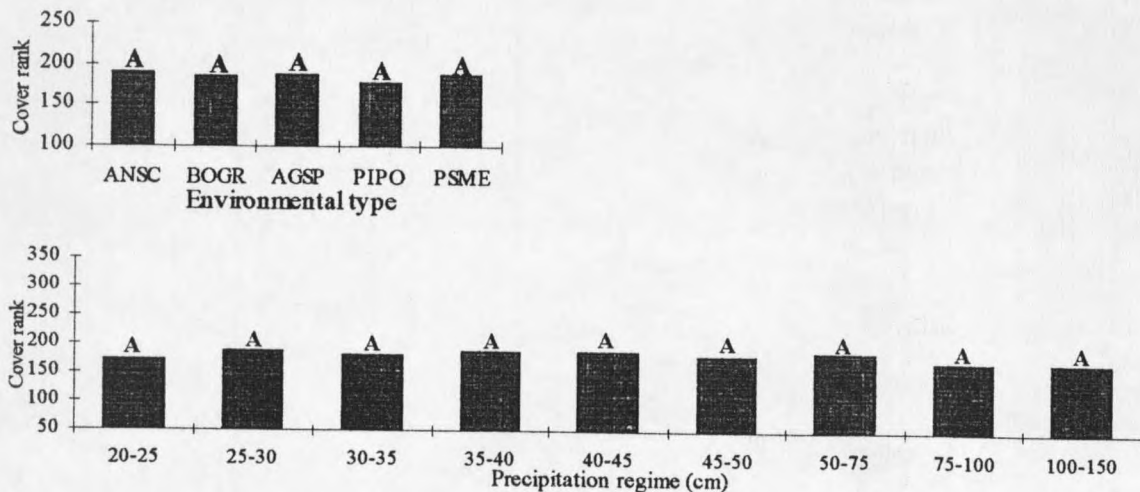


Figure 34. Effect of Environmental Type and Precipitation on Cover (%) of *Cirsium arvense*. Categories sharing a letter do not significantly differ.

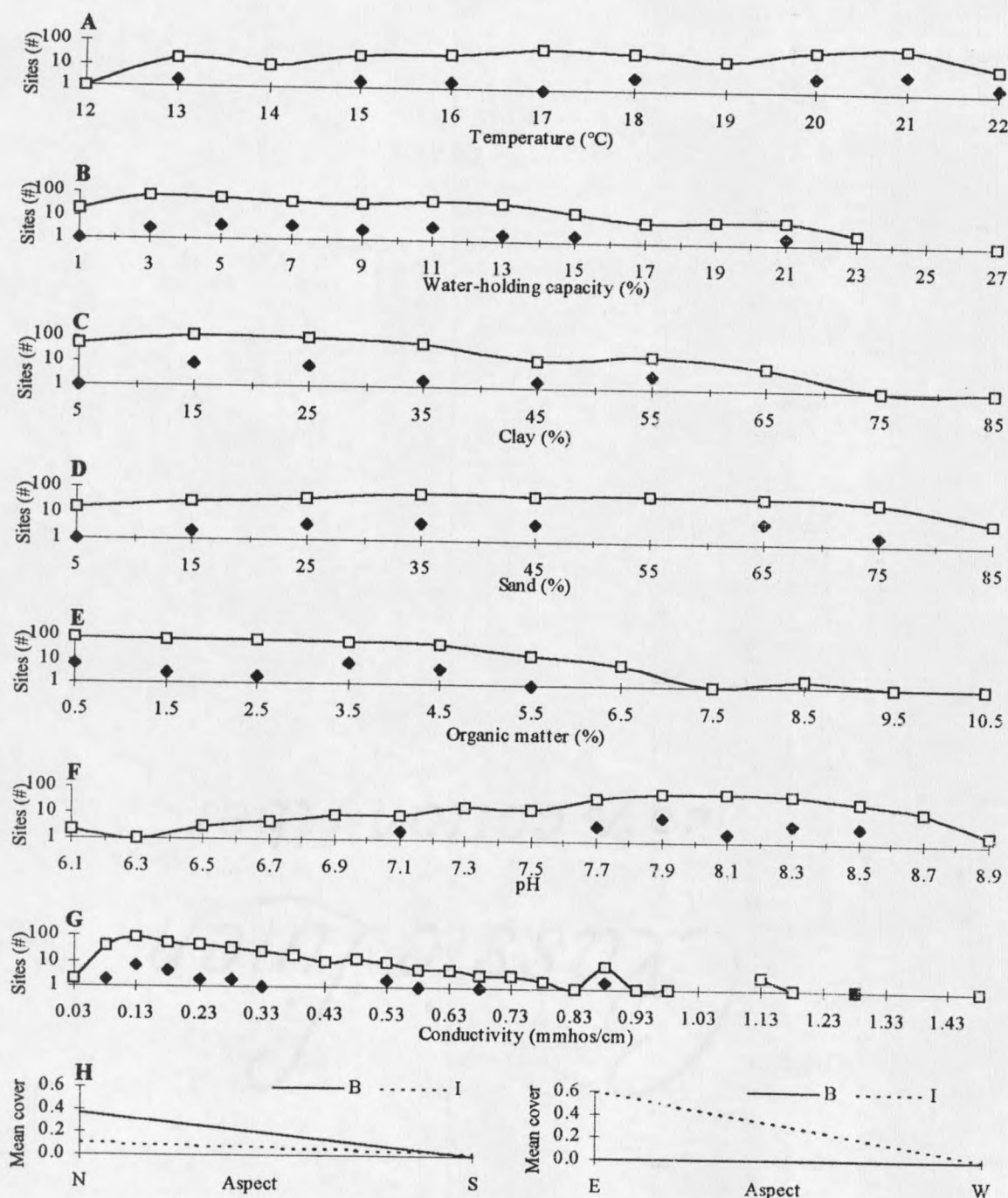


Figure 35. The Distribution of *Cirsium arvense* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Cirsium arvense* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Dactylis glomerata* (Dagl)*orchardgrass****Poaceae**

Origin, Duration and Habit¹: Exotic Perennial Grass, not vegetatively reproducing.

Environmental Type²: Dagl cover (%) is highest in the AGSP, PIPO and PSME types and lowest on ANSC and BOGR types (Fig. 36).

Temperature regime: Temperature in Dagl sites is lower than in average sites (Fig. 37A).

Precipitation²: Dagl cover (%) is highest in the category 40-45cm and above (Fig. 36)

Water-holding capacity²: Water-holding capacity of Dagl sites is lower than average sites (Fig. 37B).

Clay: Clay in Dagl sites is lower than in average roadside sites (Fig. 37C).

Sand: Sand in Dagl sites is higher than in average roadside sites (Fig. 37D).

Organic carbon: OC does not differ between Dagl sites and average sites (Fig. 37E).

pH: pH does not differ between Dagl sites and average sites (Fig. 37F).

Conductivity: Conductivity in Dagl sites does not differ from average sites (Fig. 37G).

Position and Aspect: Mean cover (%) is the same on all north and south-facing slopes. Mean cover (%) is higher on east and west-facing inslopes than backslopes. Mean percent cover is highest on west-facing inslopes (Fig. 37H).

¹ Refer to introduction (p52) for a description of each category. ² Significant category.

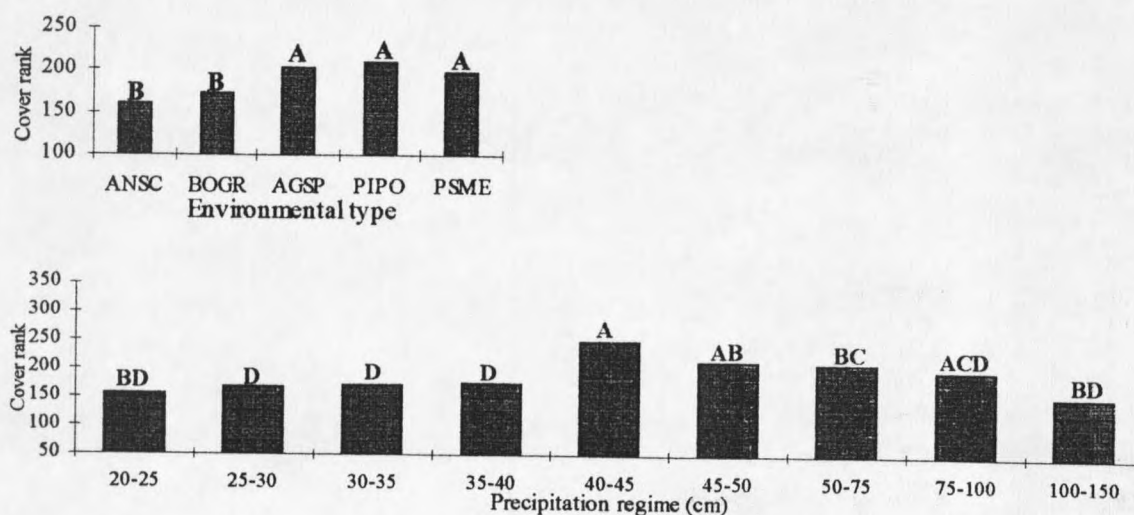


Figure 36. Effect of Environmental Type and Precipitation on Cover (%) of *Dactylis glomerata*. Categories sharing a letter do not significantly differ.

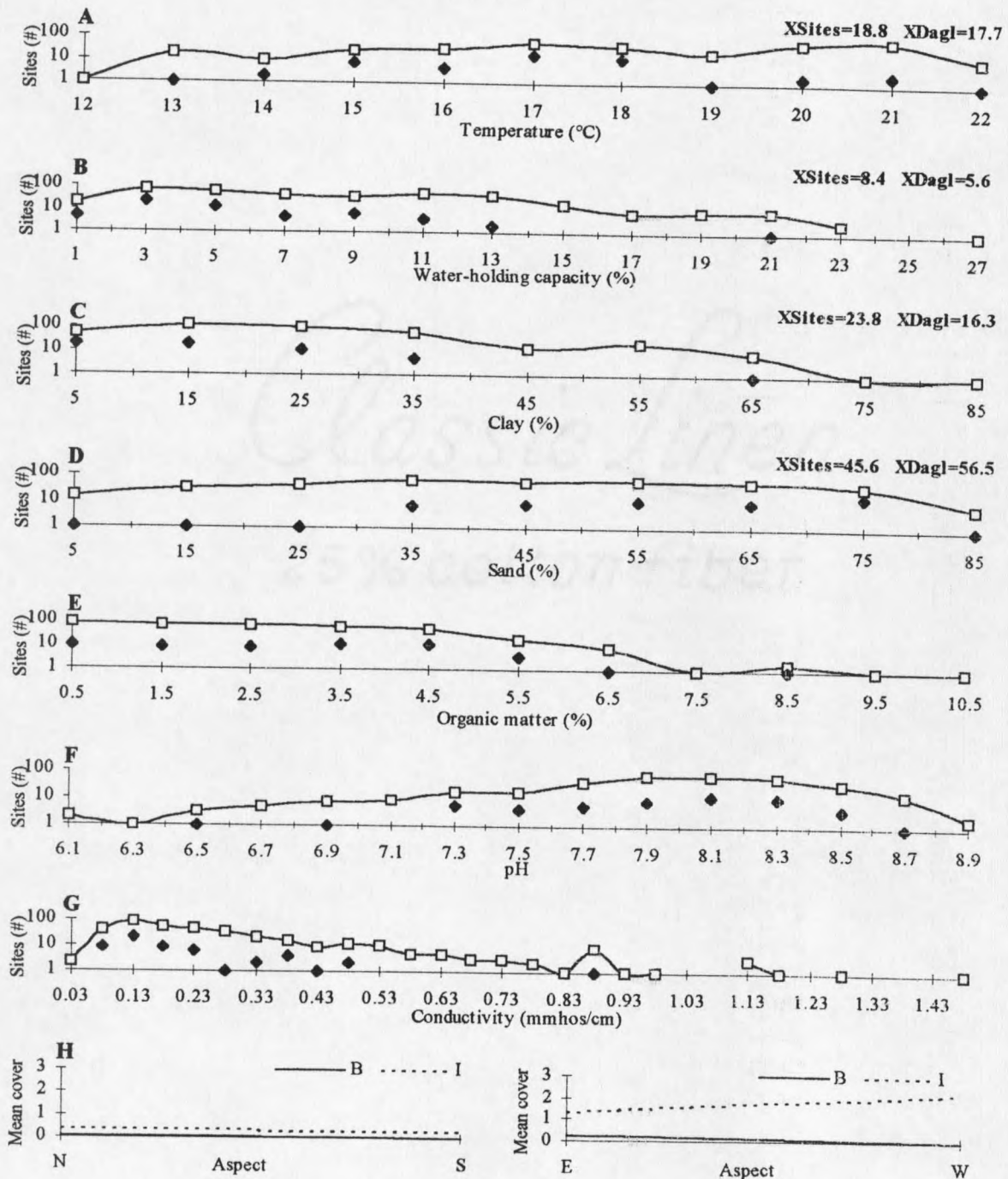


Figure 37. The Distribution of *Dactylis glomerata* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Dactylis glomerata* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Dalea purpurea (Dapu)

prairie coneflower

Asteraceae

Origin, Duration and Habit¹: Native Perennial Forb, not vegetatively reproducing.

Environmental type: Dapu cover (%) does not differ between types (Fig. 38).

Temperature: Temperature does not differ between Dapu sites and average sites (Fig. 39A).

Precipitation: Dapu cover (%) does not differ between moist and dry sites (Fig. 38).

Water-holding capacity: WHC does not differ between Dapu sites and average sites (Fig. 39B).

Clay: Clay does not differ between Dapu sites and average sites (Fig. 39C).

Sand: Sand in Dapu sites is lower than in average roadside sites (Fig. 39D).

Organic carbon: OC does not differ between Dapu sites and average sites (Fig. 39E).

pH: pH in Dapu sites is higher than in average roadside sites (Fig. 39F).

Conductivity: Conductivity does not differ between Dapu sites and average sites (Fig. 39G).

Position and Aspect: Dapu occurs sporadically throughout roadsides areas (Fig. 39H)

¹ Refer to introduction (p52) for a description of each category.

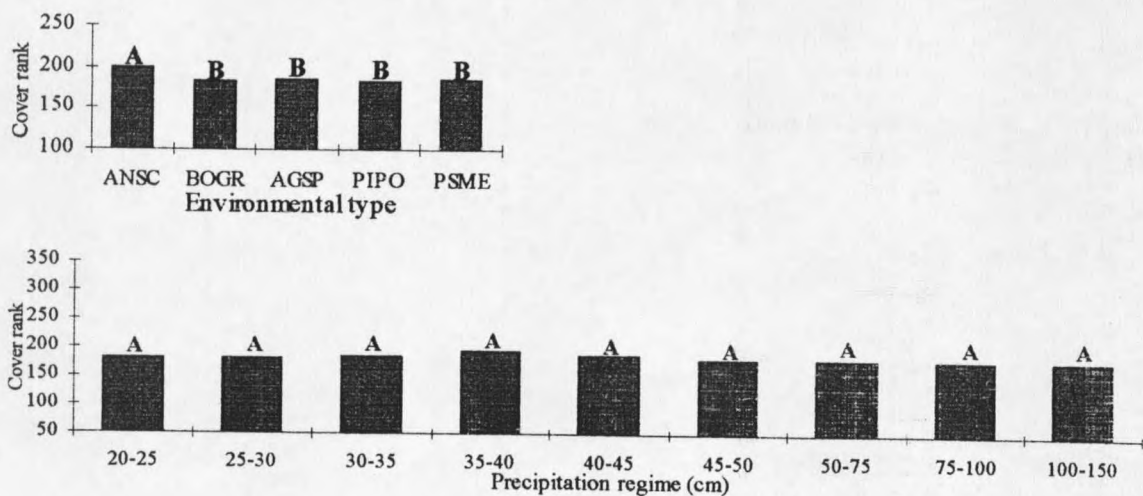


Figure 38. Effect of Environmental Type and Precipitation on Cover (%) of *Dalea purpurea*. Categories sharing a letter do not significantly differ.

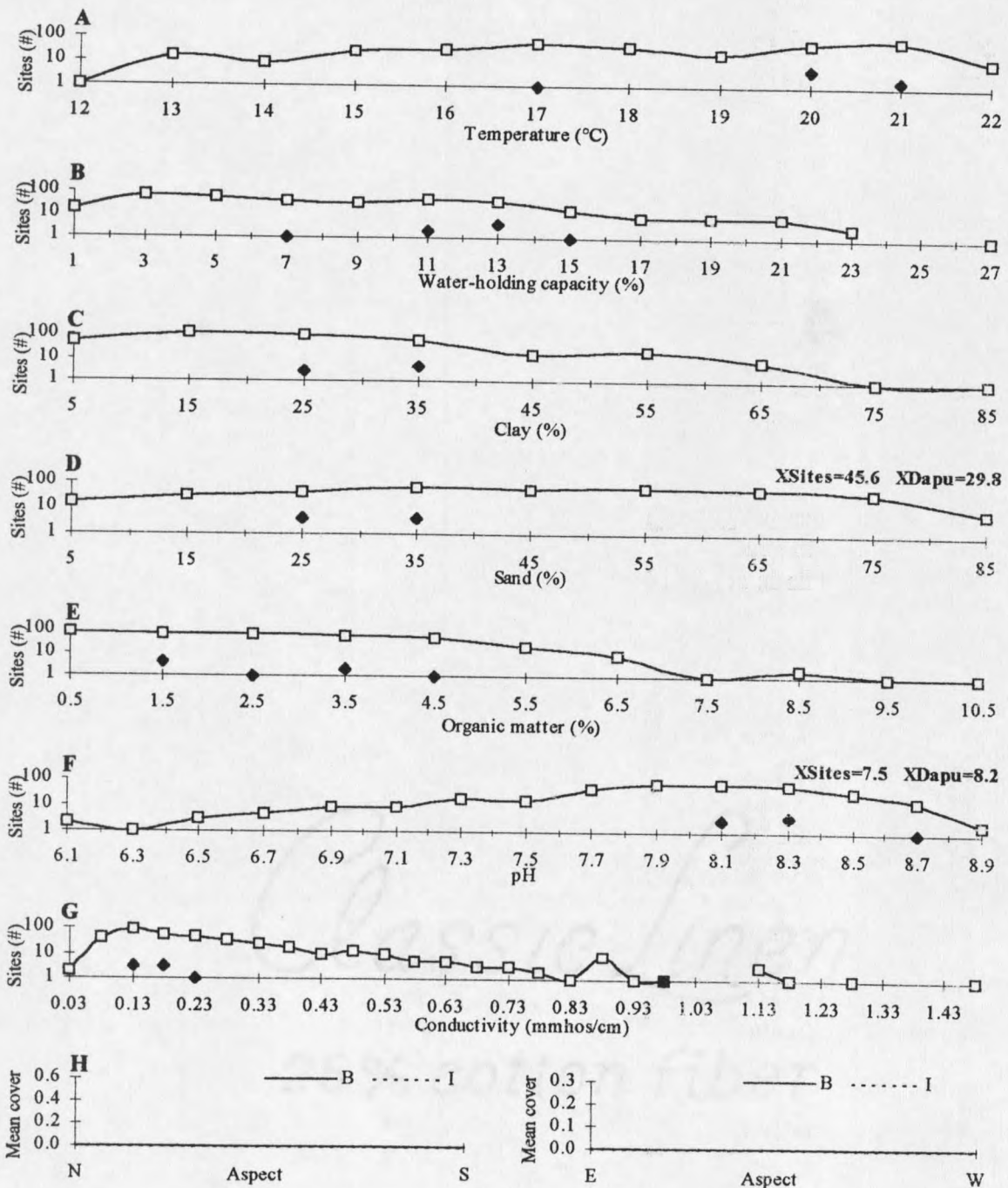


Figure 39. The Distribution of *Dalea purpurea* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Dalea purpurea* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Festuca idahoensis* (Feid)*Idaho fescue****Poaceae**

Origin, Duration and Habit¹: Native Perennial Grass, not vegetatively reproducing.

Environmental type: Feid cover (%) does not differ between types (Fig. 40).

Temperature²: Temperature in Feid sites is lower than in average sites (Fig. 41A).

Precipitation: Feid cover (%) does not differ between dry and moist sites (Fig. 40).

Water-holding capacity²: WHC in Feid sites is lower than in average sites (Fig. 41B).

Clay²: Clay in Feid sites is lower than average roadside sites (Fig. 41C).

Sand²: Sand in Feid sites is higher than average roadside sites (Fig. 41D).

Organic carbon: OC does not differ between Feid sites and average sites (Fig. 41E).

pH: pH does not differ between Feid sites and average sites (Fig. 41F).

Conductivity²: Conductivity in Feid sites is lower than in average sites (Fig. 41G).

Position and Aspect: Mean cover (%) is highest on north-facing backslopes and is absent or occurs sporadically on other sites (Fig. 41H).

¹ Refer to introduction (p52) for descriptions of each category. ² Significant category.

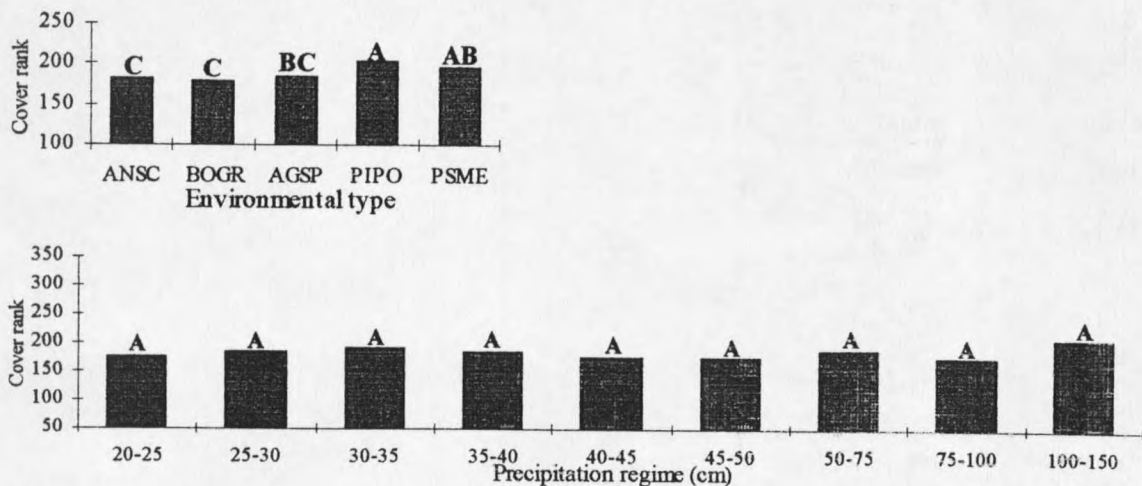


Figure 40. Effect of Environmental Type and Precipitation on Cover (%) of *Festuca idahoensis*. Categories sharing a letter do not significantly differ.

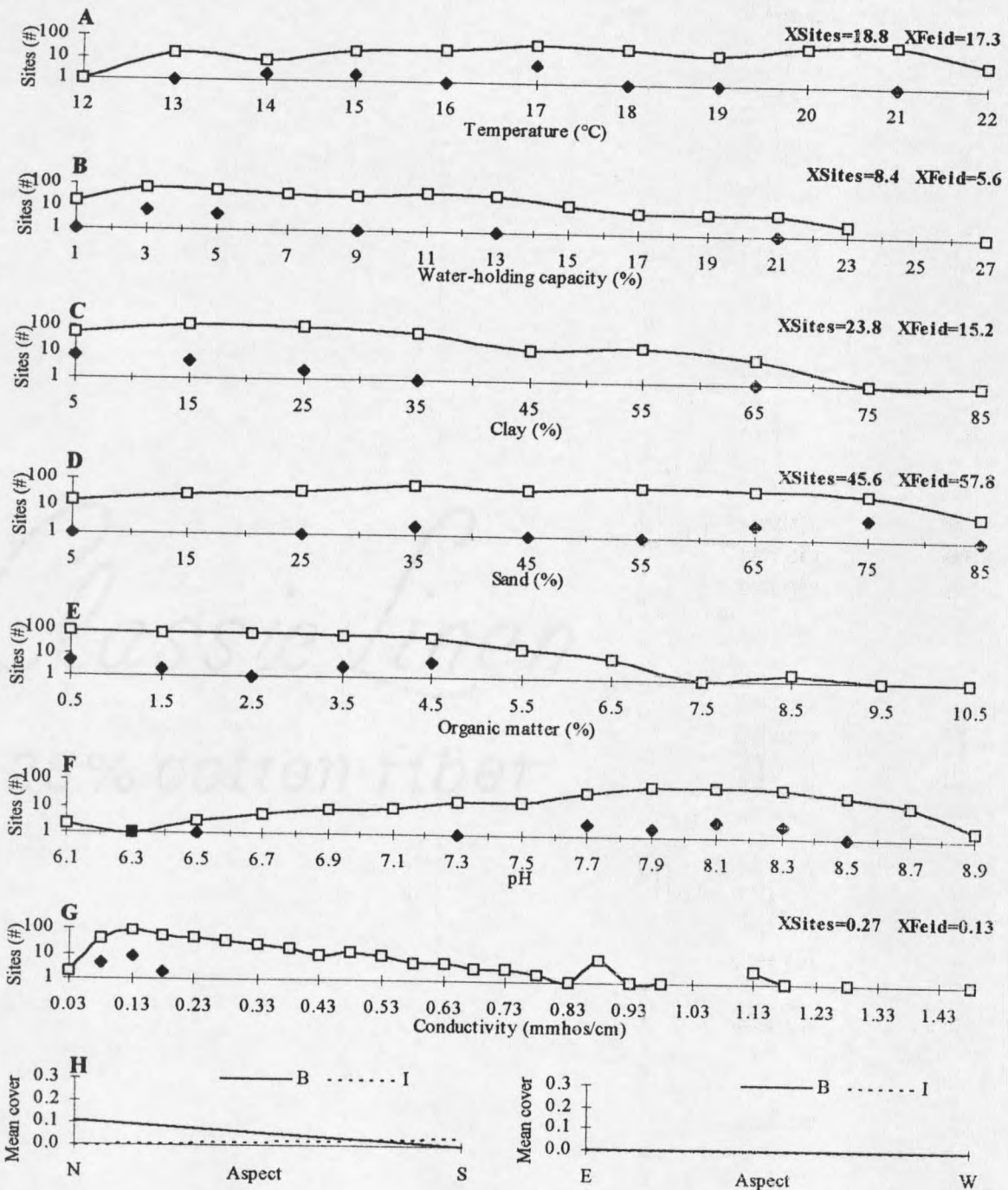


Figure 41. The Distribution of *Festuca idahoensis* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Festuca idahoensis* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Festuca ovina* (Feov)*sheep fescue****Poaceae**

Origin, Duration and Habit ¹: Native Perennial Grass, not vegetatively reproducing.

Environmental type: Feov cover (%) does not differ between types (Fig. 42).

Temperature ²: Temperature in Feov sites is lower than in average sites (Fig. 43A).

Precipitation: Feov cover (%) does not differ between dry and moist sites (Fig. 42).

Water-holding capacity ²: WHC in Feov sites is lower than in average sites (Fig. 43B).

Clay ²: Clay in Feov sites is lower than average roadside sites (Fig. 43C).

Sand ²: Sand in Feov sites is higher than average roadside sites (Fig. 43D).

Organic carbon ²: OC in Feov sites is lower than average roadside sites (Fig. 43E).

pH: pH does not differ between Feov sites and average sites (Fig. 43F).

Conductivity ²: Conductivity in Feov sites is lower than in average sites (Fig. 43G).

Position and Aspect: Mean cover (%) is higher on north-facing than south-facing backslopes, cover is approximately equal for north and south-facing slopes. Plants do not occur or are sporadic on east and west slopes (Fig. 43H).

¹ Refer to introduction (p52) for descriptions of each category. ² Significant category.

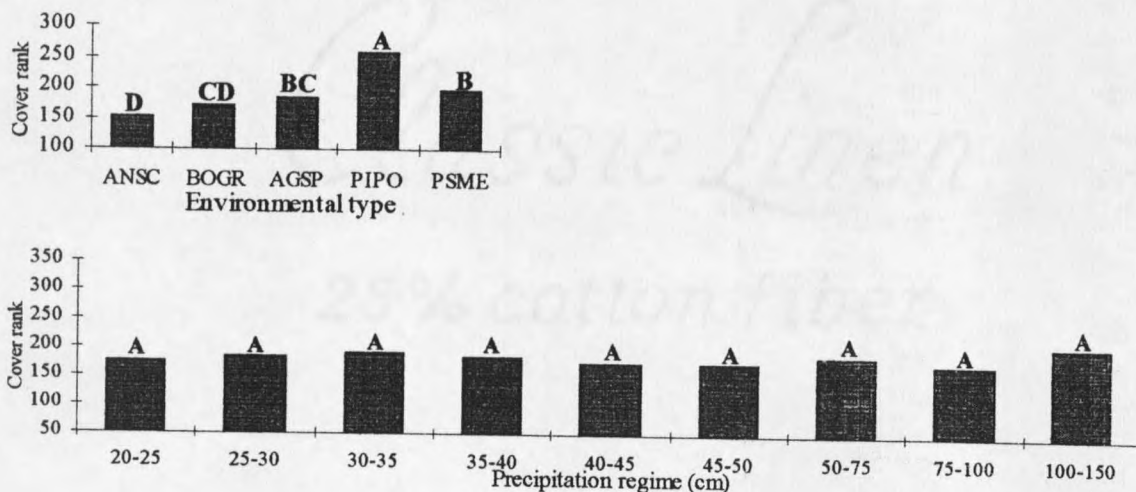


Figure 42. Effect of Environmental Type and Precipitation on Cover (%) of *Festuca ovina*. Categories sharing a letter do not significantly differ.

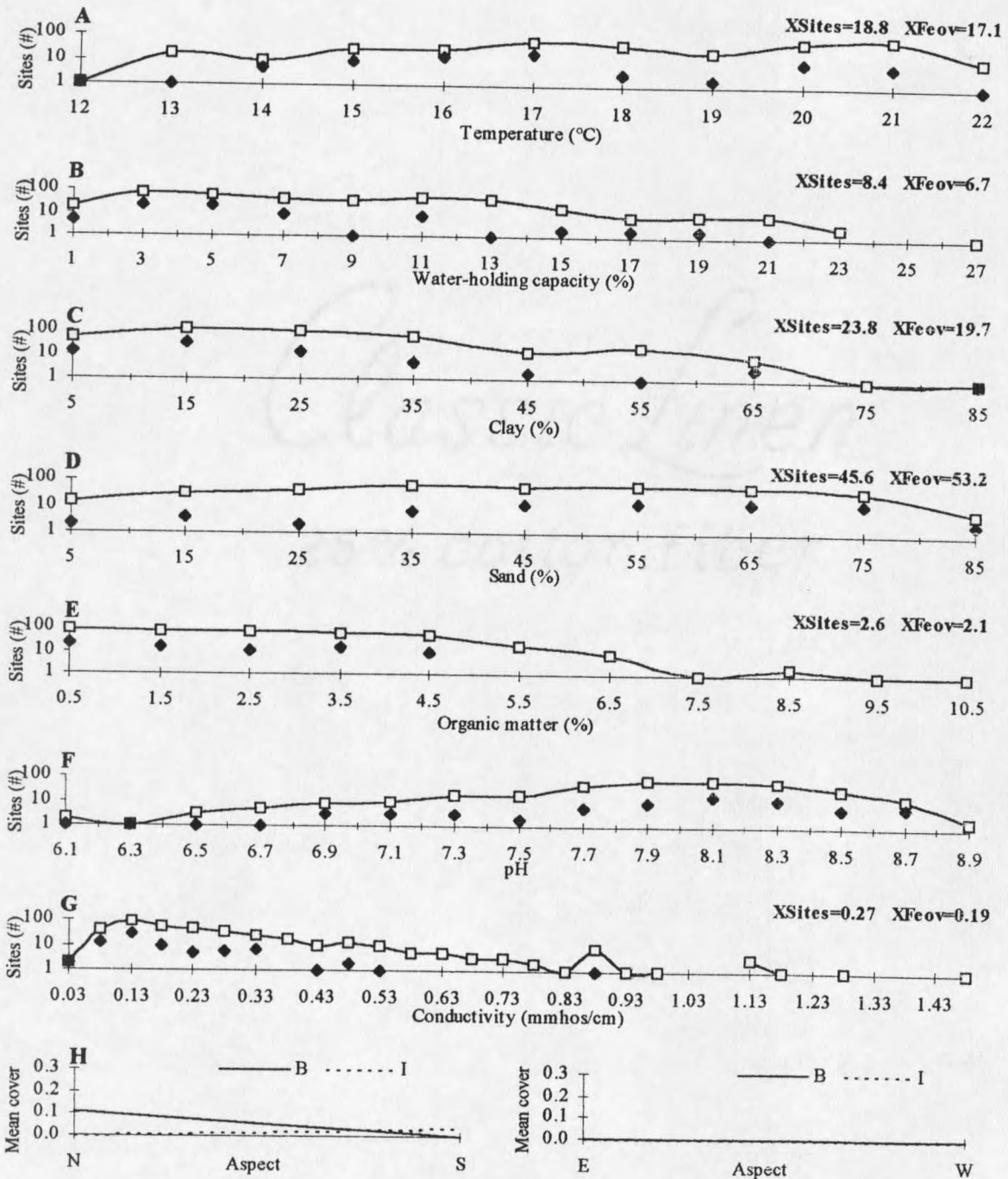


Figure 43. The Distribution of *Festuca ovina* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the means of sites occupied by *Festuca ovina* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Festuca scabrella* (Fesc)*rough fescue****Poaceae**

Origin, Duration and Habit¹: Native Perennial Grass, not vegetatively reproducing.

Environmental Type²: Fesc cover (%) is highest in the AGSP type (Fig. 44).

Temperature: Temperature does not differ between Fesc sites and average sites (Fig. 45A).

Precipitation: Fesc cover (%) does not differ between dry and moist sites (Fig. 44).

Water-holding capacity: WHC does not differ between Fesc sites and average sites (Fig. 45B).

Clay: Clay does not differ between Fesc sites and average sites (Fig. 45C).

Sand: Sand does not differ between Fesc sites and average sites (Fig. 45D).

Organic carbon: OC does not differ between Fesc sites and average sites (Fig. 45E).

pH: pH does not differ between Fesc sites and average sites (Fig. 45F).

Conductivity: Conductivity does not differ between Fesc sites and average sites (Fig. 45G).

Position and Aspect: Mean cover (%) is higher on north-facing than south-facing. Does not occur or occurs sporadically on east and west-facing slopes (Fig. 45H).

¹ Refer to introduction (p52) for descriptions of each category. ² Significant category.

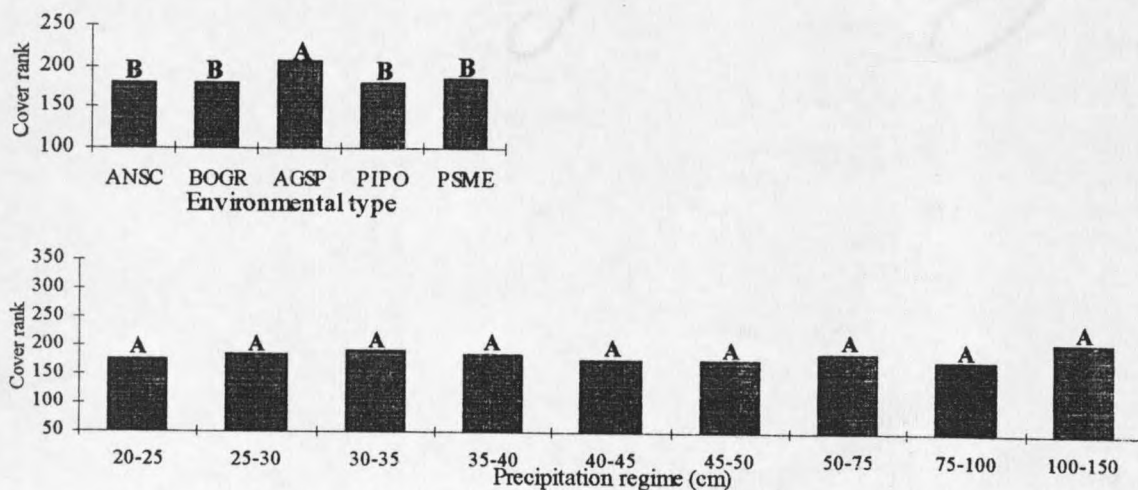


Figure 44. Effect of Environmental Type and Precipitation on Cover (%) of *Festuca scabrella*. Categories sharing a letter do not significantly differ.

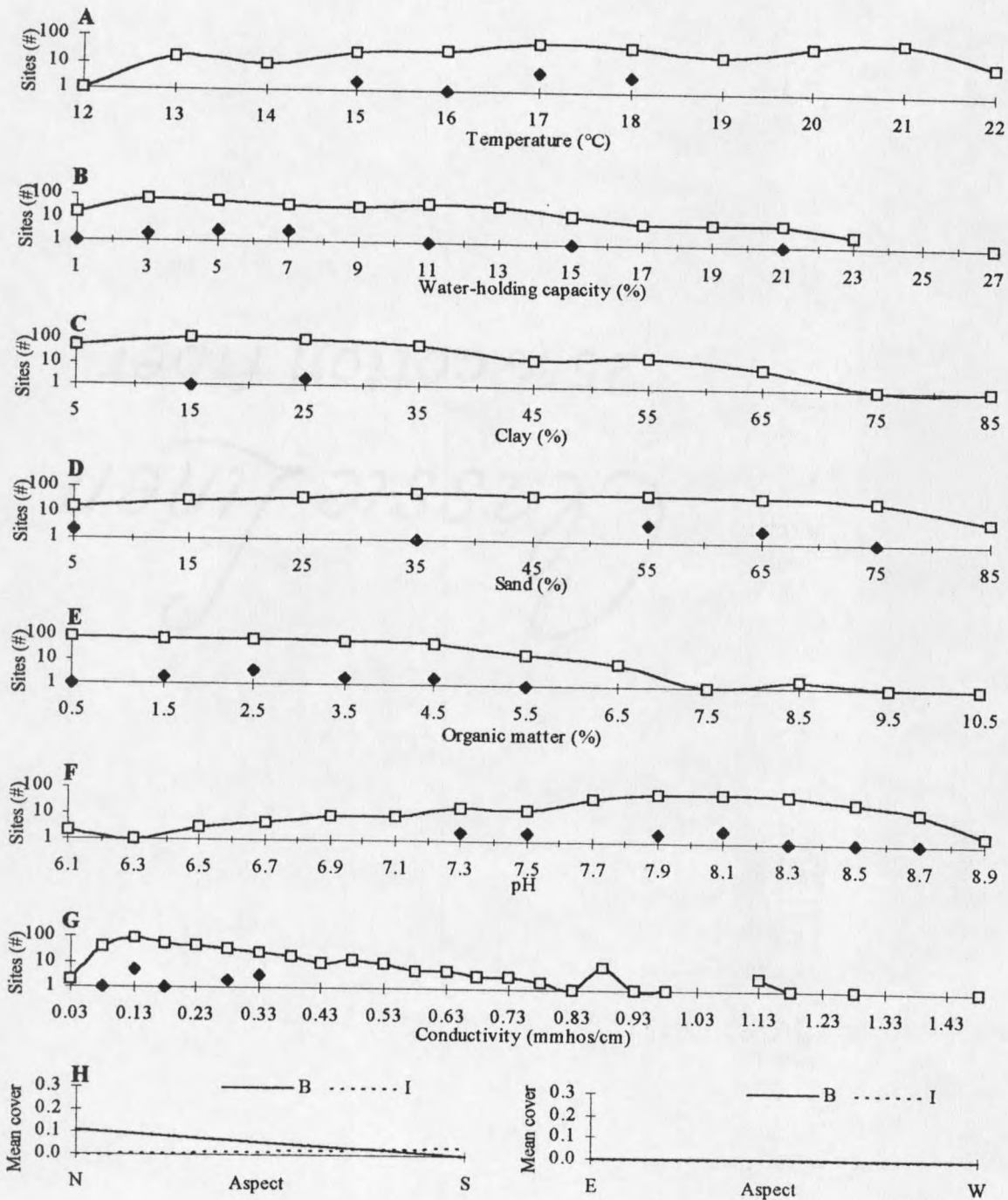


Figure 45. The Distribution of *Festuca scabrella* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied *Festuca scabrella* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Gaura coccinea* (Gaco)*scarlet gaura****Onagraceae**

Origin, Duration and Habit¹: Native Perennial Forb, not vegetatively reproducing.

Environmental type: Gaco cover (%) does not differ between types (Fig. 46).

Temperature: Temperature does not differ between Gaco sites and average sites (Fig. 47A).

Precipitation: Gaco cover (%) does not differ between dry and moist sites (Fig. 46).

Water-holding capacity: WHC does not differ between Gaco sites and average sites (Fig. 47B).

Clay: Clay does not differ between Gaco sites and average sites (Fig. 47C).

Sand: Sand does not differ between Gaco sites and average sites (Fig. 47D).

Organic carbon: Organic carbon in Gaco sites does not differ from average roadside sites (Fig. 47E).

pH: pH in Gaco sites does not differ from average roadside sites (Fig. 47F).

Conductivity: Conductivity in Gaco sites does not differ from average sites (Fig. 47G).

Position and Aspect: Mean cover (%) is generally higher on backslopes than inslopes (Fig. 47H).

¹ Refer to introduction (p52) for descriptions of each category.

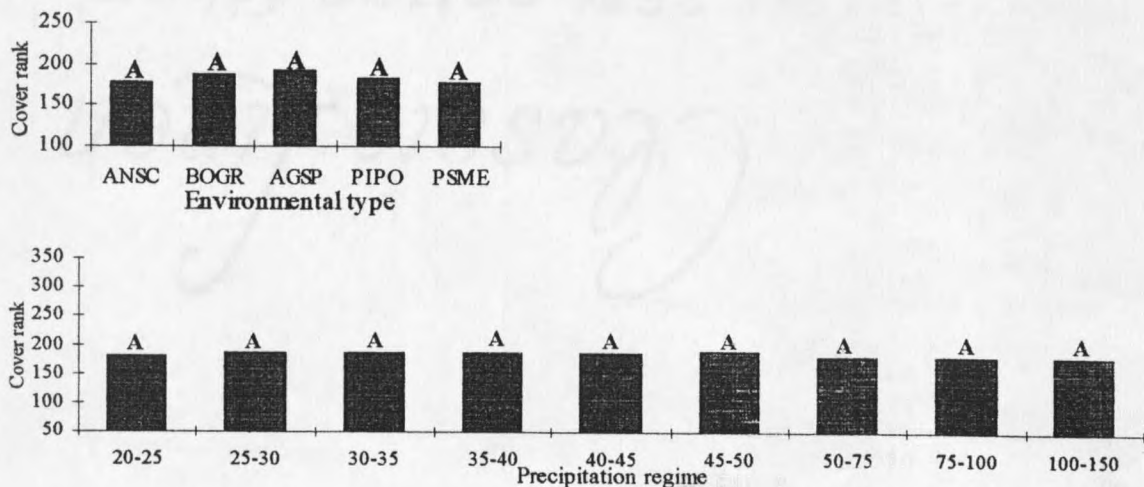


Figure 46. Effect of Environmental Type and Precipitation on Cover (%) of *Gaura coccinea*. Categories sharing a letter do not significantly differ.

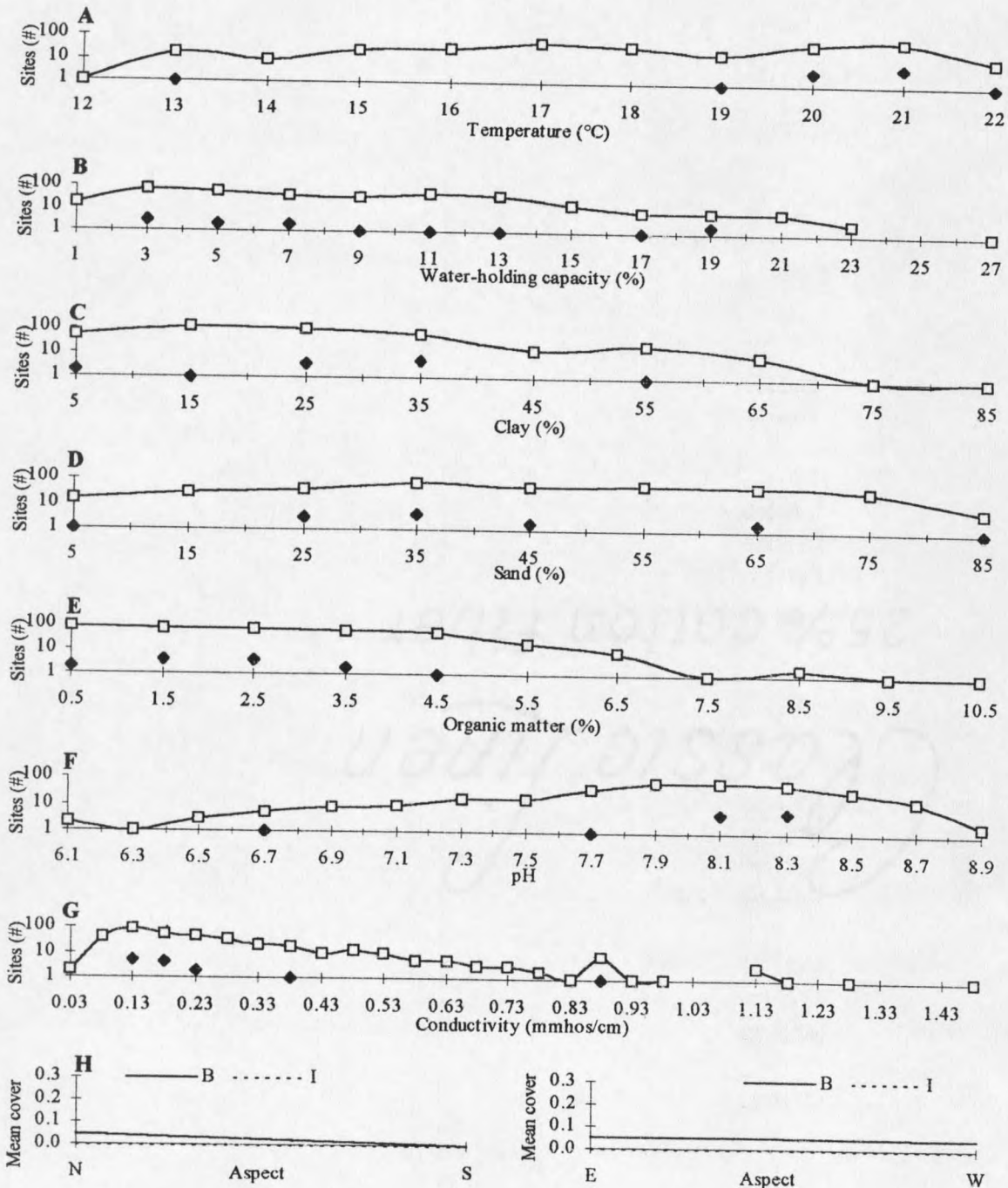


Figure 47. The Distribution of *Gaura coccinea* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Gaura coccinea* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Gutierrezia sarothrae (Gusa)

broom snakeweed

Asteraceae

Origin, Duration and Habit¹: Native Perennial Shrub, not vegetatively reproducing.

Environmental type: Gusa cover (%) does not differ between types (Fig. 48).

Temperature: Temperature does not differ between Gusa sites and average sites (Fig. 49A).

Precipitation: Gusa cover (%) does not differ between dry and moist sites (Fig. 48).

Water-holding capacity: WHC does not differ between Gusa sites and average sites (Fig. 49B).

Clay²: Clay in Gusa sites is higher than average roadside sites (Fig. 49C).

Sand²: Sand in Gusa sites is lower than average roadside sites (Fig. 49D).

Organic carbon²: OC in Gusa sites is lower than average roadside sites (Fig. 49E).

pH: pH does not differ between Gusa sites and average sites (Fig. 49F).

Conductivity: Conductivity does not differ between Gusa and average sites (Fig. 49G).

Position and Aspect: Mean cover (%) is highest on north-facing backslopes and absent or appears sporadically on all other sites (Fig. 49H)

¹ Refer to introduction (p52) for descriptions of each category. ² Significant category.

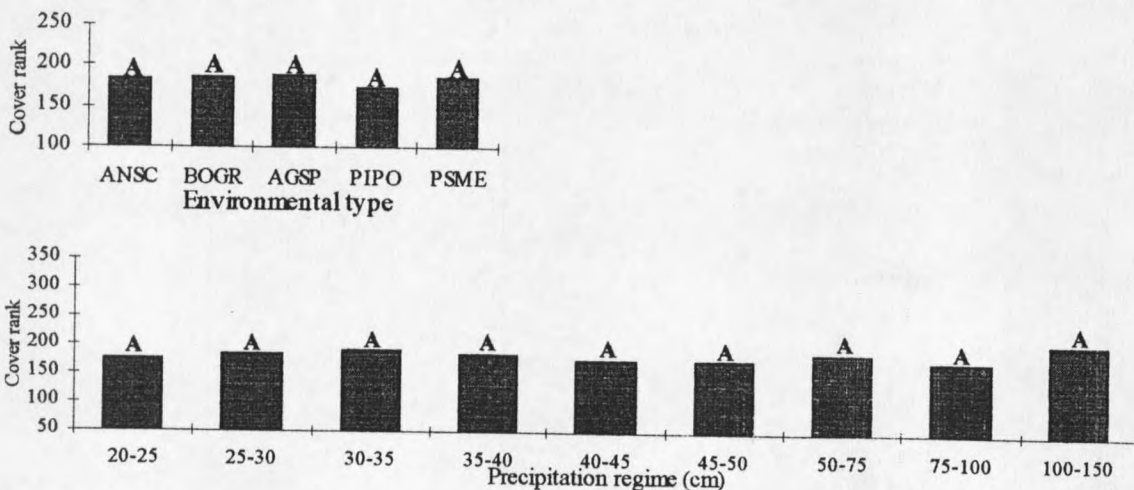


Figure 48. Effect of Environmental Type and Precipitation on Cover (%) of *Gutierrezia sarothrae*. Categories sharing a letter do not significantly differ.

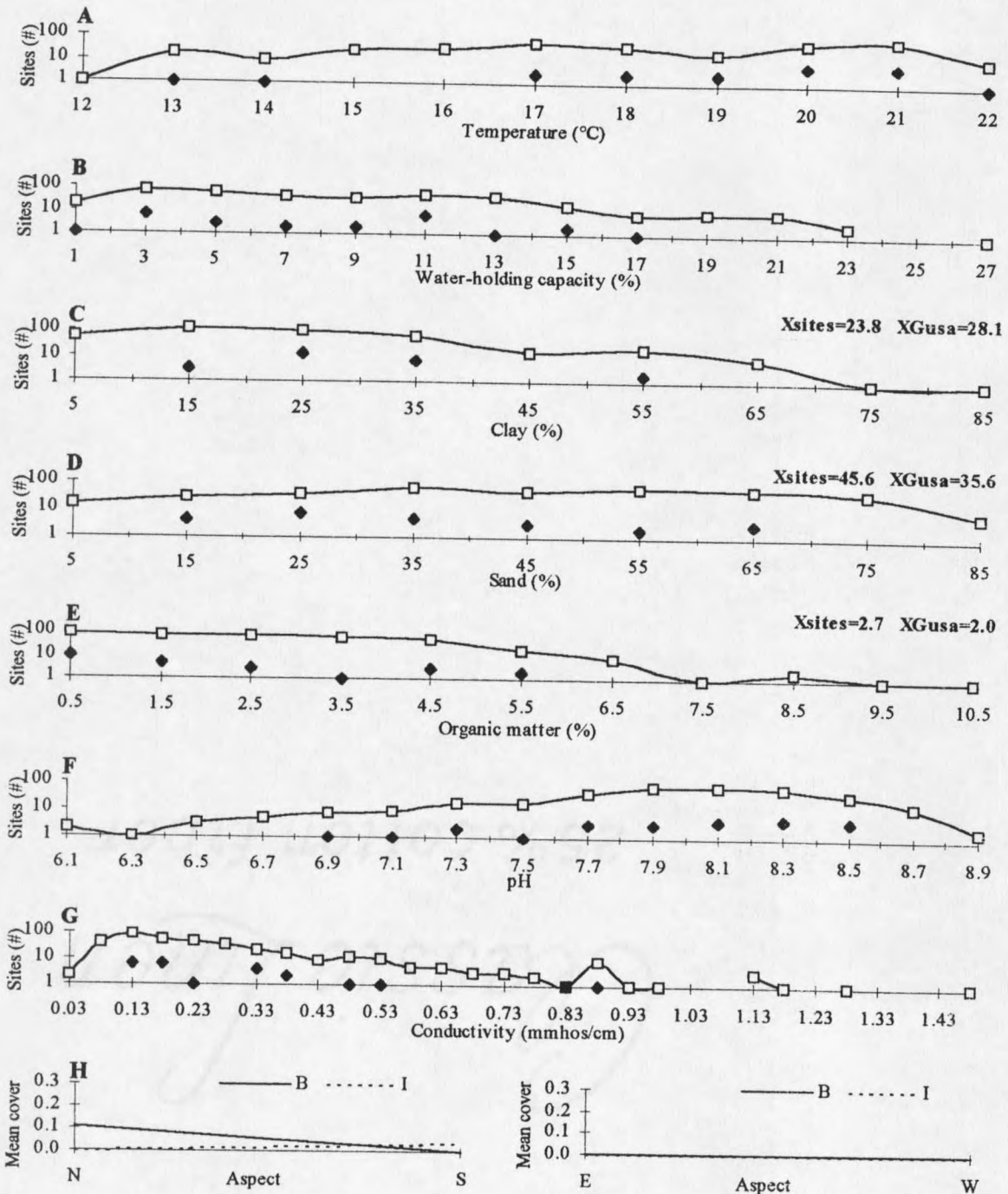


Figure 49. The Distribution of *Gutierrezia sarothrae* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Gutierrezia sarothrae* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Heterotheca villosa (Hevi)

hairy golden aster

Asteraceae

Origin, Duration and Habit¹: Native Perennial Forb, not vegetatively reproducing.

Environmental type: Hevi cover (%) does not differ between types (Fig. 50).

Temperature²: Temperature in Hevi sites is higher than average sites (Fig. 51A).

Precipitation: Hevi cover (%) does not differ between dry and moist sites (Fig. 50).

Water-holding capacity: WHC does not differ between Hevi sites and average sites (Fig. 51B).

Clay: Clay does not differ between Hevi sites and average sites (Fig. 51C).

Sand: Sand does not differ between Hevi sites and average sites (Fig. 51D).

Organic carbon: OC does not differ between Hevi sites and average sites (Fig. 51E).

pH: pH does not differ between Hevi sites and average sites (Fig. 51F).

Conductivity: Conductivity does not differ between Hevi sites and average sites (Fig. 51G).

Position and Aspect: Cover (%) of Hevi is higher in backslopes than inslopes (Fig. 51H).

¹ Refer to introduction (p52) for descriptions of each category. ² Significant category.

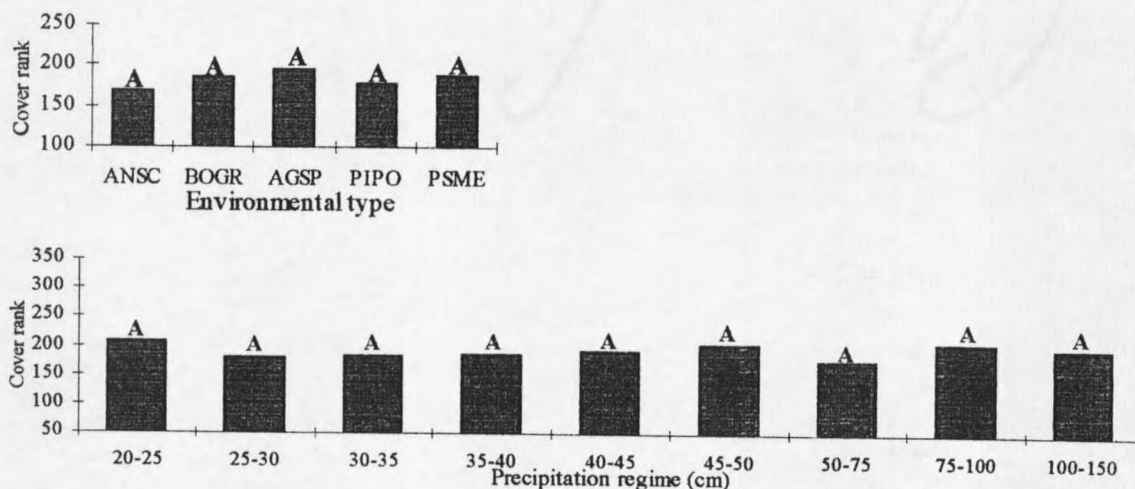


Figure 50. Effect of Environmental Type and Precipitation on Cover (%) of *Heterotheca villosa*. Categories sharing a letter do not significantly differ.

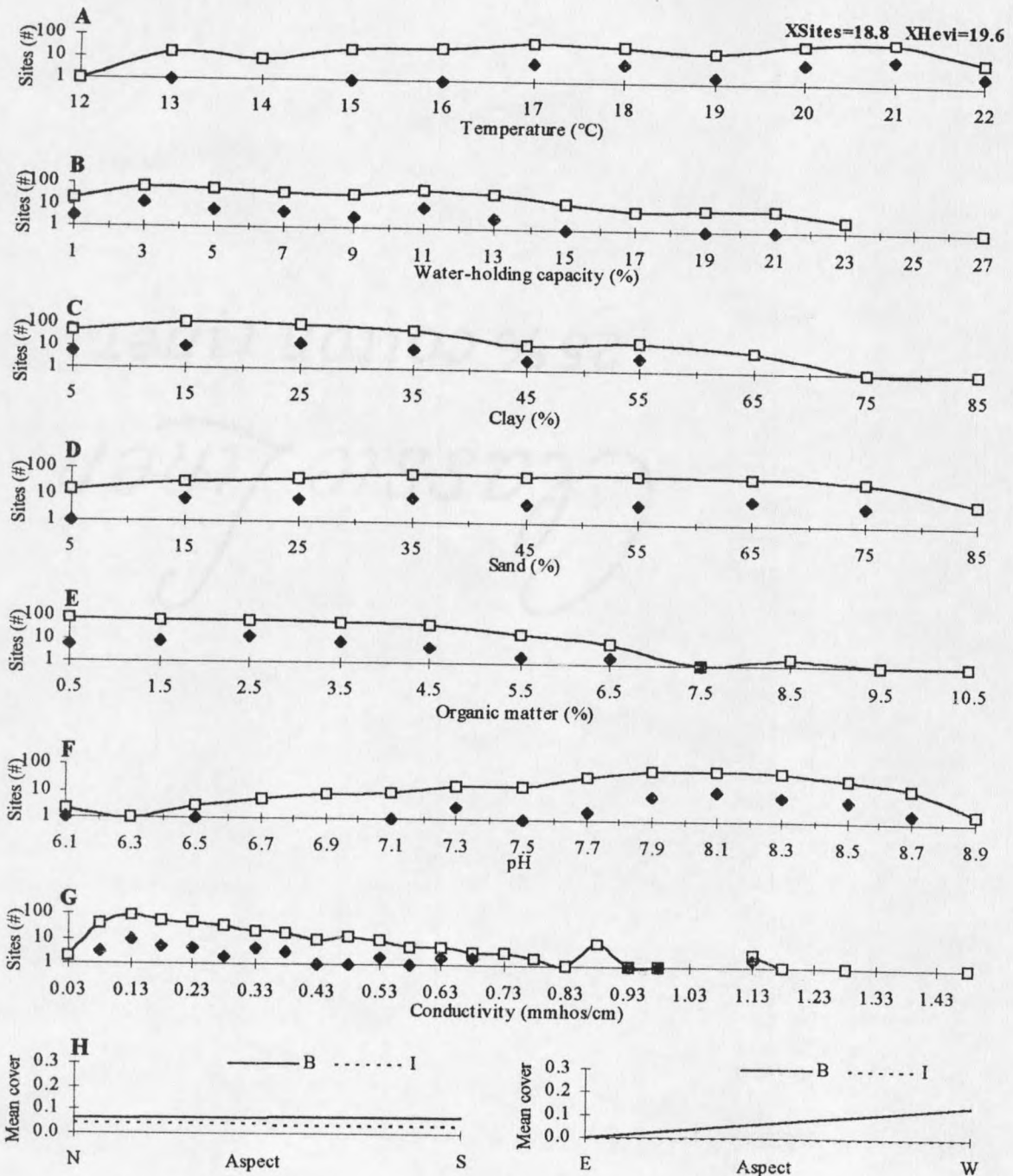


Figure 51. The Distribution of *Heterotheca villosa* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Heterotheca villosa* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Hordeum jubatum* (Hoju)*squirreltail barley****Poaceae**

Origin, Duration and Habit¹: Native Perennial Grass, not vegetatively reproducing.

Environmental Type²: Hoju cover (%) is highest in the BOGR and PIPO types, and lower in ANSC, AGSP and PSME types (Fig. 52).

Temperature²: Temperature in Hoju sites is higher than average sites (Fig. 53A)

Precipitation: Hoju cover (%) does not differ between dry and moist sites (Fig. 52).

Water-holding capacity: WHC does not differ between Hoju sites and average sites (Fig. 53B).

Clay: Clay does not differ between Hoju sites and average sites (Fig. 53C).

Sand: Sand does not differ between Hoju sites and average sites (Fig. 53D).

Organic carbon: OC does not differ between Hoju sites and average sites (Fig. 53E).

pH: pH does not differ between Hoju sites and average sites (Fig. 53F).

Conductivity²: Conductivity in Hoju sites is higher than average sites (Fig. 53G).

Position and Aspect: Mean cover (%) is highest on north-facing backslopes (Fig. 53H).

¹ Refer to introduction (p52) for descriptions of each category. ² Significant category.

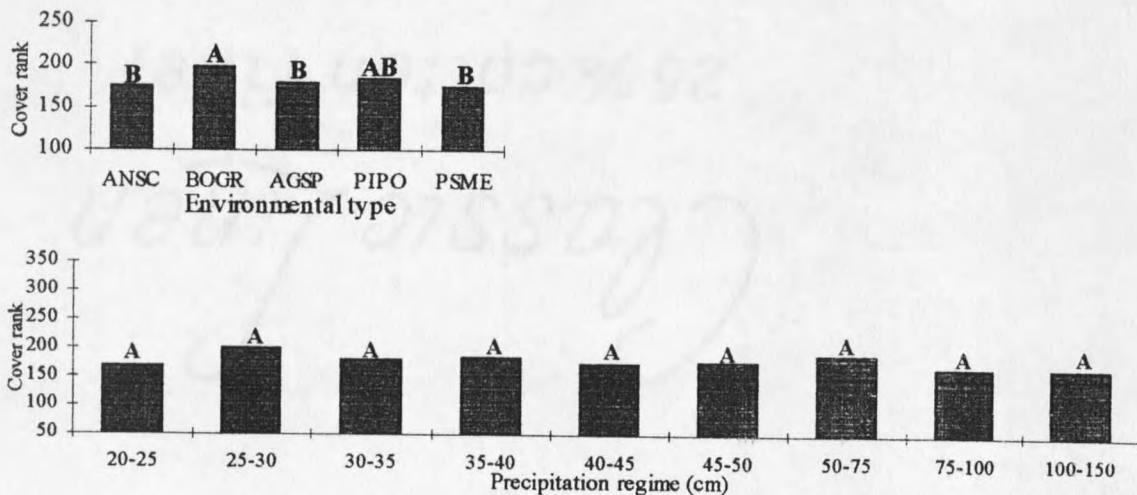


Figure 52. Effect of Environmental Type and Precipitation on Cover (%) of *Hordeum jubatum*. Categories sharing a letter do not significantly differ.

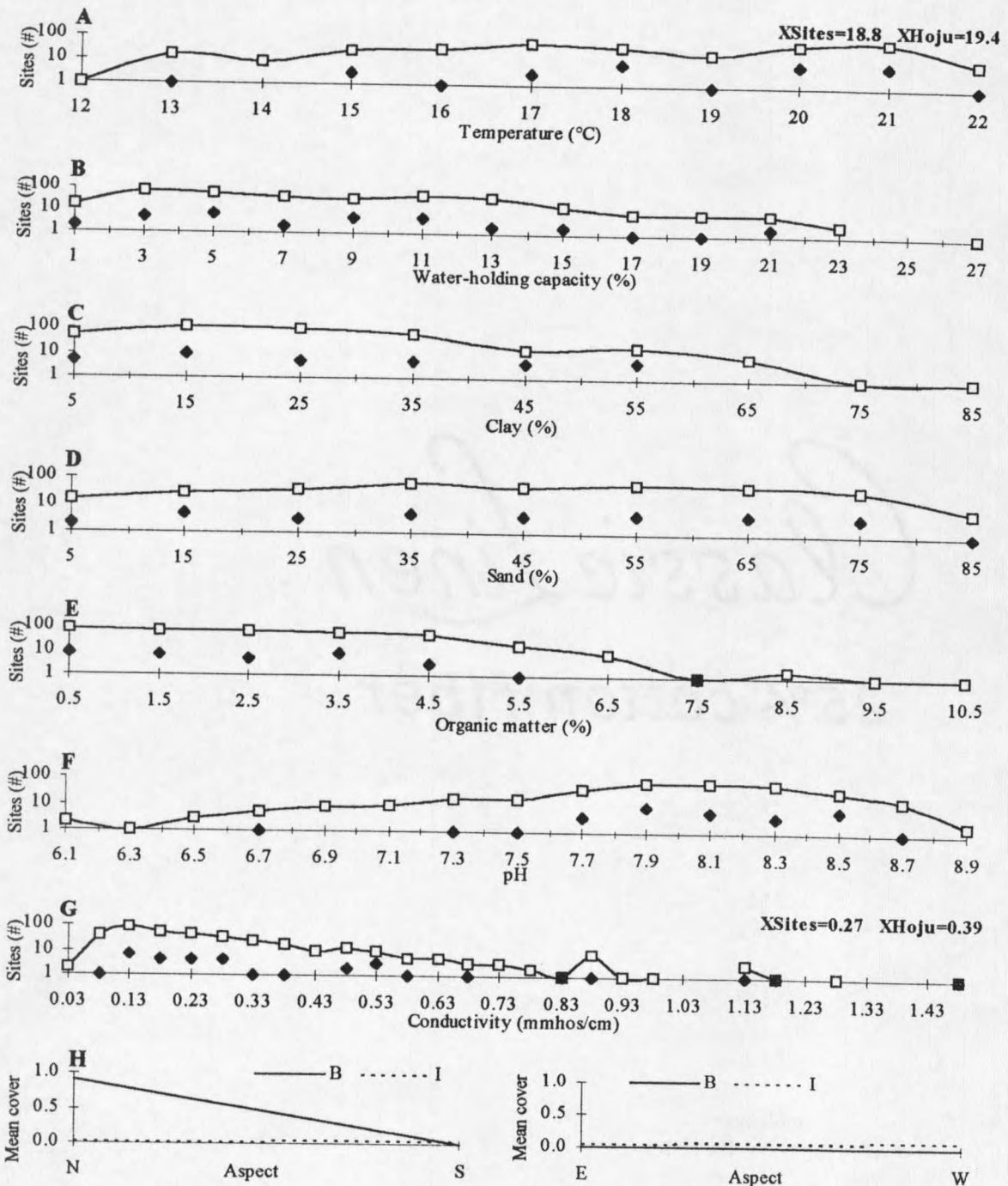


Figure 53. The Distribution of *Hordeum jubatum* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Hordeum jubatum* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Koeleri nitida* (Koni)*prairie junegrass****Poaceae**

Origin, Duration and Habit¹: Native Perennial Grass, not vegetatively reproducing.

Environmental Type²: Koni cover (%) is highest in the BOGR and PSME types and lowest in ANSC, AGSP and PIPO (Fig. 54).

Temperature: Temperature of Koni sites does not differ from average roadside sites (Fig. 55A).

Precipitation²: Koni cover (%) is highest in the moist (100-150cm) sites (Fig. 54).

Water-holding capacity: WHC does not differ between Koni sites and average sites (Fig. 55B).

Clay: Clay does not differ between Koni sites and average sites (Fig. 55C).

Sand: Sand does not differ between Koni sites and average sites (Fig. 55D).

Organic carbon: OC does not differ between Koni sites and average sites (Fig. 55E).

pH: pH does not differ between Koni sites and average sites (Fig. 55F).

Conductivity²: Conductivity in Koni sites is higher than average sites (Fig. 55G).

Position and Aspect: Mean cover (%) is highest on south-facing backslopes (Fig. 55H)

¹ Refer to introduction (p52) for descriptions of each category. ² Significant category.

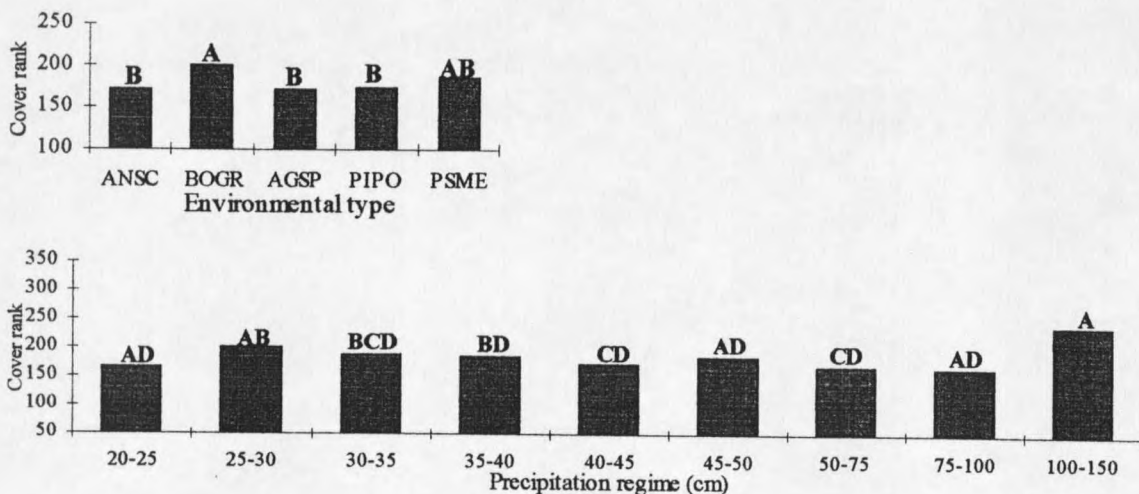


Figure 54. Effect of Environmental Type and Precipitation on Cover (%) of *Koeleri nitida*. Categories sharing a letter do not significantly differ.

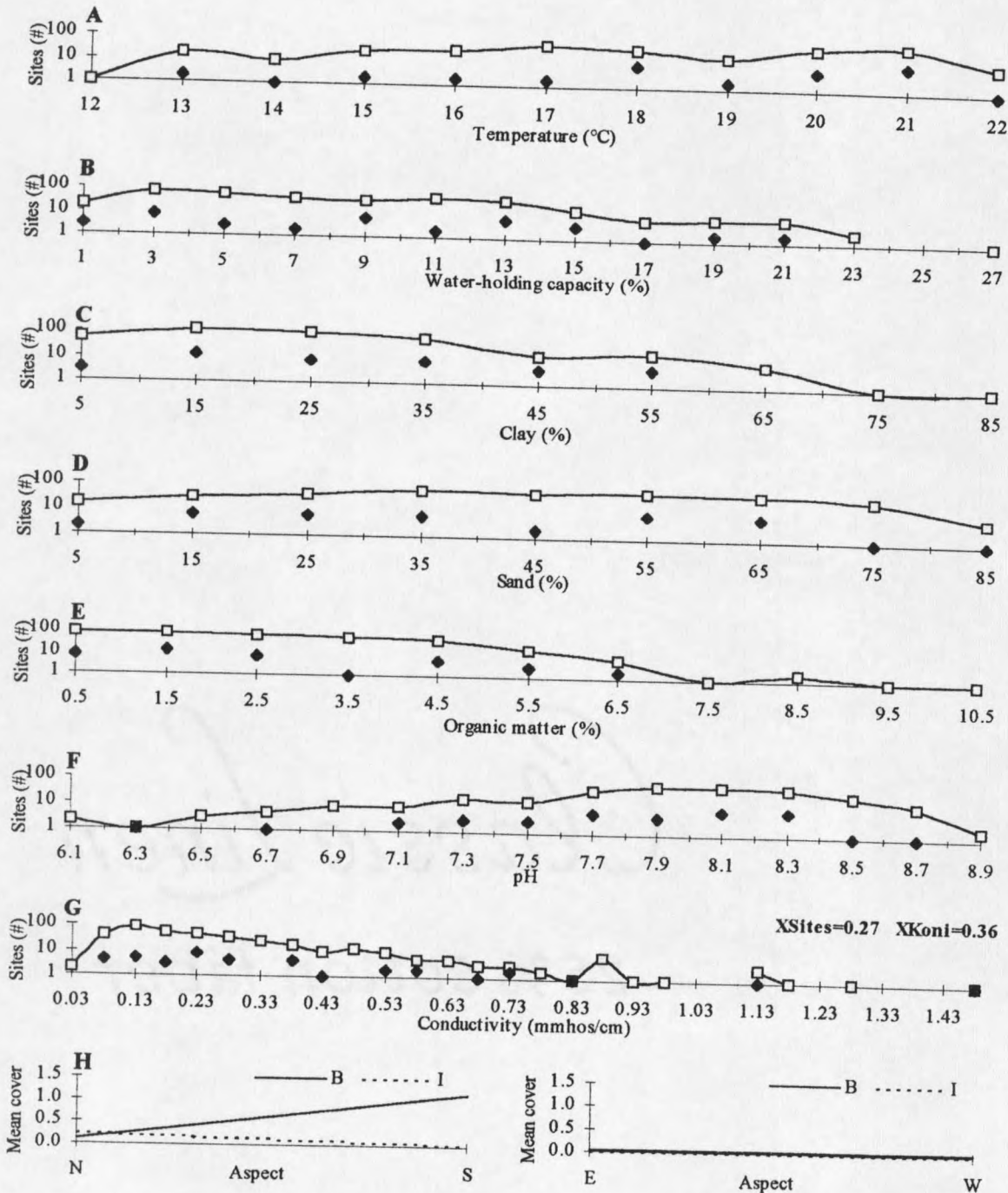


Figure 55. The Distribution of *Koeleri nitida* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where mean of sites occupied by *Koeleri nitida* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

***Kochia scoparia* (Kosc)**

summer cypress

Chenopodiaceae

Origin, Duration and Habit¹: Exotic Annual Forb, not vegetatively reproducing.

Environmental Type²: Kosc cover (%) is highest in the AGSP type (Fig. 56).

Temperature: Temperature does not differ between Kosc sites and average sites (Fig. 57A).

Precipitation: Kosc cover (%) does not differ between dry and moist sites (Fig. 56).

Water-holding capacity: WHC does not differ between Kosc sites and average sites (Fig. 57B).

Clay: Clay does not differ between Kosc sites and average sites (Fig. 57C).

Sand: Sand does not differ between Kosc sites and average sites (Fig. 57D).

Organic carbon: OC does not differ between Kosc sites and average sites (Fig. 57E).

pH: pH does not differ between Kosc sites and average sites (Fig. 57F).

Conductivity: Conductivity in Kosc sites does not differ from average sites (Fig. 57G).

Position and Aspect: Mean cover (%) is higher on north and south-facing inslopes than east and west facing backslopes. Does not occur or occurs sporadically on north and south-facing backslopes and east and west-facing inslopes (Fig. 57H).

¹ Refer to introduction (p52) for descriptions of each category. ² Significant category.

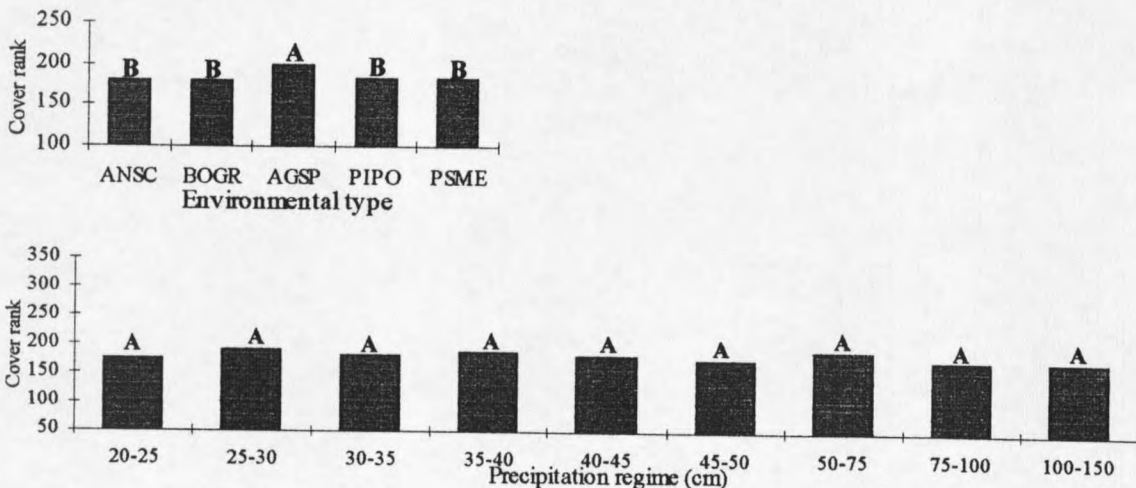


Figure 56. Effect of Environmental Type and Precipitation on Cover (%) of *Kochia scoparia*. Categories sharing a letter do not significantly differ.

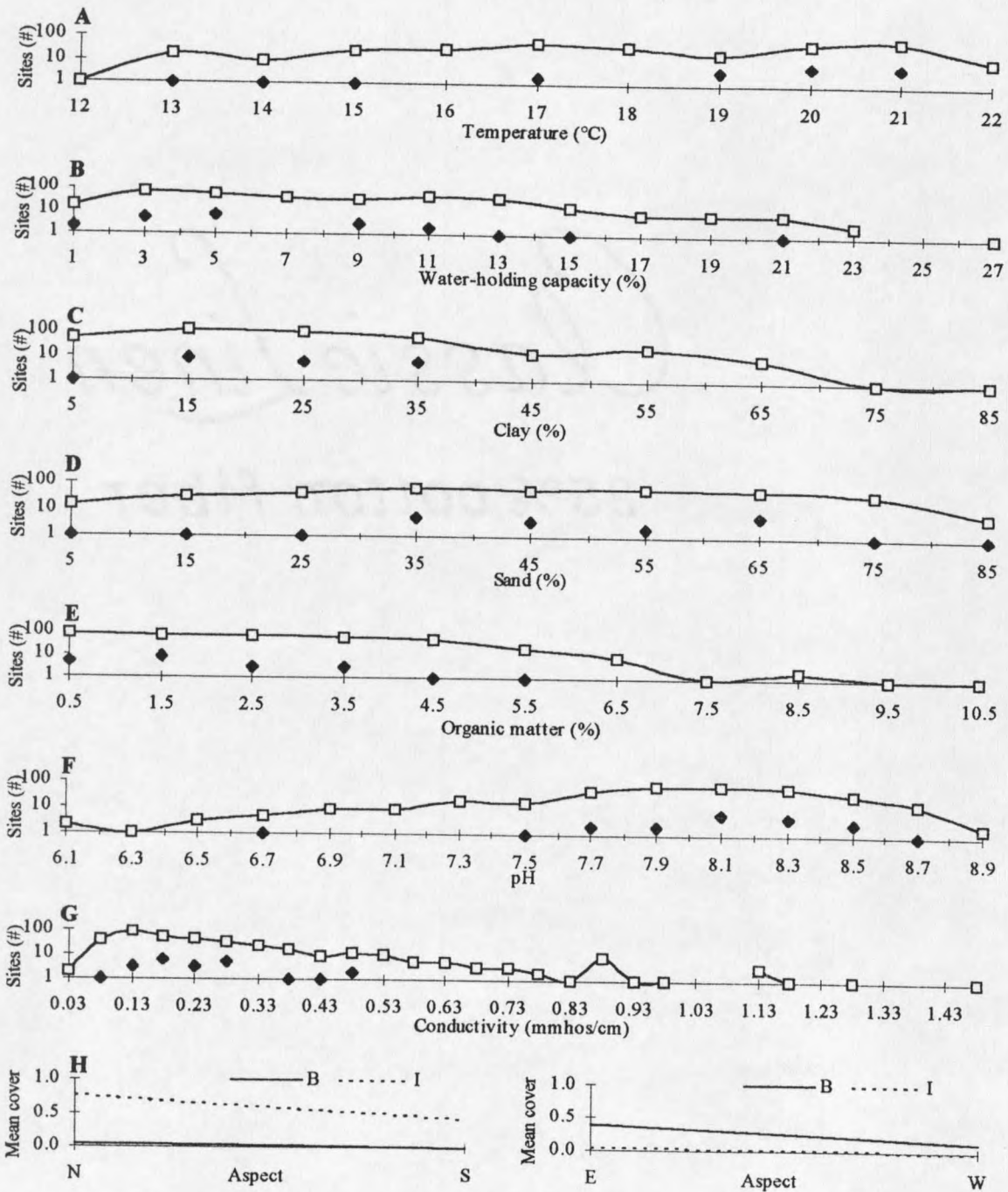


Figure 57. The Distribution of *Kochia scoparia* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Kochia scoparia* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Lactuca serriola (Lase)

prickly lettuce

Asteraceae

Origin, Duration and Habit¹: Exotic Annual Forb, not vegetatively reproducing.

Environmental Type²: Lase cover (%) is highest in the ANSC type (Fig. 58).

Temperature: Temperature does not differ between Lase sites and average sites (Fig. 59A).

Precipitation: Lase cover (%) does not differ between dry and moist sites (Fig. 58).

Water-holding capacity: WHC does not differ between Lase sites and average sites (Fig. 59B).

Clay: Clay does not differ between Lase sites and average sites (Fig. 59C).

Sand: Sand does not differ between Lase sites and average sites (Fig. 59D).

Organic carbon: OC does not differ between Lase sites and average sites (Fig. 59E).

pH: pH does not differ between Lase sites and average sites (Fig. 59F).

Conductivity: Conductivity does not differ between Lase and average sites (Fig. 59G).

Position and Aspect: Mean cover is higher on north-facing backslopes than inslopes or south-facing inslopes or backslopes. There is an interaction between plot position and aspect on east and west facing sites (Fig. 59H).

¹ Refer to introduction (p52) for descriptions of each category. ² Significant category.

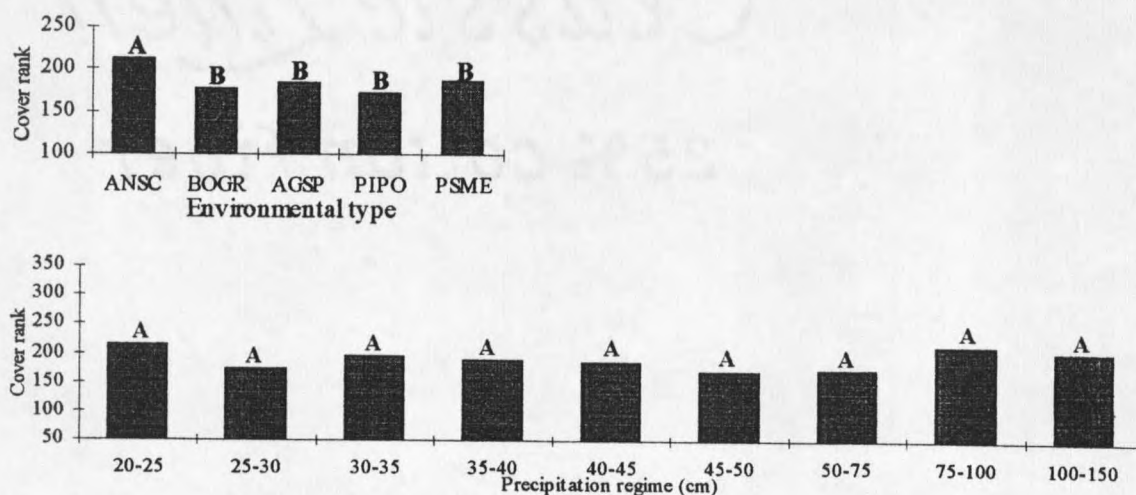


Figure 58. Effect of Environmental Type and Precipitation on Cover (%) of *Lactuca serriola*. Categories sharing a letter do not significantly differ.

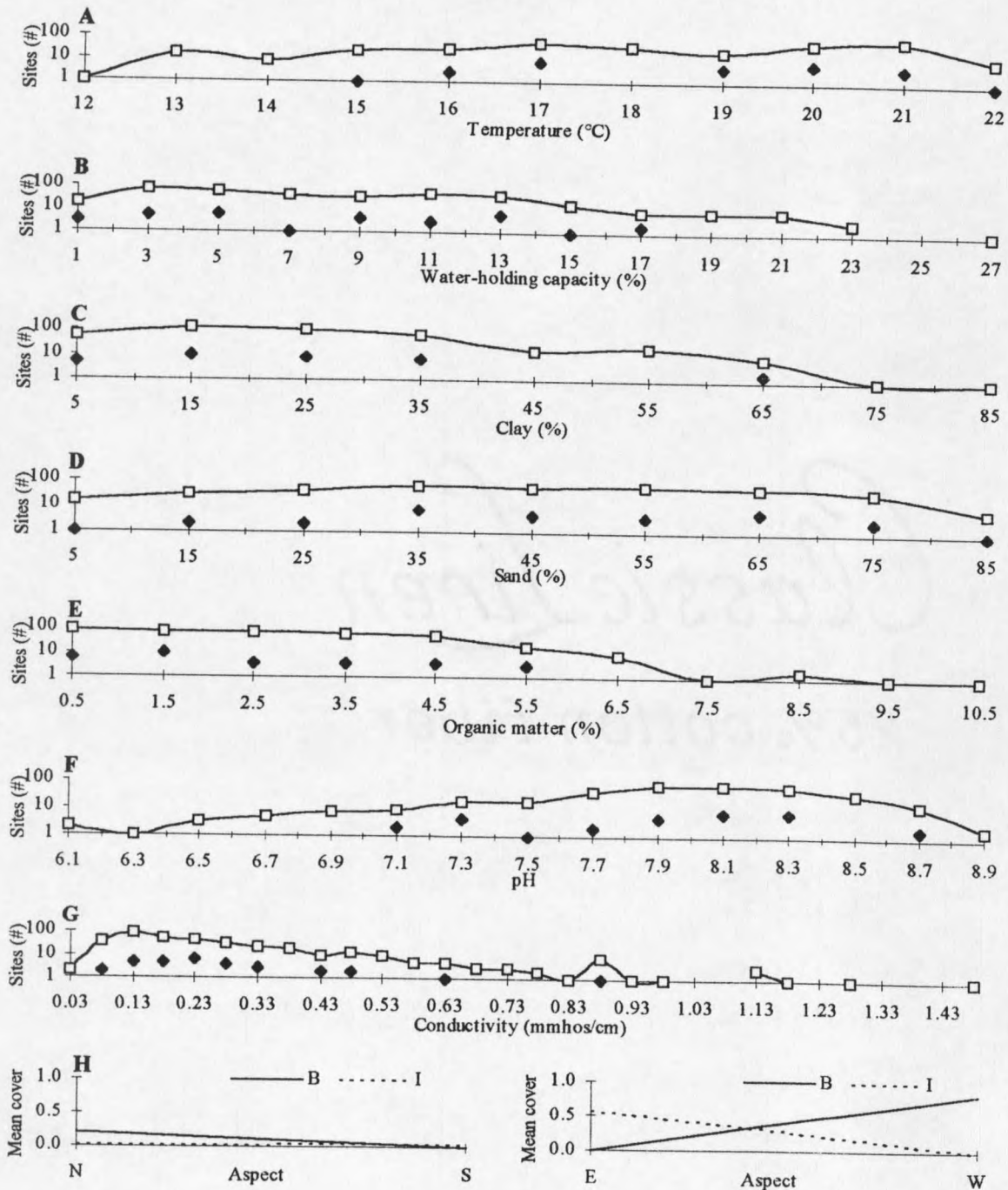


Figure 59. The Distribution of *Lactuca serriola* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Lactuca serriola* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Liatris punctata (Lipu)

liatris

Asteraceae

Origin, Duration and Habit¹: Native Perennial Forb, not vegetatively reproducing.

Environmental type: Lipu cover (%) does not differ between types (Fig. 60).

Temperature: Temperature does not differ between Lipu sites and average sites (Fig. 61A).

Precipitation: Lipu cover (%) does not differ between dry and moist sites (Fig. 60).

Water-holding capacity: WHC does not differ between Lipu sites and average sites (Fig. 61B).

Clay: Clay does not differ between Lipu sites and average sites (Fig. 61C).

Sand: Sand does not differ between Lipu sites and average sites (Fig. 61D).

Organic carbon: OC does not differ between Lipu sites and average sites (Fig. 61E).

pH: pH does not differ between Lipu sites and average sites (Fig. 61F).

Conductivity: Conductivity does not differ between Lipu sites and average sites (Fig. 61G).

Position and Aspect: Occurs only sporadically (Fig. 61H).

¹ Refer to introduction (p52) for descriptions of each category.

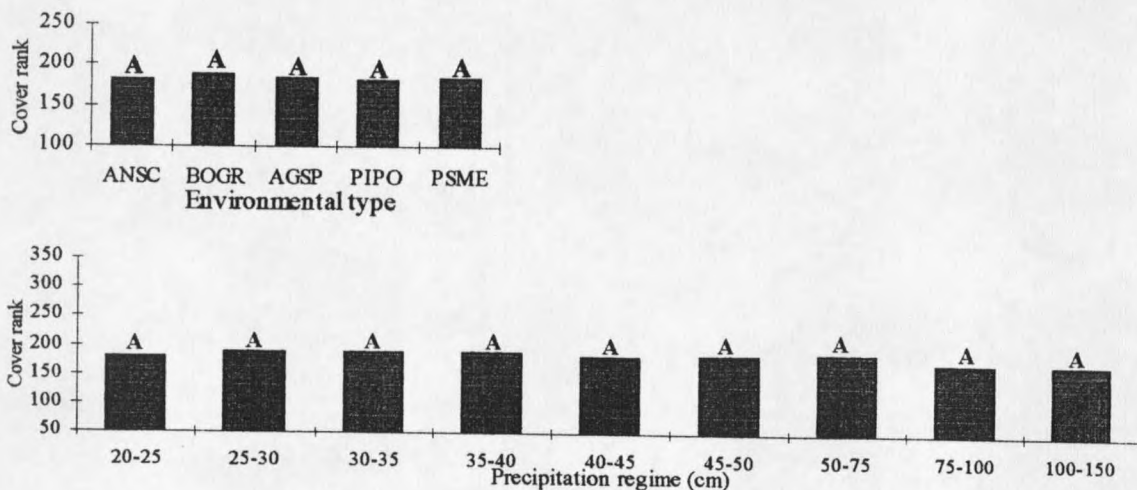


Figure 60. Effect of Environmental Type and Precipitation on Cover (%) of *Liatris punctata*. Categories sharing a letter do not significantly differ.

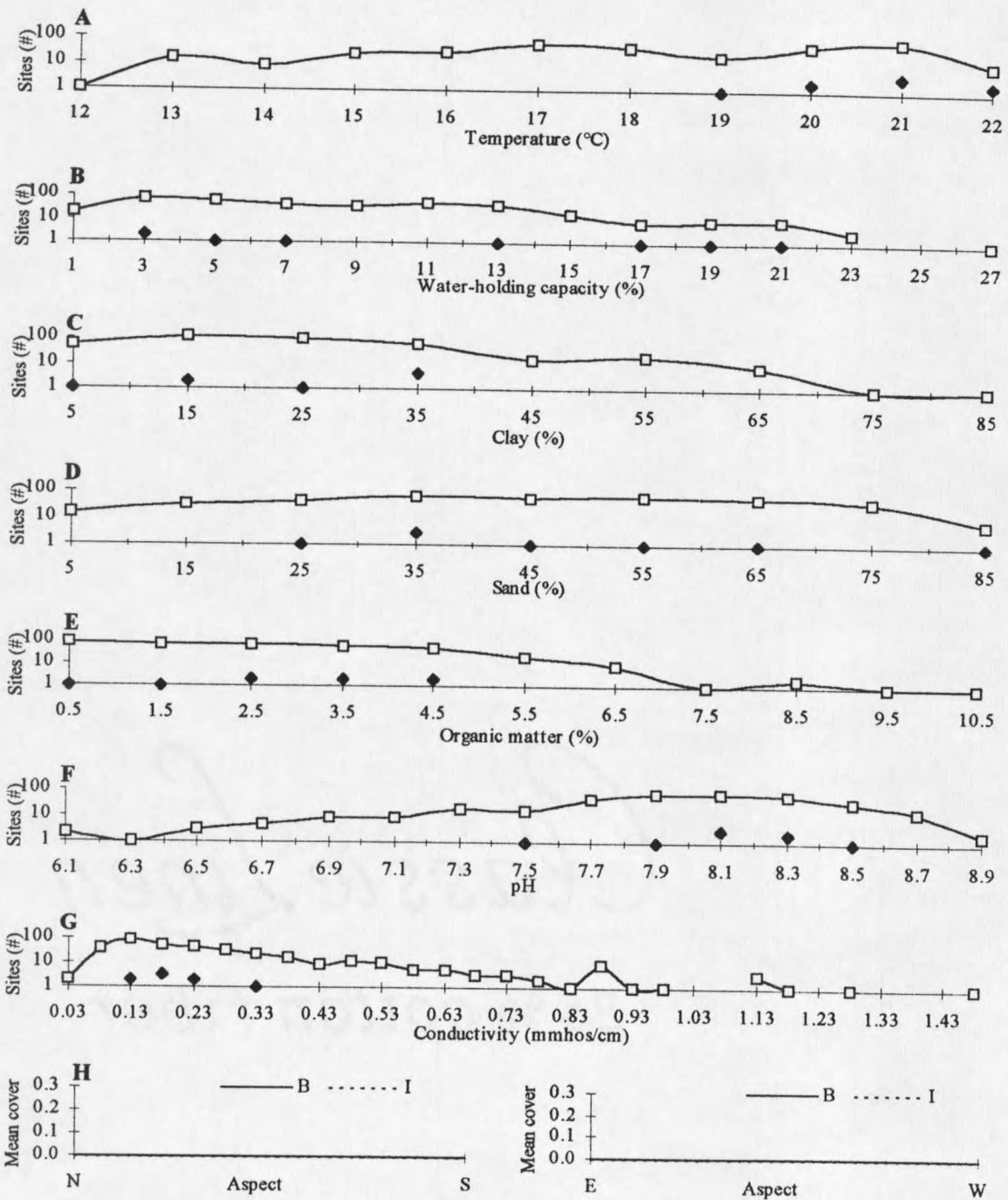


Figure 61. The Distribution of *Liatris punctata* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Liatris punctata* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Lupinus argenteus (Luar)

Lupine

Fabaceae

Origin, Duration and Habit¹: Native Perennial Forb, not vegetatively reproducing.

Environmental type: Luar cover (%) does not differ between types (Fig. 61).

Temperature²: Temperature in Luar sites is lower than average roadside sites (Fig. 62A).

Precipitation: Luar cover (%) does not differ between dry and moist sites (Fig. 61).

Water-holding capacity: WHC does not differ between Luar sites and average sites (Fig. 62B).

Clay: Clay does not differ between Luar sites and average sites (Fig. 62C).

Sand: Sand does not differ between Luar sites and average sites (Fig. 62D).

Organic carbon: OC does not differ between Luar sites and average sites (Fig. 62E).

pH²: pH in Luar sites is lower than average roadside sites (Fig. 62F).

Conductivity: Conductivity does not differ between Luar sites and average sites (Fig. 62G).

Position and Aspect: Luar occurs sporadically on roadside sites (Fig. 62H).

¹ Refer to introduction (p52) for descriptions of each category. ² Significant category.

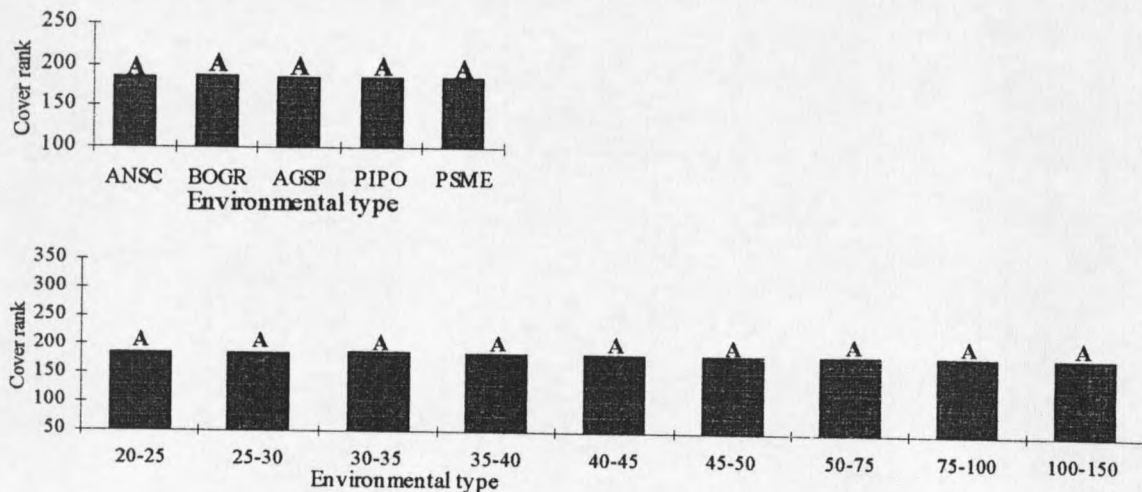


Figure 62. Effect of Environmental Type and Precipitation on Cover (%) of *Lupinus argenteus*. Categories sharing a letter do not significantly differ.

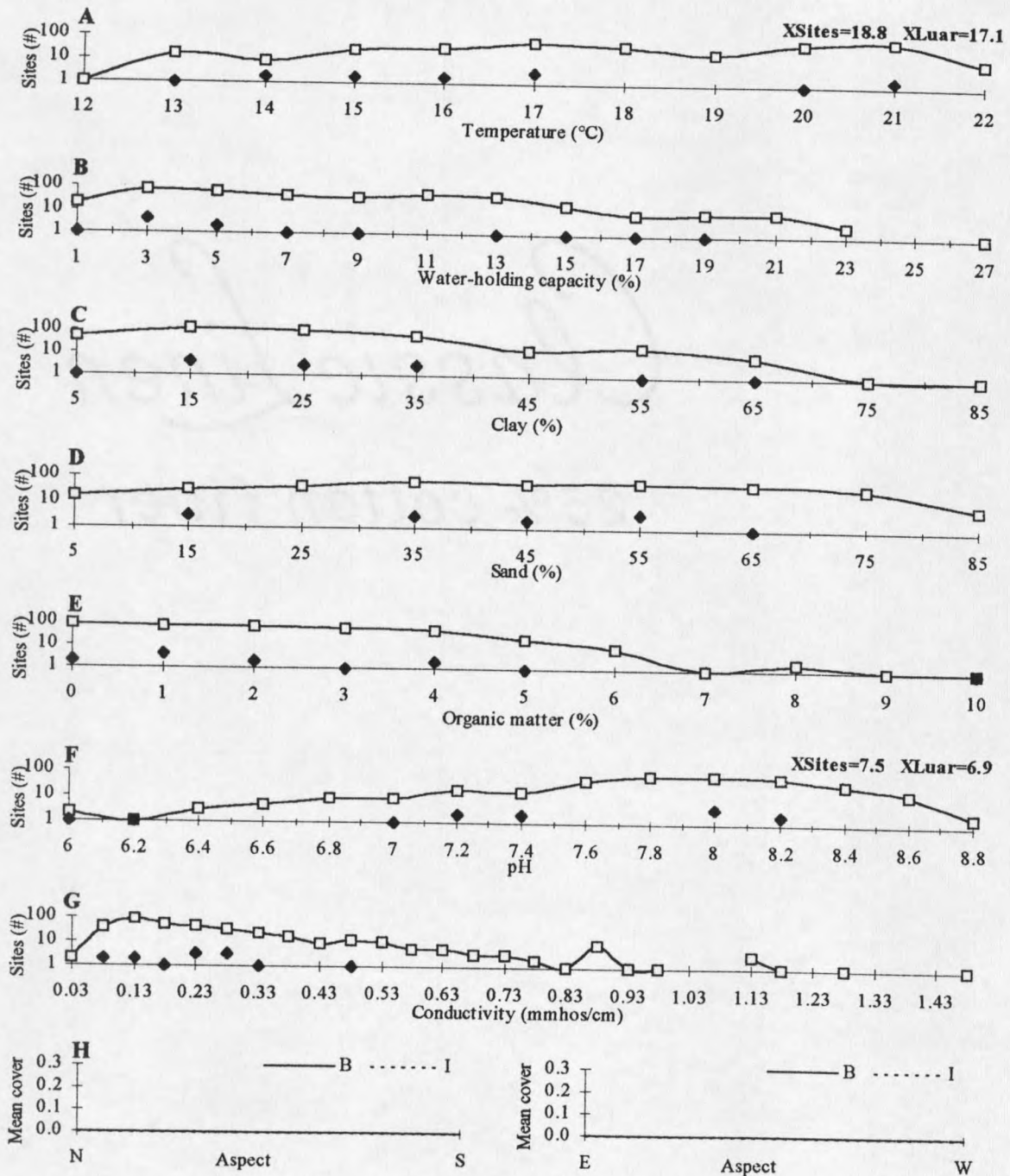


Figure 63. Distribution of *Lupinus argenteus* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Lupinus argenteus* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

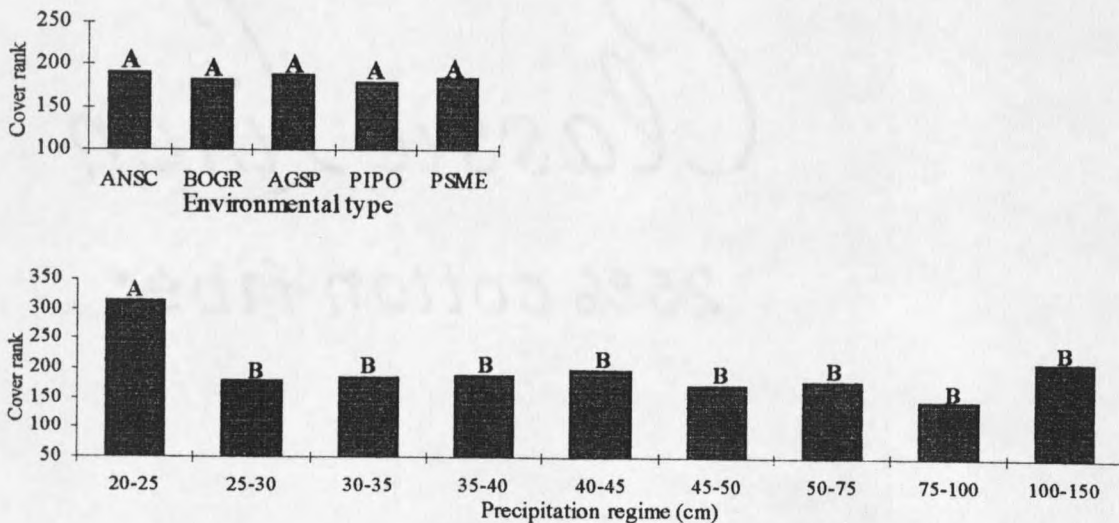
Medicago polymorpha* (Mepo)*burclover****Fabaceae**Origin, Duration and Habit¹: Exotic Annual Forb, not vegetatively reproducing.Environmental type: Mepo cover (%) does not differ between types (Fig. 64).Temperature²: Temperature in Mepo sites is lower than average sites (Fig. 65A).Precipitation²: Mepo cover (%) is highest on the driest sites (Fig. 64).Water-holding capacity²: WHC in Mepo sites is lower than in average roadside sites (Fig. 65B).Clay²: Clay in Mepo sites is lower than average roadside sites (Fig. 65C).Sand²: Sand in Mepo sites is higher than average roadside sites (Fig. 65D).Organic carbon: OC does not differ between Mepo sites and average sites (Fig. 65E).pH: pH does not differ between Mepo sites and average sites (Fig. 65F).Conductivity²: Conductivity in Mepo sites is lower than average sites (Fig. 65G).Position and Aspect: Mean cover (%) is highest on south-facing backslopes (Fig. 65H)¹ Refer to introduction (p52) for descriptions of each category. ² Significant category.

Figure 64. Effect of Environmental Type and Precipitation on Cover (%) of *Medicago polymorpha*. Categories sharing a letter do not significantly differ.

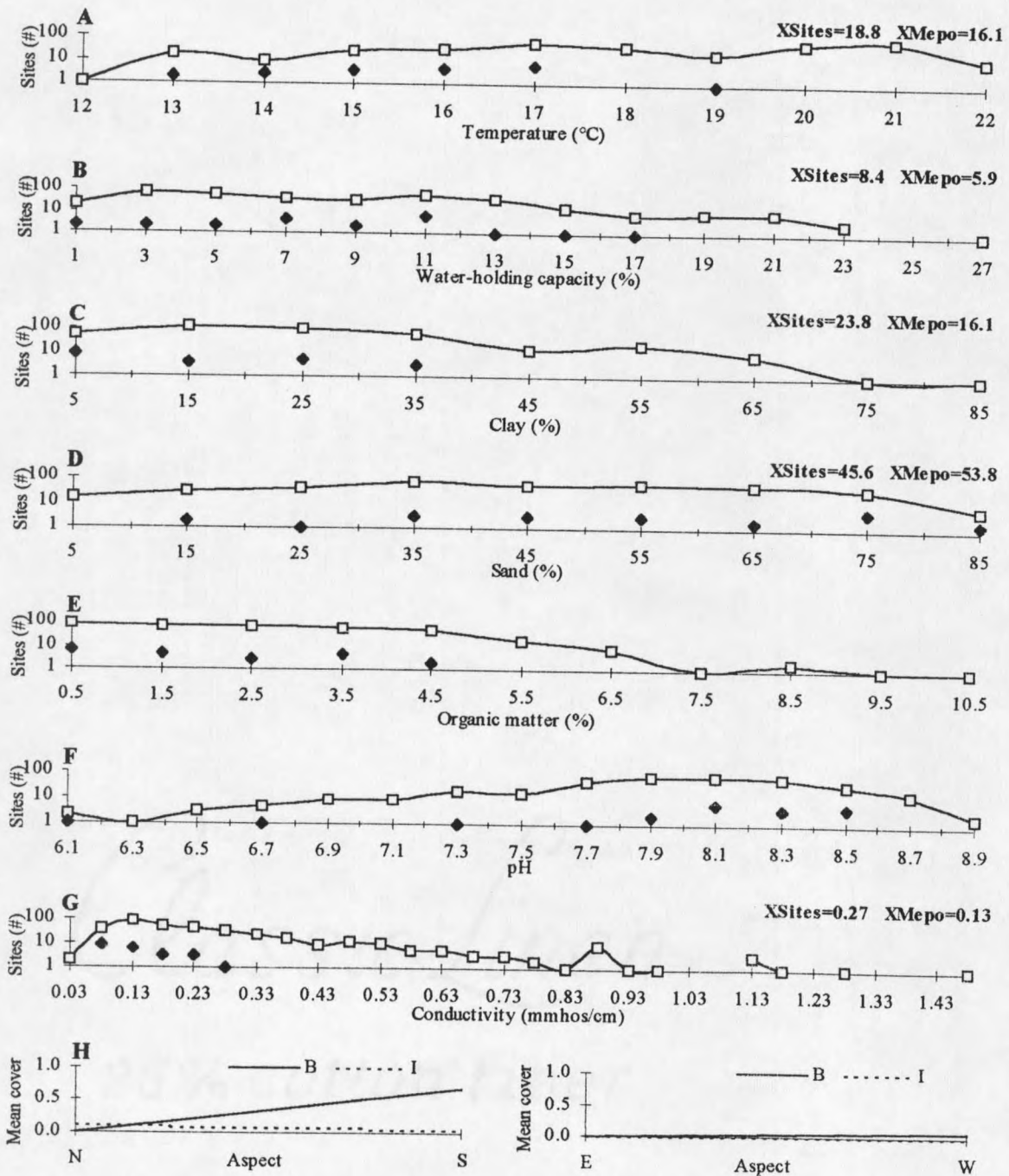


Figure 65. The Distribution of *Medicago polymorpha* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Medicago polymorpha* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Medicago sativa (Mesa)

alfalfa

Fabaceae

Origin, Duration and Habit¹: Exotic Perennial Forb, not vegetatively reproducing.

Environmental type: Mesa cover (%) does not differ between types (Fig. 66).

Temperature²: Temperature in Mesa sites is lower than average sites (Fig. 67A).

Precipitation²: Mesa cover (%) is highest on the driest (20-25cm) sites (Fig. 66).

Water-holding capacity²: WHC in Mesa sites is higher than in average roadside sites (Fig. 67B).

Clay²: Clay in Mesa sites is higher than average roadside sites (Fig. 67C).

Sand²: Sand in Mesa sites is lower than average roadside sites (Fig. 67D).

Organic carbon: OC does not differ between Mesa sites and average sites (Fig. 67E).

pH: pH does not differ between Mesa sites and average sites (Fig. 67F).

Conductivity²: Conductivity in Mesa sites is higher than average sites (Fig. 67G).

Position and Aspect: Mean cover (%) is highest on south-facing inslopes (Fig. 67H).

¹ Refer to introduction (p52) for descriptions of each category. ² Significant category.

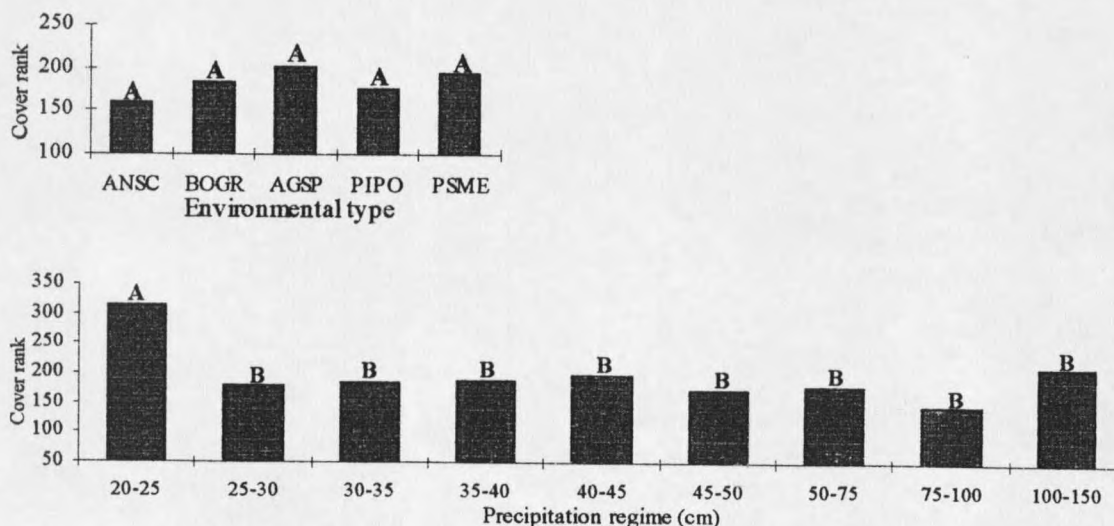


Figure 66. Effect of Environmental Type and Precipitation on Cover (%) of *Medicago sativa*. Categories sharing a letter do not significantly differ.

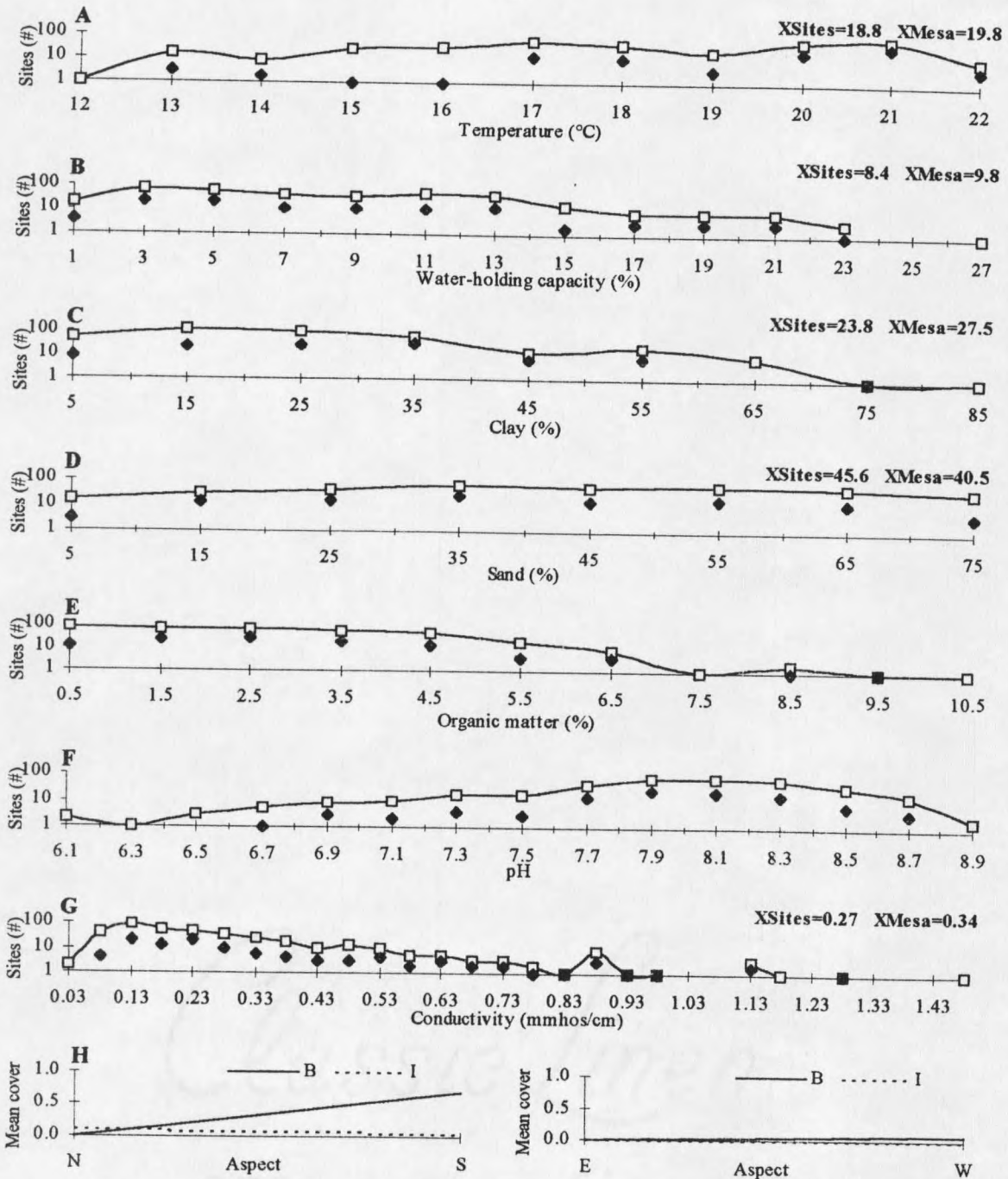


Figure 67. The Distribution of *Medicago sativa* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Medicago sativa* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Melilotus offincinalis (Meof)

yellow sweet clover

Fabaceae

Origin, Duration and Habit¹: Exotic Annual Forb, not vegetatively reproducing.

Environmental Type²: Meof cover (%) is highest in the AGSP and PSME sites, slightly lower in the PIPO and BOGR types and lowest in the ANSC type (Fig. 68).

Temperature: Temperature does not differ between Meof and average sites (Fig. 68A).

Precipitation²: Meof cover (%) is highest in the driest (20-25cm) and moist (45 and above) sites (Fig. 68).

Water-holding capacity: WHC does not differ between Meof and average sites (Fig. 69B).

Clay: Clay does not differ between Meof sites and average sites (Fig. 69C).

Sand: Sand does not differ between Meof sites and average sites (Fig. 69D).

Organic carbon²: OC in Meof sites is lower than average sites (Fig. 69E).

pH: pH does not differ between Meof sites and average sites (Fig. 69F).

Conductivity: Conductivity does not differ between Meof and average sites (Fig. 69G).

Position and Aspect: Mean cover is higher on north and south-facing backslopes than inslopes. There is an interaction between plot position and aspect in east and west-facing sites (Fig. 69H).

¹ Refer to introduction (p52) for descriptions of each category. ² Significant category.

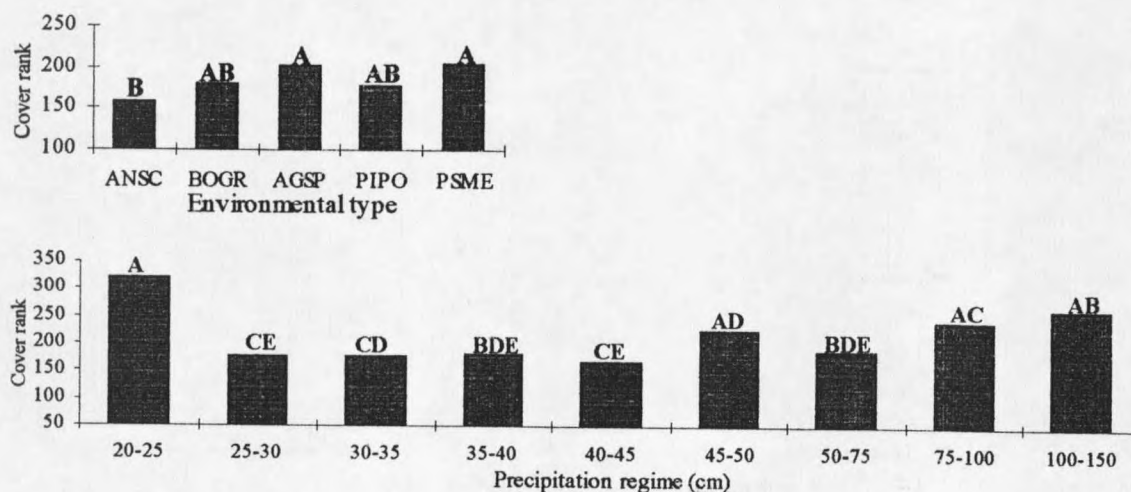


Figure 68. Effect of Environmental Type and precipitation on cover (%) of *Melilotus offincinalis*. Categories sharing a letter do not significantly differ.

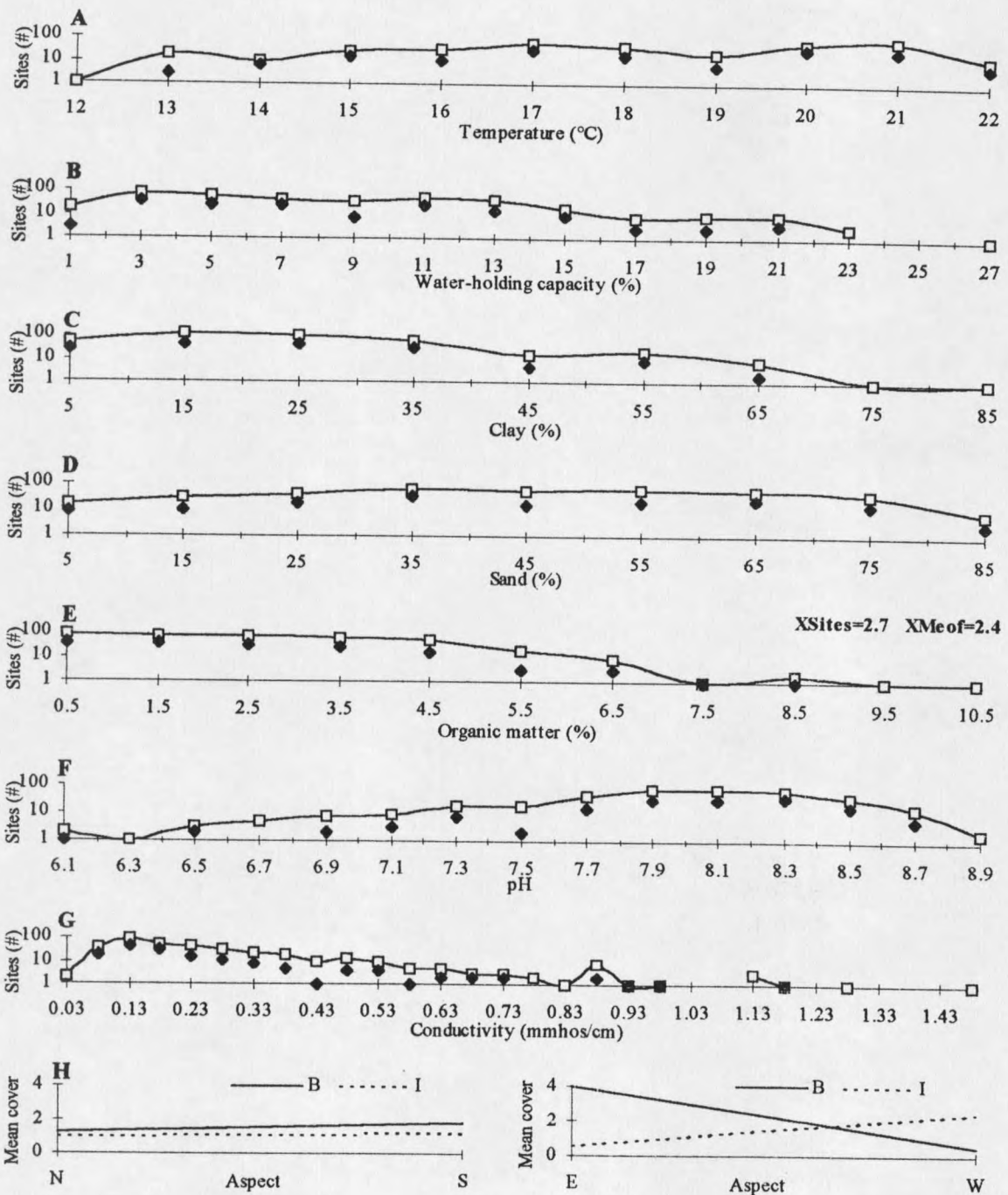


Figure 69. The Distribution of *Melilotus offincinalis* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Melilotus offincinalis* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Opuntia polycantha* (Oppo)*starvation cactus****Cactaceae**

Origin, Duration and Habit¹: Native Perennial Forb, vegetatively reproducing.

Environmental type: Oppo cover (%) does not differ between types (Fig. 70).

Temperature: Temperature does not differ between Oppo and average sites (Fig. 71A).

Precipitation: Oppo cover (%) does not differ between dry and moist sites (Fig. 70).

Water-holding capacity: WHC does not differ between Oppo sites and average sites (Fig. 71B).

Clay²: Clay in Oppo sites is higher than average roadside sites (Fig. 71C).

Sand²: Sand in Oppo sites is lower than average roadside sites (Fig. 71D).

Organic carbon²: OC in Oppo sites is lower than average roadside sites (Fig. 71E).

pH: pH does not differ between Oppo sites and average sites (Fig. 71F).

Conductivity²: Conductivity in Oppo sites is higher than average roadside sites (Fig. 71G).

Position and Aspect: Cover (%) of Oppo is higher on backslopes than inslopes (Fig. 71H).

¹ Refer to introduction (p52) for descriptions of each category. ² Significant category.

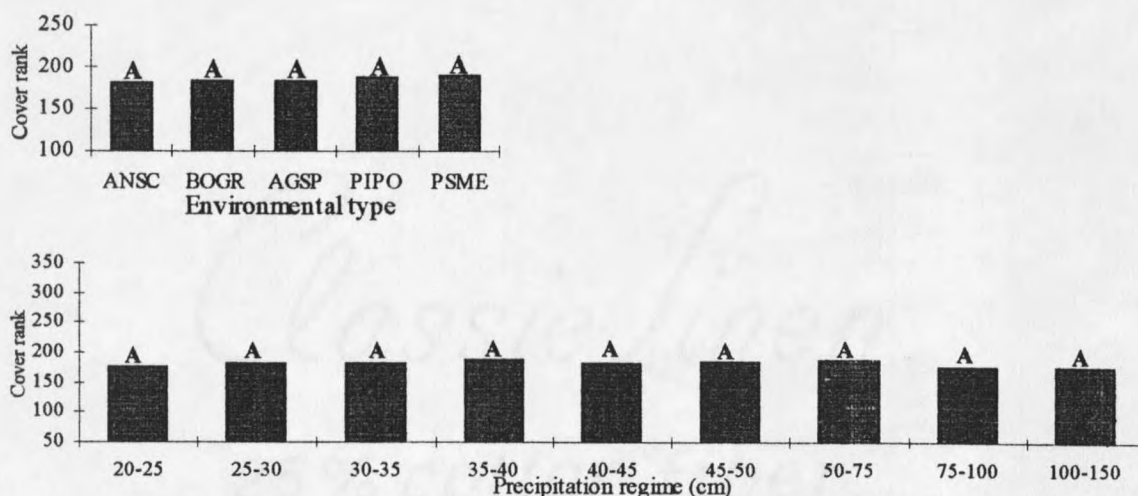


Figure 70. Effect of Environmental Type and Precipitation on Cover (%) of *Opuntia polycantha*. Categories sharing a letter do not significantly differ.

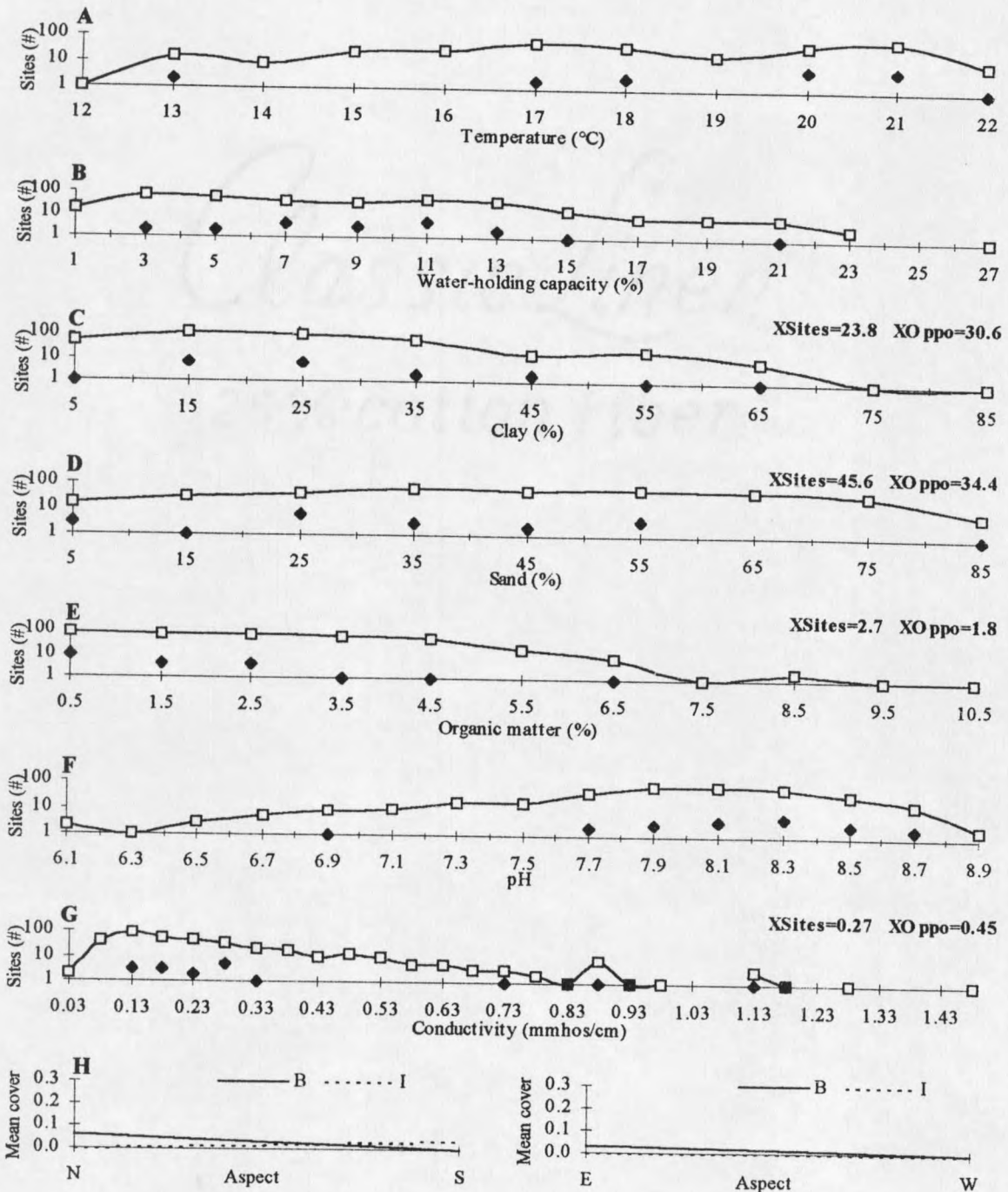


Figure 71. The Distribution of *Opuntia polyantha* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Opuntia polyantha* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Phalaris arundinacea* (Phar)*reed canarygrass****Poaceae**

Origin, Duration and Habit¹: Exotic Perennial Forb, vegetatively reproducing.

Environmental Type²: Phar cover (%) is highest in the PIPO type and slightly lower in PSME and lowest in ANSC and BOGR (Fig. 72).

Temperature²: Temperature in Phar sites is lower than average sites (Fig. 73A).

Precipitation²: Phar cover (%) is highest on moist (75-100cm) sites (Fig. 72).

Water-holding capacity²: WHC in Phar sites is lower than average roadside sites (Fig. 73B).

Clay²: Clay in Phar sites is lower than average roadside sites (Fig. 73C).

Sand²: Sand in Phar sites is higher than average roadside sites (Fig. 73D).

Organic carbon: OC does not differ between Phar sites and average sites (Fig. 73E).

pH: pH does not differ between Phar sites and average sites (Fig. 73F).

Conductivity: Conductivity does not differ between Phar and average sites (Fig. 73G).

Position and Aspect: Mean cover (%) is higher on inslopes than backslopes and highest on east-facing inslopes (Fig. 73H)

¹ Refer to introduction (p52) for descriptions of each category. ² Significant category.

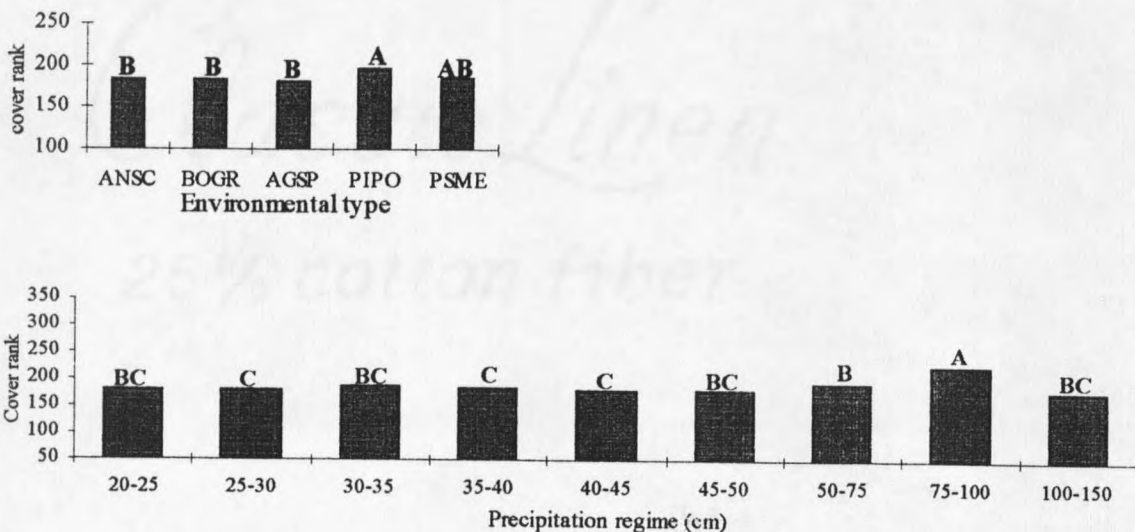


Figure 72. Effect of Environmental Type and Precipitation on Cover (%) of *Phalaris arundinacea*. Categories sharing a letter do not significantly differ.

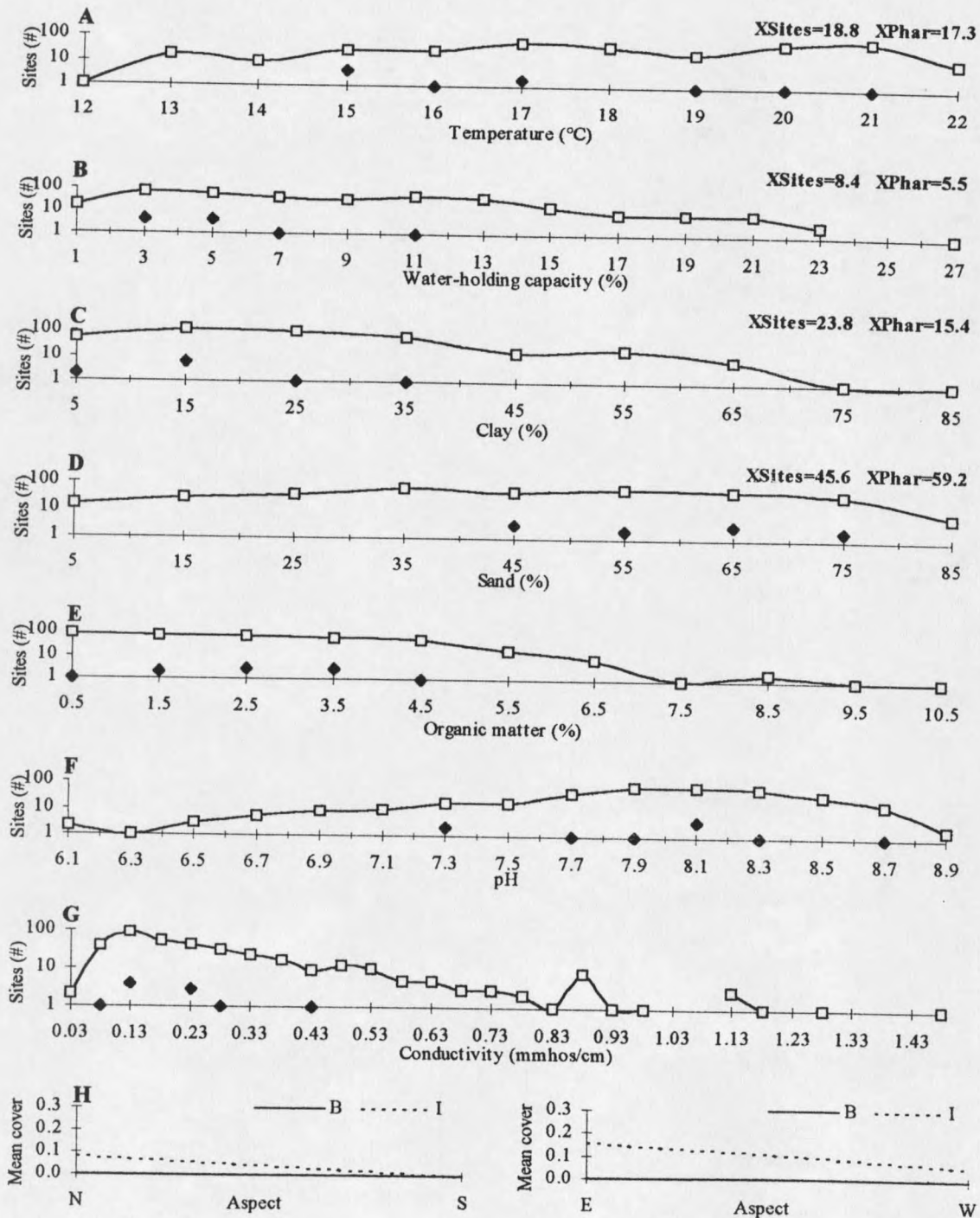


Figure 73. The Distribution of *Phalaris arundinacea* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied *Phalaris arundinacea* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Phleum pratense* (Phpr)*timothy****Poaceae**

Origin, Duration and Habit¹: Exotic Perennial Grass, not vegetatively reproducing.

Environmental type: Phpr cover (%) is highest in the PSME type, lower in the PIPO type and lowest in the ANSC, AGSP and BOGR types (Fig. 74).

Temperature: Temperature in Phpr sites is lower than average sites (Fig. 75A).

Precipitation²: Phpr cover (%) is higher on more moist sites (45-100cm) (Fig. 74).

Water-holding capacity²: Water-holding capacity in Phpr sites is lower than average roadside sites (Fig. 75B).

Clay: Clay does not differ between Phpr sites and average sites (Fig. 75C).

Sand²: Sand in Phpr sites is higher than average roadside sites (Fig. 75D).

Organic carbon: OC does not differ between Phpr sites and average sites (Fig. 75E).

pH: pH in Phpr sites does not differ from average roadside sites (Fig. 75F).

Conductivity²: Conductivity in Phpr sites is lower than average roadside sites (Fig. 75G).

Position and Aspect: There is an interaction between slope and aspect (Fig. 75H).

¹ Refer to introduction (p52) for descriptions of each category. ² Significant category.

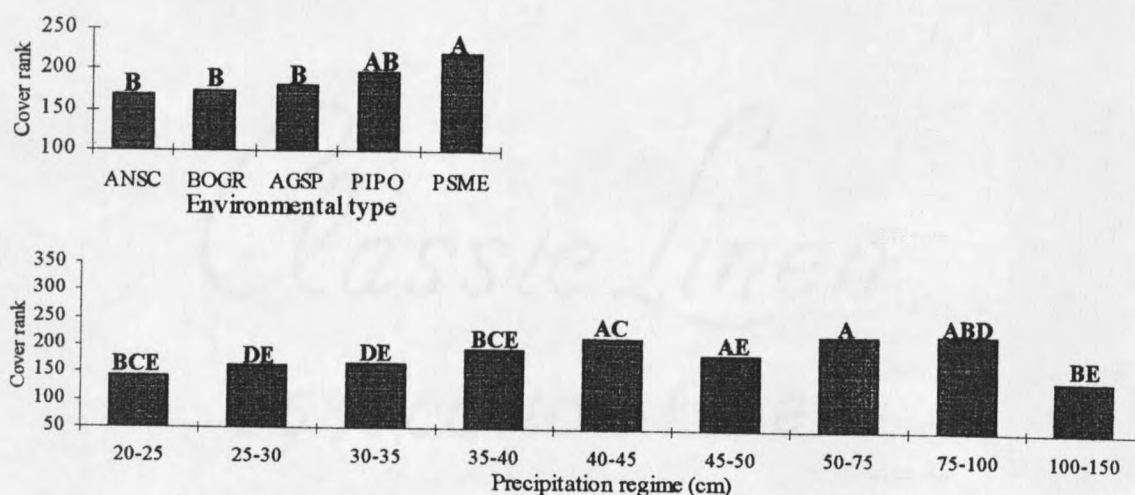


Figure 74. Effect of Environmental Type and Precipitation on Cover (%) of *Phleum pratense*. Categories sharing a letter do not significantly ($p > 0.05$) differ.

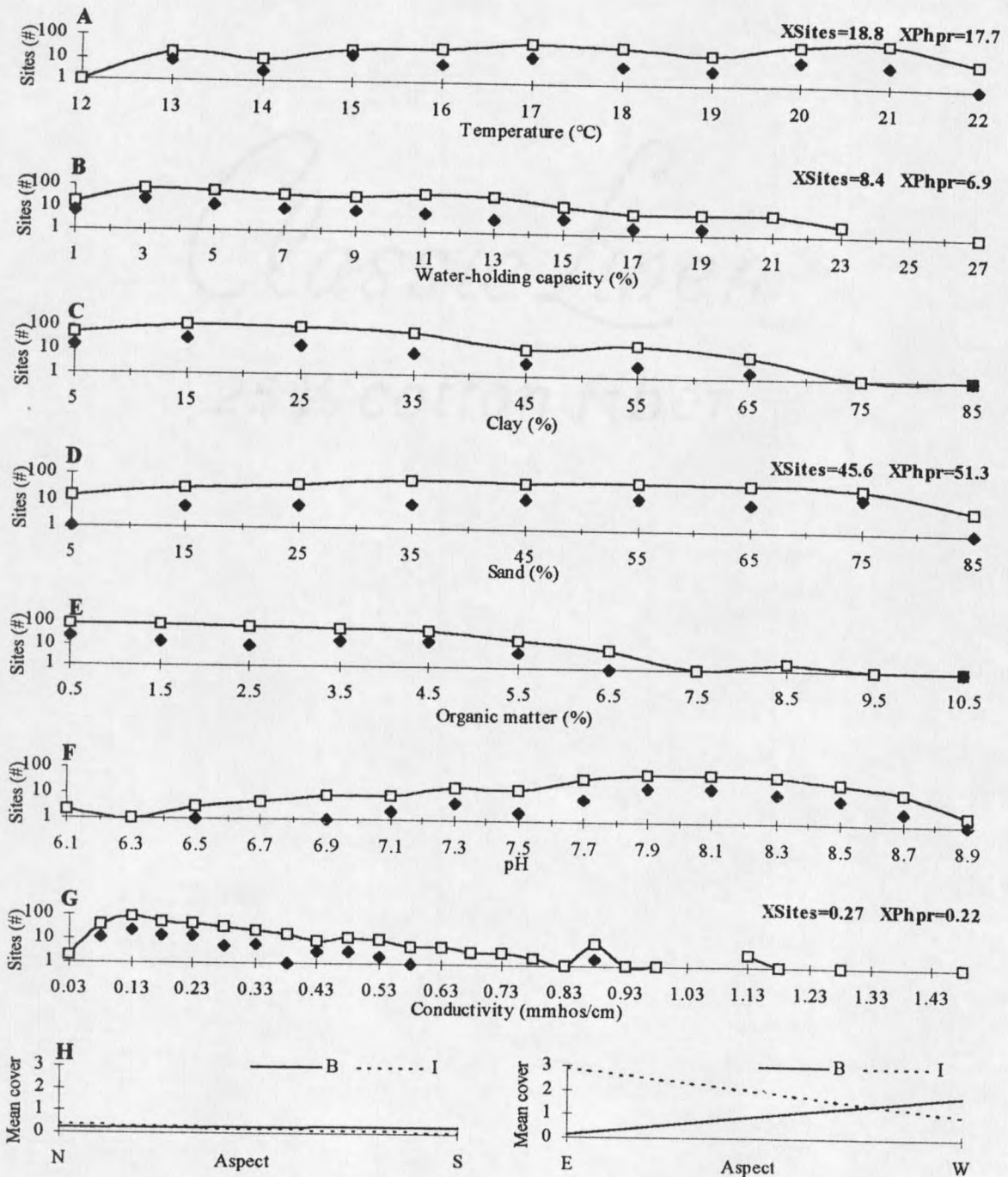


Figure 75. The Distribution of *Phleum pratense* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Phleum pratense* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Pinus ponderosa (Pipo)

ponderosa pine

Pinaceae

Origin, Duration and Habit ¹: Native Perennial Tree, not vegetatively reproducing.

Environmental type: Pipo cover (%) does not differ between types (Fig. 76).

Temperature ²: Temperature in Pipo sites is lower than average sites (Fig. 77A).

Precipitation: Pipo cover (%) does not differ between dry and moist sites (Fig. 76).

Water-holding capacity: WHC does not differ between Pipo sites and average sites (Fig. 77B).

Clay ²: Clay in Pipo sites is lower than average roadside sites (Fig. 77C).

Sand: Sand does not differ between Pipo sites and average sites (Fig. 77D).

Organic carbon: OC does not differ between Pipo sites and average sites (Fig. 77E).

pH: pH does not differ between Pipo sites and average sites (Fig. 77F).

Conductivity ²: Conductivity in Pipo sites is lower than average roadside sites (Fig. 77G).

Position and Aspect: Mean cover (%) is slightly higher on backslopes than inslopes. (Fig. 77H).

¹ Refer to introduction (p52) for descriptions of each category. ² Significant category.

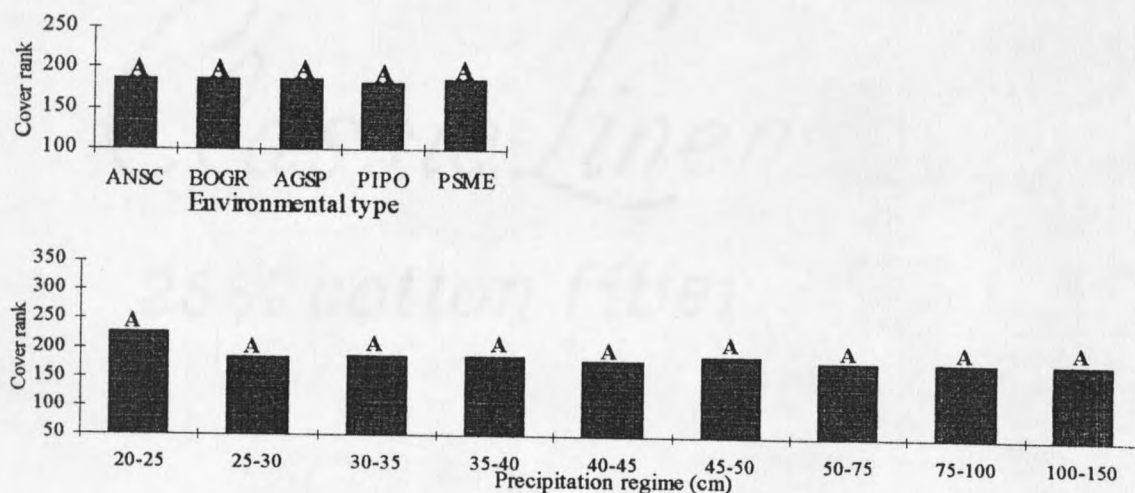


Figure 76. Effect of Environmental Type and Precipitation on Cover (%) of *Pinus ponderosa*. Categories sharing a letter do not significantly differ.

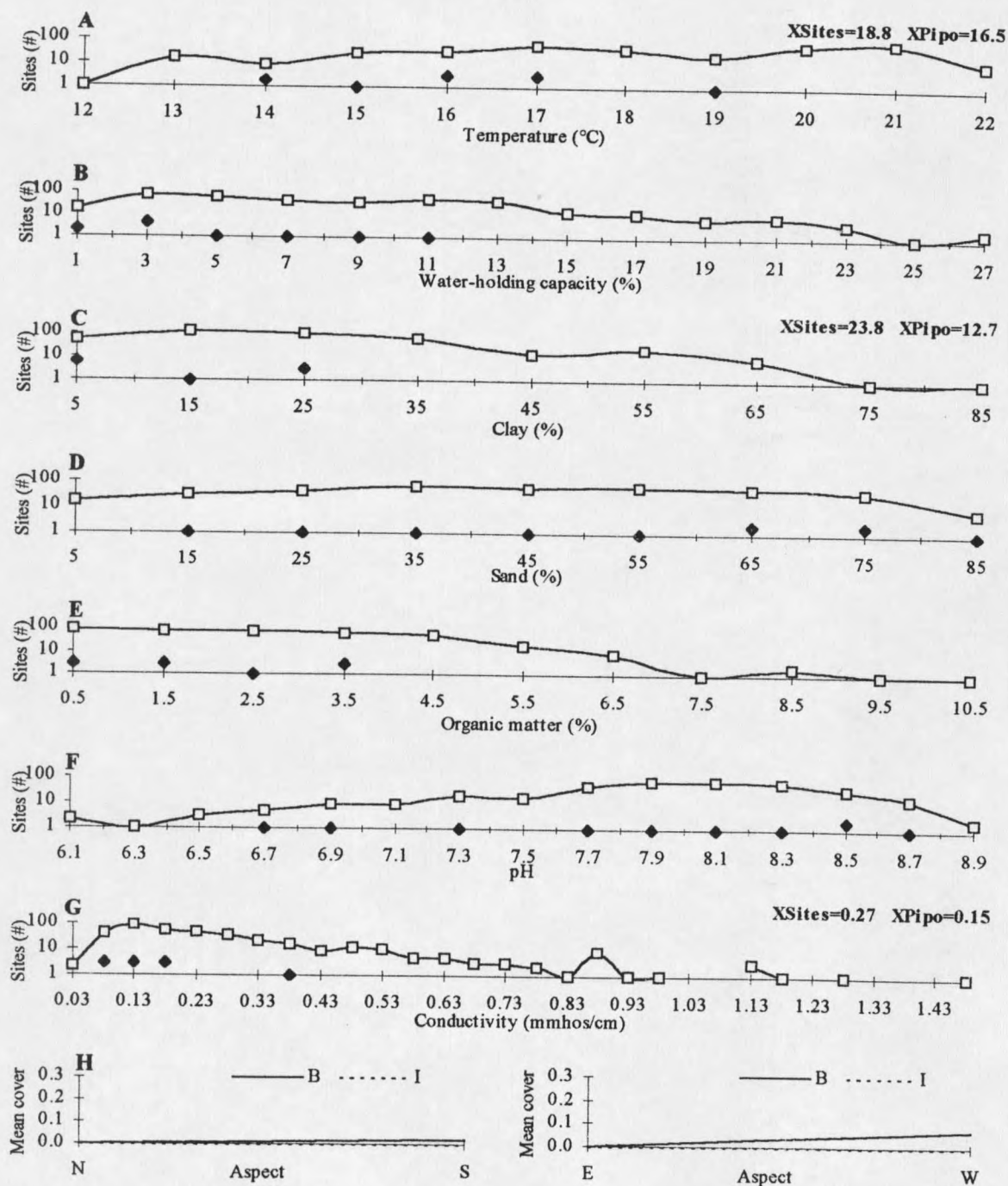


Figure 77. The Distribution of *Pinus ponderosa* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Pinus ponderosa* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Poa compressa (Poco)

Canada bluegrass

Poaceae

Origin, Duration and Habit¹: Exotic Perennial Forb, vegetatively reproducing.

Environmental Type²: Poco cover (%) is highest in the PIPO type, slightly lower in the PSME and AGSP types and lowest in BOGR and ANSC (Fig. 78).

Temperature²: Temperature in Poco sites is lower than average sites (Fig. 79A).

Precipitation: Poco cover (%) does not differ between dry and moist sites (Fig. 78).

Water-holding capacity²: WHC in Poco sites is lower than average roadside sites (Fig. 79B).

Clay²: Clay in Poco sites is lower than average roadside sites (Fig. 79C).

Sand²: Sand in Poco sites is higher than average roadside sites (Fig. 79D).

Organic carbon: OC does not differ between Poco sites and average sites (Fig. 79E).

pH: pH does not differ between Poco sites and average sites (Fig. 79F).

Conductivity²: Conductivity in Poco sites is lower than average sites (Fig. 79G).

Position and Aspect: There is an interaction between plot position and aspect for all sites (Fig. 79H).

¹ Refer to introduction (p52) for descriptions of each category. ² Significant category.

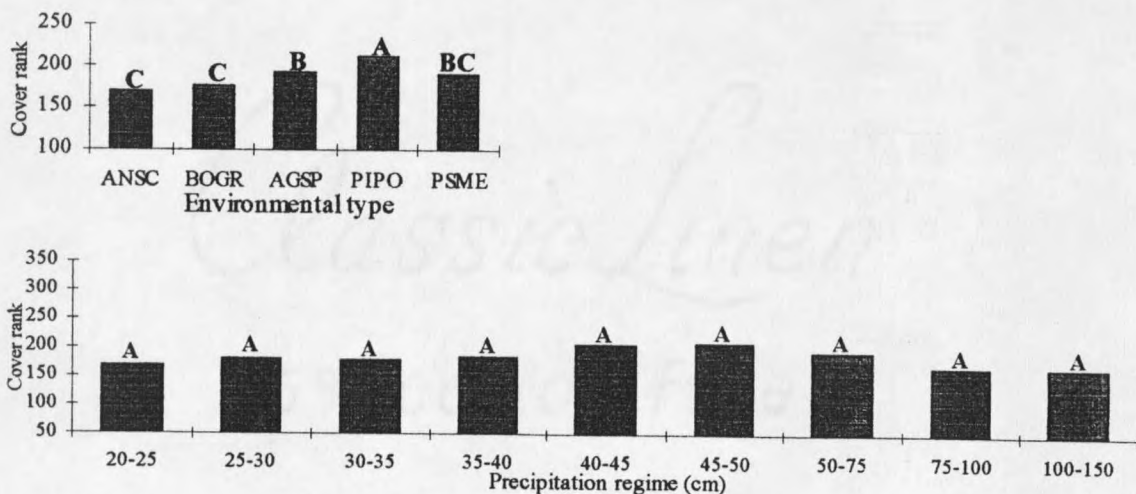


Figure 78. Effect of Environmental Type and Precipitation on Cover (%) of *Poa compressa*. Categories sharing a letter do not significantly differ.

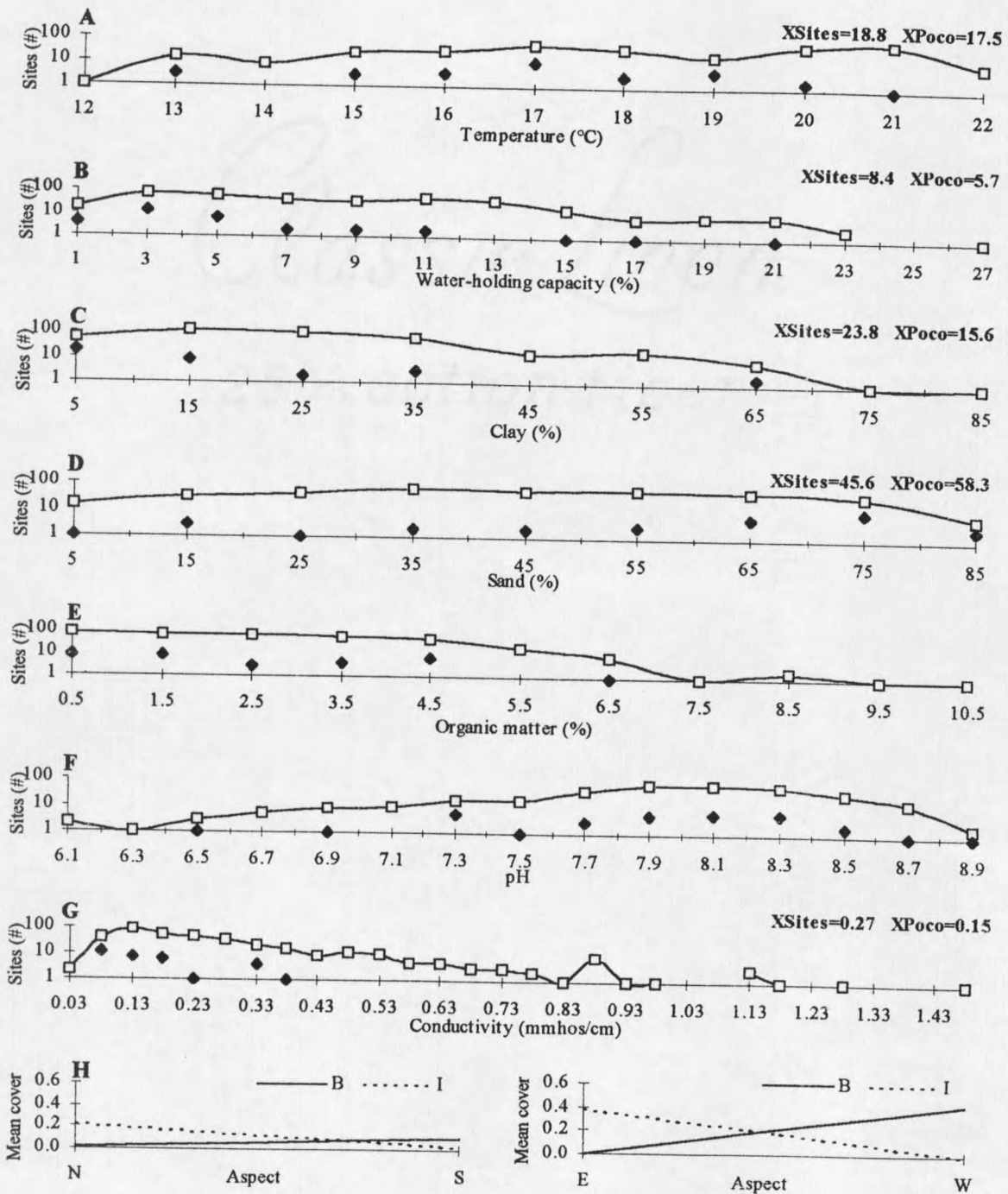


Figure 79. The Distribution of *Poa compressa* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Poa compressa* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Poa pratensis (Popr)

Kentucky bluegrass

Poaceae

Origin, Duration and Habit¹: Exotic Perennial Grass, vegetatively reproducing.

Environmental Type²: Popr cover (%) is higher in the ANSC, AGSP, FEID and PSME types than in the PIPO type (Fig. X.1).

Temperature: Temperature does not differ between Popr and average sites (Fig. 80A).

Precipitation: Popr cover (%) does not differ between dry and moist sites (Fig. 80).

Water-holding capacity: WHC does not differ between Popr and average sites (Fig. 81B).

Clay: Clay does not differ between Popr sites and average sites (Fig. 81C).

Sand: Sand does not differ between Popr sites and average sites (Fig. 81D).

Organic carbon: OC does not differ between Popr sites and average sites (Fig. 81E).

pH: pH does not differ between Popr sites and average sites (Fig. 81F).

Conductivity: Conductivity does not differ between Popr and average sites (Fig. 81G).

Position and Aspect: Mean cover (%) is highest on north and west-facing inslopes (Fig. 81H).

¹ Refer to introduction (p52) for descriptions of each category. ² Significant category.

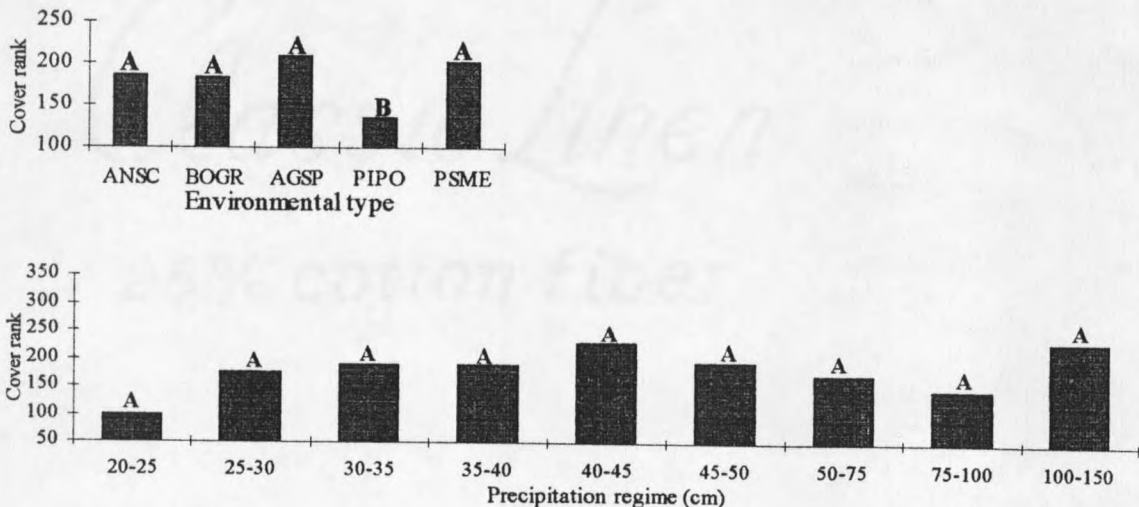


Figure 80. Effect of Environmental Type and Precipitation on Cover (%) of *Poa pratensis*. Categories sharing a letter do not significantly differ.

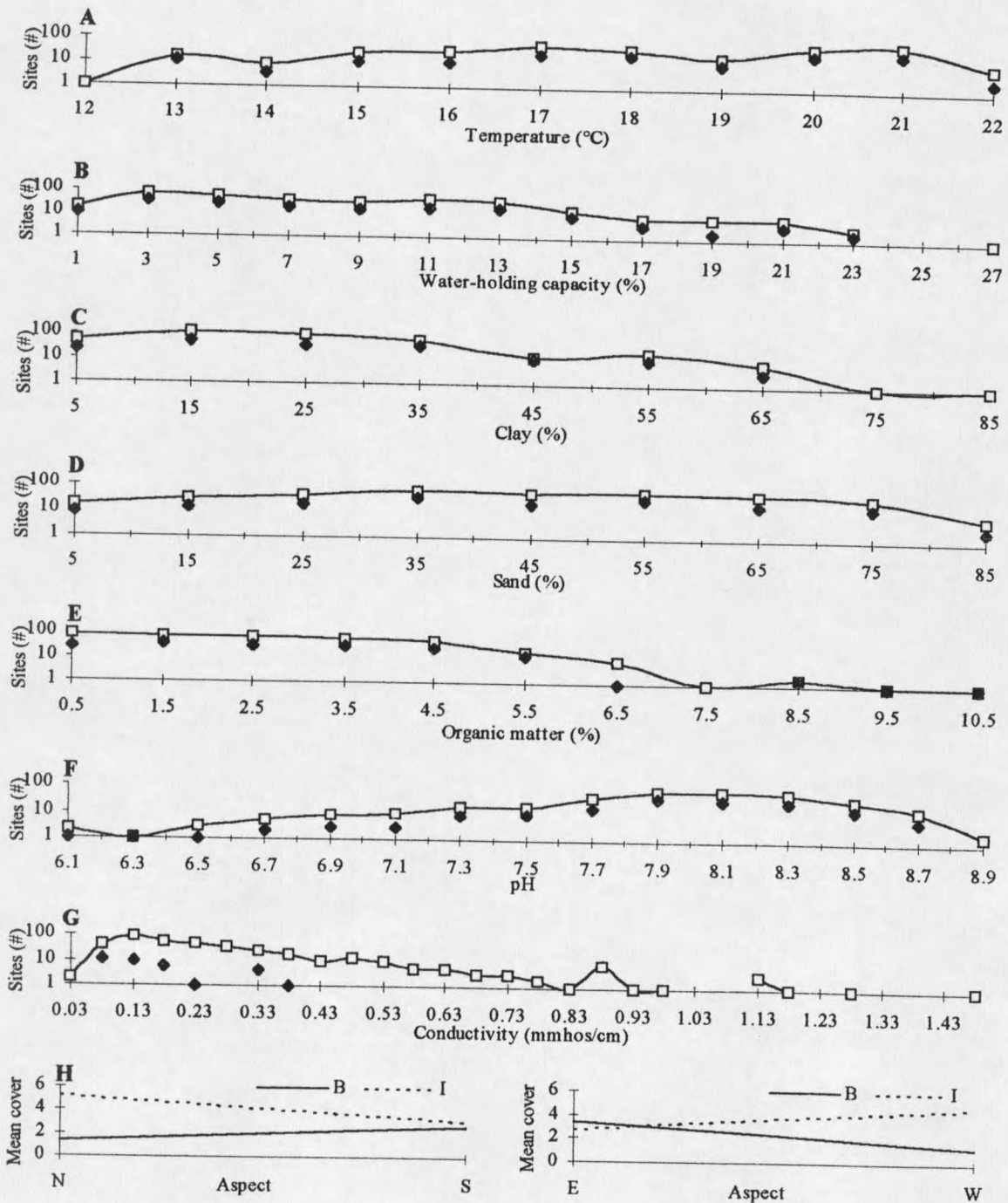


Figure 81. The Distribution of *Poa pratensis* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Poa pratensis* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Poa sandbergii* (Posa)*Sandberg's bluegrass****Poaceae**

Origin, Duration and Habit ¹: Native Perennial Grass, not vegetatively reproducing.

Environmental type: Posa cover (%) does not differ from between types (Fig. 82).

Temperature: Temperature does not differ between Posa sites and average sites (Fig. 83A).

Precipitation: Posa cover (%) does not differ between dry and moist sites (Fig. 82).

Water-holding capacity: WHC does not differ between Posa sites and average sites (Fig. 83B).

Clay: Clay does not differ between Posa sites and average sites (Fig. 83C).

Sand: Sand does not differ between Posa sites and average sites (Fig. 83D).

Organic carbon: OC does not differ between Posa sites and average sites (Fig. 83E).

pH: pH does not differ between Posa sites and average sites (Fig. 83F).

Conductivity ²: Conductivity in Posa sites is higher than average sites (Fig. 83G).

Position and Aspect: Mean cover (%) is consistently higher on inslopes than backslopes. Mean cover is highest on north-facing slopes (Fig. 83H).

¹ Refer to introduction (p52) for descriptions of each category. ² Significant category.

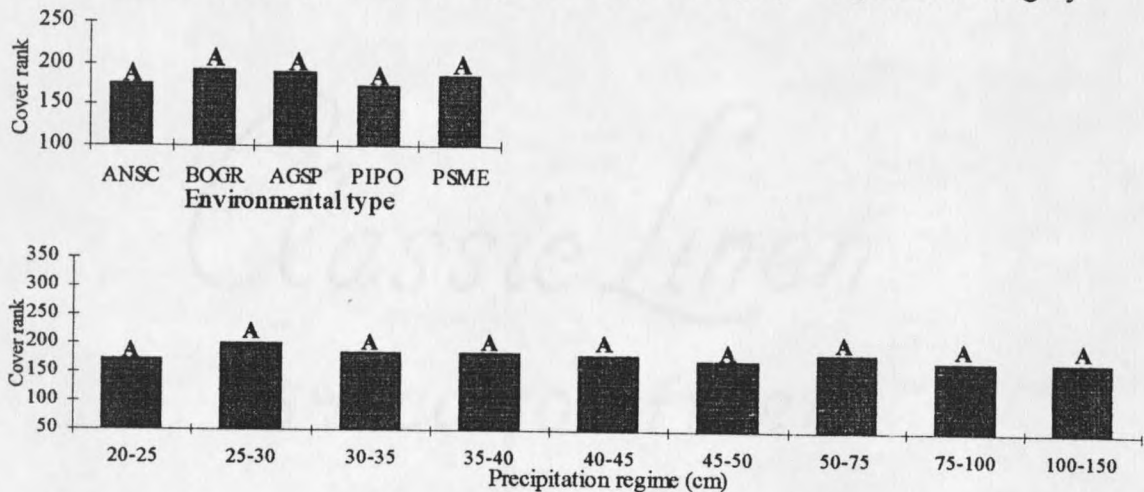


Figure 82. Effect of Environmental Type and Precipitation on Cover (%) of *Poa sandbergii*. Categories sharing a letter do not significantly differ.

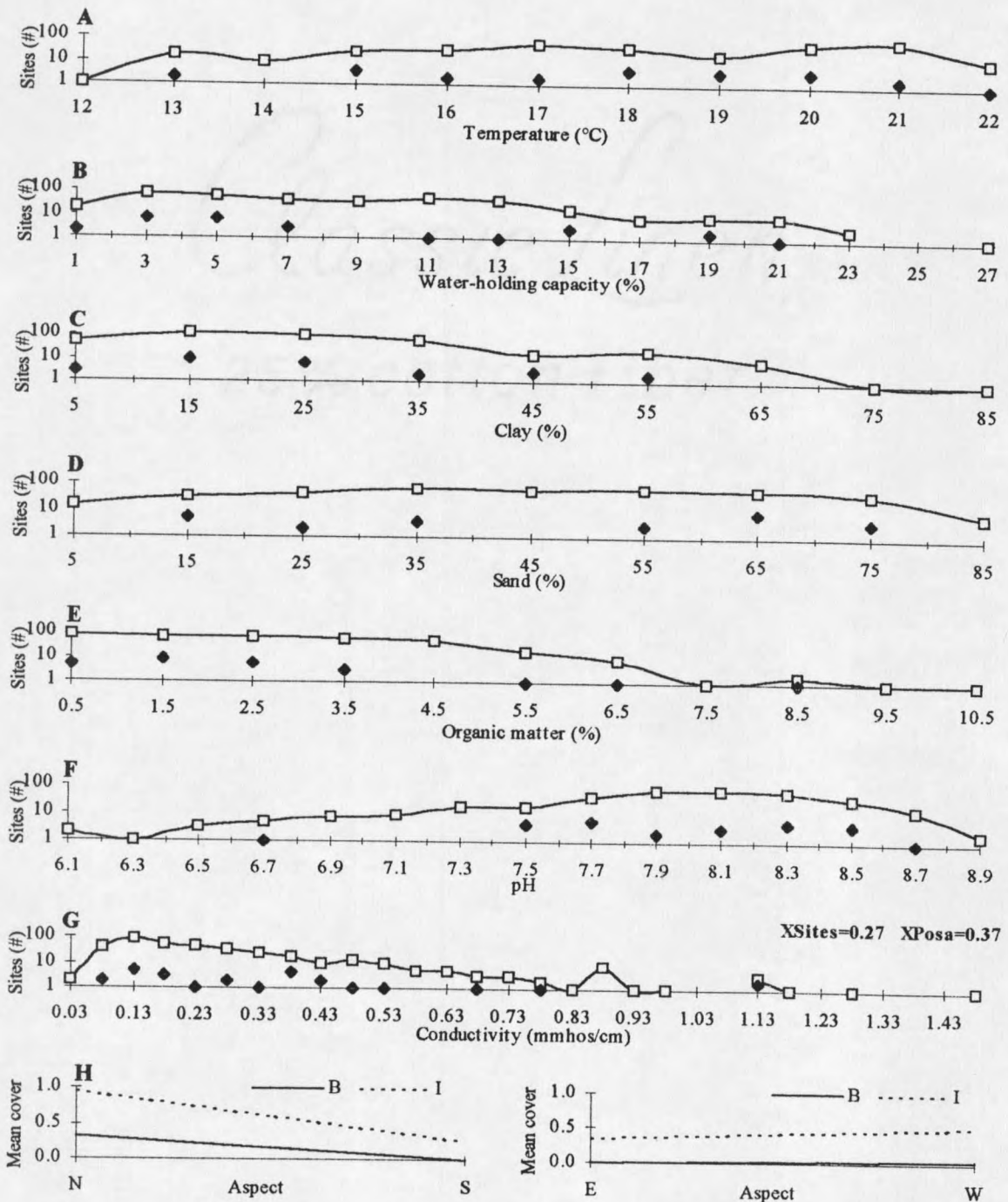


Figure 83. The Distribution of *Poa sandbergii* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Poa sandbergii* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Ratibida columnifera (Raco)

prairie coneflower

Asteraceae

Origin, Duration and Habit¹: Native Perennial Forb, not vegetatively reproducing.

Environmental type: Raco cover (%) does not differ between types (Fig. 84).

Temperature: Temperature does not differ between Raco sites and average sites (Fig. 85A).

Precipitation: Raco cover (%) does not differ between dry and moist sites (Fig. 84).

Water-holding capacity: WHC does not differ between Raco sites and average sites (Fig. 85B).

Clay: Clay does not differ between Raco sites and average sites (Fig. 85C).

Sand: Sand does not differ between Raco sites and average sites (Fig. 85D).

Organic carbon: OC does not differ between Raco sites and average sites (Fig. 85E).

pH: pH does not differ between Raco sites and average sites (Fig. 85F).

Conductivity: Conductivity does not differ between Raco sites and average sites (Fig. 85G).

Position and Aspect: There is an interaction between plot position and aspect on east and west-facing inslopes and backslopes (Fig. 85H).

¹ Refer to introduction (p52) for descriptions of each category.

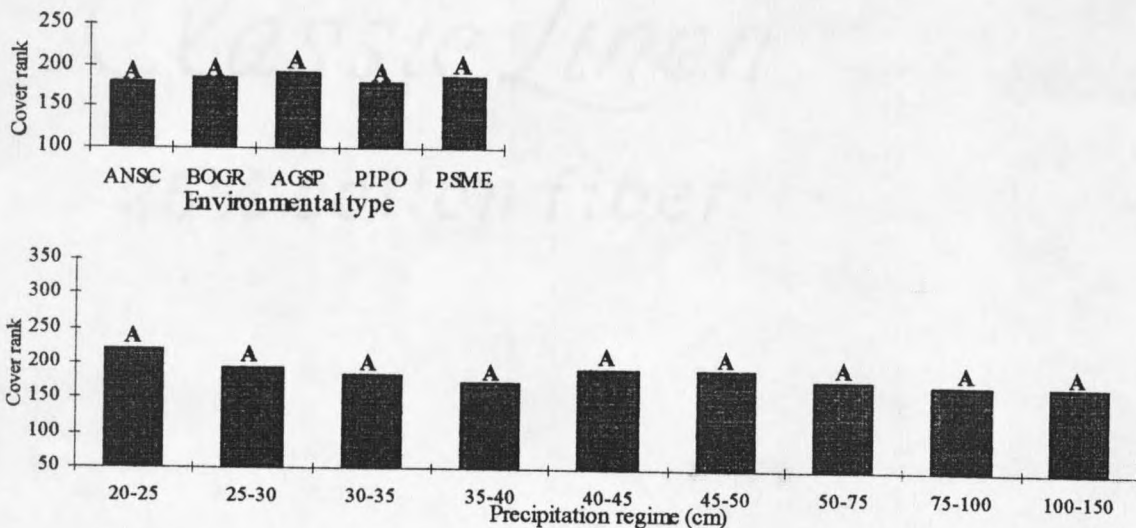


Figure 84. Effect of Environmental Type and Precipitation on Cover (%) of *Ratibida columnifera*. Categories sharing a letter do not significantly differ.

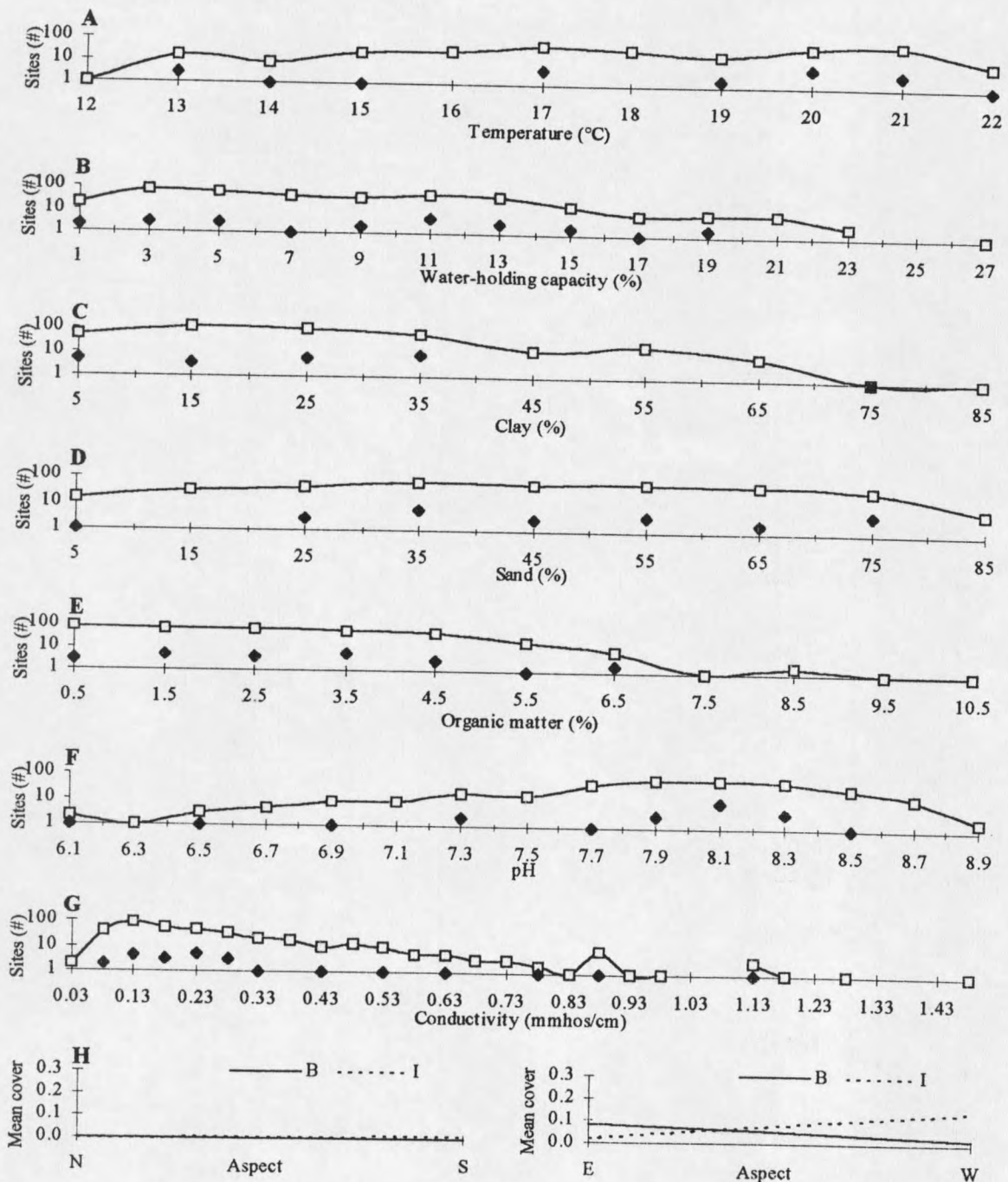


Figure 85. The Distribution of *Ratibida columnifera* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Ratibida columnifera* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Rosa woodsii (Rowo)

wood rose

Rosaceae

Origin, Duration and Habit¹: Native Perennial Shrub, vegetatively reproducing.

Environmental type: Rowo cover (%) does not differ from between types (Fig. 86).

Temperature: Temperature does not differ between Rowo sites and average sites (Fig. 87A).

Precipitation: Rowo cover (%) does not differ between dry and moist sites (Fig. 86).

Water-holding capacity: WHC does not differ between Rowo sites and average sites (Fig. 87B).

Clay: Clay does not differ between Rowo sites and average sites (Fig. 87C).

Sand: Sand does not differ between Rowo sites and average sites (Fig. 87D).

Organic carbon: OC does not differ between Rowo sites and average sites (Fig. 87E).

pH: pH does not differ between Rowo sites and average sites (Fig. 87F).

Conductivity: Conductivity does not differ between Rowo sites and average sites (Fig. 87G).

Position and Aspect: Mean cover (%) is higher on east-and west-facing slopes (Fig. 87H).

¹ Refer to introduction (p52) for descriptions of each category.

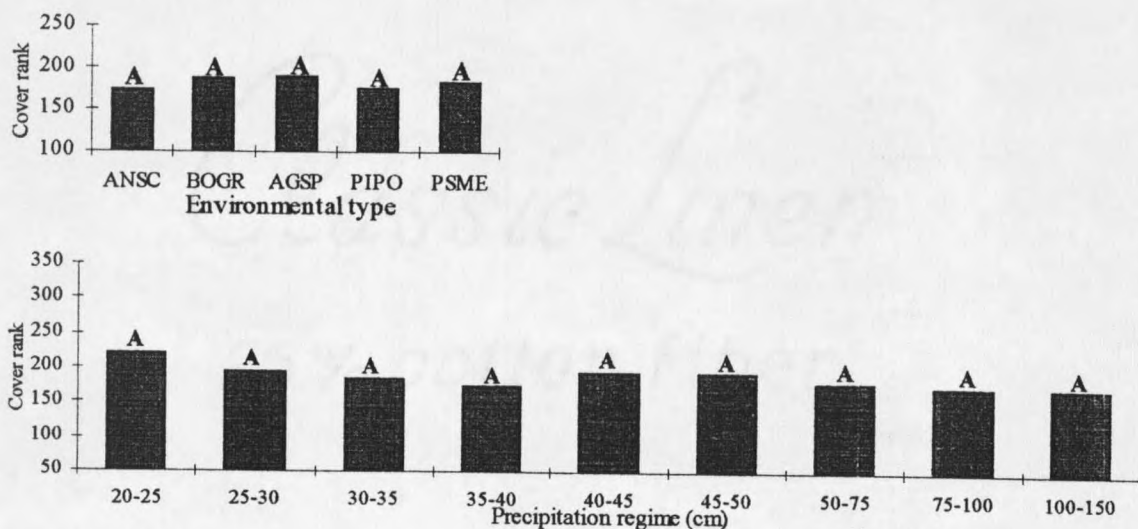


Figure 86. Effect of Environmental Type and Precipitation on Cover (%) of *Rosa woodsii*. Categories sharing a letter do not significantly differ.

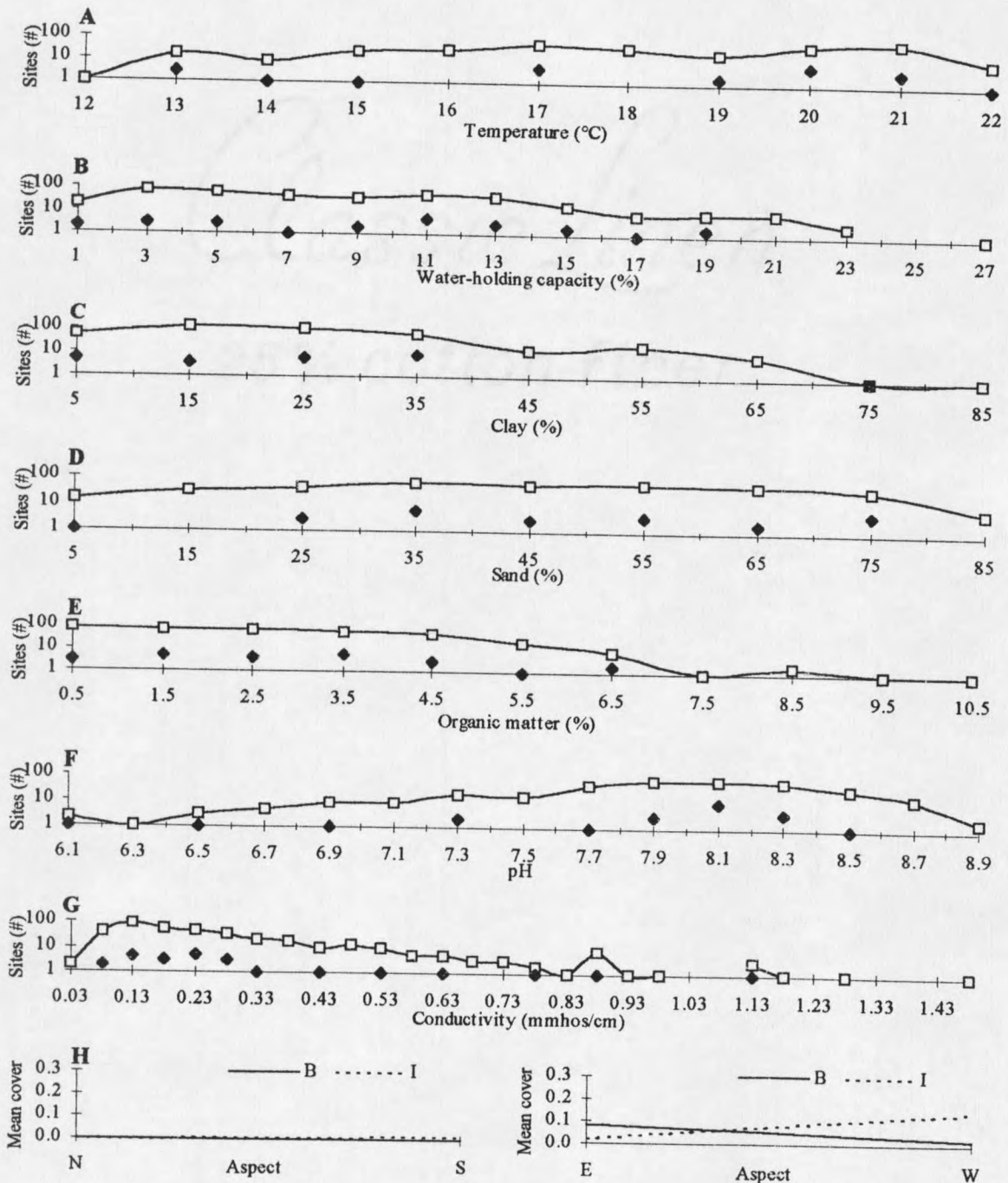


Figure 87. The Distribution of *Rosa woodsii* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Rosa woodsii* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Sphaeralcea coccinea (Spco)

desert mallow

Malvaceae

Origin, Duration and Habit¹: Native Perennial Forb, vegetatively reproducing.

Environmental type: Spco cover (%) does not differ between types (Fig. 88).

Temperature: Temperature does not differ between Spco sites and average sites (Fig. 89A).

Precipitation²: Spco cover (%) is highest on dry (20-25cm) sites (Fig. 87).

Water-holding capacity: WHC does not differ between Spco sites and average sites (Fig. 89B).

Clay: Clay does not differ between Spco sites and average sites (Fig. 89C).

Sand: Sand does not differ between Spco sites and average sites (Fig. 89D).

Organic carbon: OC does not differ between Spco sites and average sites (Fig. 89E).

pH: pH does not differ between Spco sites and average sites (Fig. 89F).

Conductivity: Conductivity does not differ between Spco sites and average sites (Fig. 89G).

Position and Aspect: Cover is highest on east-facing backslopes (Fig. 89H).

¹ Refer to introduction (p52) for descriptions of each category. ² Significant category.

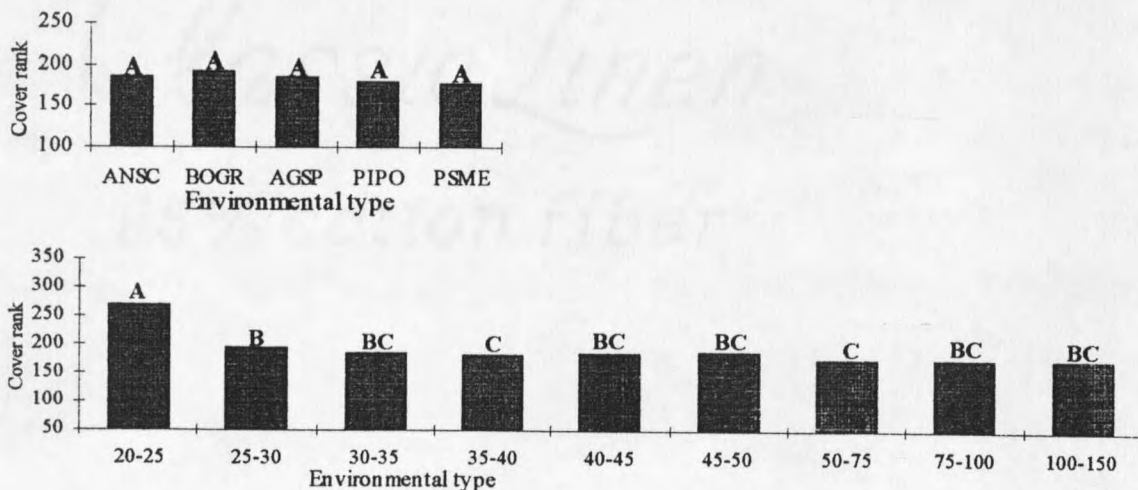


Figure 88. Effect of Environmental Type and Precipitation on Cover (%) of *Sphaeralcea coccinea*. Categories sharing a letter do not significantly differ.

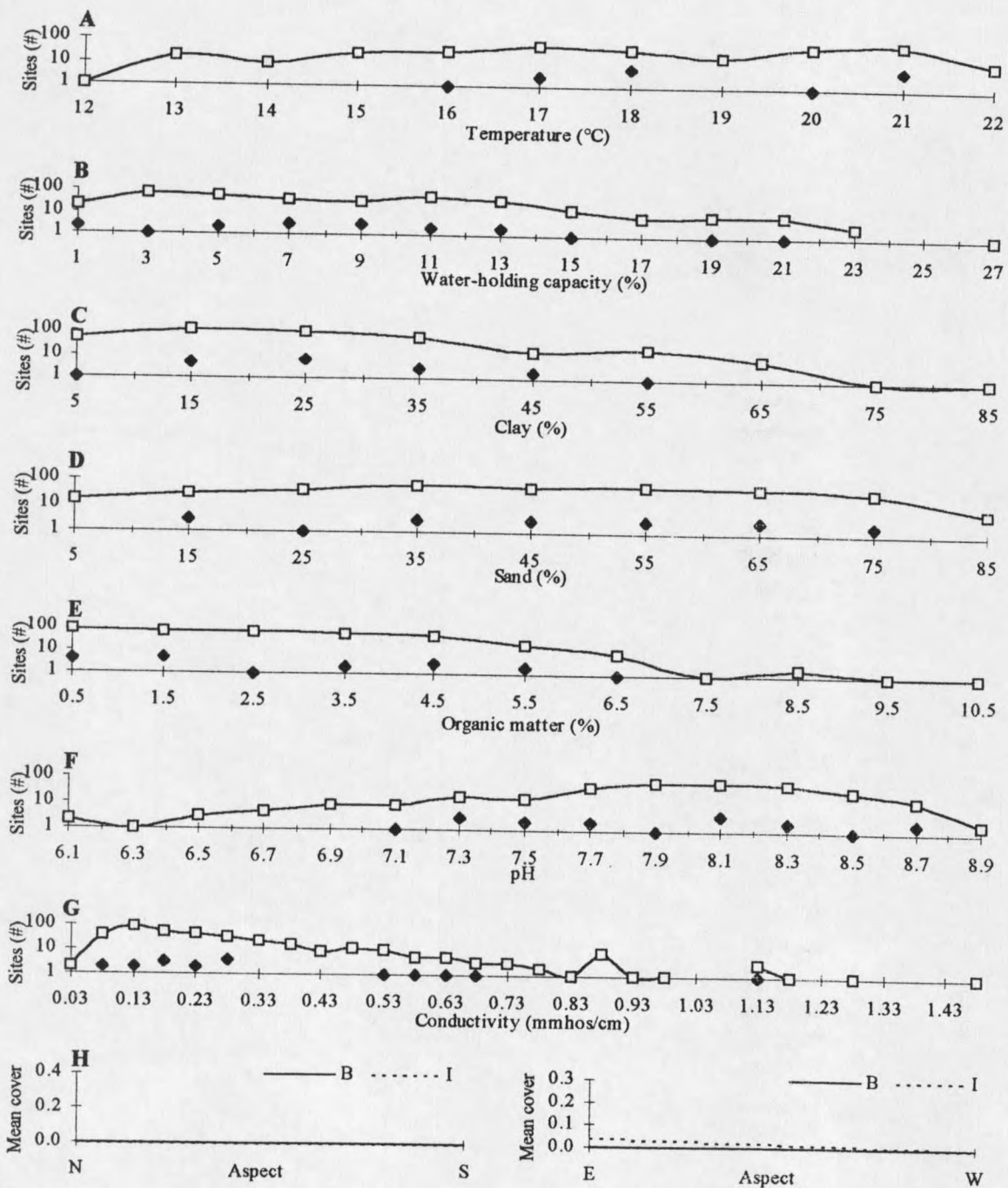


Figure 89. The Distribution of *Sphaeralcea coccinea* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Sphaeralcea coccinea* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Stipa comata* (Stco)*needle and thread grass Poaceae**

Origin, Duration and Habit¹: Native Perennial Grass, not vegetatively reproducing.

Environmental Type²: Stco cover (%) is highest in the AGSP and BOGR types, lower the ANSC and PSME types and lowest in the PIPO type (Fig. 90).

Temperature: Temperature does not differ between Stco sites and average sites (Fig. 91A).

Precipitation²: Stco cover (%) is highest in the more moist and driest sites (Fig. 90).

Water-holding capacity: WHC does not differ between Stco sites and average sites (Fig. 91B).

Clay: Clay does not differ between Stco sites and average sites (Fig. 91C).

Sand: Sand does not differ between Stco sites and average sites (Fig. 91D).

Organic carbon: OC does not differ between Stco sites and average sites (Fig. 91E).

pH: pH does not differ between Stco sites and average sites (Fig. 91F).

Conductivity: Conductivity does not differ between Stco sites and average sites (Fig. 91G).

Position and Aspect: Mean cover (%) is highest on backslopes (Fig. 91H).

¹ Refer to introduction (p52) for descriptions of each category. ² Significant category.

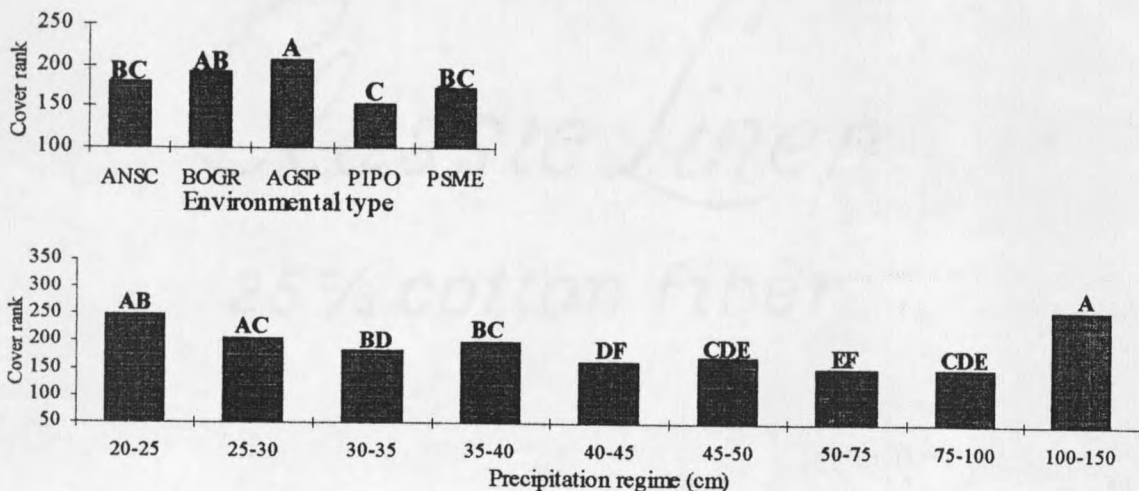


Figure 90. Effect of Environmental Type and Precipitation on Cover (%) of *Stipa comata*. Categories sharing a letter do not significantly differ.

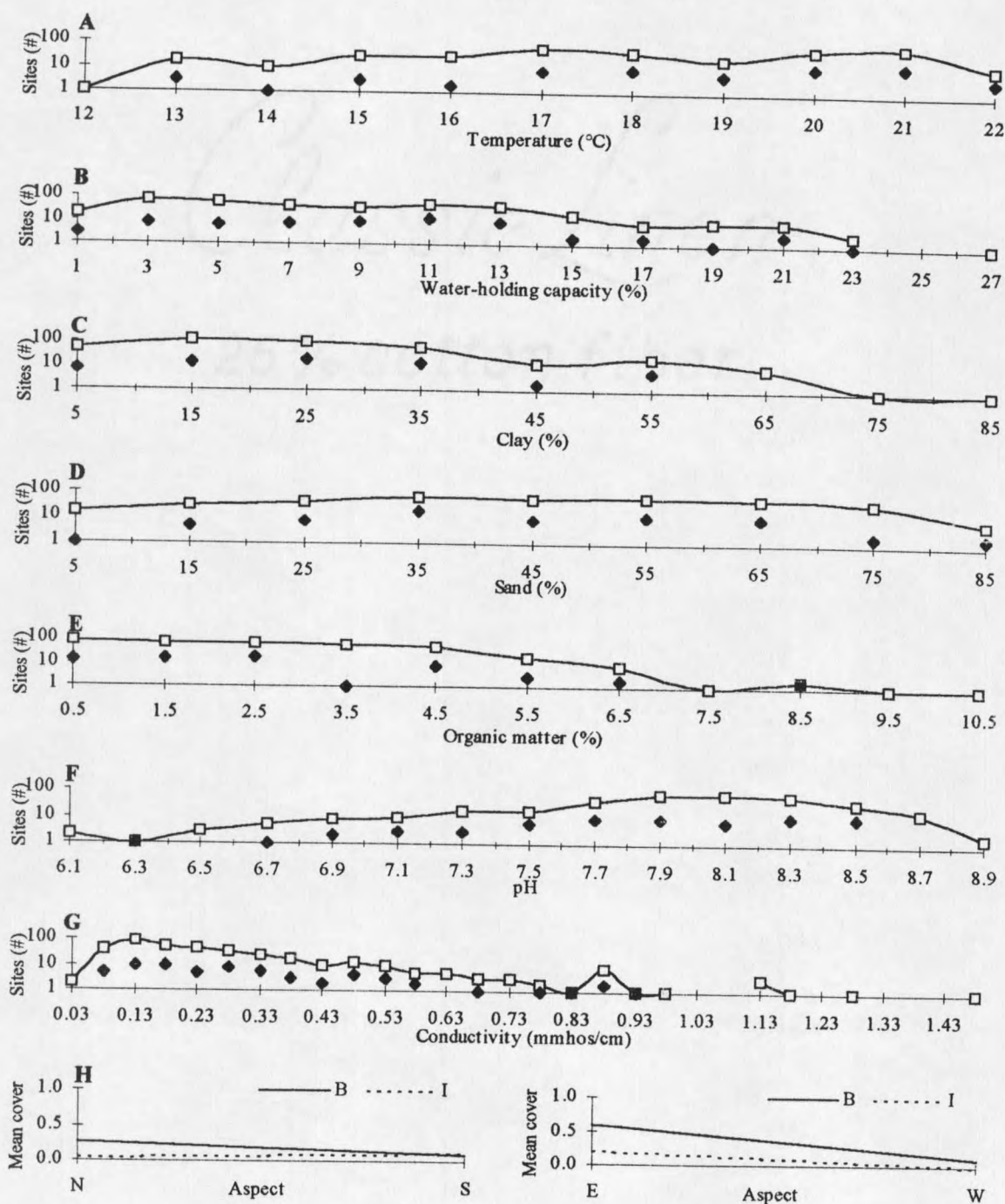


Figure 91. The Distribution of *Stipa comata* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Stipa comata* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Stipa viridula (Stvi)

green needle grass

Poaceae

Origin, Duration and Habit¹: Native Perennial Grass, not vegetatively reproducing.

Environmental Type²: Stvi cover (%) is the highest in the ANSC, BOGR and PSME types and lower in the PIPO and AGSP types (Fig. 92).

Temperature: Temperature does not differ between Stvi sites and average sites (Fig. 93A).

Precipitation: Stvi cover (%) does not differ between dry and moist sites (Fig. 92).

Water-holding capacity: WHC does not differ between Stvi sites and average sites (Fig. 93B).

Clay: Clay does not differ between Stvi sites and average sites (Fig. 93C).

Sand: Sand does not differ between Stvi sites and average sites (Fig. 93D).

Organic carbon: OC does not differ between Stvi sites and average sites (Fig. 93E).

pH: pH does not differ between Stvi sites and average sites (Fig. 93F).

Conductivity: Conductivity does not differ between Stvi sites and average sites (Fig. 93G).

Position and Aspect: Mean cover is highest on north-facing backslopes and west-facing inslopes (Fig. 93H).

¹ Refer to introduction (p52) for descriptions of each category. ² Significant category.

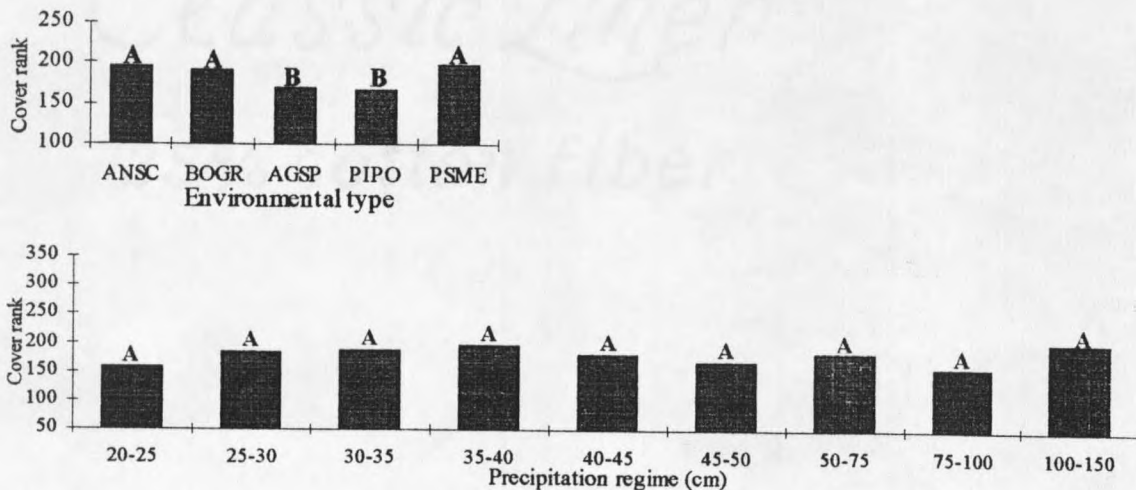


Figure 92. Effect of Environmental Type and Precipitation on Cover (%) of *Stipa viridula*. Categories sharing a letter do not significantly differ.

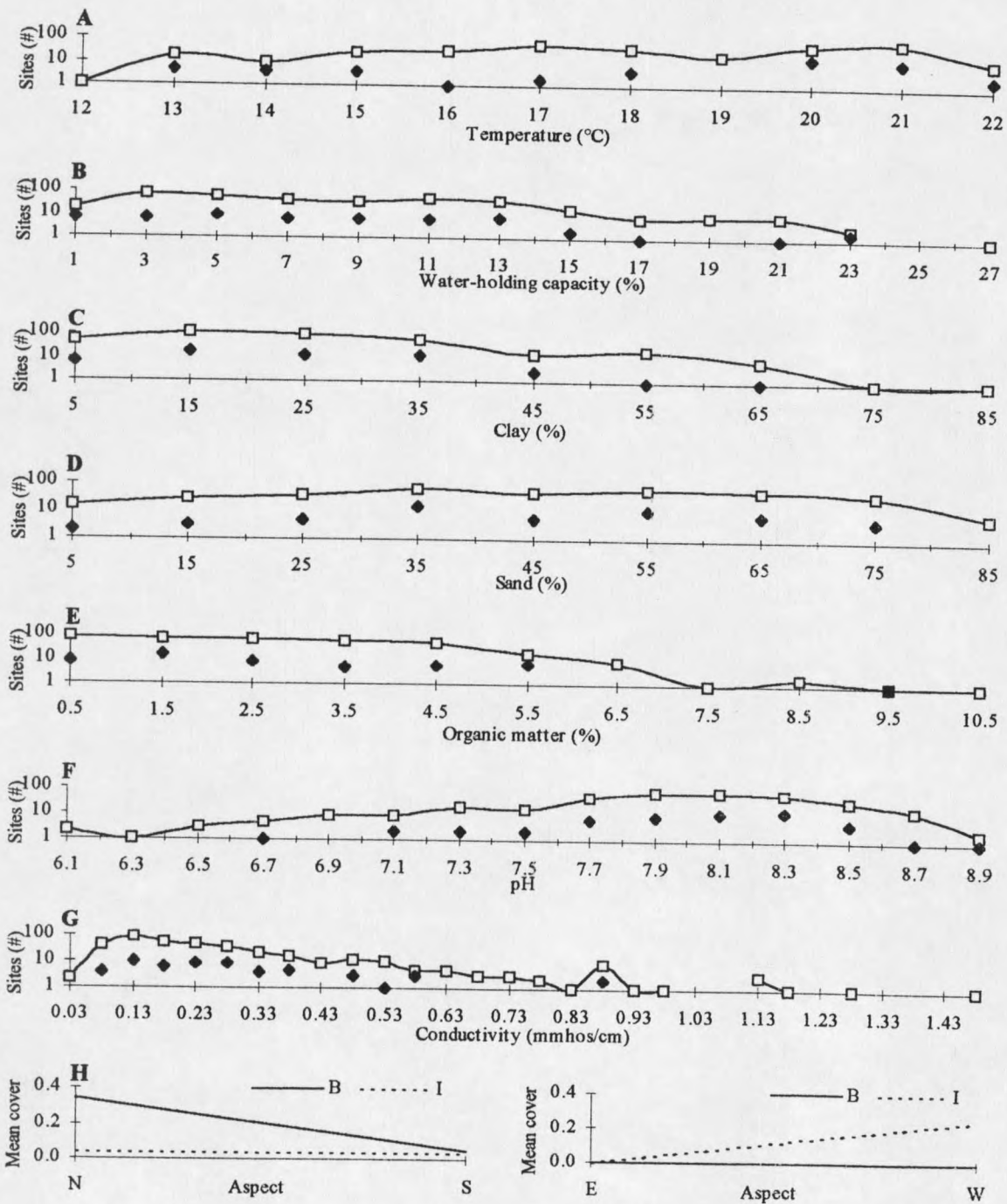


Figure 93. The Distribution of *Stipa viridula* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Stipa viridula* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Symphoricarpos albus (Syal)

snowberry

Caprifoliaceae

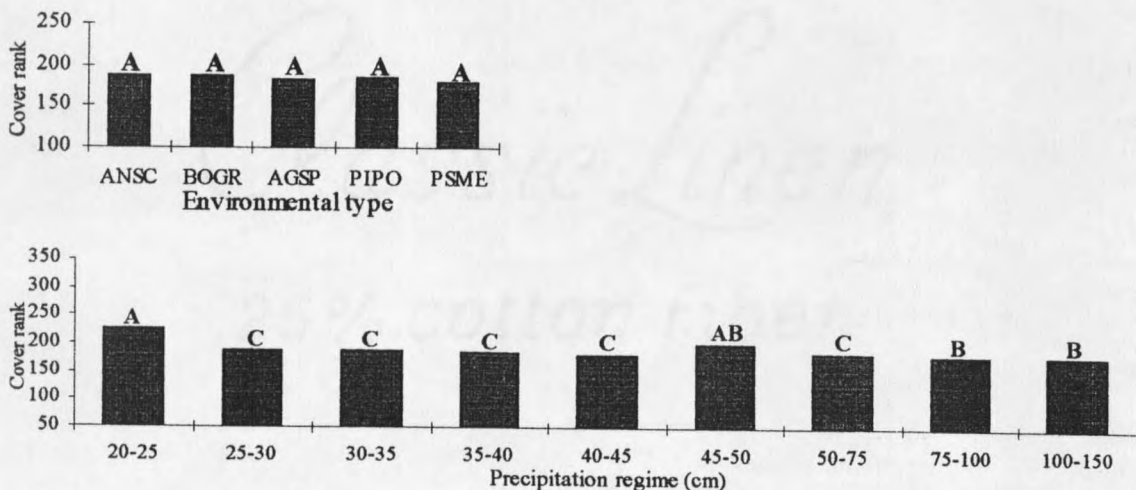
Origin, Duration and Habit¹: Native Perennial Shrub, vegetatively reproducing.Environmental type: Syal cover (%) does not differ between types (Fig. 94).Temperature: Temperature does not differ between Syal sites and average sites (Fig. 95A).Precipitation²: Syal cover (%) is highest on the driest sites (Fig. 94).Water-holding capacity: WHC does not differ between Syal sites and average sites (Fig. 95B).Clay: Clay does not differ between Syal sites and average sites (Fig. 95C).Sand: Sand does not differ between Syal sites and average sites (Fig. 95D).Organic carbon: OC does not differ between Syal sites and average sites (Fig. 95E).pH: pH does not differ between Syal sites and average sites (Fig. 95F).Conductivity: Conductivity does not differ between Syal sites and average sites (Fig. 95G).Position and Aspect: Occurs sporadically throughout roadside areas (Fig. 95H).¹ Refer to introduction (p52) for descriptions of each category. ² Significant category.

Figure 94. Effect of Environmental Type and Precipitation on Cover (%) of *Symphoricarpos albus*. Categories sharing a letter do not significantly differ.

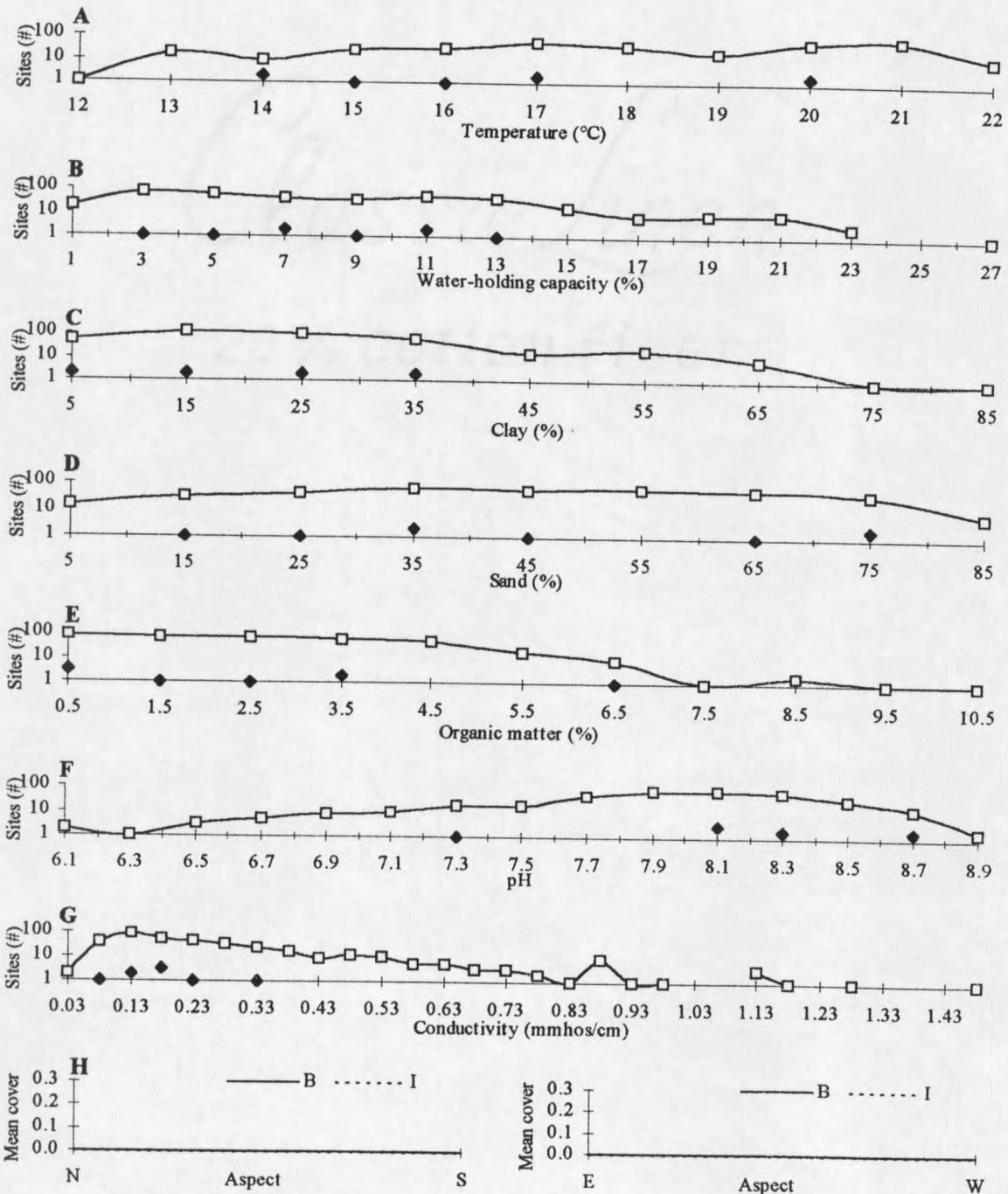


Figure 95. The Distribution of *Symphoricarpos albus* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Symphoricarpos albus* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Thlaspi arvense (Thar)

pennycress

Brassicaceae

Origin, Duration and Habit¹: Exotic Annual Forb, vegetatively reproducing.

Environmental Type²: Thar cover (%) is highest in the PSME type and BOGR type and lowest in the ANSC type (Fig. 96).

Temperature: Temperature does not differ between Thar sites and average sites (Fig. 97A).

Precipitation: Thar cover (%) does not differ between dry and moist sites (Fig. 96).

Water-holding capacity²: WHC in Thar sites is higher than in average roadside sites (Fig. 97B).

Clay: Clay does not differ between Thar sites and average sites (Fig. 97C).

Sand: Sand does not differ between Thar sites and average sites (Fig. 97D).

Organic carbon: OC does not differ between Thar sites and average sites (Fig. 97E).

pH: pH does not differ between Thar sites and average sites (Fig. 97F).

Conductivity: Conductivity does not differ between Thar sites and average sites (Fig. 97G).

Position and Aspect: Cover (%) is highest on west-facing backslopes (Fig. 97H)

¹ Refer to introduction (p52) for descriptions of each category. ² Significant category.

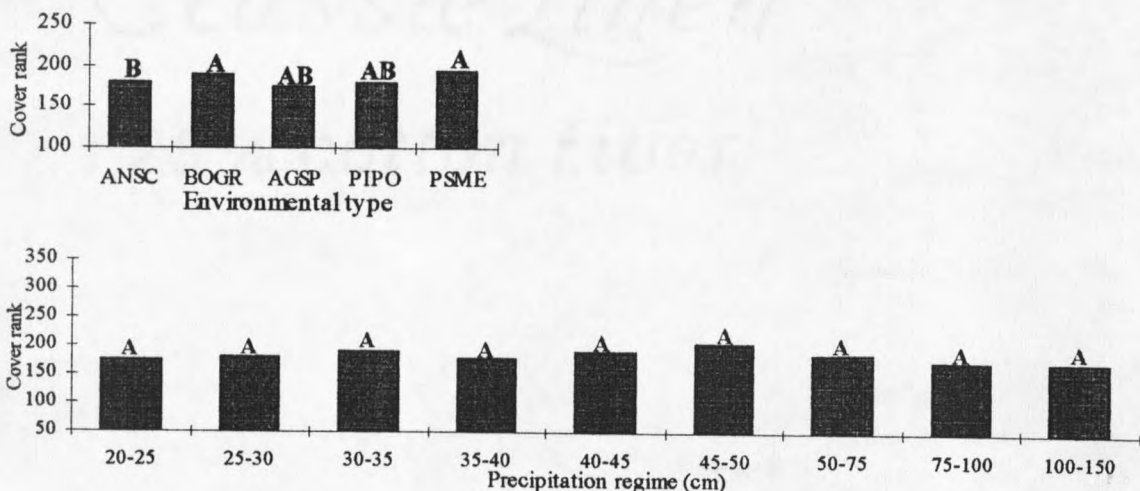


Figure 96. Effect of Environmental Type and Precipitation on Cover (%) of *Thlaspi arvense*. Categories sharing a letter do not significantly differ.

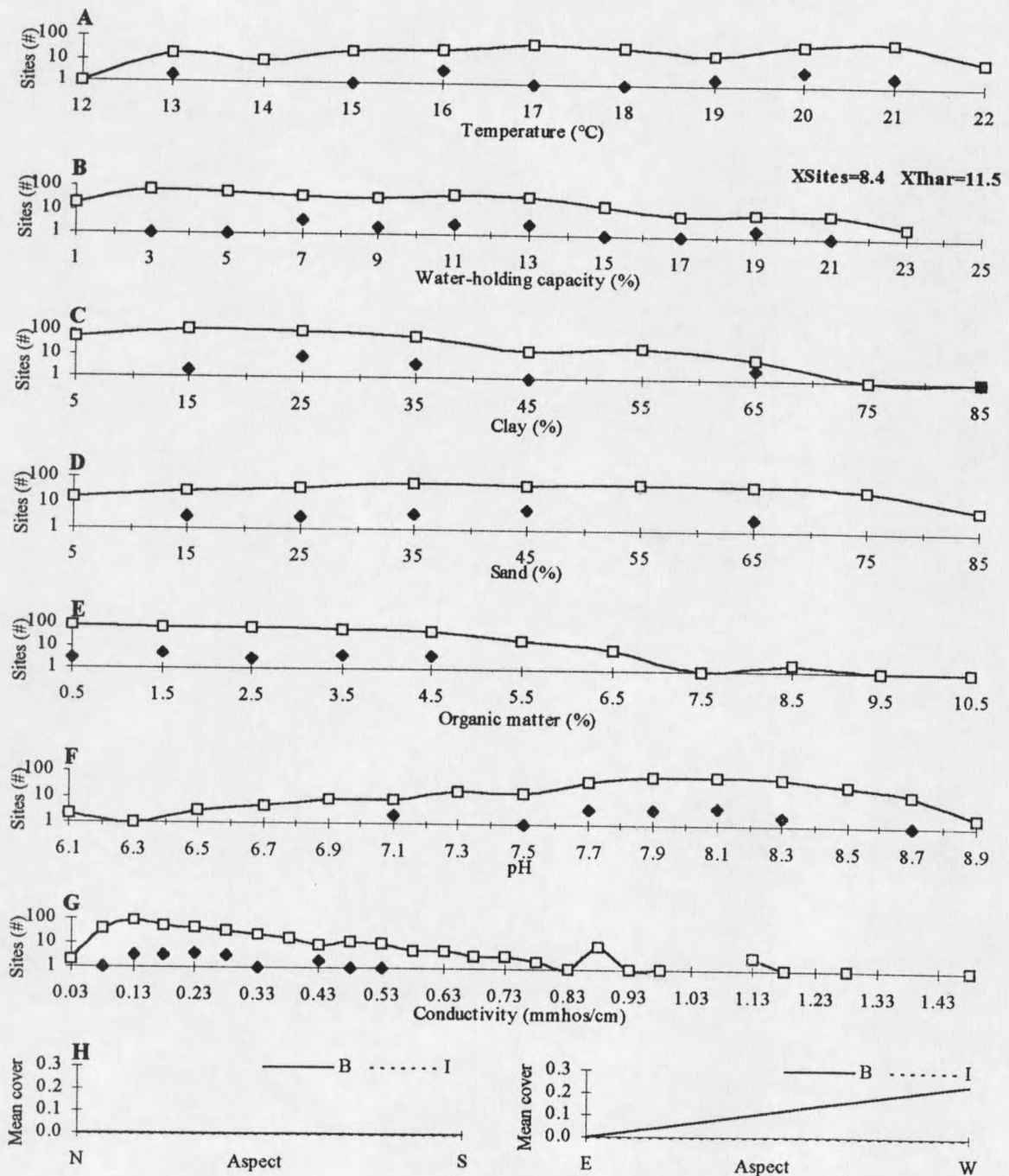


Figure 97. The Distribution of *Thlaspi arvense* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Thlaspi arvense* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Tragopogon dubius (Trdu)

yellow salsify

Asteraceae

Origin, Duration and Habit¹: Exotic Biennial Forb, not vegetatively reproducing.

Environmental type: Trdu cover (%) does not differ between types (Fig. 98).

Temperature: Temperature does not differ between Trdu sites and average sites (Fig. 99A).

Precipitation: Trdu cover (%) does not differ between dry and moist sites (Fig. 98).

Water-holding capacity: WHC does not differ between Trdu sites and average sites (Fig. 99B).

Clay: Clay does not differ between Trdu sites and average sites (Fig. 99C).

Sand: Sand does not differ between Trdu sites and average sites (Fig. 99D).

Organic carbon: OC does not differ between Trdu sites and average sites (Fig. 99E).

pH: pH does not differ between Trdu sites and average sites (Fig. 99F).

Conductivity: Conductivity does not differ between Trdu sites and average sites (Fig. 99G).

Position and Aspect: Mean cover (%) is highest on west-facing inslopes (Fig. 99H).

¹ Refer to introduction (p52) for descriptions of each category.

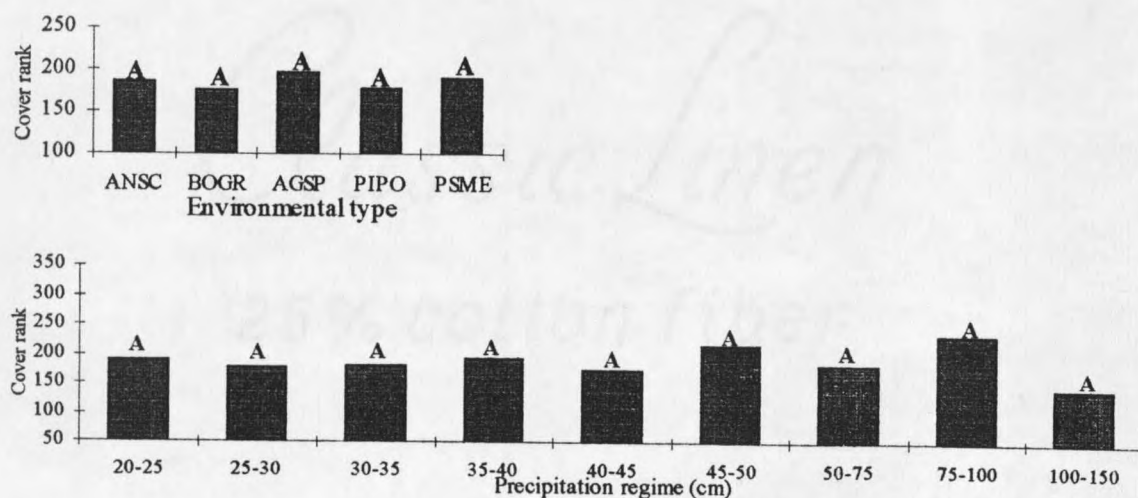


Figure 98. Effect of Environmental Type and Precipitation on Cover (%) of *Tragopogon dubius*. Categories sharing a letter do not significantly differ.

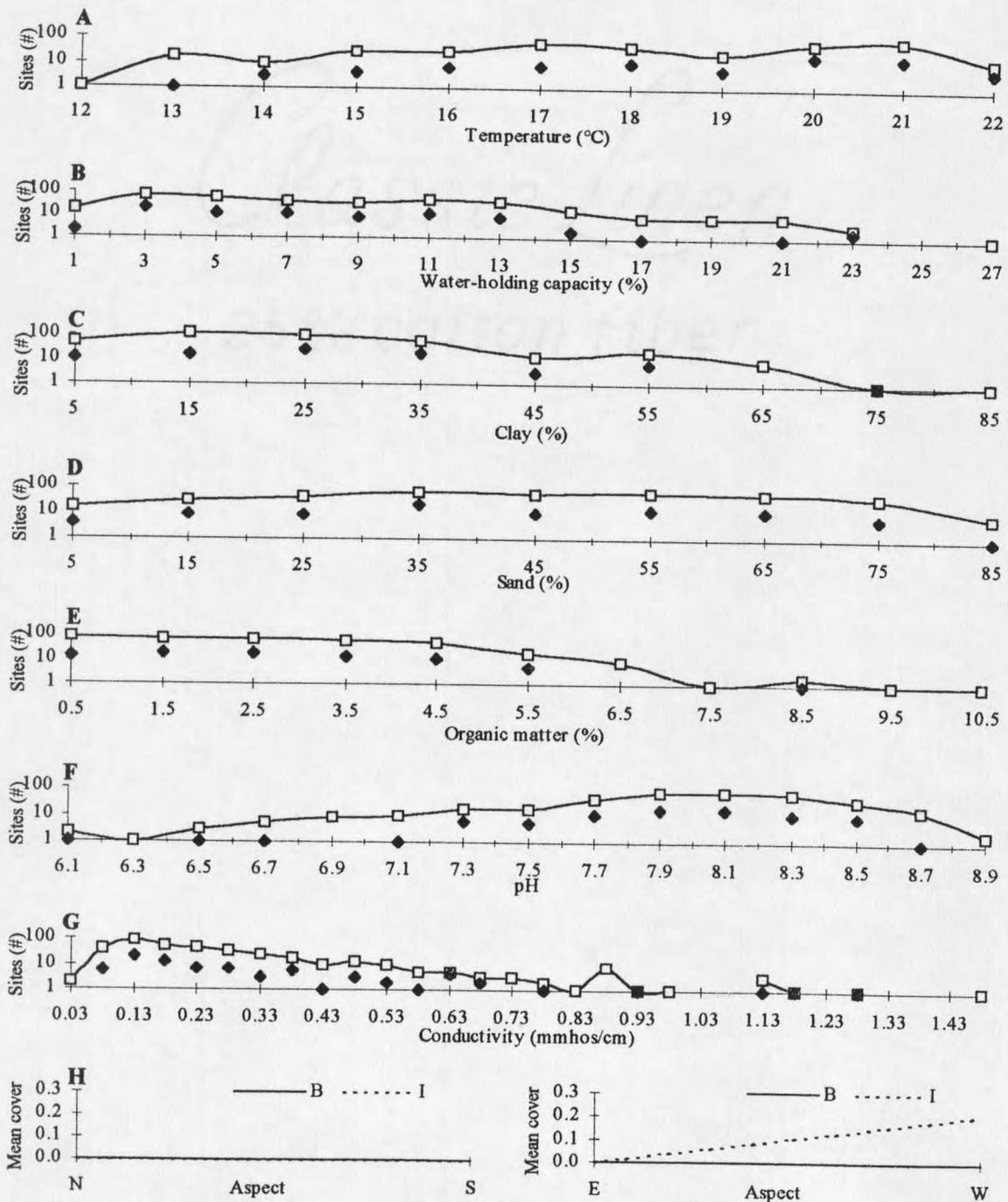


Figure 99. The Distribution of *Tragopogon dubius* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Tragopogon dubius* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Trifolium hybridum* (Trhy)*clover****Fabaceae**

Origin, Duration and Habit¹: Exotic Perennial Forb, vegetatively reproducing.

Environmental Type²: Trhy cover (%) is highest in the PSME type (Fig. 100).

Temperature²: Temperature in Trhy sites is lower than average roadside sites (Fig. 101A).

Precipitation²: Trhy cover (%) is highest in moist (100-150 cm) sites (Fig. 100).

Water-holding capacity: WHC does not differ between Trhy sites and average sites (Fig. 101B).

Clay: Clay does not differ between Trhy sites and average sites (Fig. 101C).

Sand: Sand does not differ between Trhy sites and average sites (Fig. 101D).

Organic carbon: OC does not differ between Trhy sites and average sites (Fig. 101E).

pH²: pH in Trhy sites is lower than average roadside sites (Fig. 101F).

Conductivity²: Conductivity in Trhy sites is lower than average roadside sites (Fig. 101G).

Position and Aspect: Trhy occurs sporadically on roadside sites Fig. 101H).

¹ Refer to introduction (p52) for descriptions of each category. ² Significant category.

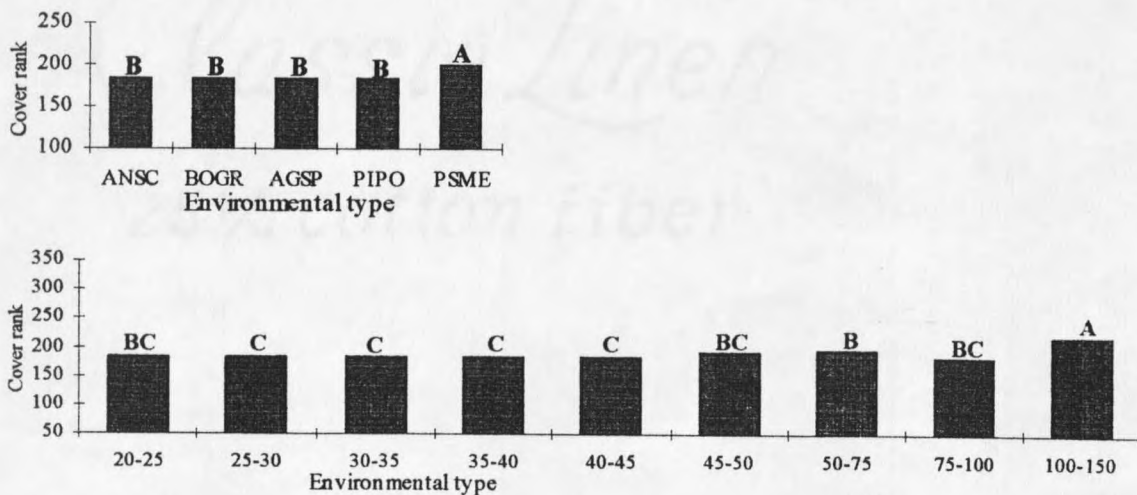


Figure 100. Effect of Environmental Type and Precipitation on Cover (%) of *Trifolium hybridum*. Categories sharing a letter do not significantly differ.

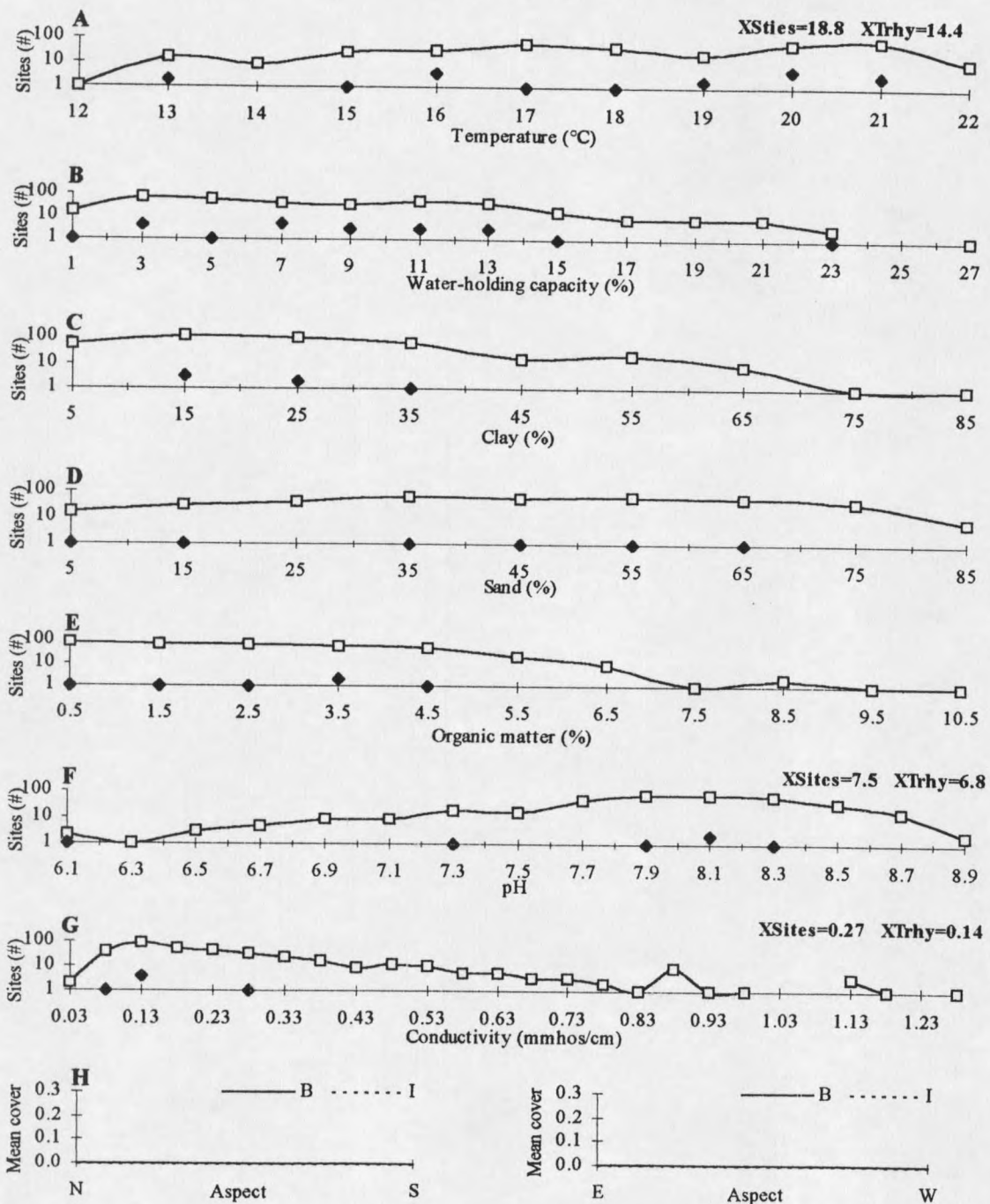


Figure 101. The Distribution of *Trifolium hybridum* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Trifolium hybridum* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

Verbascum thapsus (Veth)

woolly mullein

Scrophulariaceae

Origin, Duration and Habit¹: Exotic Biennial Forb, not vegetatively reproducing.

Environmental Type²: Veth cover (%) is highest in the PSME type (Fig. 102).

Temperature²: Temperature in Veth sites is lower than average roadside sites (Fig. 103A).

Precipitation²: Veth cover (%) is highest in the driest and more moist sites (Fig. 102).

Water-holding capacity²: WHC in Veth sites is lower than in average sites (Fig. 103B).

Clay: Clay does not differ between Veth sites and average sites (Fig. 103C).

Sand²: Sand in Veth sites is higher than average roadside sites (Fig. 103D).

Organic carbon: OC does not differ between Veth sites and average sites (Fig. 103E).

pH: pH does not differ between Veth sites and average sites (Fig. 103F).

Conductivity²: Conductivity in Veth sites is lower than in average sites (Fig. 103G).

Position and Aspect: Mean cover (%) is highest on north-facing inslopes and east-facing inslopes (Fig. 103H).

¹ Refer to introduction (p52) for descriptions of each category. ² Significant category.

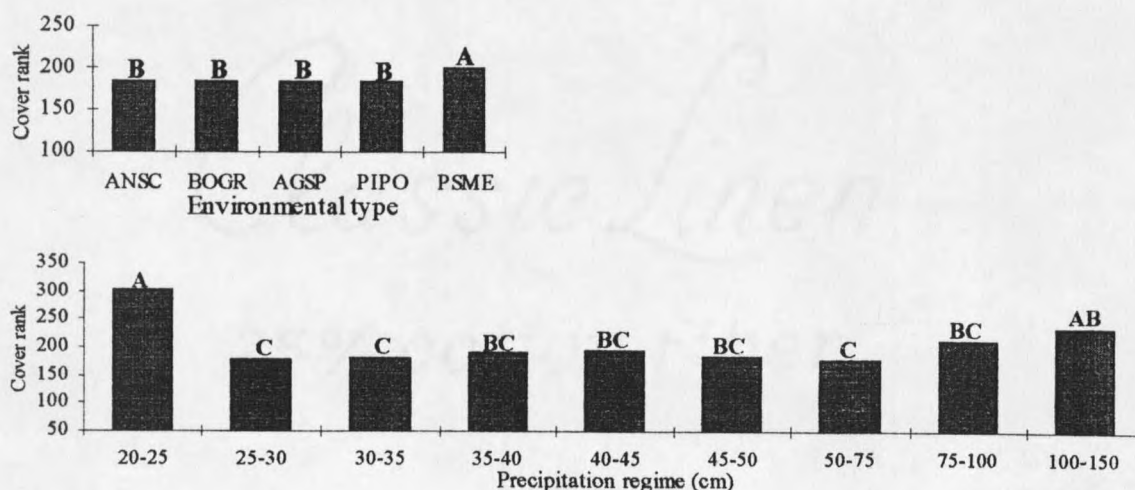


Figure 102. Effect of Environmental Type and Precipitation on Cover (%) of *Verbascum thapsus*. Categories sharing a letter do not significantly differ.

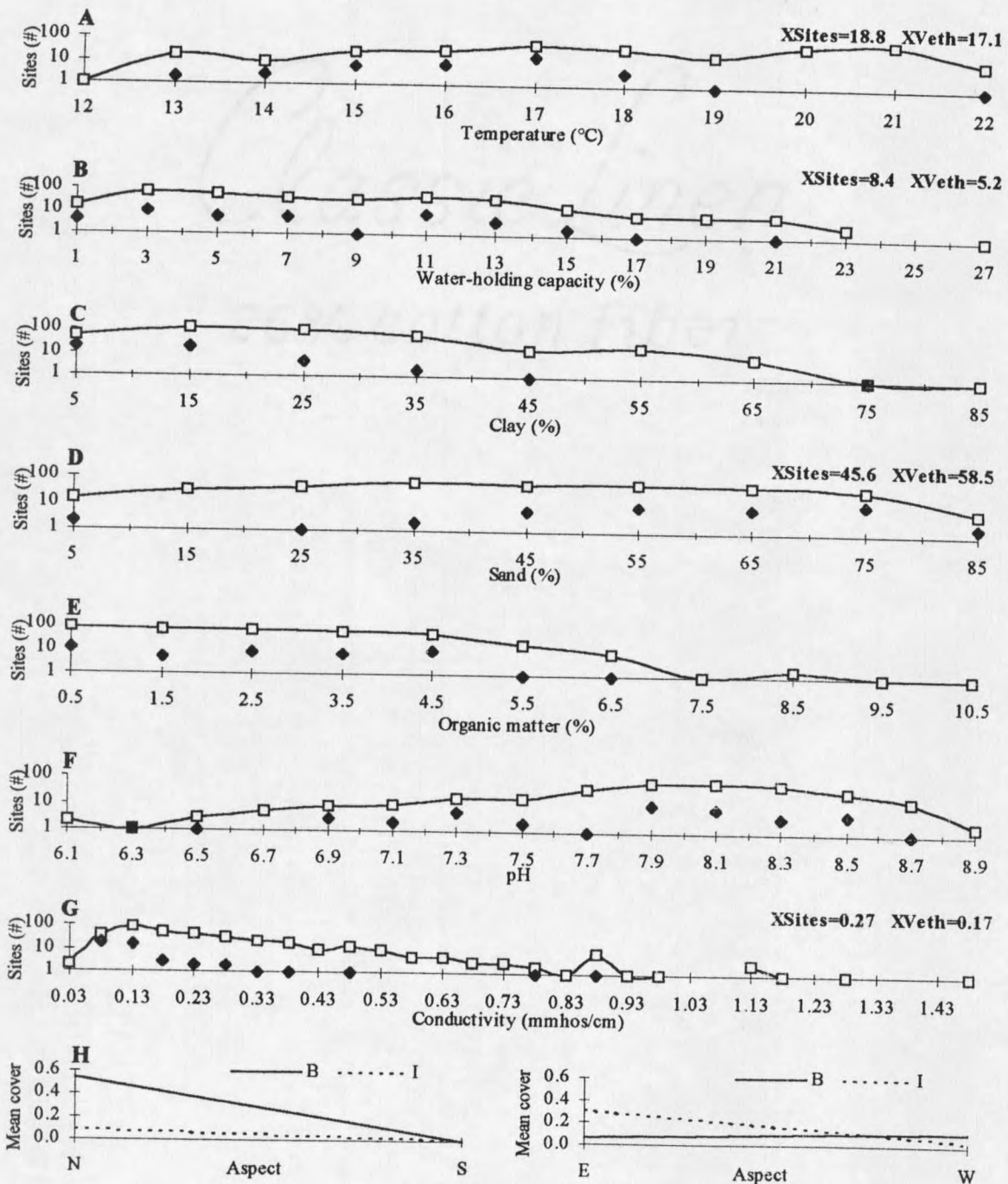


Figure 103. The Distribution of *Verbascum thapsus* Sites (solid diamonds) and all Roadside Sites (open squares) across Nine Site Characteristics. Where the mean of sites occupied by *Verbascum thapsus* is significantly ($p < 0.05$) different from the mean of all sites, both are shown in the upper right of the graph.

APPENDIX B. PLANT SPECIES

Table 12. Plant Species found on Montana roadsides. Nomenclature follows Hitchcock and Cronquist 1973 and McGregor et al. 1986.

<i>Abies lasiocarpa</i> (Hook.) Nutt.
<i>Acer</i> spp
<i>Achillea millefolium</i> L.
<i>Aegilops cylindrica</i> Host.
<i>Agropyron cristatum</i> L.
<i>Agropyron dasystachyum</i> (Hook.) Scribn.
<i>Agropyron elongatum</i> (Host) Beauv.
<i>Agropyron intermedium</i> (Host) Beauv.
<i>Agropyron repens</i> (L.) Beauv.
<i>Agropyron smithii</i> Rydb.
<i>Agropyron spicatum</i> (Pursh) Scrib. & Smith
<i>Agropyron trachycaulum</i> (Link) Malte
<i>Agrostis stolonifera</i> L.
<i>Allium cernuum</i> Roth
<i>Aloepectrus pratensis</i> L.
<i>Alyssum alyssoides</i> L.
<i>Ambrosia artemisiifolia</i> L.
<i>Amsinckia menziesii</i> (Lehm.) Nels & Macbr.
<i>Anaphalis margaritaceae</i> (L.) B. & H.
<i>Andropogon gerardii</i> Vitman
<i>Androsace chamaejasme</i> Wulf.
<i>Anemone multifida</i> Poir.
<i>Antennaria microphylla</i> Rydb.
<i>Antennaria</i> spp.
<i>Arctostaphylos uva-ursi</i> (L.) Spreng.
<i>Aristida purpurea</i> var. <i>longiseta</i> (Steudel) Vasey
<i>Artemisia ludoviciana</i> Nutt.
<i>Artemisia campestris</i> L. subssp. <i>caudata</i> (Michx) Hall & Clem.
<i>Artemisia cana</i> Nutt.
<i>Artemisia frigida</i> Willd.
<i>Artemisia</i> spp
<i>Artemisia tridentata</i> Nutt.
<i>Asclepias</i> spp
<i>Aster junciformis</i> Rydb.
<i>Aster laevis</i> L.
<i>Aster</i> spp
<i>Astragalus bisulcatus</i> (Hook.) Gray
<i>Astragalus crassicaulus</i> Nutt.
<i>Astragalus lotiflorus</i> Hook.
<i>Astragalus pectinatus</i> Doug
<i>Atriplex gardneri</i> (Moq.) Dietr.

Table 12. Continued.

<i>Avena fatua</i> L.
<i>Avena sativa</i> L.
<i>Balsamorhiza sagitata</i> (Pursh) Nutt.
<i>Beckmannia syzigachne</i> (Steudel) Fernald.
<i>Berteroa incana</i> (L.) DC.
<i>Bouteloua curtipendula</i> (Michx.) Torrey.
<i>Bouteloua gracilis</i> (H. B. K.) Lag.
<i>Brassica kaber</i> (DC.) Wheeler
<i>Bromus carinatus</i> Hooker & Arnott
<i>Bromus inermis</i> Leys.
<i>Bromus japonicus</i> Thunb.
<i>Bromus tectorum</i> L.
<i>Calamovilfa longifolia</i> Hack.
<i>Camelina sativa</i> (L.) Crantz
<i>Campanula rotundifolia</i> L.
<i>Campanula</i> spp
<i>Cardaria pubescens</i> (Meyer) Jarmol
<i>Centaurea maculosa</i> Lam.
<i>Chrysanthemum leucanthemum</i> L.
<i>Cirsium arvense</i> (L.) Scop.
<i>Cirsium scariosum</i> Nutt.
<i>Cirsium</i> spp.
<i>Cirsium vulgare</i> (Savi) Tenore
<i>Clematis ligusticifolia</i> Nutt.
<i>Cleome serrulata</i> Pursh
<i>Collomia linearis</i> Nutt.
<i>Convolvulus arvense</i> L.
<i>Conyza canadensis</i> L.
<i>Cryptantha celosioides</i> (Eastw.) Payson
<i>Dactylis glomerata</i> L.
<i>Dalea purpurea</i> Vent.
<i>Echinacea pallida</i> var <i>angustifolia</i> (Nutt.) Nutt.
<i>Elaeagnus commutata</i> Bernh.
<i>Elymus canadensis</i> (C. L. Hitchcock) Jensen
<i>Elymus cinereus</i> Scribn. & Merr.
<i>Elymus trachycaulus</i> (Link) Gould
<i>Equisetum arvense</i> L.
<i>Erigeron pumilus</i> Nutt.
<i>Erigeron</i> spp.
<i>Eriogonum flavum</i> Nutt.
<i>Eriogonum</i> spp.
<i>Erysimum aspernum</i> (Nutt) DC.

Table 12. Continued.

<i>Festuca idahoensis</i> Elmer
<i>Festuca ovina</i> L.
<i>Festuca pratense</i> Hudson
<i>Festuca scabrella</i> Torr.
<i>Fragaria</i> spp
<i>Galium boreale</i> L.
<i>Gaura coccinea</i> Nutt. ex. Pursh
<i>Geranium</i> ssp.
<i>Gilia tweedyi</i> Rydb.
<i>Glycyrrhiza lepidota</i> Pursh
<i>Gnaphalium palustre</i> Nutt.
<i>Grindelia squarrosa</i> (Pursh) Punal
<i>Gutierrezia sarothrae</i> (Pursh) Britt. & Rusby
<i>Habenaria elegans</i> (Lindl.) Bolander
<i>Haplopappus spinulosa</i> (Pursh) DC.
<i>Heliopsis helianthoides</i> (L.) Sweet var. <i>scabra</i> (Dunal) Fern. (H.S.)
<i>Heterotheca villosa</i> (Pursh) Shinnars
<i>Hordeum brachyantherum</i> Nevski
<i>Hordeum jubatum</i> L.
<i>Juniperus communis</i> L.
<i>Kochia scoparia</i> (L.) Schrad.
<i>Koeleria nitida</i> Nuttall
<i>Lactuca serriola</i> L.
<i>Lepidium ramosissimum</i> Nels.
<i>Lepidium virginicum</i> L.
<i>Lepidium perfoliantum</i> L.
<i>Liatris ligulistylis</i> (A. Nels.) Schum.
<i>Liatris punctata</i> Hook
<i>Linaria dalmatica</i> (L.)
<i>Linum lewisii</i> Pursh Rydberg
<i>Linum rigidum</i> Pursh
<i>Lupinus argenteus</i> Pursh
<i>Lupinus</i> spp.
<i>Lychnis</i> ssp
<i>Lygodesmia juncea</i> (Purch) D.Don ex. Hook
<i>Matricaria matricariodes</i> (Less.)
<i>Medicago polymorpha</i> L.
<i>Medicago sativa</i> L.
<i>Melilotus officinalis</i> (L.) Pall.
<i>Mondarda fistulosa</i> L.
<i>Oenothera villosa</i> Thunb.
<i>Opuntia polyantha</i> Haw.

Table 12. Continued.

<i>Orthocarpus luteus</i> Nutt.
<i>Orthocarpus tenuifolius</i> (Pursh) Benth
<i>Oryzopsis hymenoides</i> (R. & S.) Ricker
<i>Oxytropis serica</i> Nutt.
<i>Oxytropis</i> spp
<i>Pediomelum argophylla</i> Pursh
<i>Pediomelum esculenta</i> (Pursh) Rydb.
<i>Penstemon nitidus</i> Dougl. ex Benth.
<i>Penstemon procerus</i> Dougl. ex Grah.
<i>Penstemon</i> spp
<i>Phlaris arundinaceae</i> L.
<i>Phleum pratense</i> L.
<i>Pinus contorta</i> Dougl. ex Loud.
<i>Pinus flexilis</i> James
<i>Pinus ponderosa</i> Dougl. ex Laws. & Laws.
<i>Plantago patagonica</i> Jacq.
<i>Poa compressa</i> L.
<i>Poa gracilima</i> Vasey
<i>Poa pratensis</i> L.
<i>Polygala alba</i> Nutt.
<i>Polygonum ramosissimum</i> Michx.
<i>Populus tremuloides</i> Michx.
<i>Potentilla arguta</i> Pursh.
<i>Potentilla</i> spp.
<i>Prunella vulgaris</i> L.
<i>Pseudotsuga menziesii</i> (Mirb.) Franco
<i>Puccinellia nuttalliana</i> (Schult)
<i>Purshia tridentata</i> (Pursh) DC.
<i>Ratibida columnifera</i> (Nutt.) Wooton & Standley
<i>Rhinanthus crista-galli</i> L.
<i>Rosa woodsii</i> Lindl.
<i>Rudbeckia</i> spp.
<i>Rumex crispus</i> L.
<i>Rumex occidentalis</i> Wats.
<i>Salix</i> spp
<i>Salzola iberica</i> Sennen & Pau
<i>Sarcobatus vermiculatus</i> (Hook.) Torr.
<i>Schedonnardus paniculatus</i> (Nuttall) Trel
<i>Schizachyrium scoparium</i> (Michx.) Nash
<i>Sedum</i> spp
<i>Setaria viridis</i> (L.) Beauv.
<i>Silene vulgaris</i> (Moench) Garcke

Table 12. Continued.

<i>Sisymbrium</i> ssp.
<i>Sisyrinchium montanum</i> Greene
<i>Sitanion hystrix</i> (Nutt.) J. G. Sm var. <i>brevifolium</i> (J. G. Sm.) C. L. Hitchc
<i>Solidago canadensis</i> L.
<i>Solidago mollis</i> Bartl
<i>Solidago nemoralis</i> Ait.
<i>Solidago rigida</i> L.
<i>Sphaleracea coccinea</i> (Nutt.) Rydb.
<i>Sphenopholis obtusata</i> (Michx.) Scribn.
<i>Spiraea betulifolia</i> Pall.
<i>Sporobolus airoides</i> (Torr.) Torr.
<i>Sporobolus cryptandrus</i> (Torr.)
<i>Stipa comata</i> Trin. & Rupr.
<i>Stipa richardsonii</i> Link.
<i>Stipa viridula</i> Trin.
<i>Symphoricarpos albus</i> (L.) Blake
<i>Symphoricarpos occidentalis</i> Hook.
<i>Tanacetum vulgare</i> L.
<i>Thlaspi arvense</i> L.
<i>Thuja plicata</i> Donn.
<i>Tragopogon dubius</i> Scop.
<i>Taraxacum officinale</i> Weber in Wiggers
<i>Trifolium agrarium</i> L.
<i>Trifolium hybridum</i> L.
<i>Trifolium pratense</i> L.
<i>Trifolium</i> ssp
<i>Triticum aestivum</i> L.
<i>Tsuga heterophylla</i> (Raf.) Sarg.
<i>Vaccaria pyramidata</i> Medic.
<i>Verbascum thapsus</i> L.
<i>Vicia villosa</i> Roth
<i>Wyethia angustifolia</i>
<i>Yucca glauca</i> Nutt.

**APPENDIX C. COMMON PLANT SPECIES SELECTED FOR ANALYSIS WITH
FOUR LETTER ACRONYMS**

Table 13. Species Selected for Analysis and Appropriate Acronyms.

Species Name	Acronym
<i>Achillea millefolium</i>	ACMI
<i>Agropyron cristatum</i>	AGCR
<i>Agropyron dasystachyum</i>	AGDA
<i>Agropyron smithii</i>	APSM
<i>Agropyron spicatum</i>	AGSP
<i>Agrostis stolonifera</i>	AGST
<i>Alyssum alyssoides</i>	ALAL
<i>Artemisia cana</i>	ARCA
<i>Artemisia frigida</i>	ARFR
<i>Artemisia tridentada</i>	ARTR
<i>Avena sativa</i>	AVSA
<i>Bouteloua gracilis</i>	BOGR
<i>Bromus inermis</i>	BRIN
<i>Bromus tectorum</i>	BRTE
<i>Centaurea maculosa</i>	CEMA
<i>Cirsium arvense</i>	CIAR
<i>Dactylis glomerata</i>	DAGL
<i>Dalea purpurea</i>	DAPU
<i>Festuca idahoensis</i>	FEID
<i>Festuca ovina</i>	FEOV
<i>Festuca scabrella</i>	FESC
<i>Gaura coccinea</i>	GACO
<i>Gutierrezia sarothrae</i>	GUSA
<i>Heterotheca villosa</i>	HEVI
<i>Hordeum jubatum</i>	HOJU
<i>Kochia scoparia</i>	KOSC
<i>Koeleria nitida</i>	KONI
<i>Lactuca serriola</i>	LASE
<i>Liatris punctata</i>	LIPU
<i>Lupinus argenteus</i>	LUAR
<i>Medicago polymorpha</i>	MEPO
<i>Medicago sativa</i>	MESA
<i>Melilotus offinalis</i>	MEOF
<i>Opuntia polyacantha</i>	OPPO
<i>Phalaris arundinacea</i>	PHAR
<i>Phleum pratense</i>	PHPR
<i>Pinus ponderosa</i>	PIPO
<i>Poa compressa</i>	POCO
<i>Poa pratensis</i>	POPR
<i>Poa sandbergii</i>	POSA

Table 13. Continued.

<i>Ratibida columnifera</i>	RACO
<i>Rosa woodsii</i>	ROWO
<i>Sphaleraceae coccinea</i>	SPCO
<i>Stipa comata</i>	STCO
<i>Stipa viridula</i>	STVI
<i>Symphoricarpos albus</i>	SYAL
<i>Trifolium hybridum</i>	TRHY
<i>Tragopogon dubius</i>	TRDU
<i>Thlaspi arvense</i>	THAR
<i>Verbascum thapsus</i>	VETH

**APPENDIX D. KRUSKAL-WALLIS P-VALUES AND RANKING FOR SPECIES
RESPONSE TO ENVIRONMENTAL TYPE AND PRECIPITATION REGIME**

Table 14. Kruskal-Wallis p-values for Species Response to Environmental Type and Precipitation.

Species ¹	Origin ²	Environmental Type ³	Precipitation ⁴
Acmi	N	0.000	0.952
Agcr	E	0.000	0.000
Agda	N	0.000	0.000
Agsm	N	0.000	0.000
Agsp	N	0.065	0.546
Agst	E	0.000	0.089
Alal	E	0.426	0.094
Arca	N	0.595	0.338
Arfr	N	0.009	0.226
Artr	N	0.180	0.828
Avsa	E	0.000	0.070
Bogr	N	0.073	0.000
Brin	E	0.040	0.013
Brte	E	0.043	0.000
Cema	E	0.181	0.010
Ciar	E	0.694	0.972
Dagl	E	0.000	0.000
Dapu	N	0.003	0.117
Feid	N	0.001	0.000
Feov	N	0.000	0.000
Fesc	N	0.000	0.437
Gaco	N	0.102	0.933
Gusa	N	0.466	0.590
Hevi	N	0.190	0.785
Hoju	N	0.013	0.472
Koni	N	0.001	0.047
Kosc	E	0.027	0.777
Lase	E	0.000	0.066
Lipu	N	0.262	0.610
Luar	N	0.514	0.720
Mepo	E	0.429	0.000
Mesa	E	0.091	0.304
Meof	E	0.044	0.019
Oppo	N	0.835	0.946
Phar	E	0.046	0.037
Phpr	E	0.000	0.000

Table 14. Continued.

Species ¹	Origin ²	Environmental Type ³	Precipitation ⁴
Pipo	N	0.831	0.177
Poco	N	0.000	0.092
Popr	E	0.003	0.127
Posa	N	0.091	0.340
Raco	N	0.230	0.996
Rowo	N	0.132	0.107
Spco	N	0.094	0.001
Stco	N	0.000	0.000
Stvi	N	0.011	0.695
Syal	N	0.553	0.027
Thar	E	0.038	0.206
Trdu	E	0.361	0.406
Trhy	E	0.000	0.000
Veth	E	0.259	0.004

¹ Appendix A contains species names and acronyms, ² E/N=Exotic or Native Species, Environ ³=Environmental type as defined in Methods, Precip ⁴=Precipitation regime.

**APPENDIX E. PAIRWISE COMPARISONS FOR ENVIRONMENTAL TYPE AND
PRECIPITATION REGIME FOR ALL SIGNIFICANT ($p < 0.05$) SPECIES**

Table 15. P-values for Pairwise Comparisons of Species and Environment.

<i>Achillea</i>	environ	ANSC	PIPO	PSME	BOGR	AGSP
<i>millefolium</i>	ANSC	1.000	0.007	0.097	0.030	0.000
	PIPO	0.007	1.000	0.419	0.311	0.068
	PSME	0.097	0.419	1.000	0.966	0.015
	BOGR	0.030	0.311	0.966	1.000	0.001
	AGSP	0.000	0.068	0.015	0.001	1.000
<i>Agropyron</i>	environ	ANSC	PIPO	PSME	BOGR	AGSP
<i>cristatum</i>	ANSC	1.000	0.001	0.000	0.007	0.498
	PIPO	0.001	1.000	0.137	0.000	0.000
	PSME	0.000	0.137	1.000	0.000	0.000
	BOGR	0.007	0.000	0.000	1.000	0.028
	AGSP	0.498	0.000	0.000	0.028	1.000
<i>Agropyron</i>	environ	ANSC	PIPO	PSME	BOGR	AGSP
<i>dasystachyum</i>	ANSC	1.000	0.000	0.000	0.022	0.000
	PIPO	0.000	1.000	0.530	0.000	0.877
	PSME	0.000	0.530	1.000	0.000	0.614
	BOGR	0.022	0.000	0.000	1.000	0.000
	AGSP	0.000	0.877	0.614	0.000	1.000
<i>Agropyron</i>	environ	ANSC	PIPO	PSME	BOGR	AGSP
<i>smithii</i>	ANSC	1.000	0.552	0.603	0.000	0.338
	PIPO	0.552	1.000	0.269	0.002	0.714
	PSME	0.603	0.269	1.000	0.000	0.145
	BOGR	0.000	0.002	0.000	1.000	0.006
	AGSP	0.338	0.714	0.145	0.000	1.000
<i>Agrostis</i>	environ	ANSC	PIPO	PSME	BOGR	AGSP
<i>stolonifera</i>	ANSC	1.000	0.738	0.355	0.000	0.768
	PIPO	0.738	1.000	0.517	0.000	0.969
	PSME	0.355	0.517	1.000	0.012	0.479
	BOGR	0.000	0.000	0.012	1.000	0.000
	AGSP	0.768	0.960	0.479	0.000	1.000
<i>Artemisia</i>	environ	ANSC	PIPO	PSME	BOGR	AGSP
<i>frigida</i>	ANSC	1.000	0.052	0.100	0.004	0.000
	PIPO	0.052	1.000	0.909	0.492	0.089
	PSME	0.100	0.909	1.000	0.470	0.103
	BOGR	0.004	0.492	0.470	1.000	0.191
	AGSP	0.000	0.089	0.103	0.191	1.000

Table 15. Continued.

<i>Bromus inermis</i>	environ	ANSC	PIPO	PSME	BOGR	AGSP
	ANSC	1.000	0.394	0.005	0.027	0.043
	PIPO	0.394	1.000	0.034	0.189	0.223
	PSME	0.005	0.034	1.000	0.204	0.277
	BOGR	0.037	0.189	0.204	1.000	0.936
	AGSP	0.043	0.223	0.277	0.936	1.000
<i>Bromus tectorum</i>	environ	ANSC	PIPO	PSME	BOGR	AGSP
	ANSC	1.000	0.085	0.044	0.009	0.003
	PIPO	0.085	1.000	0.635	0.505	0.198
	PSME	0.044	0.635	1.000	0.966	0.503
	BOGR	0.009	0.505	0.966	1.000	0.402
	AGSP	0.003	0.198	0.503	0.402	1.000
<i>Dactylis glomerata</i>	environ	ANSC	PIPO	PSME	BOGR	AGSP
	ANSC	1.000	0.002	0.000	0.306	0.000
	PIPO	0.002	1.000	0.316	0.007	0.674
	PSME	0.000	0.316	1.000	0.001	0.516
	BOGR	0.306	0.007	0.001	1.000	0.001
	AGSP	0.000	0.674	0.516	0.001	1.000
<i>Dalea purpurea</i>	environ	ANSC	PIPO	PSME	BOGR	AGSP
	ANSC	1.000	0.003	0.001	0.000	0.002
	PIPO	0.003	1.000	0.575	0.686	0.943
	PSME	0.001	0.575	1.000	0.776	0.611
	BOGR	0.000	0.685	0.776	1.000	0.737
	AGSP	0.002	0.943	0.611	0.737	1.000
<i>Festuca idahoensis</i>	environ	ANSC	PIPO	PSME	BOGR	AGSP
	ANSC	1.000	0.042	0.003	0.711	0.809
	PIPO	0.042	1.000	0.250	0.004	0.051
	PSME	0.003	0.250	1.000	0.000	0.004
	BOGR	0.711	0.004	0.000	1.000	0.474
	AGSP	0.809	0.051	0.004	0.474	1.000
<i>Festuca ovina</i>	environ	ANSC	PIPO	PSME	BOGR	AGSP
	ANSC	1.000	0.000	0.000	0.089	0.009
	PIPO	0.000	1.000	0.000	0.011	0.291
	PSME	0.000	0.000	1.000	0.000	0.000
	BOGR	0.089	0.011	0.000	1.000	0.164
	AGSP	0.009	0.291	0.000	0.164	1.000

Table 15. Continued.

<i>Festuca scabrella</i>	environ	ANSC	PIPO	PSME	BOGR	AGSP
	ANSC	1.000	0.326	1.000	1.000	0.000
	PIPO	0.326	1.000	0.352	0.224	0.000
	PSME	1.000	0.352	1.000	1.000	0.000
	BOGR	1.000	0.224	1.000	1.000	0.000
	AGSP	0.000	0.000	0.000	0.000	1.000
<i>Hordeum jubatum</i>	environ	ANSC	PIPO	PSME	BOGR	AGSP
	ANSC	1.000	0.923	0.364	0.011	0.737
	PIPO	0.923	1.000	0.300	0.004	0.646
	PSME	0.364	0.300	1.000	0.188	0.515
	BOGR	0.011	0.004	0.188	1.000	0.015
	AGSP	0.737	0.646	0.515	0.015	1.000
<i>Koeleria nitida</i>	environ	ANSC	PIPO	PSME	BOGR	AGSP
	ANSC	1.000	0.195	0.902	0.002	0.887
	PIPO	0.195	1.000	0.271	0.079	0.121
	PSME	0.902	0.271	1.000	0.006	0.791
	BOGR	0.002	0.79	0.006	1.000	0.000
	AGSP	0.887	0.121	0.791	0.000	1.000
<i>Kochia scoparia</i>	environ	ANSC	PIPO	PSME	BOGR	AGSP
	ANSC	1.000	0.826	0.855	0.953	0.014
	PIPO	0.826	1.000	0.987	0.737	0.019
	PSME	0.855	0.987	1.000	0.787	0.036
	BOGR	0.953	0.737	0.787	1.000	0.002
	AGSP	0.014	0.019	0.036	0.002	1.000
<i>Lactuca serriola</i>	environ	ANSC	PIPO	PSME	BOGR	AGSP
	ANSC	1.000	0.008	0.000	0.000	0.003
	PIPO	0.008	1.000	0.174	0.179	0.776
	PSME	0.000	0.174	1.000	0.701	0.255
	BOGR	0.000	0.179	0.701	1.000	0.289
	AGSP	0.003	0.776	0.255	0.289	1.000
<i>Melilotus offinalis</i>	environ	ANSC	PIPO	PSME	BOGR	AGSP
	ANSC	1.000	0.008	0.298	0.130	0.010
	PIPO	0.008	1.000	0.155	0.095	0.862
	PSME	0.298	0.155	1.000	0.864	0.194
	BOGR	0.130	0.095	0.864	1.000	0.125
	AGSP	0.010	0.862	0.194	0.125	1.000

Table 15. Continued.

<i>Phalaris arundinacea</i>	environ	ANSC	PIPO	PSME	BOGR	AGSP
	ANSC	1.000	0.681	0.024	0.938	0.517
	PIPO	0.681	1.000	0.050	0.671	0.260
	PSME	0.024	0.050	1.000	0.010	0.003
	BOGR	0.938	0.671	0.010	1.000	0.369
	AGSP	0.517	0.260	0.003	0.369	1.000
<i>Phleum pratense</i>	environ	ANSC	PIPO	PSME	BOGR	AGSP
	ANSC	1.000	0.000	0.048	0.627	0.342
	PIPO	0.000	1.000	0.148	0.000	0.003
	PSME	0.048	0.148	1.000	0.058	0.223
	BOGR	0.627	0.000	0.058	1.000	0.516
	AGSP	0.342	0.003	0.223	0.516	1.000
<i>Poa compressa</i>	environ	ANSC	PIPO	PSME	BOGR	AGSP
	ANSC	1.000	0.029	0.000	0.343	0.013
	PIPO	0.029	1.000	0.027	0.090	0.810
	PSME	0.000	0.027	1.000	0.000	0.040
	BOGR	0.343	0.090	0.000	1.000	0.040
	AGSP	0.013	0.810	0.040	0.040	1.000
<i>Poa pratensis</i>	environ	ANSC	PIPO	PSME	BOGR	AGSP
	ANSC	1.000	0.360	0.014	0.864	0.223
	PIPO	0.360	1.000	0.001	0.189	0.769
	PSME	0.014	0.001	1.000	0.006	0.000
	BOGR	0.864	0.189	0.006	1.000	0.086
	AGSP	0.223	0.769	0.000	0.086	1.000
<i>Sphaeralcea coccinea</i>	environ	ANSC	PIPO	PSME	BOGR	AGSP
	ANSC	1.000	0.651	1.000	0.017	0.404
	PIPO	0.651	1.000	0.668	0.045	0.695
	PSME	1.000	0.668	1.000	0.026	0.431
	BOGR	0.017	0.045	0.026	1.000	0.105
	AGSP	0.404	0.696	0.431	0.105	1.000
<i>Stipa comata</i>	environ	ANSC	PIPO	PSME	BOGR	AGSP
	ANSC	1.000	0.701	0.077	0.219	0.026
	PIPO	0.701	1.000	0.139	0.074	0.006
	PSME	0.077	0.139	1.000	0.001	0.000
	BOGR	0.219	0.074	0.001	1.000	0.154
	AGSP	0.026	0.006	0.000	0.154	1.000

Table 15. Continued.

<i>Stipa viridula</i>	environ	ANSC	PIPO	PSME	BOGR	AGSP
	ANSC	1.000	0.789	0.031	0.569	0.020
	PIPO	0.789	1.000	0.013	0.347	0.006
	PSME	0.061	0.013	1.000	0.043	0.922
	BOGR	0.569	0.347	0.043	1.000	0.022
	AGSP	0.020	0.006	0.922	0.022	1.000
<i>Thlaspi arvense</i>	environ	ANSC	PIPO	PSME	BOGR	AGSP
	ANSC	1.000	0.066	0.929	0.098	0.632
	PIPO	0.066	1.000	0.099	0.613	0.013
	PSME	0.929	0.099	1.000	0.151	0.584
	BOGR	0.098	0.613	0.151	1.000	0.015
	AGSP	0.632	0.013	0.584	0.015	1.000
<i>Trifolium hybridum</i>	environ	ANSC	PIPO	PSME	BOGR	AGSP
	ANSC	1.000	0.000	1.000	1.000	1.000
	PIPO	0.000	1.000	0.000	0.000	0.000
	PSME	1.000	0.000	1.000	1.000	1.000
	BOGR	1.000	0.000	1.000	1.000	1.000
	AGSP	1.000	1.000	1.000	1.000	1.000

Table 16. Kruskal-Wallis Rankings for Species Response to Environment.

Species	Environmental Type				
	ANSC	PSME	PIPO	BOGR	AGSP
<i>Achillea millefolium</i>	158.50	190.54	180.35	180.82	210.56
<i>Agropyron cristatum</i>	187.25	131.08	104.43	227.38	198.44
<i>Agropyron dasystachyum</i>	139.50	209.74	219.24	168.11	211.78
<i>Agropyron smithii</i>	161.55	171.85	151.64	214.68	177.70
<i>Agropyron spicatum</i>	170.50	181.77	179.23	192.74	189.22
<i>Agrostis stolonifera</i>	172.50	175.38	181.27	201.40	174.98
<i>Alyssum alyssoides</i>	181.65	176.26	193.79	184.46	191.07
<i>Artemisia cana</i>	175.65	187.29	185.62	182.23	194.94
<i>Artemisia frigida</i>	151.68	181.52	179.65	190.04	205.64
<i>Artemisia tridentata</i>	172.50	184.16	181.40	190.84	184.44
<i>Avena sativa</i>	220.25	177.00	177.00	183.35	174.98
<i>Bouteloua gracilis</i>	185.54	178.5	178.5	191.63	183.75
<i>Bromus inermis</i>	216.75	200.25	156.79	179.68	178.48
<i>Bromus tectorum</i>	157.63	181.98	189.03	189.59	198.77
<i>Centaurea maculosa</i>	206.98	184.75	179.64	182.36	177.54
<i>Cirsium arvense</i>	190.55	188.10	177.24	184.65	186.19
<i>Dactylis glomerata</i>	161.25	198.39	211.21	171.99	203.09
<i>Dalea purpurea</i>	199.29	184.44	181.50	182.81	184.11
<i>Festuca idahoensis</i>	181.01	195.13	203.53	178.79	182.64
<i>Festuca ovina</i>	152.01	197.45	257.10	170.98	184.89
<i>Festuca scabrella</i>	179.50	185.29	179.50	179.50	205.63
<i>Gaura coccinea</i>	178.50	178.50	183.01	187.63	191.48
<i>Gutierrezia sarothrae</i>	184.27	185.12	173.50	186.56	189.14
<i>Heterotheca villosa</i>	169.00	188.68	179.89	185.19	195.32
<i>Hordeum jubatum</i>	175.48	174.52	185.38	197.55	178.73
<i>Kochia scoparia</i>	180.92	182.71	182.57	180.51	200.37
<i>Koeleri nitida</i>	172.33	186.04	173.76	201.07	170.87
<i>Lactuca serriola</i>	212.45	187.40	173.80	177.18	184.92
<i>Liatris punctata</i>	181.00	183.93	181.00	188.85	183.60
<i>Lupinus argenteus</i>	184.50	184.5	184.5	187.12	184.50
<i>Medicago polymorpha</i>	192.00	183.35	178.83	182.46	190.03
<i>Medicago sativa</i>	160.04	194.32	177.00	184.04	201.65
<i>Melilotus offinalis</i>	157.28	204.35	177.63	180.46	201.51
<i>Opuntia polycantha</i>	182.04	189.52	188.07	184.22	182.89
<i>Phalaris arundinacea</i>	184.03	186.33	197.92	184.40	180.50
<i>Phleum pratense</i>	167.92	221.24	199.29	173.96	181.22
<i>Pinus ponderosa</i>	187.06	185.83	180.00	185.28	185.17
<i>Poa compressa</i>	169.50	190.44	212.77	177.33	192.55
<i>Poa pratensis</i>	185.31	201.99	135.70	182.60	206.93

Table 16. Continued.

<i>Poa sandbergii</i>	176.94	184.48	172.50	190.91	190.54
<i>Ratibida columnifera</i>	180.50	186.34	180.50	184.41	190.93
<i>Rosa woodsii</i>	173.00	184.52	177.32	188.88	191.04
<i>Sphaeralcea coccinea</i>	183.60	176.50	181.00	192.20	184.30
<i>Stipa comata</i>	178.63	173.67	153.50	192.29	206.71
<i>Stipa viridula</i>	195.97	199.24	166.87	189.94	168.11
<i>Symphoricarpos albus</i>	187.58	180.50	184.99	187.02	183.09
<i>Trifolium hybridum</i>	182.50	200.12	182.50	182.50	182.50
<i>Tragopogon dubius</i>	186.46	190.73	179.05	176.91	198.42
<i>Thlaspi arvense</i>	179.55	193.57	180.29	190.46	176.00
<i>Verbascum thapsus</i>	198.60	183.52	193.98	178.60	183.75

Table 17. P-values for Pairwise Comparisons of Species Performance Among Precipitation Levels.

		Precipitation class (cm)							
<i>Agropyron cristatum</i>									
class	40-45	35-40	45-50	30-35	20-25	25-30	50-75	100-150	75-100
40-50	1.000	0.000	0.410	0.000	0.000	0.000	0.706	0.567	0.530
35-40	0.000	1.000	0.015	0.955	0.017	0.055	0.000	0.204	0.019
45-50	0.410	0.015	1.000	0.016	0.001	0.000	0.202	0.953	0.284
30-35	0.000	0.955	0.016	1.000	0.016	0.044	0.000	0.209	0.019
20-25	0.000	0.017	0.001	0.016	1.000	0.094	0.000	0.007	0.001
25-30	0.000	0.055	0.000	0.044	0.094	1.000	0.000	0.055	0.044
50-75	0.706	0.000	0.202	0.000	0.000	0.000	1.000	0.426	0.635
100-150	0.567	0.204	0.953	0.209	0.007	0.055	0.426	1.000	0.356
75-100	0.530	0.019	0.284	0.019	0.001	0.044	0.635	0.356	1.000
<i>Agropyron dasystachyum</i>									
class	40-45	35-40	45-50	30-35	20-25	25-30	50-75	100-150	75-100
40-45	1.000	0.000	0.624	0.000	0.113	0.001	0.011	0.006	0.924
35-40	0.000	1.000	0.001	0.716	0.788	0.207	0.034	0.427	0.042
45-50	0.624	0.001	1.000	0.002	0.200	0.014	0.077	0.017	0.716
30-35	0.000	0.716	0.002	1.000	0.867	0.340	0.064	0.362	0.052
20-25	0.113	0.788	0.200	0.867	1.000	0.901	0.655	0.454	0.200
25-30	0.001	0.207	0.014	0.340	0.901	1.000	0.361	0.221	0.102
50-75	0.011	0.034	0.077	0.064	0.655	0.361	1.000	0.117	0.194
100-150	0.006	0.427	0.017	0.362	0.454	0.221	0.117	0.000	0.036
75-100	0.924	0.042	0.716	0.052	0.200	0.102	0.194	0.036	1.000
<i>Agropyron smithii</i>									
class	40-45	35-40	45-50	30-35	20-25	25-30	50-75	100-150	75-100
40-45	1.000	0.160	0.043	0.001	0.597	0.000	0.321	0.016	0.316
35-40	0.160	1.000	0.233	0.003	0.239	0.001	0.661	0.059	0.667
45-50	0.043	0.233	1.000	0.580	0.101	0.331	0.160	0.258	0.882
30-35	0.001	0.003	0.580	1.000	0.042	0.467	0.003	0.347	0.666
20-25	0.597	0.239	0.101	0.042	1.000	0.025	0.311	0.029	0.245
25-30	0.000	0.001	0.331	0.467	0.025	1.000	0.001	0.493	0.517
50-75	0.321	0.661	0.160	0.003	0.311	0.001	1.000	0.044	0.569
100-150	0.016	0.059	0.258	0.347	0.029	0.493	0.044	1.000	0.332
75-100	0.316	0.667	0.882	0.666	0.245	0.517	0.569	0.332	1.000

Table 17. Continued.

		Precipitation class (cm)							
<i>Agropyron spicatum</i>									
class	40-45	35-40	45-50	30-35	20-25	25-30	50-75	100-150	75-100
40-45	1.000	0.884	0.004	0.495	0.707	0.580	0.424	0.680	0.000
35-40	0.884	1.000	0.000	0.409	0.240	0.547	0.191	0.712	0.000
45-50	0.004	0.000	1.000	0.000	0.048	0.000	0.010	0.031	0.009
30-35	0.495	0.409	0.000	1.000	0.922	0.882	0.043	0.913	0.000
20-25	0.707	0.240	0.048	0.922	1.000	0.887	0.444	1.000	0.000
25-30	0.580	0.547	0.000	0.882	0.887	1.000	0.079	0.874	0.000
50-75	0.424	0.191	0.010	0.043	0.444	0.079	1.000	0.397	0.000
100-150	0.680	0.712	0.031	0.973	1.000	0.874	0.397	1.000	0.000
75-100	0.000	0.000	0.009	0.000	0.000	0.000	0.000	0.000	1.000
<i>Bouteloua gracilis</i>									
class	40-45	35-40	45-50	30-35	20-25	25-30	50-75	100-150	75-100
40-45	1.000	0.429	0.354	0.636	0.000	0.043	1.000	1.000	1.000
35-40	0.429	1.000	0.681	0.617	0.000	0.066	0.305	0.698	0.727
45-50	0.354	0.681	1.000	0.482	0.000	0.462	0.293	0.575	0.608
30-35	0.636	0.617	0.482	1.000	0.000	0.019	0.534	0.817	0.835
20-25	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000
25-30	0.043	0.066	0.462	0.019	0.000	1.000	0.010	0.308	0.358
50-75	1.000	0.305	0.293	0.534	0.000	0.010	1.000	1.000	1.000
100-150	1.000	0.698	0.575	0.817	0.000	0.308	1.000	1.000	1.000
75-100	1.000	0.727	0.608	0.835	0.000	0.358	1.000	1.000	1.000
<i>Bromus inermis</i>									
class	40-45	35-40	45-50	30-35	20-25	25-30	50-75	100-150	75-100
40-45	1.000	0.214	0.501	0.850	0.046	0.170	0.163	0.488	0.046
35-40	0.214	1.000	0.055	0.026	0.120	0.803	0.735	0.177	0.120
45-50	0.501	0.055	1.000	0.516	0.202	0.043	0.043	0.788	0.020
30-35	0.850	0.026	0.516	1.000	0.029	0.202	0.026	0.516	0.029
20-25	0.046	0.120	0.020	0.029	1.000	0.142	0.156	0.035	0.000
25-30	0.170	0.803	0.043	0.020	0.142	1.000	0.917	0.154	0.142
50-75	0.163	0.735	0.043	0.026	0.156	0.917	1.000	0.147	0.156
100-150	0.488	0.177	0.788	0.516	0.035	0.154	0.147	1.000	0.035
75-100	0.046	0.120	0.020	0.029	0.000	0.142	0.156	0.035	1.000

Table 17. Continued.

		Precipitation class (cm)							
<i>Centaurea maculosa</i>									
class	40-45	35-40	45-50	30-35	20-25	25-30	50-75	100-150	75-100
40-45	1.000	0.807	0.664	0.735	0.006	0.469	0.649	0.034	0.087
35-40	0.807	1.000	0.463	0.366	0.006	0.475	0.340	0.032	0.090
45-50	0.664	0.463	1.000	0.818	0.004	0.252	0.932	0.021	0.057
30-35	0.735	0.366	0.818	1.000	0.002	0.118	0.836	0.015	0.051
20-25	0.006	0.006	0.004	0.002	1.000	0.011	0.002	0.517	0.434
25-30	0.469	0.475	0.252	0.118	0.011	1.000	0.128	0.060	0.144
50-75	0.649	0.340	0.932	0.836	0.002	0.128	1.000	0.014	0.047
100-150	0.034	0.032	0.021	0.015	0.517	0.060	0.014	1.000	0.860
75-100	0.087	0.090	0.057	0.051	0.434	0.144	0.047	0.860	1.000
<i>Dactylis glomerata</i>									
class	40-45	35-40	45-50	30-35	20-25	25-30	50-75	100-150	75-100
40-45	1.000	0.000	0.081	0.000	0.007	0.000	0.023	0.003	0.151
35-40	0.000	1.000	0.013	0.690	0.567	0.430	0.001	0.526	0.453
45-50	0.081	0.013	1.000	0.006	0.096	0.004	0.928	0.068	0.659
30-35	0.000	0.690	0.006	1.000	0.645	0.661	0.000	0.608	0.387
20-25	0.007	0.567	0.096	0.645	1.000	0.747	0.085	1.000	0.340
25-30	0.000	0.430	0.004	0.661	0.747	1.000	0.000	0.720	0.322
50-75	0.023	0.001	0.928	0.000	0.085	0.000	1.000	0.057	0.673
100-150	0.003	0.526	0.068	0.608	1.000	0.720	0.057	1.000	0.314
75-100	0.151	0.453	0.659	0.387	0.340	0.322	0.673	0.314	1.000
<i>Festuca idahoensis</i>									
class	40-45	35-40	45-50	30-35	20-25	25-30	50-75	100-150	75-100
40-45	1.000	0.232	0.048	0.103	0.928	0.083	0.102	0.746	0.233
35-40	0.232	1.000	0.001	0.514	0.533	0.396	0.000	0.809	0.075
45-50	0.048	0.001	1.000	0.000	0.315	0.000	0.447	0.130	0.941
30-35	0.103	0.514	0.000	1.000	0.418	0.793	0.000	0.654	0.049
20-25	0.928	0.533	0.315	0.418	1.000	0.377	0.501	0.757	0.401
25-30	0.083	0.396	0.000	0.793	0.377	1.000	0.000	0.595	0.042
50-75	0.102	0.000	0.447	0.000	0.501	0.000	1.000	0.234	0.637
100-150	0.746	0.809	0.130	0.654	0.757	0.595	0.234	1.000	0.232
75-100	0.233	0.075	0.941	0.049	0.401	0.042	0.637	0.232	1.000

Table 17. Continued.

		Precipitation class (cm)							
<i>Festuca ovina</i>									
class	40-45	35-40	45-50	30-35	20-25	25-30	50-75	100-150	75-100
40-45	1.000	0.232	0.048	0.103	0.928	0.083	0.102	0.746	0.233
35-40	0.232	1.000	0.001	0.514	0.533	0.396	0.000	0.809	0.075
45-50	0.048	0.001	1.000	0.000	0.315	0.000	0.447	0.130	0.941
30-35	0.103	0.514	0.000	1.000	0.118	0.793	0.000	0.654	0.049
20-25	0.928	0.533	0.315	0.418	1.000	0.377	0.501	0.757	0.401
25-30	0.083	0.396	0.000	0.793	0.377	1.000	0.000	0.595	0.042
50-75	0.102	0.000	0.447	0.000	0.501	0.000	1.000	0.234	0.637
100-150	0.746	0.809	0.130	0.654	0.757	0.595	0.234	1.000	0.232
75-100	0.233	0.075	0.941	0.049	0.401	0.042	0.637	0.232	1.000
<i>Koeleria nitida</i>									
class	40-45	35-40	45-50	30-35	20-25	25-30	50-75	100-150	75-100
40-45	1.000	0.396	0.526	0.270	0.804	0.039	0.761	0.019	0.804
35-40	0.396	1.000	0.994	0.704	0.524	0.707	0.127	0.036	0.524
45-50	0.526	0.994	1.000	0.832	0.552	0.266	0.318	0.056	0.552
30-35	0.270	0.704	0.832	1.000	0.455	0.132	0.061	0.047	0.455
20-25	0.804	0.524	0.552	0.455	1.000	0.231	0.908	0.055	1.000
25-30	0.039	0.070	0.266	0.132	0.231	1.000	0.003	0.145	0.231
50-75	0.761	0.127	0.318	0.061	0.908	0.003	1.000	0.009	0.908
100-150	0.019	0.036	0.056	0.047	0.050	0.145	0.009	1.000	0.055
75-100	0.804	0.524	0.552	0.455	1.000	0.231	0.908	0.055	1.000
<i>Medicago polycantha</i>									
class	40-45	35-40	45-50	30-35	20-25	25-30	50-75	100-150	75-100
40-45	1.000	0.265	0.076	0.146	0.000	0.075	0.058	0.480	0.308
35-40	0.265	1.000	0.249	0.613	0.000	0.304	0.225	0.194	0.561
45-50	0.076	0.249	1.000	0.381	0.000	0.615	0.753	0.077	1.000
30-35	0.146	0.613	0.381	1.000	0.000	0.559	0.418	0.144	0.660
20-25	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000
25-30	0.075	0.304	0.615	0.559	0.000	1.000	0.798	0.101	0.796
50-75	0.058	0.225	0.753	0.418	0.000	0.798	1.000	0.085	0.868
100-150	0.480	0.194	0.077	0.144	0.000	0.101	0.085	1.000	0.183
75-100	0.308	0.561	1.000	0.660	0.000	0.796	0.868	0.183	1.000

Table 17. Continued.

Precipitation class (cm)									
<i>Melilotus officinalis</i>									
class	40-45	35-40	45-50	30-35	20-25	25-30	50-75	100-150	75-100
40-45	1.000	0.504	0.045	0.591	0.003	0.671	0.426	0.034	0.136
35-40	0.504	1.000	0.069	0.832	0.004	0.746	0.804	0.053	0.201
45-50	0.045	0.069	1.000	0.051	0.070	0.046	0.119	0.406	0.739
30-35	0.591	0.832	0.051	1.000	0.003	0.893	0.666	0.045	0.180
20-25	0.003	0.004	0.070	0.003	1.000	0.003	0.006	0.386	0.248
25-30	0.671	0.746	0.049	0.893	0.003	1.000	0.606	0.043	0.171
50-75	0.426	0.804	0.119	0.666	0.006	0.606	1.000	0.071	0.240
100-150	0.034	0.053	0.406	0.045	0.386	0.043	0.071	1.000	0.725
75-100	0.136	0.201	0.739	0.180	0.248	0.171	0.240	0.725	1.000
<i>Phalaris arundinaceae</i>									
class	40-45	35-40	45-50	30-35	20-25	25-30	50-75	100-150	75-100
40-45	1.000	0.548	1.000	0.412	1.000	1.000	0.049	1.000	0.003
35-40	0.548	1.000	0.591	0.741	0.790	0.395	0.048	0.768	0.005
45-50	1.000	0.591	1.000	0.463	1.000	1.000	0.073	1.000	0.004
30-35	0.412	0.741	0.463	1.000	0.719	0.241	0.082	0.689	0.006
20-25	1.000	0.790	1.000	0.719	1.000	1.000	0.354	1.000	0.025
25-30	1.000	0.395	1.000	0.241	1.000	1.000	0.009	1.000	0.002
50-75	0.049	0.048	0.073	0.082	0.354	0.009	1.000	0.305	0.032
100-150	1.000	0.768	1.000	0.689	1.000	1.000	0.305	1.000	0.018
75-100	0.003	0.005	0.004	0.006	0.025	0.002	0.032	0.018	1.000
<i>Phleum pratense</i>									
class	40-45	35-40	45-50	30-35	20-25	25-30	50-75	100-150	75-100
40-45	1.000	0.161	0.198	0.003	0.070	0.003	0.799	0.047	0.857
35-40	0.161	1.000	0.764	0.018	0.197	0.016	0.030	0.151	0.418
45-50	0.198	0.764	1.000	0.283	0.289	0.233	0.091	0.246	0.374
30-35	0.003	0.018	0.283	1.000	0.536	0.795	0.000	0.491	0.138
20-25	0.070	0.197	0.298	0.536	1.000	0.593	0.046	1.000	0.130
25-30	0.003	0.016	0.233	0.795	0.593	1.000	0.000	0.553	0.121
50-75	0.799	0.030	0.091	0.000	0.046	0.000	1.000	0.027	0.946
100-150	0.047	0.151	0.246	0.491	1.000	0.553	0.027	1.000	0.110
75-100	0.857	0.418	0.374	0.138	0.130	0.121	0.946	0.110	1.000

Table 17. Continued.

Precipitation class (cm)									
<i>Sphaeralcea coccinea</i>									
class	40-45	35-40	45-50	30-35	20-25	25-30	50-75	100-150	75-100
40-45	1.000	0.850	0.868	0.960	0.000	0.227	0.414	0.685	0.712
35-40	0.850	1.000	0.712	0.828	0.000	0.043	0.369	0.734	0.760
45-50	0.868	0.712	1.000	0.805	0.000	0.372	0.352	0.620	0.650
30-35	0.960	0.828	0.805	1.000	0.000	0.061	0.272	0.682	0.713
20-25	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.001
25-30	0.227	0.043	0.372	0.061	0.000	1.000	0.009	0.299	0.350
50-75	0.414	0.369	0.352	0.272	0.000	0.009	1.000	1.000	1.000
100-150	0.685	0.734	0.620	0.682	0.000	0.229	1.000	1.000	1.000
75-100	0.712	0.760	0.650	0.713	0.001	0.350	1.000	1.000	1.000
<i>Stipa comata</i>									
class	40-45	35-40	45-50	30-35	20-25	25-30	50-75	100-150	75-100
40-45	1.000	0.018	0.576	0.148	0.016	0.006	0.668	0.003	0.846
35-40	0.018	1.000	0.147	0.142	0.133	0.521	0.000	0.044	0.210
45-50	0.576	0.147	1.000	0.540	0.040	0.071	0.306	0.011	0.617
30-35	0.148	0.142	0.540	1.000	0.055	0.044	0.012	0.013	0.401
20-25	0.016	0.133	0.404	0.055	1.000	0.195	0.007	0.816	0.047
25-30	0.006	0.521	0.071	0.044	0.195	1.000	0.000	0.076	0.149
50-75	0.668	0.000	0.306	0.012	0.007	0.000	1.000	0.001	1.000
100-150	0.003	0.044	0.011	0.013	0.816	0.076	0.001	1.000	0.020
75-100	0.846	0.210	0.617	0.401	0.047	0.149	1.000	0.020	1.000
<i>Symphoricarpos albus</i>									
class	40-45	35-40	45-50	30-35	20-25	25-30	50-75	100-150	75-100
40-45	1.000	0.750	0.018	0.385	0.003	0.417	1.000	1.000	1.000
35-40	0.750	1.000	0.010	0.398	0.002	0.461	0.679	0.876	0.888
45-50	0.018	0.010	1.000	0.035	0.104	0.040	0.007	0.146	0.184
30-35	0.385	0.398	0.035	1.000	0.005	0.976	0.256	0.672	0.703
20-25	0.003	0.002	0.104	0.005	1.000	0.005	0.002	0.015	0.021
25-30	0.417	0.461	0.040	0.976	0.005	1.000	0.303	0.682	0.713
50-75	1.000	0.679	0.007	0.256	0.002	0.303	1.000	1.000	1.000
100-150	1.000	0.876	0.146	0.672	0.015	0.682	1.000	1.000	1.000
75-100	1.000	0.888	0.184	0.703	0.021	0.713	1.000	1.000	1.000

Table 17. Continued.

		Precipitation class (cm)							
<i>Trifolium hybridum</i>									
class	40-45	35-40	45-50	30-35	20-25	25-30	50-75	100-150	75-100
40-45	1.000	1.000	0.160	1.000	1.000	1.000	0.010	0.001	1.000
35-40	1.000	1.000	0.090	1.000	1.000	1.000	0.000	0.000	1.000
45-50	0.160	0.090	1.000	0.087	0.436	0.099	0.461	0.017	0.436
30-35	1.000	1.000	0.087	1.000	1.000	1.000	0.000	0.000	1.000
20-25	1.000	1.000	0.436	1.000	1.000	1.000	0.228	0.016	1.000
25-30	1.000	1.000	0.099	1.000	1.000	1.000	0.001	0.000	1.000
50-75	0.010	0.000	0.461	0.000	0.228	0.001	1.000	0.033	0.228
100-150	0.001	0.000	0.017	0.000	0.016	0.000	0.033	1.000	0.016
75-100	1.000	1.000	0.436	1.000	1.000	1.000	0.228	1.000	1.000
<i>Verbascum thapsus</i>									
class	40-45	35-40	45-50	30-35	20-25	25-30	50-75	100-150	75-100
40-45	1.000	0.733	0.556	0.293	0.001	0.251	0.251	0.156	0.525
35-40	0.733	1.000	0.685	0.275	0.000	0.245	0.245	0.093	0.412
45-50	0.556	0.685	1.000	0.836	0.000	0.721	0.721	0.083	0.344
30-35	0.293	0.275	0.836	1.000	0.000	0.794	0.794	0.043	0.258
20-25	0.001	0.000	0.000	0.000	1.000	0.000	0.000	0.089	0.035
25-30	0.287	0.283	0.801	0.930	0.000	0.867	0.867	0.042	0.251
50-75	0.251	0.245	0.721	0.794	0.000	1.000	1.000	0.038	0.231
100-150	0.156	0.093	0.083	0.043	0.089	0.038	0.038	1.000	0.598
75-100	0.525	0.412	0.344	0.258	0.035	0.231	0.231	0.598	1.000

Table 18. Kruskal-Wallis Rankings for Species Performance Among Precipitation Levels.

	Precipitation level (cm)								
	40-45	35-40	45-50	30-35	20-25	25-30	50-75	100-150	75-100
Acmi ^A	195.2	179.0	189.1	186.0	204.4	185.1	186.7	195.2	158.5
Agcr	122.5	201.7	145.5	201.0	314.3	229.8	114.1	148.2	91.5
Agda	245.9	168.1	234.2	172.2	178.9	183.9	197.1	139.5	249.9
Agsm	136.6	165.8	193.5	206.2	110.5	216.7	158.8	245.8	186.0
Agsp	184.8	183.6	216.8	179.3	177.5	180.1	191.8	177.5	268.8
Agst	179.9	174.4	200.1	196.5	172.5	186.1	183.2	172.5	172.5
Alal	174.9	181.9	167.5	183.9	167.5	191.5	192.3	167.5	259.5
Arca	206.4	187.9	209.9	185.7	155.0	176.1	179.1	155.0	155.0
Arfr	231.9	182.6	195.1	183.3	135.0	179.1	178.4	177.8	190.1
Artr	188.1	182.7	172.5	190.8	172.5	183.1	186.3	172.5	172.5
Avsa	177.0	197.5	177.0	186.1	177.0	182.2	177.0	177.0	177.0
Bogr	178.5	184.6	188.1	182.1	271.8	194.6	178.5	178.5	178.5
Brin	203.3	174.5	224.2	207.6	92.88	170.4	168.4	238.1	92.9
Brte	160.9	187.3	184.3	183.6	146.5	200.3	181.7	146.5	236.3
Cema	182.0	185.9	172.7	176.8	284.8	193.8	174.3	254.5	246.3
Ciar	187.6	187.3	182.6	182.0	173.0	188.9	187.8	173.0	173.0
Dagl	248.7	175.9	215.3	172.3	157.5	168.0	213.8	157.5	200.0
Dapu	188.9	193.7	171.5	183.3	181.5	181.5	181.5	181.5	181.5
Feid	184.8	183.6	216.8	179.3	177.5	180.1	191.8	177.5	268.8
Feov	196.1	176.9	239.1	170.2	199.6	167.2	224.6	184.8	242.0
Fesc	196.1	176.9	239.1	170.2	199.6	167.2	224.6	184.8	242.0
Gaco	186.1	186.5	189.0	185.8	178.5	186.5	178.5	178.5	178.5
Gusa	173.5	183.7	173.5	190.0	173.5	184.1	187.6	210.1	173.5
Hevi	191.1	186.2	203.8	184.1	207.5	180.5	176.4	198.4	207.5
Huju	175.8	184.7	178.1	181.2	168.5	198.7	189.4	168.5	168.5
Koni	173.1	184.1	184.2	187.2	165.5	200.6	168.9	239.2	165.5
Kosc	181.8	186.3	174.0	181.4	174.0	189.9	191.3	174.0	174.0
Lase	184.6	188.1	169.5	194.8	214.6	174.9	173.0	205.6	214.6
Lipu	181.0	181.0	181.0	188.3	181.0	189.0	184.6	181.0	181.0
Luar	184.5	184.5	184.5	188.2	184.5	184.5	184.5	184.5	184.5
Mepo	196.8	186.6	174.5	183.6	313.6	179.9	178.0	210.9	174.5
Meof	167.5	181.6	225.6	178.8	319.5	176.8	185.7	265.0	242.9
Mesa	192.7	173.3	219.8	185.3	228.0	177.4	198.6	199.3	131.5
Oppo	182.3	189.2	185.2	182.3	175.0	183.1	189.1	175.0	175.0
Phar	180.5	184.5	180.5	186.0	180.5	180.5	194.8	180.5	227.9
Phpr	217.6	193.6	187.8	167.5	143.5	164.4	222.4	143.5	225.0
Pipo	180.0	186.1	190.2	187.3	225.9	182.7	180.0	180.0	180.0
Poco	206.4	183.6	210.0	178.5	169.5	180.3	194.5	169.5	169.5

Table 18. Continued.

	Precipitation level (cm)								
	40-45	35-40	45-50	30-35	20-25	25-30	50-75	100-150	75-100
Popr	231.9	187.4	194.1	188.0	97.5	174.3	171.8	233.6	147.5
Posa	180.0	184.6	172.5	183.4	172.5	199.3	183.4	172.5	172.5
Raco	187.9	184.5	180.5	186.0	180.5	185.8	184.0	180.5	180.5
Rowo	194.8	175.0	194.0	185.6	221.0	194.7	180.0	173.0	173.0
SpcO	184.2	182.6	186.2	183.8	268.8	195.2	176.5	176.5	176.5
Stco	160.6	197.1	172.2	182.6	249.4	204.0	153.5	260.0	153.5
Stvi	179.5	195.8	167.5	184.8	158.0	184.0	183.1	200.3	158.0
Syal	180.5	182.5	201.2	186.0	226.5	185.8	180.5	180.5	180.5
Thar	190.8	178.0	205.1	190.7	176.0	181.3	18.6	176.0	176.0
Trdu	173.4	192.5	215.6	180.8	190.0	178.7	182.9	144.0	236.0
Trhy	182.5	182.5	192.2	182.5	182.5	182.5	196.7	219.5	182.5
Veth	193.5	189.0	182.8	179.7	301.6	178.9	177.1	234.4	213.6

**APPENDIX F. SAMPLE MEANS FOR SEVEN ENVIRONMENTAL VARIABLES
OCCUPIED BY 50 SPECIES**

Table 19. Sample Means of Seven Environmental Variables for 50 Species. Significant ($p < 0.05$) deviations from overall means are marked with a + or - indicating into which tail the mean of the species falls when compared to the distribution of 1000 randomly generated sample means. Appendix A contains single species summaries for graphs clarifying these distributions.

Species ¹	Origin ²	Temp ³	Environmental variables			OC ⁷	pH ⁸	EC ⁹
			WHC ⁴	Clay ⁵	Sand ⁶			
Acmi	N	18.2	8.0	22.0	48.9	2.7	7.4	0.29
Agcr	E	+19.6	+9.3	+26.2	-42.0	2.5	7.6	+0.32
Agda	N	-17.7	-6.5	-18.2	+54.1	2.4	7.4	-0.21
Agsm	N	+19.2	9.2	+26.6	-42.4	2.6	7.6	+0.33
Agsp	N	18.8	8.2	25.0	43.0	2.3	7.3	0.30
Agst	E	19.4	8.7	24.1	46.4	2.8	7.7	+0.36
Alal	E	19.1	8.9	24.1	44.7	2.5	-7.2	0.33
Arca	N	19.1	9.0	+28.4	-39.6	2.7	7.6	+0.40
Arfr	N	+19.8	+9.6	+27.2	-40.0	2.3	+7.7	+0.33
Artr	N	18.3	9.4	26.7	-36.7	2.2	7.7	0.27
Avsa	E	+19.8	8.1	23.1	46.0	3.1	7.9	0.31
Bogr	N	+20.0	8.4	22.6	48.9	2.2	7.6	0.30
Brin	E	18.8	8.6	24.2	45.3	2.6	7.6	0.27
Brte	E	19.0	-7.5	22.8	47.1	2.5	7.6	0.28
Cema	E	-16.9	-5.1	-13.2	+58.7	2.4	-7.1	-0.15
Ciar	E	19.1	9.4	26.2	42.7	2.7	7.8	0.33
Dagl	E	-17.7	-5.6	-16.3	+56.5	3.0	7.6	0.19
Dapu	N	20.1	11.8	30.5	-29.8	2.5	+8.2	0.26
Feid	N	-17.3	-5.6	-15.3	+57.8	2.5	7.1	-0.13
Feov	N	17.5	-6.7	-19.7	+53.2	-2.1	7.3	-0.19
Fesc	N	17.5	7.6	21.4	48.4	2.9	7.7	0.19
Gaco	N	19.7	10.8	26.9	41.2	2.2	7.6	0.24
Gusa	N	19.5	10.1	28.1	-35.6	-2.0	7.7	0.30
Hevi	N	+19.6	9.7	25.6	43.1	2.8	7.5	+0.35
Hoju	N	+19.4	8.9	26.9	43.7	2.4	7.8	+0.39
Koni	N	19.2	9.4	27.3	41.1	2.4	7.4	+0.36
Kosc	E	19.4	8.7	22.0	46.6	2.0	7.7	0.24
Lase	E	19.0	8.4	24.0	47.1	2.5	7.7	0.28
Lipu	N	19.5	9.2	22.6	47.1	2.8	8.0	0.19
Luar	N	-17.1	8.0	26.5	39.0	3.1	-6.9	0.22
Mepo	E	-16.1	-5.9	-16.1	+53.8	2.1	7.3	-0.13
Mesa	E	+19.8	+9.8	+27.5	-40.5	2.9	7.7	+0.34
Meof	E	18.8	8.6	24.1	44.9	-2.4	7.6	0.24
Oppo	N	19.5	10.5	+30.6	-34.4	-1.8	7.9	+0.45
Phar	E	-17.3	-5.5	-15.4	+59.2	2.5	7.7	0.20

Table 19. Continued.

	Origin ¹	Temp ²	Environmental variables			OC ⁶	pH ⁷	EC ⁸
			WHC ⁵	Clay ⁴	Sand ³			
Phpr	E	-17.7	-6.9	21.2	+51.9	2.7	7.7	-0.22
Pipo	N	-16.5	5.7	-12.7	54.4	2.0	7.3	-0.15
Poco	E	-17.5	-5.7	-15.8	+58.3	2.4	7.5	-0.15
Popr	E	18.7	8.4	24.9	44.6	2.9	7.5	0.28
Posa	N	18.4	7.9	23.5	47.2	2.4	7.7	+0.37
Raco	N	19.9	11.6	24.1	40.2	3.6	7.4	0.22
Rowo	N	18.8	9.0	23.8	47.4	2.9	7.2	0.33
SpcO	N	19.4	9.1	22.6	45.1	2.7	7.6	0.34
Stco	N	19.1	9.4	25.3	44.7	2.7	7.4	0.32
Stvi	N	19.1	8.5	23.7	50.0	2.7	7.7	0.28
Syal	N	17.8	8.0	19.6	47.0	2.3	7.9	0.17
Thar	E	18.3	+11.5	26.0	37.5	2.5	7.6	0.26
Trdu	E	19.2	9.1	25.8	42.3	2.6	7.5	0.30
Trhy	E	-14.4	8.7	20.2	38.3	2.7	-6.8	-0.14
Veth	E	-17.1	-5.2	14.5	+58.5	2.6	7.3	-0.17

¹ Refer to Appendix B for species names and acronyms, ² Origin = Exotic or Native species as determined by Cronquist (1973) or McGregor et al. (1986), ³ Temp= mean annual July temperature (°C), ⁴ WHC=water-holding capacity (%), ⁵ Clay(%), ⁶ Sand (%), ⁷ OC = Organic Carbon (%), ⁸ pH, ⁹ EC=electrical conductivity (mmhos/cm).

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