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Title: HERITABILITY ESTIMATES FOR SEED AND PLANT CHARACTERISTICS IN WHITE CLOVER (TRIFOLIUM REPENS L.)

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Genetic differences, extent of hybrid vigor, nature of gene action, heritability estimates, and associations among characteristics, and between progenies and their respective mid-parents were determined for seed and plant characteristics in white clover (*Trifolium repens* L.).

Ten seed and seedling vigor characteristics, including seed weight, ATP content in seed, seed respiration, and seedling vigor index were studied for a diallel cross consisting of 28 single crosses, five test-crosses, four checks, and eight open-pollinated seed and seedlings.

Twenty-three plant characteristics on stolon, petiole, leaf, and forage were examined on the eight clones diallel cross, five test-crosses, three checks, the eight parental clones of single crosses, and six parent clones of the test-crosses. These 14 parent clones

for this study were assembled on the basis of diverse morphology and origin.

Most seed and seedling vigor characteristics, except RQ values, and most plant characteristics, except internode length, LAR and diurnal ratio in SLW, expressed significant differences among and within most groups of progenies and parental clones.

All seed and seedling vigor characteristics, except RQ values, responded primarily to the nonadditive type of gene action. This suggests that the plant breeder should design his breeding program to develop varieties where hybrid vigor can be used to advantage. Among the criteria used in this study to measure seed and seedling vigor, ATP content per seed was closely associated with seedling vigor index and with certain plant characteristics, including forage yield per plant. The associations of seed weight with other seed and seedling vigor characteristics were negative or poor.

Most plant characteristics showed apparent hybrid vigor when progenies were compared with their respective mid-parents. With few exceptions, most plant characteristics, stolon, petiole, leaf and forage yield per plant, responded primarily to the nonadditive gene system. This indicated that the plant breeder may use the hybrid approach to white clover variety development. The exceptions were leaf ratio and SLW which responded primarily to additive gene action, and area and dry weight per leaf appeared to respond equally to additive and nonadditive gene action. Genetic differences were more readily identified for stolon number and length when measurements were taken after 70 days of growth.

Yield components, such as number, length, and diameter of stolon, petiole length, number of leaves per plant, and dry weight per leaf were closely related to each other. The leaf components of yield, dry weight per leaf and number of leaves per plant, had the highest direct and indirect effects on forage yields per plant among the yield components.

This study showed nonadditive gene action primarily responsible for most seed and plant characteristics. Considering the ease of vegetative propagation in this species along with the self-incompatibility mechanisms, it is suggested that parent geneotypes may be developed by some recurrent selection procedure, then crossed on a two clone synthetic basis to form experimental lines for testing purposes.

Heritability Estimates for Seed and Plant Characteristics in White Clover (*Trifolium repens* L.)

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INTRODUCTION

White clover (*Trifolium repens* L.) is one of the most widely distributed forage legumes in the world. It is considered to be high in nutritional value and is very palatable to livestock. White clover is grown in all temperate regions of the world and as far north as 71°N.

Good seedling vigor is required in all varieties used for forage and seed production so a uniform stand can rapidly establish and compete with weeds and associated plants. Various methods of testing for seedling vigor have been used on different species. Little work, however, has been done in white clover. The plant breeder is in need of an efficient test for seed and seedling vigor, and forage yield, to help him select parent material for variety development in white clover and other legumes. Information about plant characteristics, including forage yield in terms of the agronomic, physiological, and genetic aspects, is needed by the forage breeder.

Selection for improvement in one characteristic may alter the expression of other important characteristics. The breeder needs information about gene action and the degree of relationship among seed and plant characteristics.

The objectives of this study were:

1. To determine differences among and within single crosses of a diallel cross, test-crosses, checks, and open-pollinated seed and seedlings for seed weight, adenosine triphosphate (ATP) content in seed, seed respiration, and seedling vigor index.
2. To determine differences among and within groups of a diallel cross, test-crosses, checks, parents of single crosses, and parents of test-crosses, for the following agronomic and physiological characteristics of the plant: number, length, diameter, and internode length of stolons; length and diameter of petioles; width, length and ratio of the middle leaflet; area and dry weight per leaf and specific leaf weight (SLW); SLW diurnal ratio; number of trifoliate leaves, total leaf area, leaf area ratio (LAR), and forage yield per plant.
3. To determine the extent of hybrid vigor on the above mentioned variables.
4. To determine the nature of gene action and estimate heritability for the above mentioned variables.
5. To determine the relationships between single crosses and their mid-open-pollinated seed and seedlings for

seed characteristics and between progenies and their mid-parents for plant characteristics.

6. To determine the relationships among seed and seedling vigor characteristics, among plant and forage yield characteristics, and between important seed and plant characteristics.

LITERATURE REVIEW

According to Vavilov (1951), the probable center of origin of white clover (*Trifolium repens* L.) is the Mediterranean region.

The variation that exists in natural populations is great and the highly polymorphic and heterogeneous nature of this species in plant morphology and chemistry was recognized by Hawkins (1960).

Seed and Seedling Vigor Characteristics

Little work has been done to examine seed and seedling vigor in white clover. Seed and seedling vigor are required if a variety is to establish rapidly, develop a uniform stand, and compete well with associated species.

Many investigations have been conducted with other crops to evaluate various methods of testing relative seed and seedling vigor characteristics. One of the first characteristics studied was seed size.

Associations of seed size with the growth and vigor of seedlings in subterranean clover (*Trifolium subterraneum* L.) were reviewed by Black (1956). The size of a seed may be the result of either genetic or environmental factors or the combination of both.

Draper and Wilsie (1965) were able to increase seed size of 'Viking' and 'Empire' birdsfoot trefoil (*Lotus corniculatous* L.) in three cycles of recurrent selection for large seed by an average of 20 and 6.25 percentage per cycle.

Henson and Tayman (1961) reported seed size and seedling vigor of birdsfoot trefoil were positively correlated.

Twamley (1969) suggested that seedling vigor could be improved in birdsfoot trefoil by discarding 80% of the experimental material, based on seed size. He did report, however, some large seeded lines with poor seedling vigor and small seeded lines with high seedling vigor.

The most common method of measuring seed and seedling vigor has been weight of the seedling after a given period of growth, rate of root and shoot elongation, leaf expansion rates, and relative growth rate.

Lawrence (1963) evaluated clonal lines of Russian wild ryegrass (Elymus junceus Fitsch.) for seedling vigor by using the speed of germination. This was expressed by the ratio of number of seed germinated to the number of days required for germination.

Twanley (1969) also used a visual speed of germination rating in birdsfoot trefoil to study seedling vigor.

Beveridge and Wilsie (1969) used emergence rate in alfalfa (Medicago sativa L.) to study seedling vigor. Emergence rate was slower from deeper plantings in the greenhouse, but this was not always so in field.

Woodstock and Feeley (1965) have demonstrated that tissue respiration is correlated with seedling vigor in corn (*Zea mays* L.).

Woodstock and Grabe (1967) reported that oxygen uptake was significantly correlated with shoot growth of corn at times of maximum respiration.

Heterosis of barley (*Hordeum vulgare* L.) hybrids was described by McDaniel (1968) in terms of seed weight, genotype and mitochondrial respiration rate.

Kittock and Law (1968) concluded that respiration mainly measures the nongenetic factors of seedling vigor. On the other hand, tetrazoilium chloride reduction was significantly correlated with seedling vigor which was measured by rate of emergence and shoot dry weight in wheat (*Triticum aestivum* L.).

Moutray (1971) investigated seed and seedling vigor characteristics in single crosses, first generation selfed progeny (S1), topcross and open-pollinated seed and seedlings in tall fescue (*Festuca Arundinacea* Schreb.). There was a high degree of association between most seed and seedling vigor characteristics in the single crosses and S1's. Most seed and seedling vigor characteristics were often associated with fall vigor ratings in the field, but not with other plant characteristics.

Cantrell, Hodges and Keim (1972) examined respiration rates in corn at different stages of seed germination and seedling development. A high positive correlation (r=.930) was found between 24-hour kernel respiration rate and seedling vigor. A negative relationship was found between seedling shoot respiration rate and seedling vigor, and a low correlation (r=.270) was observed between root tip respiration rate of the young seedlings and seedling vigor.

Qualls and Cooper (1968) reported that one of four birdsfoot trefoil varieties examined for speed of germination and elongation, were different from others, but the greater speed of germination and elongation values were not associated with more rapid water absorption or more rapid seed respiration rates.

Seed germination requires biological energy, adenosine triphosphate (ATP), not only for biogenesis of new cellular constituents in seedlings, but also for the formation of protein-synthesizing machinery in producing enzymes for compounds. The availability of ATP is a definite controlling factor in germination and seedling growth. (Ching, 1972).

In most cases, the supply of ATP does not appear to be limiting during germination in a suitable temperature range with normal oxygen supply. However, if the environmental conditions are changed to adverse ones, ATP could be limiting and germination arrested. (Ching, 1972).

An attempt was made to correlate seed vigor with ATP content by Ching (1973) in imbibed seeds of Dixie crimson clover (Trifolium incarnatum cultivar 'Dixie'), annual ryegrass (Iolium multiflorum L.) and rape (Brassica napus L.). It was reported that ATP content as a biochemical index of seed vigor was significantly correlated with seed weight, and seedling size in the three species.

Ching and Kronstad (1972) reported that the overall average level and energy charge are indeed higher in seedlings of higher growth potential in wheat (Triticum aestivum L.). It was speculated that one of the means by which genes control growth is the synthesizing ability of adenosine phosphate, not only ATP by competent mitochondria, but also adenosine diphosphate (ADP) and adenosine monophosphate (AMP).

McDaniel and Sarkissian (1968) reported that the increased quantity of mitochondrial protein of seedlings produced from heavy seeds is indicative of a higher respiratory rate and greater amount of energy (ATP) production. These seedlings have a greater growth potential than seedlings produced from lighter seeds of the same pure line. Because of the effects of seed size on seedling vigor, it is important to use seed of similar size to study genetic difference.

Plant Characteristics

Knight (1953), based on greenhouse studies with white clover (*Trifolium repens* L.), reported the total number of stolons, stolon diameter score, vigor after flowering, and disease score for one year of the experiment, were significantly correlated with winter survival in the field. Disease resistant clones and progenies produced a large number of stolons having relatively small diameters.

Ahlgren and Sprague (1940) found a high degree of genetic variability in plant spread (length x width), leafiness, number of stolons, height of flowering stalk, length of internode, height of petiole, date of flowering, leaf color, water mark, and length and width of middle leaflet in both the native and commercial strains of white clover. They concluded that rapid spreading plants do not form a dense top growth.

Carnahan and Brown (1955) reported leaflet length and width to be inherited quantitatively in white clover.

Various workers have used mass selection, maternal line selection, polycross and diallel crosses, but there is little comparative data available on the efficiency of different breeding methods in white clover. (Davies, 1970).

Barclay (1960) was able to increase winter growth 53% and summer growth 36% by polycrossing 54 plants of New Zealand white clover and selecting the seven best parents to produce a new synthetic line. Diallel crosses of these seven plants grown as spaced plants and grazed by sheep showed differences in general and specific combining ability.

Gibson et al. (1963) concluded that clonal evaluation of the vegetatively propagated propagules generally agreed with polycross progeny performance.

Davies (1960) showed that selection of good and poor plants (ratio of yield 4:1) on the basis of F_1 vigor had no effect on F_2 yields, but continued selection on the same basis to produce F_3's resulted in good x good crosses giving a relative yield of 108 (100=yield of outcross) compared with 70 in poor x poor crosses.

Suzuki, Atachi and Yamada (1968) have studied heritability estimates of ten characteristics in a ladino clover population by parent-offspring regressions. The lowest heritability was for forage yield, while plant height, leaf length and stolon diameter had heritability values of about 50%. They concluded that phenotype selection to increase yield had theoretical validity and suggested using a selection index combining more heritable characteristics associated with yield in order to gain effective improvement.

Echeverri (1961) reported that the heritability estimates increased for length of petiole, length of middle leaflet, length of the longest stolon and plant spread as the plants grew older but decreased for number of internodes on the longest stolon and total number of stolons. It was suggested that yield improvement may be made if selection for length of the petiole, width of middle leaflet, length of the longest stolon is done in late stage of growth. Based on genetic expressions, it was also proposed that selection would be more effective for spread of the plant and number of stolons per clone in the early stage of growth. Four variables which most influenced yield were length of the petiole, total number of stolons per clone, length of the longest stolon, and dry matter percentage in ten genotypes of ladino clover.

Atwood and Garber (1942) found that growth habit of spaced plants of white clover plants was not closely correlated with its performance in sod. However, Gibson (1964) reported later that transplanting individual seedlings at spacings of 15.24 and 30.48 centimeters and broadcasting seed at the rate of three pounds per acre gave similar evaluations of the six varieties examined when the forage produced the first spring after planting was used as a basis for comparing methods of planting. It was concluded that for a valid evaluation of strains and varieties, small quantities of seed produced by hand pollination can be used at 15.24 centimeter spacing established alone or with an associated species.

Barnes et al. (1959) reported significant variation within and among varieties for specific leaf weight ranking of alfalfa was not influenced by stage of maturity. Specific leaf weight and leaf area appeared to be under independent genetic control. Later (1969), they found that specific leaf weight and net photosynthesis of 13 alfalfa clones were positively correlated (r=.790). Specific leaf weight-net photosynthesis relationships were similar under various environmental conditions.

Chatterton et al. (1972) suggested the use of diurnal change in specific leaf weight as a measure of productivity potential because diurnal change in specific leaf weight of fully expanded leaves reflects the photosynthate production-translocation balance in alfalfa and corn.

MATERIALS AND METHODS

Materials

Fourteen parent clones of white clover were assembled on the basis of diverse morphology and origin.

Eight parent clones were selected from Umatilla county, northeastern Oregon. These were 'Dutch' white clover and are believed to be well adapted to the area. The name 'Dutch' can be applied to any white clover. A diallel consisting of 28 single crosses was obtained by hand pollination of these eight plants. Open-pollinated progenies of these eight plants were used for the studies of seed and seedling vigor characteristics.

Five ladino clover clones selected from Oregon-NWM which was derived from a five clone synthetic of upright genotypes with no water mark were crossed with one clone selected from New Zealand white clover (NZW). This provided five test-crosses between ladino and the New Zealand white clover tester plant.

New Zealand white clover, Oregon-NWM, one single cross between a ladino genotype and a Umatilla genotype, and bulked seed from a polycross block of the Umatilla sources were used as checks.

All 59 entries are identified and described in Table 1.

Table 1. Identification number, genotype code, origin and group for white clovers used to study seed and plant characteristics. (Corvallis, Oregon. 1972)

Ident. number	Genotype code	Origin	Group
1	U71-1 x U71-2	Umatilla county, Or.	Single cross(SX)
2	U71-1 x U71-3	"	"
3	U71-1 x U71-4	"	"
4	U71-1 x U71-5	"	"
5	U71-1 x U71-6	"	"
6	U71-1 x U71-7	"	"
7	U71-1 x U71-8	"	"
8	U71-2 x U71-3	"	"
9	U71-2 x U71-4	"	"
10	U71-2 x U71-5	"	"
11	U71-2 x U71-6	"	"
12	U71-2 x U71-7	"	"
13	U71-2 x U71-8	"	"
14	U71-3 x U71-4	"	"
15	U71-3 x U71-5	"	"
16	U71-3 x U71-6	"	"
17	U71-3 x U71-7	"	"
18	U71-3 x U71-8	"	"
19	U71-4 x U71-5	"	"
20	U71-4 x U71-6	"	"
21	U71-4 x U71-7	"	"
22	U71-4 x U71-8	"	"
23	U71-5 x U71-6	"	"
24	U71-5 x U71-7	"	"
25	U71-5 x U71-8	"	"
26	U71-6 x U71-7	"	"
27	U71-6 x U71-8	"	"
28	U71-7 x U71-8	"	"
29	NWM 1 x NZW 8		Test-cross (TX)
30	NWM 2 x NZW 8		"
31	NWM 3 x NZW 8		"
32	NWM 4 x NZW 8		"
33	NWM 5 x NZW 8		"
34	U71-7 x NWM 1		Check
35	NZW variety	New Zealand white	"
36	NWM variety	Oregon ladino (5 clone synthetic variety with no water mark)	"

Continued

Table 1--Continued.

Ident. number	Genotype code	Origin	Group
37	U71-1	Selection from Umatilla	Parent of SX
38	U71-2	"	"
39	U71-3	"	"
40	U71-4	"	"
41	U71-5	"	"
42	U71-6	"	"
43	U71-7	"	"
44	U71-8	"	"
45	NWM 1	Selection from NWM Var.	Parent of TX
46	NWM 2	"	"
47	NWM 3	"	"
48	NWM 4	"	"
49	NWM 5	"	"
50	NZW 8	Selection from NZW Var.	Tester of TX
51	OP of U71-1	Open-pollinated seed	Open-pollin.
52	OP of U71-2	"	"
53	OP of U71-3	"	"
54	OP of U71-4	"	"
55	OP of U71-5	"	"
56	OP of U71-6	"	"
57	OP of U71-7	"	"
58	OP of U71-8	"	"
59	Bulked seed of a random Umatilla source		Check

Measurements

Seed and Seedling Vigor Characteristics

Seeds from the diallel cross, five test-crosses, eight open-pollinated, and four checks were used in these studies.

25-Seed Weight. Four 25-seed samples, taken at random, were weighed to the nearest .1 mg.

Seedling Vigor Index. Speed of germination was measured as an index for seedling vigor by following formula: (Number of seeds germinated in 3 days/3) + (Number of seeds germinated in 5 days/5) + (Number of seeds germinated in 7 days/7).

Adenosine Triphosphate (ATP) Content in Seed. Seeds were sized with two screens, one 1.016 mm and the other 1.270 mm in diameter. Four air-dried 10-seed samples were examined for each entry. Each sample was weighed to the nearest .1 mg. The seeds were individually scarified between two sheets of emery cloth. Four 10-seed samples were placed on two layers of filter paper, 11.43 x 11.43 cm, in a germination box of the same size. Five ml of water were added and the seeds were covered with two more layers of filter paper before an additional three ml of water were added. Seeds were imbibed at $20^{\circ}C$ for two hours. Based on preliminary tests, two hours of imbibition was satisfactory. The imbibed 10-seed samples were quickly dropped into five ml of boiling glass distilled water and extracted for 10 minutes. Steward and Guinn (1969).

The extract was cooled in an ice bath. One aliquot of the extract was diluted two fold with a buffer to a final concentration of .025 M N-2-hydroxyethypiperazine-N'-2-ethene-sulfonic acid, pH7.5 and .025 M MgSO4-$7H_2O$. ATP standard solutions, 2.5×10^{-5}, 2.5×10^{-6}, 2.5×10^{-7}, were diluted two fold with the same buffer.

The crude luciferin-luciferase was activated and endogeneous ATP was depleted by adding 5 ml of cold glass distilled water to 50 ml firefly extract (Sigma FLE-50) and placed in cold room for 16-24 hours prior to use. The enzyme preparation was centrifuged at 10, 000 g for 10 minutes at $0^{\circ}C$ in a Corex tube. The supernatant was kept cool by placing it in an ice bath immediately after centrifuging.

The ATP content was determined in 0.2 ml of the diluted extract and ATP standard solution with an Aminco Chem-Glow photometer by adding 0.1 ml of enzyme preparation.

Each sample was measured twice. ATP standard solutions were measured before and after each series of the experiment and averaged in converting the extract readings to ATP content. For the analysis, data were expressed as ATP content in pico mole per seed, and ATP content pico mole per mg of seed.

Seed Respiration. Two 25-seed samples were used for the measurement of oxygen uptake, and two for the measurement of total gas exchange. Preliminary data suggested that a surface sterilization was not necessary because of a smooth seed coat, and the relatively short three-hour period of imbibition. Seeds were individually scarified between two sheets of emery cloth. The scarified seed sample was placed in a 15 ml single armed Warburg flask with 0.5 ml of distilled water. In measuring oxygen uptake, 0.2 ml of 4N KOH was added to the center well with a filter paper to increase the carbon dioxide absorbing area for the KOH. For the measurement of total gas exchange, 0.2 ml distilled water was added to the center well. Oxygen and total gas exchange measurements were made by using a Gilson Differential Respirometer in a water bath temperature of 20°C.

Water was placed in two flasks without seed and attached to the first and last position of the respirometer which served as thermal barometers to indicating pressure change other than gas exchange of imbibed seeds. Barometric pressure and room temperature were recorded at each reading to account for differences during the experiment due to these factors. The microliter readings were adjusted as follows to obtain microliters of dry gas at 760 mm Hg. (Gregory and Winter, 1965):

$$\frac{(273)}{(t + 273)} \quad \frac{(Pb)}{(760)} = \text{correction factor},$$

where t is temperature in C°, and Pb is barometric pressure in mm.

The readings were taken each 30 minutes for a three-hour imbibition period. The measurements for analysis were:

Oxygen uptake per 25-seed in ml.

Oxygen uptake per mg of seed in ml.

Carbon dioxide evolution per 25 seed in ml.

Carbon dioxide evolution per mg of seed in ml.

Respiration quotient (RQ) per 25-seed, calculated by dividing carbon dioxide evolution by oxygen uptake on the basis of 25-seed.

RQ per mg of seed.

Plant Characteristics

To study plant characteristics in the greenhouse, seeds of 28 single crosses representing the diallel, five test-crosses and checks except the bulked seed were scarified and germinated at 20^{o}C in 11.43 x 11.43 cm plastic germination boxes. Seedlings from the germination box were transplanted in 10.79 x 10.79 cm plastic pots in the greenhouse after innoculation with Rhizobium spp.

Fourteen parental genotypes were increased vegetatively. Three cm cutting of each parent was rooted in flats filled with perlite about seven days after transplanting of the seedlings. The rooted cuttings were innoculated and transplanted about five days later.

These 50 entries were arranged in a randomized block design, with four replication, five plants per replication in each entry, one plant per pot.

Gro-Lux flourescent illumination was provided for 16 hours for the first 30 days and 12 hours for the remaining period of the experiment. The room temperature was kept near 20^{o}C for 24 hours a day.

To measure leaf length and width of middle leaflet of trifoliate leaves, leaf area and leaf dry weight per trifoliate leaf, four fully developed leaves per plant were used.

Each leaf sample was placed on a sheet of white paper between plastic covers and reproduced in a photocopy machine. The middle leaflet length and width measurements were taken from the photocopy. Each figure of leaf was cut out and weighed to the nearest .1 mg. The weight of paper was then converted to the leaf area in cm^2. After photocopying, the fresh leaves were placed in a bottle without a cover and oven-dried for 24 hours at 105 ^{o}C, and weighed to the nearest .1 mg. Petiole and stolon diameter was measured to the nearest .01 cm with a caliper.

The measurements for analysis were:

Stolon number at 50 days: number of stolons per plant at 50 days after transplanting.

Stolon number at 70 days: number of stolons per plant at 70 days after transplanting.

Stolon number growth rate: Average increase in stolon number between 50 and 70 days.

Stolon length at 50 days: Sum of stolon length per plant in cm at 50 days after transplanting.

Stolon length at 70 days: Sum of stolon length per plant in cm at 70 days after transplanting.

Stolon length growth rate: average increase in stolon length in cm between 50 and 70 days.

Stolon diameter: diameter of the second internode of the longest stolon measured in mm at 70 days after transplanting.

Internode length; length of the second internode of the longest stolon in cm at 70 days after transplanting.

Petiole length: length of the petiole at the second node of the longest stolon measured in cm at 70 days after transplanting.

Petiole diameter: diameter of the petiole at the second node of the longest stolon measured in mm at 70 days after transplanting.

Leaf width: width of the middle leaflet of a trifoliate leaf in cm at 75 days after transplanting.

Leaf length: length of the middle leaflet of a trifoliate leaf in cm at 75 days after transplanting.

Leaf ratio: ratio of leaf length to leaf width.

Area per leaf: average area of a trifoliate leaf in cm^2 at 75 days after transplanting.

Dry weight per leaf: average dry weight of a trifoliate leaf in mg at 75 days after transplanting.

Specific leaf weight (SLW): the ratio of dry weight to leaf area per trifoliate leaf in mg/cm^2.

Diurnal ratio in SLW (AM/Noon): ratio of SLW measured at 7:00 a.m. to SLW measured at noon for the same entry.

Diurnal ratio in SLW (Noon/PM): ratio of SLW measured at noon to SLW measured at 4:00 p.m. for the same entry.

Diurnal ratio in SLW (AM/PM): ratio of SLW measured at 7:00 a.m. to SLW measured at 4:00 p.m. for the same entry.

Number of leaves per plant: number of trifoliate leaves per plant at 65 days after transplanting.

Total leaf area per plant: leaf area per trifoliate leaf multiplied by number of trifoliate leaves per plant.

Leaf area ratio (LAR): ratio of total leaf area to forage yield per plant in cm^2/gm.

Forage yield per plant: oven dry weight of forage harvested three cm above the soil surface in g at 76 days after transplanting.

Statistical Analysis

All characteristics were analyzed with the analysis of variance procedures as outlined by Li (1948).

The diallel analysis, random model, experimental method four, as explained by Griffing (1956) was used to test general (GCA) and specific (SCA) combining ability (Table 2). In this analysis, the following assumptions were made, that all genes behave diomically as a diploid organism; the variables are fixed; epistasis is absent; and the parent plants are equally heterozygous. Since pairing and disjunction have given rise to 16 bivalents and no polyvalents, it has been concluded that white clover is probably an amphidiploid showing mostly disomic inheritance with a chromosome number of 2n=32, Atwood and Hill (1940). Fertility of white clover is controlled by a series of S alleles that produce a gametophytic type of self-incompatibility. The large number of S alleles present in populations ensures a high level of cross-compatibility in natural populations with less than one percent of the matings being cross-incompatible. Atwood (1944).

Heritability estimates were obtained from the mean square components of the combining ability analysis (Table 3), and by

Table 2. Expected mean squares in the analysis of variance for general (GCA) and specific (SCA) combining ability using model II.

Source of variation	Degree of freedom	Expected mean square
GCA	p - 1	Ve + rVs + r(p-2) Vg
SCA	p (p - 3)/2	Ve + rVs
Error	m	Ve

where: p = number of parents, Vg = variance for general combining ability, Vs = variance for specific combining ability, Ve = error mean square, m = degree of freedom for experimental error, r = number of replications.

Table 3. Heritability estimates based on the combining ability analysis. Gardner (1963).

Broad sense heritability: $\frac{4Vg + 4Vs}{4Vg + 4Vs + Ve}$

Narrow sense heritability: $\frac{4Vg}{4Vg + 4Vs + Ve}$

where: Vg, Vs and Ve are same as in Table 2, additive genetic variance = 4Vg since Vg is 1/4 of additive genetic variance when noninbred parents are used in cross-pollinated crops, nonadditive genetic variance = 4Vs since Vs is 1/4 of dominant genetic variance when noninbred parents are used in cross-pollinated crops, total genetic variance = 4Vg + 4Vs, and total variance = 4Vg + 4Vs + Ve.

regression of single cross on mid-parent.

All possible simple correlation coefficients were calculated among seed and seedling vigor characteristics, among plant characteristics, and between important seed and plant characteristics on the basis of single crosses. Parent-progeny relationships were examined by determining simple correlation coefficients between single crosses and their mid-open-pollinated parent values for seed and seedling vigor characteristics, and between single crosses and mid-parents for plant characteristics. Simple regression coefficients were also calculated between important seed and plant characteristics.

The path-coefficient analysis, developed by Wright (1921), was used to study further the association among certain components and yield.

RESULTS

Seed and Seedling Vigor Characteristics

Measurements of 25-seed weight, ATP content, seed respiration, and seedling vigor index were recorded for a diallel cross including 28 single crosses (SX), five test-crosses (TX), four checks, and eight open-pollinated (OP) seeds and seedlings; 1) to determine differences among and within these four groups, 2) to determine gene action for each characteristic with combining ability and heritability estimates, and 3) to examine relationships among seed and seedling vigor characteristics.

Seed Weight and Seedling Vigor Index

The average weight of four 25-seed samples per entry ranged from 10.9 to 18.9 mg and seedling vigor index ranged from 5.26 to 12.89 (Table 4).

The test-cross seed weight average was the heaviest of the four groups. The average seed weight of single crosses was heavier than those of open-pollinated progenies. The average seedling vigor index of open-pollinated progenies was the highest among the four groups (Table 4 and Appendix Tables 1 and 2).

Seed weight was significantly different among entries, among

Table 4. Ranges, means, standard errors of mean ($s_{\bar{x}}$), and coefficients of variation (C. V.) for seed and seedling characteristics of white clover. (Corvallis, Oregon, 1972)

Seed and seedling vigor characteristics	Range	Mean				$s_{\bar{x}}$	C. V.
		SX	TX	OP	Checks		
1. 25-Seed weight	10.9-18.9	14.7	16.4	12.7	13.7	.3290	4.55%
2. ATP content/seed	65.7-232.8	180.7	171.4	216.2	180.5	6.2187	6.89%
3. ATP content/mg of seed	88.4-380.5	290.9	264.7	342.5	288.0	10.9040	7.57%
4. O_2 uptake/25-seed	1.985-6.537	4.585	4.301	4.559	4.399	.4773	15.34%
5. O_2 uptake/mg of seed	.1126-.5630	.3132	.2631	.3012	.2988	.0139	20.79%
6. CO_2 evolved/25-seed	.841-4.833	3.209	2.865	3.091	1.745	.5186	24.28%
7. CO_2 evolved/mg of seed	.1012-.5561	.2847	.2184	.2750	.2281	.0144	23.83%
8. RQ/25-seed	.407-.826	.687	.647	.669	.563	.0212	14.16%
9. RQ/mg of seed	.630-.979	.899	.799	.895	.950	.0469	7.46%
10. Seedling vigor index	5.26-12.89	9.771	11.12	11.82	6.73	.4224	5.96%

Table 5. Mean squares and level of significance for 25-seed weight and seedling vigor index of white clover. (Corvallis, Oregon. 1972)

Source of variation	d. f.	25-seed weight	d. f.	Seedling vigor index
Entries	44	16.6884**	44	7.1539**
Among groups	3	63.3753**	3	51.2785**
Within groups	41	13.0504**	41	3.9253**
Among SX	27	13.0839**	27	5.1571**
Among TX	4	8.7720**	4	.6921
Among checks	3	38.0357**	3	2.8433**
Among OP	7	1.5336**	7	1.4609**
Error	135	.433	45	.3549

** Significant at the 1% level.

and within groups, and for all groups at the one percent level. The seedling vigor index was significantly different among entries, among and within groups, and for all groups, except among test-cross progenies (Table 5).

The coefficients of variation (C. V.) were relatively small, and both characteristics exhibited genetic differences, indicated by significant differences among and within groups.

General and specific combining ability were significant at the one percent level for seed weight but for the seedling vigor index, only specific combining ability was significant (Table 8). This indicates that seed weight is controlled by both additive and nonadditive gene systems, whereas the seedling vigor index responds primarily to a nonadditive scheme.

In seed weight, the variance for the specific combining ability was larger than that for general combining ability (Table 9). Even though general combining ability was significant, the nonadditive effects were more evident than the additive effects.

The heritability estimates from the combining ability analysis gave a relatively high narrow sense heritability and a high broad sense heritability for seed weight (Table 10).

The breeder will achieve genetic improvement for these characteristics, where the nonadditive effects are more prominent than the additive effects, by taking advantage of specific combining ability through a hybrid breeding program. The improvement of seed weight, however, will not be the prime objective in a forage breeding program unless it is highly correlated with seedling vigor in field.

Adenosine Triphosphate (ATP) Content in Seed

Measurements of ATP content were made on seeds of similar size. ATP content per seed is the concentration of ATP in a seed, and ATP content per mg of seed represents the ATP concentration per unit of seed density in pico mole (p mole).

Averages of ATP content ranged from 65.7 to 232.8 p mole per seed and 88.4 to 380.5 p mole per mg of seed. The ATP content of open-pollinated seed was the highest among the four groups for both measurements (Table 4 and Appendix Table 1).

There were significant differences at the one percent level among entries, among and within groups, and for all groups in ATP content per seed. The ATP content per mg of seed were significantly different at the one percent level among entries, among and within groups, and for all groups except test-cross progenies (Table 6).

The combining ability analysis resulted in significant differences at the one percent level for specific combining ability only, for both ATP measurements (Table 8). The variance for specific combining ability was much larger than that for general combining ability for both ATP measurements (Table 9). ATP content, therefore, seems to respond primarily to the effects of nonadditive gene action.

ATP content per mg of seed gave a very high broad sense heritability estimate and a low narrow sense heritability estimate. This must be true for the ATP content per seed because of the large variance for specific combining ability. The variation of ATP content in the seed was large as indicated by significant differences among and within groups.

This suggests that breeding and selection for higher ATP content would be successful. Since both measurements respond primarily to nonadditive gene action, the investigator can then use specific combining effects by crossing, followed by selection in later generation.

Table 6. Mean squares and level of significance for ATP (adenosine triphosphate) content in seeds of white clover. (Corvallis, Oregon. 1972)

Source of variation	d. f.	ATP content per seed	ATP content per mg of seed
Replications	3	645.5676**	526.4167
Entries	44	3,868.4722**	11,766.4832**
Among groups	3	36,469.6652**	89.372.1400**
Within groups	41	1,483.0191**	6,088.0205**
Among SX	27	1,368.2292**	5,692.5900**
Among TX	4	195.6431**	517.5225
Among checks	3	6,268.0897**	21,627.4833**
Among OP	7	610.6789**	4,136.6243**
Error	132	154.6878	475.5891

** Significant at the 1% level.

Seed Respiration

Oxygen uptake ranged from 1.985 to 6.537 ul per 25-seeds and from .1126 to .5630 ul per mg of seed. Carbon dioxide evolution ranged from .841 to 4.833 ul per 25-seeds and from .1012 to .5561 ul per mg of seed. Respiration quotient (RQ) values ranged from .407 to .826 per 25-seeds and .630 to .979 per mg of seed. The average of the single crosses was the highest among the four groups for oxygen uptake and carbon dioxide evolution measurements. Respiration quotient per 25-seeds of the single crosses was the highest and respiration quotient per mg of seed of checks was the highest among four groups. The averages of the single crosses, however, were not significantly different from the average or open-pollinated progenies (Table 4 and Appendix Tables 1 and 2).

Oxygen uptake and carbon dioxide evolution measured on 25-seeds were significantly different at the one percent level among entries, among and within groups, among single crosses, and among checks. Oxygen uptake and carbon dioxide evolution based on mg of seed were significantly different at the one percent level among entries, among and within groups, and for all groups except among test-cross entries. There were significant differences among groups and among checks at the one percent level for respiration quotient per 25-seeds. Respiration quotient per mg of seed was significantly different at the one percent level among entries, among and within groups, and among test-cross progenies, and at the five percent level among open-pollinated seeds (Table 7).

In general, respiration quotient measurements did not exhibit large variation. There were not significant differences among single crosses. Therefore, if genetic differences are not evident, these measurements may be of little value to the breeder.

Oxygen uptake and carbon dioxide evolution resulted in large variations and significant differences among and within groups with frequent exceptions in test-corss and open-pollinated progeny seeds.

Both measurements of oxygen uptake were significant at the one and five percent levels only for specific combining ability,

Table 7. Mean squares and levels of significance for seed respiration characteristics of white clover. (Corvallis, Oregon. 1972)

Source of variation	d. f.	O_2 uptake per 25-seeds	O_2 uptake per mg of seed	CO_2 evolution per 25-seeds	CO_2 evolution per mg of seed	RQ per 25-seeds	RQ per mg of seed
Entries	44	1.8416**	.01599**	1.5499**	.01785**	.01439	.011523**
Among groups	3	6.6410**	.02143**	5.0847**	.05330**	.03788**	.039033**
Within groups	41	14.9046**	.01560**	1.2913**	.01525**	.01267	.009510**
Among SX	27	1.5351**	.01260**	1.3220**	.01388**	.01171	.006700
Among TX	4	.3310	.00243	.3263	.00583	.00230	.027800**
Among checks	3	4.4461**	.06191**	3.3408**	.03870**	.04450**	.001567
Among OP	7	.6981	.01621**	.8458	.03010**	.00864	.013300*
Error	45	.4556	.00386	.5378	.00413	.00896	.004418

*, ** Significant at the 5 and 1% level, respectively.

Table 8. Mean squares, levels of significance and coefficient of variation (C. V.) in general (GCA) and specific (SCA) combining ability analysis for seed and seedling vigor characteristics of white clover single crosses. (Corvallis, Oregon. 1972)

Seed and seedling vigor characteristics	Single crosses	GCA	SCA	Error	C. V.
1. 25-seed weight	14.005**	32.004**	7.705**	.418	4.3%
2. ATP content/seed	1,368.229**	538.939	1,658.481**	167.356	7.16%
3. ATP content/mg of seed	5,692.590**	7,724.946	4,981.266**	486.0152	7.58%
4. O_2 uptake/25-seeds	1.5351**	2.7528	1.1089*	.4769	15.06%
5. O_2 uptake/mg of seed	.01260**	.01439	.01198**	.00441	21.20%
6. CO_2 evolution/25-seeds	1.3220*	2.3654	.9569	.5309	22.70%
7. CO_2 evolution/mg of seed	.01388**	.01639	.01300*	.00507	25.01%
8. RQ/25-seeds	.01171	.02009	.00877	.00949	14.18%
9. RQ/mg of seed	.00670	.00914	.00585	.00498	7.84%
10. Seedling vigor index	5.1571**	3.3099	5.8086**	.0666	2.64%

*, ** Significant at the 5 and 1% level, respectively.

Table 9. Variances for general (GCA) and specific (SCA) combining ability for seed and seedling vigor characteristics of white clover single crosses. (Corvallis, Oregon. 1972)

Seed and seedling vigor characteristics	Variances for GCA	Variances for SCA
1. 25-seeds weight	1.0124	1.8217
2. ATP content per seed	--*	372.7813
3. ATP content per mg of seed	114.3200	1,123.8126
4. O_2 uptake per 25-seeds	.1370	.3160
5. O_2 uptake per mg of seed	.00021	.00349
6. CO_2 evolution per 25-seeds	.1174	.2130
7. CO_2 evolution per mg of seed	.000283	.003970
8. RQ per 25-seeds	.00094	--*
9. RQ per mg of seed	.000274	.000440
10. Seedling vigor index	--*	2.871

* Negative value.

respectively. Carbon dioxide evolution per mg of seed was significant at the five percent level only for specific combining ability (Table 8). The variance for specific combining ability was much larger than that for general combining ability for both measurements of oxygen uptake and carbon dioxide evolution per mg of seed (Table 9). These characteristics, therefore, seem to respond primarily to the effects of nonadditive gene action. Even though oxygen uptake and carbon dioxide evolution per mg of seed were significant for specific combining ability, the respiration quotient

Table 10. Heritability estimates for seed and seedling vigor characteristics of white clover single crosses, calculated on the basis of components of variance from the combining ability analysis. (Corvallis, Oregon. 1972)

Seed and seedling vigor characteristics	Broad sense heritability estimate (Hb)	Narrow sense heritability estimate (Hn)
25-seeds weight	73.02%	26.09%
ATP content per seed	--*	--*
ATP content per mg of seed	91.06%	8.41%
O_2 uptake per 25-seeds	79.16%	23.94%
O_2 uptake per mg of seed	78.33%	3.95%
CO_2 evolution per 25-seeds	89.56%	32.92%
CO_2 evolution per mg of seed	77.02%	5.12%
RQ per 25-seeds	--*	--*
RQ per mg of seed	36.28%	14.02%
Seedling vigor index	--*	--*

* Negative values are involved in calculation.

per mg of seed was not significant in the combining ability analysis because of the very close relationship between these two variables (r=.9861). The ratio of the two variables resulted in a series of values with no significant difference. This demonstrated that with certain characteristics, when considered together, an entirely different pattern of variation may be observed (Tables 8 and 12).

Both oxygen uptake and carbon dioxide measurements gave relatively high broad and low narrow sense heritability estimates. The deviation between two heritability estimates was large as

Table 11. Means, standard errors of mean ($s\bar{x}$), and coefficient of variation (C. V.) of two checks for seed and seedling vigor characteristics of white clover. (Corvallis, Oregon, 1972)

Seed and seedling characteristics	Means of checks		$s\bar{x}$	C. V.
	New Zealand white clover	No water mark ladino clover		
1. 25-seeds weight	18.2	13.0	.3290	4.55%
2. ATP content per seed	65.7	149.3	6.2187	6.89%
3. ATP content per mg of seed	88.4	252.6	10.9040	7.57%
4. O_2 uptake per 25-seeds	1.985	2.954	.4773	15.34%
5. O_2 uptake per mg of seed	.1126	.2156	.0139	20.79%
6. CO_2 evolution per 25 seeds	.841	1.649	.5186	24.28%
7. CO_2 evolution per mg of seed	.1021	.2050	.0144	23.83%
8. RQ per 25-seeds	.407	.542	.0212	14.16%
9. RQ per mg of seed	.915	.949	.6469	7.46%
10. Seedling vigor index	5.26	7.75	.4224	5.96%

expected (Table 10). Therefore, if these characteristics are used as a criteria for seed vigor, hybrid breeding program may be successful.

Checks

Ladino is a large type of white clover, and New Zealand white clover is an intermediate type. The comparison of New Zealand white and Oregon-NWM (ladino clover with no water mark) varieties indicated the apparent differences between these two white clovers. In seed weight, New Zealand white clover was heavier than the Oregon-NWM ladino. Oregon-NWM ladino clover, however, was higher than New Zealand white clover in all other seed and seedling vigor characteristics (Table 11).

Associations Among Seed and Seedling Vigor Characteristics

Simple correlation coefficients among seed and seedling vigor characteristics based on the 28 single crosses are listed on Table 12.

25-seeds weight was negatively correlated with ATP content per mg of seed and was significant at the one percent level.

ATP content per seed and ATP content per mg of seed were significantly correlated with seedling vigor index at the one percent level.

Seed respiration characteristics gave poor relationships with other seed and seedling vigor characteristics. Oxygen uptake per 25 seeds was significantly correlated with oxygen uptake per mg of seed, both measurements of carbon dioxide evolution, and respiration quotient per 25 seeds at the one percent level and respiration quotient per mg of seed at the five percent level. Oxygen uptake per mg of seed was significantly correlated with both measurements of carbon dioxide evolution and respiration quotient per mg of seed. Carbon dioxide evolution per 25 seeds was correlated with carbon dioxide

Table 12. Simple correlation coefficients* among seed and seedling characteristics in 28 single crosses of white clover. (Corvallis, Oregon. 1972)

	ATP content per seed	ATP content per mg of seed	O_2 uptake per 25 seeds	O_2 uptake per mg of seed	CO_2 evolution per 25 seeds	CO_2 evolution per mg of seed	RQ per 25 seeds	RQ per mg of seed	Seedling vigor index
1. 25-seed weight	.1025	-.5347	.1596	-.3056	.2069	-.3033	.1631	-.1459	.0057
2. ATP content per seed		.6522	.1681	.1693	.0004	.2321	-.2898	.3524	.8250
3. ATP content per mg of seed			.1130	.3252	-.0489	.3914	-.2670	.4838	.4943
4. O_2 uptake per 25-seeds				.7271	.9436	.7259	.5026	.4678	-.0322
5. O_2 uptake per mg of seed					.6638	.9861	.2995	.4979	.0477
6. CO_2 evolution per 25 seeds						.6434	.7502	.3309	-.1459
7. CO_2 evolution per mg of seed							.2541	.6229	.1000
8. RQ per 25-seeds								-.0375	-.2719
9. RQ per mg of seed									.2346

* Correlation coefficients of .373 and .478 are significant at the 5 and 1% level, respectively.

evolution per mg of seed and respiration quotient per 25 seeds at the one percent level. Carbon dioxide evolution per mg of seed was correlated with respiration quotient per mg of seed at the one percent level. These close relationships among seed respiration characteristics, especially between oxygen uptake and carbon dioxide evolution measurements resulted in frequent nonsignificant differences for the respiration quotient measurements. The poor relationships of seed respiration characteristics with other seed and seedling vigor characteristics suggest that seed respiration characteristics may not serve as a criteria for the improvement of seed and seedling vigor.

ATP measurements may be a better indicator of seed and seedling vigor than seed respiration characteristics because of the high correlation with other characteristics, and the role in biogenesis and the formation of protein-synthesizing machinery.

Negative association of seed weight with ATP content per mg of seed and poor relationship of seed weight with seedling vigor index and seed respiration characteristics were apparent in the comparison of two types of white clover checks. This low relationship was evident on 28 single crosses and on two different populations which represent the two types of white clover used as checks.

Relationships Between Single Crosses and Mid-open Pollinated Progenies

There were poor relationships between single crosses and mid-open-pollinated progenies for all seed and seedling vigor characteristics, except seed weight. 25-seed weight gave a coefficient of determination (.3360) which suggests about one third of the variation in the dependent variable can be accounted for the variation in the independent variable (Table 13).

Frequent minus values were observed for the simple regression coefficients of single crosses on mid-open-pollinated progenies, thus they may be of little value in estimating gene action. The results do not agree with the heritability estimates based on the combining ability analysis where only single crosses were used to estimate gene action (Tables 10 and 13).

Plant Characteristics

Measurements of 23 plant characteristics on stolon, petiole, leaf, and forage yield were made for an eight clone diallel cross, five test-crosses, three checks, eight parent clones of the diallel cross, and six parent clones of the test-cross; 1) to determine differences among and within these five groups, 2) to study the nature of gene action by the combining ability analysis and heritability estimates, 3) to determine relationships among these plant

Table 13. Simple correlation coefficients* (r), coefficients of determination (r^2) and regression coefficients**(b) between 28 single crosses and mid-open-pollinated progenies for seed and seedling vigor characteristics of white clover. (Corvallis, Oregon. 1972)

Seed and seedling characteristics	r	r^2	$b_{SX \cdot MOP}$**
25-seeds weight	.5769	.3360	2.1939
ATP content per seed	-.0221	.0005	-.0530
ATP content per mg of seed	.2771	.0768	.5566
O_2 uptake per 25 seeds	.1723	.0297	.2420
O_2 uptake per mg of seed	-.0065	.0000	-.0071
CO_2 evolution per 25 seeds	.0302	.0009	.0452
CO_2 evolution per mg of seed	.1330	.0177	.1502
RQ per 25 seeds	-.3639	.1324	-.6812
RQ per mg of seed	.3693	.1364	.4209
Seedling vigor index	-.1023	.0105	-.2754

* Correlation coefficients of .373 and .478 are significant at the 5 and 1% level, respectively.

** Regression coefficients of single crosses on mid-open-pollinated progenies $b_{SX \cdot MOP}$.

characteristics, and 4) to determine relationships between important seed and plant characteristics.

Stolon Characteristics

Four measurements of stolon number and length, stolon diameter, and internode length were investigated.

Stolon Number. The average stolon number ranged from 1.00 to 2.65 for the measurement at 50 days, from 1.95 to 5.50 for the measurement at 70 days after transplanting, and from .70 to 3.20 for the growth rate expressed as the difference between the two measurements. The variation of stolon number at 70 days was larger than that of stolon number at 50 days and that of the growth rate. The average of single crosses was significantly higher than those of their parents for stolon number at 70 days and stolon number growth rate. This was also true for the comparison between test-crosses and their parents. This suggests that hybrid vigor is very evident in the single crosses and test-crosses for the later measurement of stolon number and growth rate (Table 14 and Appendix Table 3).

Stolon number at 50 days was significantly different from entries, among groups, and among single crosses at the one percent level and within groups at the five percent level. Stolon number at 70 days was significantly different among entries, among and within groups, among parents of single crosses, and among parents of test-crosses at the one percent level, and among checks at the five percent level. Stolon number growth rate was significantly different at the one percent level among entries, among and within groups, and for all groups except among test-crosses and among checks (Table 15).

No significant differences were observed among test-crosses for all stolon number characteristics (Table 15).

Table 14. Ranges, means, standard errors of the mean ($s\bar{x}$), and coefficients of variation (C.V.) for plant characteristics of white clover. (Corvallis, Oregon. 1972)

Plant characteristics	Range	Mean						
		SX	TX	Check	Parents of SX	Parents of TX	$s\bar{x}$	C.V.
1. Stolon number at 50 days	1.00- 2.65	1.92	1.76	1.55	1.26	1.19	.2727	32.35%
2. Stolon number at 70 days	1.95- 5.50	4.67	4.38	4.30	2.88	2.69	.2637	12.88%
3. Stolon number growth rate	.70- 3.20	2.70	2.62	2.83	1.63	1.52	.2819	23.40%
4. Stolon length at 50 days	1.20- 9.08	4.51	3.33	3.37	2.68	2.10	.7871	42.10%
5. Stolon length at 70 days	5.88- 44.25	30.06	27.71	23.54	13.34	11.72	3.4204	28.43%
6. Stolon length growth rate	4.48- 22.45	25.53	19.38	20.18	10.67	9.62	3.0141	30.93%
7. Stolon diameter	1.96- 2.85	2.17	2.38	2.35	2.20	2.58	.0582	5.16%
8. Internode length	1.06- 1.95	1.75	1.62	1.67	1.43	1.47	.1269	15.42%
9. Petiole length	8.33- 14.83	11.93	13.48	12.13	10.33	11.92	.6071	10.19%
10. Petiole diameter	1.22- 2.05	1.34	1.42	1.37	1.38	1.40	.0642	9.18%
11. Number of leaves per plant	6.20- 31.75	23.94	22.35	16.17	11.09	19.73	1.8867	19.12%
12. Leaf width	1.37- 2.70	1.60	1.75	1.74	1.57	1.86	.0751	6.44%
13. Leaf length	1.56- 2.96	1.78	1.97	2.03	1.75	2.34	.1177	8.88%
14. Leaf ratio	.99- 1.44	1.11	1.12	1.17	1.12	1.26	.0127	4.98%
15. Area per leaf	4.64- 12.54	6.71	8.09	8.08	6.25	9.73	.4373	12.11%
16. Dry weight per leaf	10.04- 27.43	14.27	16.73	16.58	14.50	20.92	.9724	12.56%
17. Specific leaf weight (SLW)	1.92- 2.48	2.13	2.07	2.05	2.26	2.15	.0782	7.30%
18. Total leaf area per plant	42.97-232.84	161.32	165.72	157.98	70.70	98.99	16.2310	7.29%
19. Leaf area ratio (LAR)	102.71-209.47	127.73	137.31	140.66	129.00	147.40	11.8434	17.49%
20. Diurnal ratio in SLW(AM/Noon)	.874-1.051	.963	.934	.907	.949	.924	.0367	5.49%
21. Diurnal ratio in SLW(Noon/PM)	.874-1.305	.950	.981	.998	.969	.957	.0480	7.06%
22. Diurnal ratio in SLW(AM/PM)	.800- .992	.913	.961	.898	.916	.884	.0367	5.72%
23. Forage yield per plant	.29 -1.67	1.27	1.20	1.15	.32	.72	.1213	22.41%

Table 15. Mean squares and levels of significance for stolon number characteristics of white clover. (Corvallis, Oregon. 1972)

Source of variation	d. f.	Stolon number at 50 days	Stolon number at 70 days	Stolon number Growth rate
Replications	3	.3470	.7976*	1.0896*
Entries	49	.7686**	3.5146**	1.6393**
Among groups	4	4.5033**	33.2362**	13.5197**
Within groups	45	.4366*	.8727**	.5830**
Among SX	27	.6015**	.4899*	.3800**
Among TX	4	.2770	.2975	.3795
Among checks	2	.1300	.9700*	.2234
Among parents of SX	7	.1520	1.8264**	1.2110**
Among parents of TX	5	.1897	1.9937**	1.1147**
Error	147	.2975	.2781	.3179

*, ** Significant at the 5 and 1% level, respectively.

No significant differences were observed among test-crosses for all stolon number characteristics (Table 15).

In the combining ability analysis, only stolon number at 70 days was significant at the five percent level, and then, only for specific combining ability. This suggests that stolon number at 70 days responding primarily to a nonadditive gene action. Variances for specific combining ability, however, were always larger than those for general combining ability for all stolon number characteristics (Tables 23 and 24).

Broad sense heritability estimate for stolon number at 70 days was the highest for the three stolon number characteristics. This estimate also deviated the most from the narrow sense heritability estimate. But the heritability estimates of stolon number characteristics were relatively low in both narrow and broad sense. This indicates that the measured variation in stolon number is largely due to environmental effects rather than genetic difference, especially for the earlier measurement (Table 25).

The results from the analysis of variance, combining ability analysis, and heritability estimates suggest that the measurement at 70 days is controlled primarily by a nonadditive gene system, and is probably a better method to determine the differences among and within groups and to study the nature of gene action than the measurement at 50 days. The additional growth period permits genetic expression of stolon number characteristics, that is not evident at the 50 days stage.

It is suggested that breeding and selection program for higher stolon number would be successful if the breeder could use specific combining ability by crossing, followed by screening in later generation, and choose the later stage of growth for the measurement of this characteristic.

Stolon Length. Total stolon length per plant ranged from 1.20 to 9.80 cm for the measurement at 50 days, from 5.88 to 44.25 cm for the measurement at 70 days after transplanting, and from 4.48 to 22.45 cm for the growth rate. Variation is larger at the 70 day than at the 50 day stage. The single cross average was higher than that of their parents for the measurement at 70 days and the growth rate, and was the highest of the five groups for three stolon length characteristics. The average of test-crosses was significantly higher than that of their parents only for stolon length at 70 days. This indicates an apparent effect of hybrid vigor for the growth of stolon length in single crosses and test-crosses (Table 14 and Appendix Table 3).

Stolon length at 50 days was significantly different among entries, among and within groups, among single crosses, and among the parents of single crosses at the one percent level and among checks at the five percent level. There were significant differences at the one percent level among entries, among and within groups, and for all groups except among test-crosses, for stolon length at 70 days. There were significant differences among entries, among and within groups, and for all groups except among test-cross and among parents of test-cross at the one percent level for growth rate of the stolon length. Differences among test-crosses were not significant for all three stolon length characteristics (Table 16).

Stolon length measurements, both at 50 and 70 days, were significant at the one percent level and the growth rate was significant at the five percent level for specific combining ability. Therefore, these three characteristics respond primarily to a nonadditive gene system. Variance for specific combining ability was also larger than that for general combining ability for all stolon length characteristics (Tables 23 and 24).

Stolon length at 50 days gave a higher broad sense heritability estimate than the growth rate. Narrow sense heritability estimates were low in both characteristics, and the growth rate gave lower narrow sense heritability estimate than the measurement at 50 days. The relative magnitude of deviation between broad and narrow sense heritability estimates, was similar for these two characteristics (Table 25).

The coefficient variation (C. V.) was larger at 50 than at 70 days for stolon length.

Table 16. Mean squares and levels of significance for stolon length characteristics of white clover. (Corvallis, Oregon. 1972)

Source of variation	d. f.	Stolon length at 50 days	Stolon length at 70 days	Stolon length growth rate
Replications	3	13.0814**	70.0890	126.1923*
Entries	49	12.6718**	377.5331**	276.5632**
Among groups	4	43.5431**	2,849.8602**	2,196.7167**
Within groups	45	9.9277**	157.7707**	105.8829**
Among SX	27	12.7959**	151.3404**	94.5856**
Among TX	4	1.9218	32.5245	34.1963
Among checks	2	6.4251*	507.7559**	400.2475**
Among parents of SX	7	9.1651**	187.3405**	126.6053**
Among parents of TX	5	3.3124	111.2994**	77.4807
Error	147	2.4778	46.7958	36.3396

*, ** Significant at the 5 and 1% level, respectively.

It is suggested from the results of the analysis of variance combining ability analysis, and heritability estimates that the improvement of stolon length would be achieved by adopting a hybrid breeding program.

Stolon Diameter and Internode Length. Stolon diameter ranged from 1.96 to 2.85 mm and internode length ranged from 1.06 to 1.95 cm. The comparisons between single crosses and their parent averages, and between test-crosses and their parent averages did not show significant differences for both characteristics. This indicates no apparent hybrid effect for these two characteristics

(Table 14 and Appendix Table 4).

Stolon diameter was significantly different at the one percent level among entries, among and within groups, and for all groups except among test-cross progenies. Stolon internode length was significantly different at the one percent level among entries, among and within groups, among single cross parents, and among test-cross parents (Table 17).

Specific combining ability was significant at the one percent level for stolon diameter but not for internode length. This indicates that stolon diameter responds primarily to a nonadditive gene system (Table 23).

The high broad sense heritability estimate which deviates considerably from the narrow sense heritability estimate for stolon diameter, supports the result of the combining ability analysis (Table 25).

The improvement of stolon diameter would be successful if the breeder could consider the nonadditive gene action in choosing the breeding and selection program.

The measurement of internode length may not be useful at this growth stage because of frequent insignificance in analysis of variance and combining ability analysis, and relatively low heritability.

Table 17. Mean squares and levels of significance for stolon diameter and internode length characteristics of white clover. (Corvallis, Oregon. 1972)

Source of variation	d. f.	Stolon diameter	Internode length
Replications	3	.0505*	1.5196**
Entries	49	.1624**	.2073**
Among groups	4	.9351**	.8372**
Within groups	45	.0831**	.1513**
Among SX	27	.0469**	.0845
Among TX	4	.0046	.1121
Among checks	2	.4390**	.1780
Among parents of SX	7	.0380	.3218**
Among parents of TX	5	.3570**	.2937**
Error	147	.0140	.0645

*, ** Significant at the 5 and 1% level, respectively.

Petiole Characteristics

Petiole Length and Diameter. Petiole length ranged from 8.33 to 14.83 cm and petiole diameter ranged from 1.22 to 2.05 mm. In both characteristics, there were no significant differences between single crosses and their parents averages, and between test-crosses and their parents averages even though some progenies showed hybrid vigor in petiole length (Table 14 and Appendix Table 4).

Differences among entries, among and within groups, among single crosses, among parents of single crosses, and among parents of test-crosses were significant at the one percent level, and differences among test-crosses were significant at the five percent level for the petiole length. There were significant differences at the one percent level among entries, among and within groups, among checks, and among parents of test-crosses, and at the five percent level among parents of single crosses for the petiole diameter (Table 18).

Table 18. Mean squares and levels of significance for petiole length and diameter characteristics of white clover. (Corvallis, Oregon. 1972)

Source of variation	d. f.	Petiole length	Petiole diameter
Replications	3	3.5205*	.1358**
Entries	49	8.0023**	.1100**
Among groups	4	31.3653**	.6944**
Within groups	45	5.5771**	.0581**
Among SX	27	3.1381**	.0184
Among TX	4	4.4093*	.0194
Among checks	2	2.7634	.1008**
Among parents of SX	7	13.5053**	.0486*
Among parents of TX	5	8.5077**	.2974**
Error	147	1.4742	.0165

*, ** Significant at the 5 and 1% level, respectively.

In the combining ability analysis, differences among single crosses were significant at the five percent level for petiole diameter. Specific combining ability was significant for petiole length at the one percent level and for petiole diameter at the five percent level. This suggests both petiole characteristics respond primarily to the effect of a nonadditive gene action (Table 23).

Heritability estimates in the narrow and broad sense for petiole diameter was low, but the broad sense heritability estimate gave large deviation from the narrow sense heritability estimate. The variance for specific combining ability was much larger than that for general combining ability for petiole diameter (Tables 24 and 25).

The breeding program for the improvement of both petiole characteristics would be successful if the nonadditive gene system is properly used by the investigator.

Leaf Characteristics

Leaf Shape (Leaf Width, Leaf Length, and Leaf Ratio). Leaf width, width of middle leaflet of a fully developed trifoliate leaf, ranged from 1.37 to 2.70 cm. Leaf length, length of middle leaflet of the same leaf, ranged from 1.56 to 2.96 cm. Leaf ratio, ratio of leaf length to width, ranged from .99 to 1.44. The average of test-cross parents was significantly higher than that of test-crosses for leaf ratio. There were not significant differences between the

Table 19. Mean squares and levels of significance of leaf shape characteristics of white clover. (Corvallis, Oregon. 1972)

Source of variation	d. f.	Leaf width	Leaf length	Leaf ratio
Replications	1	.0004	.0993	.15690**
Entries	49	.04767**	.15151**	.01397**
Among groups	4	.22785**	.90133**	.05695**
Within groups	45	.03166**	.08486**	.01015**
Among SX	27	.01154	.02436	.00554*
Among TX	4	.02735	.11005**	.00768
Among checks	2	.01820	.10005*	.02250**
Among parents of SX	7	.02769*	.08050*	.00796*
Among parents of TX	5	.15470**	.39140**	.03512**
Error	49	.01128	.02772	.00320

*, ** Significant at the 5 and 1% level, respectively.

averages of parents and progenies although some crosses showed significant positive and negative heterosis for leaf width and length characteristics (Table 14 and Appendix Table 5).

Leaf width was significantly different at the one percent level among entries, among and within groups, and among parents of test-crosses, and at the five percent level among single cross parents. Leaf length was significantly different at the one percent level among entries, among and within groups, among test-crosses, and among parents of test-crosses, and at the five percent level among checks and among parents of single crosses. Leaf ratio was significantly different at the one percent level among entries, among and within groups, among checks and among parents of test-crosses, and at the five percent level among single crosses and among single cross parents (Table 19).

All three characteristics were significantly different among single crosses at the one percent level in the combining ability analysis. Leaf width was significant for general combining ability at the five percent level and for specific combining ability at the one percent level. This was true for leaf length, whereas leaf ratio gave significance at the one percent level only for general combining ability (Table 23). However, the variances of specific combining ability for leaf width and length measurements were larger than those of general combining ability (Table 24). This indicates that the nonadditive effects are more evident than the additive effects for both characteristics. Since leaf ratio was significant for only general combining ability and its variance for general combining ability was larger than that for specific combining ability, it is concluded that leaf ratio responds primarily to an additive gene system. This conclusion was supported by the heritability estimates. Both narrow and broad sense heritability estimates for leaf ratio were very high. This characteristic seems to be controlled primarily by an additive gene system since the broad sense heritability estimate did not deviate much from the narrow sense heritability estimate. On the other hand, the broad sense heritability estimates were very high and narrow sense heritability estimates were relatively low for width and length. These differences support the results from the combining ability analysis for leaf width and length characteristics (Table 25).

Area and Dry Weight Per Leaf, and Specific Leaf Weight (SLW). Area per leaf ranged from 4.64 to 12.54 cm^2 and dry weight per leaf ranged from 10.04 to 27.43 mg. Specific leaf weight (SLW) ranged from 1.92 to 2.48 mg/cm^2. The average of test-cross parents was significantly higher than that of test-crosses for area and dry weight per leaf (Table 14 and Appendix Table 5).

Both area and dry weight per leaf showed significant differences among entries, among and within all five groups at the one percent level. SLW was significantly different among entries, among and within groups, and for all groups except among test-crosses and among checks (Table 20).

In the combining ability analysis, both area and dry weight per leaf were significant for both general and specific combining ability at the one percent level. However, the variance for general combining ability was larger than that of specific combining ability for area per leaf, but this was reversed for dry weight per leaf. The differences between the two variances for both characteristics are small, and it is difficult to identify the primary gene action involved. SLW was significant only for general combining ability at the five percent level, and the variance for general combining

Table 20. Mean squares and levels of significance for area and dry weight per leaf and specific leaf weight (SLW) characteristics of white clover. (Corvallis, Oregon. 1972)

Source of variation	d. f.	Area per leaf	Dry weight per leaf	Specific leaf weight (SLW)
Replications	3	7.8221**	72.4541**	.66880**
Entries	49	9.5898**	50.7238**	.06950**
Among groups	4	5.8315**	237.7022**	.17480**
Within groups	45	5.2587**	34.1035**	.06014**
Among SX	27	1,8565**	12.6001**	.05054**
Among TX	4	2.9213**	15.9612**	.02012
Among checks	2	7.9708**	53.0706**	.04800
Among parents of SX	7	4.0966**	44.5288**	.11063**
Among parents of TX	5	26.0422**	14.2554**	.07810**
Error	147	.7648	3.7819	.02446

*, ** Significant at the 5 and 1% level, respectively.

ability was much larger than that for specific combining ability. This indicates that SLW responds primarily to an additive gene action (Tables 23 and 24).

Heritability estimates for both, area and dry weight per leaf, were about the same. This supports the result from the combining ability analysis. SLW gave lower heritability estimates than the other two characteristics. The deviation of broad sense heritability from narrow sense heritability estimate for SLW was smaller than the other two characteristics (Table 25).

Table 21. Mean squares and levels of significance for diurnal ratio characteristics of white clover. (Corvallis, Oregon. 1972)

Source of variation	d.f.	Diurnal ratio in SLW (AM/Noon)	Diurnal ratio in SLW (Noon/PM)	Diurnal ratio in SLW (AM/PM)
Replication	1	.0021	.0389**	.0279**
Entries	49	.0036	.0034	.0032
Among groups	4	.0076*	.0050	.0044
Within groups	45	.0032	.0033	.0031
Among SX	27	.0024	.0036	.0022
Among TX	4	.0019	.0011	.0018
Among checks	2	.0085	.0081	.0006
Among parents of SX	7	.0069*	.0027	.0070*
Among parents of TX	5	.0018	.0020	.0052
Error	49	.0027	.0046	.0027

*, ** Significant at the 5 and 1% level, respectively.

The broad sense heritability estimates for area and dry weight per leaf were high. For the improvement of these three characteristics, the plant breeder might use a combined breeding and selection program in which he could take advantage of both gene systems.

Diuranal Ratio in Specific Leaf Weight (SLW). There was little variation and few significant differences for the three measurements of diurnal ratio in SLW (Tables 21, 24 and 25). Based on the methods of measurement used in this study, the diurnal ratio of SLW did not contribute to the description of this plant material.

Number of Leaves Per Plant, Total Leaf Area, Leaf Area Ratio (LAR) and Forage Yield. Number of leaves per plant ranged from 6.20 to 31.75 and total leaf area ranged from 42.97 to 232.84 cm^2. Leaf area ratio (LAR), ratio of total leaf area to forage yield, ranged from 102.71 to 209.47 cm^2/gm and forage yield per plant ranged from .29 to 1.67 gm. The average of single crosses was higher than that of their parents for number of leaves, total leaf area, and forage yield per plant. The average of text-crosses was higher than that of their parents for total leaf area and forage yield per plant. This suggests that hybrid vigor is evident (Table 14 and Appendix Table 4 and 6).

There were significant differences at the one percent level among entries, among and within groups, among single crosses, among single crosses parents, and among test-crosses parents for number of leaves per plant. Total leaf area per plant was significantly different among entries, among and within groups, among single crosses, among single crosses parents, and among test-crosses parents at the one percent level, and among test-crosses at the five percent level. LAR was significantly different at the one percent level among entries, among and within entries, among single crosses parents, and among test-crosses parents. Forage yield per plant was significant at the one percent level among entries, among and within groups, among single crosses, among test-crosses,

Table 22. Mean squares and levels of significance for the leaf characteristics and yield of white clover. (Corvallis, Oregon. 1972).

Source of variation	d.f.	Number of leaves per plant	Total leaf area per plant	Leaf area ratio (LAR)	Forage yield per plant
Replications	3	6.9567	3,493.758*	3,103.811	.1900*
Entries	49	172.5635**	8,460.927**	1,268.976**	.4925**
Among groups	4	1,579.8025**	65,497.560**	2,398.336**	3.7721**
Within groups	45	47.4756**	3,391.001**	1,168.589**	.2010**
Among SX	27	49.6133**	3,453.773**	262.729	.1886**
Among TX	4	26.5150	3,347.167*	249.133	.1046**
Among checks	2	13,6000	1,971.588	1,606.077	.0001
Among parents of SX	7	39.9700**	3,203,067**	2,696.158**	.3138**
Among parents of TX	5	76.7580**	3,917.969**	4,502.205**	.2675**
Error	147	14.2381	1,053.784	561.068	.0589

*, ** Significant at the 5 and 1% level, respectively.

Table 23. Mean squares, levels of significance and coefficients of variation (C. V.) in general (GCA) and specific (SCA) combining ability analysis for 23 plant characteristics of 28 white clover single crosses. (Corvallis, Oregon, 1972)

Plant characteristics	Single crosses	GCA	SCA	Error	C. V.
1. Stolon number at 50 days	.6015	.7171	.5610	.4129	33.50%
2. Stolon number at 70 days	.4899**	.5464	.4702*	.2370	10.43%
3. Stolon number growth rate	.3800	.5310	.3269	.2694	18.93%
4. Stolon length at 50 days	12.7959**	19.0263	10.6153**	3.3936	40.80%
5. Stolon length at 70 days	151.3404**	146.3662	153.0814**	64.9372	26.80%
6. Stolon length growth rate	94.5856*	99.3370	92.9226*	51.2878	28.05%
7. Stolon diameter	.04694**	.06353	.04113**	.01450	5.50%
8. Internode length	.08448	.09996	.07907	.0590	13.00%
9. Petiole length	3.1381**	2.9690	3.1973**	1.0954	8.77%
10. Petiole diameter	.01844*	.01872	.01834*	.01062	7.71%
11. Number of leaves per plant	49.6133**	66.8429	43.5830**	12.9273	14.99%
12. Leaf width	.011544**	.022186*	.007820**	.003022	3.44%
13. Leaf length	.02436**	.05017*	.01533**	.00586	4.30%
14. Leaf ratio	.005541**	.016586**	.001675	.001281	3.22%
15. Area per leaf	1.8565**	4.7759**	.8347**	.3635	8.98%
16. Dry weight per leaf	12.6001**	31.6356**	5.9317**	2.7351	11.67%
17. Specific leaf weight (SLW)	.05037**	.10371*	.03193	.02277	7.10%
18. Total leaf area per plant	3,453.773**	4,429.311	3,112.335**	1,300.776	22.36%
19. Leaf area ratio (LAR)	262.7291	353.5039	230.9580	266.7006	12.79%
20. Diurnal ratio in SLW (AM/Noon)	.0024	.0017	.0026	.0033	5.96%
21. Diurnal ratio in SLW(Noon/PM)	.0036	.0023	.0040	.0033	6.04%
22. Dirunal ratio in SLW(AM/PM)	.0022	.0012	.0025	.0031	6.10%
23. Forage yield per plant	.1886**	.2210	.1773**	.0723	21.12%

*, ** Significant at the 5 and 1% level, respectively.

Table 24. Variances of general (GCA) and specific (SCA) combining ability for plant characteristics of white clover. (Corvallis, Oregon. 1972)

Plant characteristics	Variances for GCA	Variances for SCA
1. Stolon number at 50 days	.0065	.0370
2. Stolon number at 70 days	.0032	.0583
3. Stolon number growth rate	.0086	.0151
4. Stolon length at 50 days	.3505	1.80543
5. Stolon length at 70 days	--*	22.0361
6. Stolon length growth rate	.2672	10.4087
7. Stolon diameter	.00090	.00666
8. Internode length	.00089	.00679
9. Petiole length	--*	.5255
10. Petiole diameter	.000015	.001930
11. Number of leaves per plant	.9692	7.6639
12. Leaf width	.001197	.002399
13. Leaf length	.00290	.00474
14. Leaf ratio	.00124	.000194
15. Area per leaf	.1642	.1178
16. Dry weight per leaf	1.0707	1.2042
17. Specific leaf weight (SLW)	.00299	.00229
18. Total leaf area per plant	54.8740	452.8896
19. Leaf area ratio (LAR)	5.1061	--*
20. Dirunal ratio in SLW (AM/Noon)	--*	--*
21. Diurnal ratio in SLW (Noon/PM)	--*	--*
22. Diurnal ratio in SLW (AM/PM)	--*	--*
23. Forage yield per plant	.00182	.02625

* Negative value.

Table 25. Heritability estimates for plant characteristics of white clover, calculated on the basis of components of variance from the combining ability analysis and on the basis of regression of SX on mid-parents. (Corvallis, Oregon. 1972)

Plant characteristics	From combining ability analysis		Regression of SX on MP
	Broad sense heritability estimates	Narrow sense heritability estimates	
1. Stolon number at 50 days	29.66	4.43	.5678
2. Stolon number at 70 days	50.92	2.63	.0246
3. Stolon number growth rate	25.95	9.40	-.3927
4. Stolon length at 50 days	71.76	11.67	.9925
5. Stolon length at 70 days	--*	--*	.2084
6. Stolon length growth rate	45.53	1.14	.1170
7. Stolon diameter	67.66	8.25	.5421
8. Internode length	37.13	4.22	.1435
9. Petiole length	--*	--*	.2643
10. Petiole diameter	42.28	..33	.4111
11. Number of leaves per plant	72.76	8.17	.2618
12. Leaf width	82.64	27.51	.3711
13. Leaf length	84.00	31.94	.4295
14. Leaf ratio	81.80	70.61	.7976
15. Area per leaf	75.63	44.04	.7500
16. Dry weight per leaf	73.24	41.91	.5407
17. Specific leaf weight (SLW)	48.12	27.25	.5573
18. Total leaf area per plant	60.96	6.59	.5976
19. Leaf area ratio (LAR)	--*	--*	.1780

Continued

Table 25--Continued.

Plant characteristics	From combining ability analysis		Regression of SX on MP
	Broad sense heritability estimates	Narrow sense heritability estimates	
20. Dirunal ratio in SLW (AM/Noon)	--*	--*	.2400
21. Diurnal ratio in SLW (Noon/PM)	--*	--*	-.2543
22. Diurnal ratio in SLW (AM/PM)	--*	--*	-.1135
23. Forage yield per plant	60.83	3.94	.4361

* Negative values are involved in calculation.

among single crosses parents and among test-crosses parents (Table 22).

Number of leaves per plant was significant only for specific combining ability at the one percent level. This was also true for total leaf area and forage yield per plant. Variances of specific combining ability for these three characteristics were much larger than those of general combining ability. LAR was not significant for combining ability. This indicates these three characteristics respond primarily to a nonadditive gene action (Tables 23 and 24).

These three characteristics gave high broad and low narrow sense heritability estimates. This supports the same conclusion as the results of combining ability analysis (Table 25).

For the improvement of these characteristics the breeder should take advantage of hybrid vigor and nonadditive gene action by crossing and screening through a hybrid breeding program.

Association Among Plant Characteristics

Correlation Among Plant Characteristics. Simple correlation coefficients among 23 plant characteristics were listed in Table 26.

Plant characteristics which correlated significantly with forage yield were stolon number at 50 and 70 days, three stolon length measurements, stolon diameter, petiole length and diameter, number of leaves per plant, leaf length, area and dry weight per leaf, specific leaf weight, and total leaf area per plant (Table 26).

Stolon number at 70 days was correlated significantly with stolon number at 50 days, three measurements of stolon length, petiole length, number of leaves per plant, and total leaf area. And it had high correlation with forage yield. Although stolon number at 50 days had higher and significant correlation with forage yield, stolon number at 70 days is more biologically sound to use it for path-coefficient analysis because of its closeness to harvesting date for forage yield (Tables 26 and 27).

Stolon length at 70 days was significantly correlated with stolon number at 50 and 70 days, stolon length at 50 days and the growth rate, internode and petiole length, number of leaves per plant, dry weight per leaf and SLW, and total leaf area per leaf. And it had high correlation with forage yield. Although stolon length at 50 days had a higher and a significant correlation with forage yield, the later measurement of stolon length was used for the same reason as stolon number (Tables 26 and 27). The close associations of stolon length at 70 days with dry weight per leaf and SLW were not clear.

Stolon diameter was significantly correlated with petiole length and diameter, leaf width and leaf length, area and dry weight per leaf, total leaf area, and forage yield per plant.

Petiole length had significant correlation with stolon number

Table 26. Simple correlation coefficients* among plant characteristics in 28 single crosses of white clover. (Corvallis, Oregon. 1972)

		X_3	X_5	X_7	X_9	X_{11}	X_{13}	X_{15}	X_{17}
Stolon number at 50 days	X_1	.6373	-.5140	.8217	.5814	.4377	.2910	-.0848	.6186
Stolon number at 70 days	X_3		.3181	.6064	.5592	.4878	.0443	.0493	.3794
Stolon number growth rate	X_5			-.3006	-.0583	.0362	-.2415	.1475	-.3416
Stolon length at 50 days	X_7				.7848	.6278	.2678	.0786	.6477
Stolon length at 70 days	X_9					.9747	.2688	.4537	.5876
Stolon length growth rate	X_{11}						.2432	.5425	.5078
Stolon diameter	X_{13}							.1639	.5171
Internode length	X_{15}								.3797
Petiole length	X_{17}								
Petiole diameter	X_{19}								
Number of leaves per plant	X_{21}								
Leaf width	X_{23}								
Leaf length	X_{25}								
Leaf ratio	X_{27}								
Area per leaf	X_{29}								
Dry weight per leaf	X_{31}								
Specific leaf weight (SLW)	X_{33}								
Total leaf area per plant	X_{35}								
Leaf area ratio (LAR)	X_{37}								
Diurnal ratio in in SLW (AM/Noon)	X_{39}								
Dirunal ratio in SLW (Noon/PM)	X_{41}								
Diurnal ratio in SLW (AM/PM)	X_{43}								
Forage yield per plant	X_{45}								

Table 26--Continued.

		X_{19}	X_{21}	X_{23}	X_{25}	X_{27}	X_{29}	X_{31}	X_{33}
Stolon number at 50 days	X_1	.2634	.8081	.1991	.2204	.1053	.2886	.4535	.5480
Stolon number at 70 days	X_3	-.1970	.7805	-.0621	-.0836	-.0679	-.0315	.0464	.1926
Stolon number growth rate	X_5	-.5174	-.0865	-.2881	-.3480	-.1865	-.3540	-.4731	-.4537
Stolon length at 50 days	X_7	.2002	.7911	.1824	.2540	.1631	.2557	.4720	.6494
Stolon length at 70 days	X_9	.0537	.6506	.0466	.3211	.3444	.2710	.3919	.4517
Stolon length growth rate	X_{11}	-.0116	.5364	-.0066	.3049	.3624	.2463	.3181	.3277
Stolon diameter	X_{13}	.5929	.1374	.4938	.4775	-.0059	.6536	.6416	.2593
Internode length	X_{15}	.1066	-.0922	.2600	.1734	.1316	.2622	.3102	.2555
Petiole length	X_{17}	.4505	.4003	.4396	.4081	-.0210	.5143	.5992	.4766
Petiole diameter	X_{19}		.0641	.4941	.5487	.1999	.6698	.6630	.2843
Number of leaves per plant	X_{21}			.0093	.0398	.1208	.0820	.2014	.3285
Leaf width	X_{23}				.4299	.0143	.3948	.5297	.4519
Leaf length	X_{25}					.6686	.7871	.7348	.2412
Leaf ratio	X_{27}						.3893	.4128	.2456
Area per leaf	X_{29}							.9099	.2368
Dry weight per leaf	X_{31}								.6134
Specific leaf weight (SLW)	X_{33}								
Total leaf area per plant	X_{35}								
Leaf area ratio (LAR)	X_{37}								
Diurnal ratio in SLW (AM/Noon)	X_{39}								
Diurnal ratio in SLW (Noon/PM)	X_{41}								
Diurnal ratio in SLW (AM/PM)	X_{43}								
Forage yield per plant	X_{45}								

Table 26--Continued.

		X_{35}	X_{37}	X_{39}	X_{41}	X_{43}	X_{45}
Stolon number at 50 days	X_1	.7746	-.0395	-.1188	.2812	.2579	.8146
Stolon number at 70 days	X_3	.5881	-.0153	-.1733	.1319	.1800	.6009
Stolon number growth rate	X_5	-.2518	.0650	-.0557	-.1496	-.0534	-.2979
Stolon length at 50 days	X_7	.7623	-.0922	-.1674	.3107	.3067	.8170
Stolon length at 70 days	X_9	.6656	-.0315	-.2641	.1953	.1625	.6634
Stolon length growth rate	X_{11}	.5632	-.0082	-.2659	.1310	.0937	.5409
Stolon diameter	X_{13}	.4697	.0189	-.1492	.3290	.1195	.4601
Internode length	X_{15}	.0969	-.1468	.0506	.0923	-.1276	.1270
Petiole length	X_{17}	.6065	-.0639	.0017	.2187	.0439	.6383
Petiole diameter	X_{19}	.4309	.0425	.0351	.2766	.1187	.4517
Number of leaves per plant	X_{21}	.8181	.1855	-.1735	.3116	.4561	.7765
Leaf width	X_{23}	.2290	-.2618	-.3004	.7742	.0269	.3483
Leaf length	X_{25}	.4741	-.1825	-.1858	.1754	-.1448	.5309
Leaf ratio	X_{27}	.3196	-.1187	-.2717	.1274	-.0591	.3454
Area per leaf	X_{29}	.6316	.1006	.1425	.0604	-.0422	.5954
Dry weight per leaf	X_{31}	.6739	-.0786	.0639	.2748	.0725	.7055
Specific leaf weight (SLW)	X_{33}	.3886	-.4144	-.1068	.4868	.2410	.5455
Total leaf area per plant	X_{35}		.2149	-.0757	.2897	.3356	.9410
Leaf area ratio (LAR)	X_{37}			.1667	-.1204	.2766	-.1132
Diurnal ratio in SLW(AM/Noon)	X_{39}				-.5769	.2121	-.1373
Diurnal ratio in SLW (Noon/PM)	X_{41}					.4009	.3625
Diurnal ratio in SLW (AM/PM)	X_{43}						.2585
Forage yield per plant	X_{45}						

* Correlation coefficients of .373 and .478 are significant at the 5 and 1% level, respectively.

at 50 and 70 days, three measurements of stolon length, stolon diameter and internode length, petiole diameter, number of leaves per plant, leaf width and length, area and dry weight per leaf, SLW, total leaf area per plant, and forage yield.

Number of leaves per plant was significantly correlated with stolon number at 50 and 70 days, three stolon length characteristics, petiole length, total leaf area per plant, diurnal ratio in SLW (AM/PM), and forage yield.

Dry weight per leaf was significantly correlated with stolon number at 50 days, stolon length at 50 and 70 days, stolon diameter, petiole length and diameter, leaf width, and length, leaf ratio, area per leaf, SLW, total leaf area per plant, and forage yield per plant. It had a negative association with stolon number growth rate.

Important plant characteristics have close associations with each other and most relationships are biologically sound. These close associations will be helpful to the plant breeder.

Path-coefficient Analysis. Among 22 variables representing plant characteristics, seven important variables were chosen on the basis of simple correlation coefficients with forage yield and their biological meaning. A path-coefficient analysis was determined using 28 single crosses performances on these seven independent variables and forage yield.

The partial regression predictive equation based on the following eight variables, with yield as the dependent variable, was generated:

X_3 = stolon number at 70 days.

X_9 = stolon length at 70 days.

X_{13} = stolon diameter

X_{17} = petiole length

X_{19} = petiole diameter

X_{21} = number of leaves per plant

X_{31} = dry weight per leaf

Y = forage yield

$$Y = -1.4498 + .1367 X_3 + .0013 X_9 - .0773 X_{13} - .0044 X_{17} + .4788 X_{19} + .0296 X_{21} + .0642 X_{31}$$

The multiple correlation coefficient for these seven variables was R = .9664, and coefficient of determination was $R^2 = .9341$. Thus, 93 percent of the variation in forage yield is accounted for by variation in the seven independent variables.

The direct and indirect effects of these seven variables of forage yield are listed in Table 27. Dry weight per leaf had the largest direct effect, and number of leaves per plant had the next largest direct effects on forage yield. Stolon diameter and petiole length had negative direct effects. Indirect effects were small, negligible or negative except through number of leaves per plant

Table 27. Path-coefficient analysis for seven variables on yield in 28 single crosses of white clover (Corvallis, Oregon. 1972)

Stolon number at 70 days		Stolon length at 70 days	
Direct[1]	.2195	Direct	.0388
via stolon length[2]	.0217	via stolon number	.1227
via stolon diameter	-.0017	via stolon diameter	-.0103
via petiole length	-.0068	via petiole length	-.0105
via petiole diameter	-.0298	via petiole diameter	.0079
via number of leaves	.3731	via number of leaves	.3110
via dry wt. per leaf	.0242	via dry wt. per leaf	.2047
r =	.6009	r =	.6634

Stolon diameter		Petiole length	
Direct	-.0384	Direct	-.0179
via stolon number	.0097	via stolon number	.0833
via stolon length	.0104	via stolon length	.0228
via petiole length	-.0093	via stolon diameter	-.0199
via petiole diameter	.0872	via petiole diameter	.0663
via number of leaves	.0657	via number of leaves	.1913
via dry wt. per leaf	.3351	via dry wt. per leaf	.3130
r =	.4601	r =	.6383

Petiole diameter		Number of leaves per plant	
Direct	.1471	Direct	.4780
via stolon number	-.0432	via stolon number	.1713
via stolon length	.0021	via stolon length	.0252
via stolon diameter	-.0228	via stolon diameter	-.0053
via petiole length	-.0081	via petiole length	-.0072
via number of leaves	.0306	via petiole diameter	.0094
via dry wt. per leaf	.3463	via dry wt. per leaf	.1052
r =	.4517	r =	.7765

Continued

Table 27--Continued.

Dry weight per leaf	
Direct	.5223
via stolon number	.0102
via stolon length	.0152
via stolon diameter	-.0246
via petiole length	-.0107
via petiole diameter	.0975
via number of leaves	.0963
r =	.7065

[1] The direct effect is the standardized partial regression coefficient between stolon number and yield.

[2] Via stolon length is the indirect effect of stolon number on yield through stolon length, calculated by = correlation between stolon number and stolon length times the standardized partial regression coefficient between stolon length and yield.

and dry weight per leaf. Of the stolon components of yield stolon number at 70 days had the largest direct effect. Petiole diameter had larger direct effect on yield than petiole length. Leaf components of yield had larger direct and indirect effects than stolon and petiole components of yield (Table 27).

From this study, the relative contribution of leaf, petiole, stolon components on yield became obvious. Leaf components, dry weight per leaf and number of leaves per plant, had the largest direct and indirect effects on yield although forage yield in this study included most above ground parts of the plant.

Relationships Between Single Cross and Mid-Parent. Simple correlation coefficients (r) and simple coefficient of determination (r^2) between single crosses and their respective mid-parent values for plant characteristics are listed on Table 28. There were significant relationships between single crosses and their parents for stolon length at 50 days, petiole diameter, leaf length, leaf ratio, area per leaf, dry weight per leaf, and specific leaf weight. These characteristics were significant for general combining ability and gave relatively high narrow sense heritability estimates (Tables 23, 25 and 28).

These relationships are true for the simple regression coefficient of single crosses on mid-parent (Tables 25 and 28). These relationships could be explained and justified in terms of gene action. However, the simple regression coefficients of single cross on mid-parent did not agree well with the heritability estimates from combining ability variances.

Relationships Between Seed and Plant Characteristics

Simple correlation coefficients between important seed and plant characteristics and simple regression coefficients of seed characteristics on plant characteristics were listed on Tables 29 and 30.

Plant characteristics which were correlated with 25 seed weight

Table 28. Correlation coefficients* (r) and simple coefficients of determination (r^2) between single cross and mid-parent for plant characteristics of white clover. (Corvallis, Oregon. 1972)

Plant characteristics	r	r^2
Stolon number at 50 days	.1789	.0320
Stolon number at 70 days	.0296	.0009
Stolon number growth rate	-.4361	.1902
Stolon length at 50 days	.5152	.2654
Stolon length at 70 days	.1469	.0216
Stolon length growth rate	.0845	.0071
Stolon diameter	.3174	.1007
Internode length	.1740	.0303
Petiole length	.3441	.1184
Petiole diameter	.4418	.1951
Number of leaves per plant	.1465	.0215
Leaf width	.1221	.0149
Leaf length	.4866	.2367
Leaf ratio	.5836	.3406
Area per leaf	.6934	.4808
Dry weight per leaf	.6341	.4021
Specific leaf weight (SLW)	.5223	.2728
Total leaf area per plant	.3588	.1287
Leaf area ratio (LAR)	.3556	.1265
Diurnal ratio in SLW (AM/Noon)	.2539	.0647
Diurnal ratio in SLW (Noon/PM)	-.0750	.0056
Diurnal ratio in SLW (AM/PM)	-.1272	.0162
Forage yield per plant	.3530	.1246

* Correlation coefficients of .373 and .478 are significant at the 5 and 1% level, respectively.

Table 29. Simple correlation coefficients* between plant and seed and seedling vigor characteristics based on the performance of 28 single crosses of white clover. (Corvallis, Oregon. 1972)

Plant characteristics	Seed and seedling vigor characteristics			
	25-seed weight	ATP content per seed	ATP content per mg of seed	Seedling vigor index
Stolon number at 70 days	.3900	.1029	-.1569	.0342
Stolon length at 70 days	.3211	.1242	-.1676	.0811
Stolon diameter	.3170	-.0898	-.3125	.1967
Petiole length	.5226	-.2231	-.5577	.1269
Petiole diameter	.0859	-.1445	-.1923	.1340
Number of leaves per plant	.3056	.0359	-.1897	.0581
Leaf width	.1761	.1921	-.0371	.3175
Leaf length	.0240	.0181	-.0503	.1600
Leaf ratio	-.1386	.1318	.1795	.1150
Area per leaf	.3192	-.0561	-.3267	.1514
Dry weight per leaf	.4580	-.0237	-.3831	.1197
Specific leaf weight	.4421	.0079	-.3041	-.0495
Diurnal ratio in SLW (AM/PM)	.0566	-.0269	-.0707	-.0475
Forage yield	.3991	.4943	-.3025	.1002

* Correlation coefficients of .373 and .478 are significant at the 5 and 1% level, respectively.

Table 30. Simple regression coefficients between plant and seed and seedling vigor characteristics based on the performance of 28 single crosses of white clover. (Corvallis, Oregon. 1972)

Plant characteristics	Seed and seedling vigor characteristics			
	25-seed weight	ATP content per seed	ATP content per mg of seed	Seedling vigor indes
Stolon number at 70 days	.0735	.0019	-.0014	.0074
Stolon length at 70 days	1.0655	.0413	-.0256	.3094
Stolon diameter	.0185	-.0005	-.0008	.0132
Petiole length	.2498	-.0107	-.0123	.0697
Petiole diameter	.0031	-.0005	-.0003	.0056
Number of leaves per plant	.5808	.0068	-.0165	.1269
Leaf width	.0210	.0023	-.0002	.0435
Leaf length	.0014	.0001	-.0001	.0109
Leaf ratio	-.0040	.0004	.0002	.0038
Area per leaf	.1174	-.0021	-.0055	.0640
Dry weight per leaf	.4386	-.0023	-.0169	.1316
Specific leaf weight (SLW)	.0265	.0004	-.0008	-.0034
Diurnal ratio in SLW (AM/PM)	.0010	-.0003	-.0006	-.0010
Forage yield	.0470	.0003	-.0016	.0135

were stolon number at 70 days, petiole length, dry weight per leaf, specific leaf weight, and forage yield.

ATP content per seed was significantly correlated with forage yield at the one percent level. ATP content per mg of seed had a negative relationship with petiole length.

The seedling vigor index was not significantly correlated with any plant characteristic studied.

25-seed weight and ATP content per seed may be good indicators for forage yield. Since ATP content per seed has significantly correlated with the seedling vigor index, ATP content per seed may serve as a better selecting tool for high forage yield, as well as seed and seedling vigor.

DISCUSSION

Seed and Seedling Vigor Characteristics

All seed and seedling vigor characteristics except respiration quotient (RQ) measurements resulted in significant differences among and within most groups. These differences represent the source of genetic improvement used by plant breeders. These differences suggest that one may expect to improve seedling vigor of this species by breeding and selection.

In this study most seed and seedling vigor characteristics including, seed weight, ATP content in seed, oxygen uptake measurements, carbon dioxide evolution per mg of seed, and seedling vigor index responded to specific combining ability. Seed weight was also significant for general combining ability. However, the variance due to general combining ability was smaller than that due to specific combining ability. Therefore, the nonadditive genetic effects are more evident than the additive genetic effects. The seed and seedling vigor characteristics expressed relatively high broad sense and low narrow sense heritability estimates. The relatively large difference between these two heritability estimates is as expected, based on the conclusions from the combining ability analysis. It is suggested the plant breeder can take advantage of nonadditive gene action with a hybrid breeding program, followed by selection in later generations.

Among the various criteria used to measure seed and seedling vigor in this study, ATP content measurements in the seed, and seedling vigor index were in close agreement. ATP content may be a good indicator of seedling vigor.

A negative association of seed weight with ATP content per mg of seed and poor relationships of seed weight with the other seed and seedling vigor characteristics was apparent in the correlation study which was based on 28 single crosses, representing one population. This association was true in the comparison of two types of white clover in the check group. These two types are believed to represent two different populations. This may indicate that selection for heavier seed weight in white clover may result in lower ATP content per mg of seed and may not result in improvement for other seed and seedling vigor characteristics.

RQ measurements appear to be of little value as a selection tool due to the small variation among entries. This lack of variation may be because of the close association between oxygen uptake and carbon dioxide evolution measurements. RQ is the ratio of these two measurements.

The predominant nonadditive gene action for most seed and seedling vigor characteristics suggests that hybridization and selection would be a satisfactory breeding program to follow.

Plant Characteristics

Most plant characteristics, except internode length, leaf area ratio (LAR) and diurnal ratios in specific leaf weight (SLW) exhibited large differences among and within groups. Due to the lack of differences, for internode length, LAR and diurnal ratios in SLW, they may be of little value as selection criteria in a breeding program. Most of other plant characteristics showed apparent hybrid vigor.

Results from the combining ability analysis indicate that most stolon and petiole characteristics, and forage yield, were significant for specific combining ability. Their variances for specific combining ability were also larger than those for general combining ability. This suggests that these characteristics also respond primarily to nonadditive gene action. These characteristics resulted in relative low narrow and high broad sense heritability estimates. The differences between broad and narrow sense heritability estimates were relatively large. This is as expected for characteristics that are controlled by gene systems that deviate from the additive scheme.

Results of this study suggest the later measurements of stolon number and length for determining genetic differences in these characteristics are desirable.

Among the leaf characteristics, number of leaves per plant and total leaf area per plant were significant only for specific combining ability.

Leaf ratio and SLW were significant only for general combining ability. This indicated that the effects of additive gene action was more evident than that of nonadditive. These two characteristics exhibited relatively small differences between their broad and narrow sense heritability estimates. For characteristics influenced to a large extent by an additive gene system, we would expect these two estimates to be similar.

Leaf width and length, area and dry weight per leaf, were significant for both general and specific combining ability. For leaf width and length, variances for specific combining ability were larger than those of general combining ability. It is concluded for these characteristics that the nonadditive effects are more evident than the additive. The heritability estimates support this conclusion. However, area and dry weight per leaf did not show an apparent difference between the variance for general combining ability and the variance for specific combining ability. Therefore, it appears that additive and nonadditive gene actions are equally important. The breeder should use a breeding approach for the improvement of these two characteristics, such as recurrent selection, that would utilize both gene systems.

The investigator may wish to select for closely related characteristics such as dry weight per leaf (r=.9099) in which the measuring procedure is simple and when the experimental population is large. The plant breeder may wish to disregard area per leaf because it is so closely associated with dry weight per leaf and the latter has a close relationship with forage yield per plant. This was strongly supported by the results from the path-coefficient analysis where dry weight per leaf had a high direct and indirect effect on forage yield.

In general, it is concluded that most of the important characteristics, including forage yield, respond to a nonadditive gene system. In addition, the apparent hybrid vigor, especially the large magnitude of positive heterosis in forage yield, may justify additional expense in hybrid seed production. The ease of vegetative propagation and the prevalence of self-incompatibility mechanisms in this species make single cross and double cross hybrids a definite possibility. Two clone synthetic variety development would be advisable for this species.

Association studies showed that important plant characteristics when directly measured were closely related to each other. The reasons for the unexpected outcome of the third characteristics derived from two biologically related variables may be due to the close associations between paired variables which resulted in an entirely different pattern of variation for the derived characteristics.

The path-coefficient analysis showed that leaf components of yield, dry weight per leaf and number of leaves per plant, had the largest direct and indirect effects on forage yield. The relative contribution of leaf components on yield must be magnified in pasture where white clover is commonly grown.

The associations between the performances of single crosses and their mid-parent were high for those characteristics which gave relatively high narrow sense heritability estimates based on the combining ability analysis. However, the simple regression coefficients of single cross on mid-parent were not in good agreement with the heritability estimates from the combining ability analysis.

The association study between seed and plant characteristics suggested that ATP content per seed may be a useful criteria for selection of high forage yield and seedling vigor.

SUMMARY

Ten seed and seedling vigor characteristics including 25-seed weight, ATP content in seed, seed respiration, and seedling vigor index were studied for a diallel cross consisting of 28 single crosses, five test-crosses, four checks, and eight open-pollinated seed and seedlings.

Measurements of 23 plant characteristics on stolon, petiole, leaf and forage yield, were examined to study the genetic differences, types of gene action, and associations for these characteristics on an eight clones diallel cross, five test-crosses, three checks, the eight parental clones of single crosses, and six parent clones of the test-crosses.

The important conclusions of this study are summarized as follows:

1. There were significant differences among and within the groups of plant material, for all seed characteristics except RQ values.
2. Most of the seed characteristics responded primarily to the nonadditive type of gene action. This suggests that the plant breeder should design his program to develop varieties where hybrid vigor can be used to advantage.

3. Among the criteria used in this study to measure seed and seedling vigor, ATP content per seed was closely associated with seedling vigor index.
4. The associations of seed weight with other seed and seedling vigor characteristics were negative or poor.
5. Most plant characteristics, except internode length, LAR and diurnal ratio in SLW, had large variations resulting in significant differences among and within most groups.
6. These characteristics showed apparent hybrid vigor when progenies were compared with their respective mid-parents.
7. Stolon and petiole characteristics responded primarily to nonadditive gene action.
8. Genetic differences were more readily identified for stolon number and length when measurements were taken after 70 days of growth.
9. Among the leaf characteristics, leaf width and length, number of leaves per plant, and total leaf area per plant responded primarily to nonadditive gene action.
10. Leaf ratio and SLW responded primarily to additive gene action.
11. Area and dry weight per leaf appeared to respond equally to additive and nonadditive gene action.

12. Among plant characteristics, yield components, such as stolon number, length, and diameter, petiole length, number of leaves per plant, and dry weight per leaf were closely related to each other.

13. The leaf components of forage yield, dry weight per leaf and number of leaves per plant, had the highest direct and indirect effects on forage yield per plant among the yield components.

14. ATP content per seed was highly correlated with certain plant characteristics, including forage yield per plant.

15. It is concluded that the plant breeder may use the hybrid approach to white clover variety development, because of the large extent of hybrid vigor and nonadditive gene action observed in this study. In addition, ease of vegetative propagation and prevalence of self-imcompatibility mechanisms in white clover make this conclusion a definite possibility. Parent genotypes may be developed by a recurrent selection procedure, then crossed on a two clone synthetic basis for testing purposes.

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APPENDIX

Appendix Table 1. Means, standard errors of the mean ($s\bar{x}$) and coefficients of variation (C. V.) for five characteristics of white clover. (Corvallis, Oregon. 1972)

Identification number *	25-seed weight		ATP content per seed		ATP content per mg of seed		O_2 uptake per 25-seed		O_2 uptake per mg of seed	
	SX Progeny and Mid-OP Progeny									
	SX	MOP	SX	MOP	SX	MOP	SX	MOP	SX	MOP
1	15.4	12.4	159.0	207.7	236.2	337.1	3.099	4.053	.1981	.2341
2	16.1	13.4	165.5	208.9	235.7	317.8	4.678	4.081	.3005	.2240
3	17.8	12.8	176.9	213.0	277.0	331.9	4.864	4.299	.2697	.2013
4	16.2	12.7	206.1	204.5	299.0	344.5	3.539	3.669	.2284	.2565
5	14.8	13.4	146.0	198.8	263.2	298.4	5.619	3.140	.3351	.2175
6	15.2	12.5	215.8	206.1	334.5	331.3	3.891	4.040	.2563	.2363
7	17.3	13.2	185.0	205.3	261.3	310.5	4.907	3.674	.2844	.3698
8	14.9	12.6	199.6	223.5	313.2	361.2	6.537	5.227	.5630	.2799
9	13.3	12.1	157.4	227.6	283.1	375.3	4.445	5.446	.3463	.2572
10	13.6	11.9	165.5	219.1	294.4	367.9	3.188	4.816	.1995	.3124
11	13.2	12.7	178.5	213.4	301.3	341.8	4.486	4.287	.3114	.2734
12	13.4	11.8	191.5	220.7	330.1	374.7	4.440	5.187	.2978	.2922
13	14.0	12.5	157.4	219.9	254.8	353.9	4.253	4.821	.2736	.4257
14	13.3	13.0	160.6	228.8	258.2	355.9	5.432	5.474	.3906	.2471
15	15.9	12.9	193.1	220.3	290.1	348.5	4.562	4.844	.2947	.3022
16	17.3	13.6	180.1	214.6	255.5	222.4	4.629	4.315	.2692	.2633
17	18.1	12.7	179.1	221.9	249.5	355.4	4.153	5.215	.2302	.2820
18	17.3	13.4	201.2	221.1	283.7	334.5	5.607	4.849	.3270	.1629
19	10.9	12.3	191.5	224.3	360.1	362.6	4.551	5.062	.4556	.2796
20	14.9	13.0	207.7	218.6	343.2	336.5	5.561	4.533	.3584	.2406
21	13.3	12.1	163.9	225.9	285.1	369.5	4.107	5.433	.3059	.2594
22	16.0	12.9	197.9	225.1	316.4	348.6	6.163	5.067	.3854	.3929
23	14.1	12.9	185.0	210.1	319.1	329.1	4.549	3.903	.4157	.2958
24	12.3	12.0	170.4	217.4	261.8	362.1	3.323	4.803	.2830	.3145
25	14.6	12.7	163.1	216.6	250.8	341.2	5.122	4.437	.3722	.4480

Continued

Appendix Table 1--Continued.

Identification number	25-seed weight		ATP content per seed		ATP content per mg of seed		O_2 uptake per 25-seed		O_2 uptake per mg of seed	
	SX	MOP	SX	MOP	SX	MOP	SX	MOP	SX	MOP
26	11.9	12.7	207.7	211.7	377.0	336.0	4.028	4.274	.2988	.2756
27	15.6	13.5	173.6	210.9	277.9	315.1	3.830	3.908	.2422	.4091
28	13.2	12.6	181.7	218.2	333.5	348.1	5.328	4.809	.2828	.4278
Average	14.7	12.7	180.7	216.2	290.9	342.5	4.585	4.559	.3132	.3012
$s_{\bar{x}}$	.3236		6.4683		11.0229		.4883		.0148	
C.V.	4.39%		7.16%		7.58%		15.06%		21.20%	
					TX Progeny					
29	15.4		179.3		268.6		4.570		.2930	
30	16.7		175.2		282.7		4.155		.2534	
31	15.6		164.7		259.6		4.800		.3044	
32	15.4		169.6		253.5		3.738		.2436	
33	18.9		181.7		259.3		4.245		.2213	
Average	16.4		171.4		264.7		4.301		.2631	
					OP Progeny					
51	13.7		193.1		293.7		2.906		.1782	
52	11.7		222.3		380.5		5.199		.2900	
53	13.5		224.7		341.8		5.255		.2697	
54	12.4		232.8		370.0		5.692		.2244	
55	12.2		215.8		355.2		4.432		.3347	
56	13.6		204.4		303.0		3.374		.2568	
57	11.9		219.0		368.9		5.174		.2943	
58	13.3		217.4		327.2		4.442		.5613	
Average	12.7		216.2		342.5		4.559		.3012	

Continued

Appendix Table 1--Continued.

Identification number	25-seed weight	ATP content per seed	ATP content per mg of seed	O_2 uptake per 25 seed	O_2 uptake per mg of seed
	SX MOP	SX MOP	SX MOP	SX MOP	SX MOP
			Checks		
59	12.5	145.2	233.3	2.532	.1896
34	11.3	101.4	176.6	4.111	.4334
35	18.2	65.7	88.4	1.985	.1126
36	13.0	149.3	252.6	2.954	.2156
Average	13.7	115.4	187.6	2.895	.2378
Grand mean	14.5	180.5	288.0	4.399	.2988
$s\bar{x}$	.3290	6.2187	10.9040	.4773	.0139
C.V.	4.55%	6.89%	7.57%	15.34%	20.79%

* Identification number in Table 1.

Appendix Table 2. Means, standard errors of the mean ($s\bar{x}$) and coefficients of variation (C. V.) for five characteristics of white clover. (Corvallis, Oregon. 1972)

Identification number*	CO_2 evolved per 25-seed		CO_2 evolved per mg of seed		RQ per 25-seed		RQ per mg of seed		Seedling vigor index	
	SX Progeny and Mid-OP Progeny									
	SX	MOP	SX	MOP	SX	MOP	SX	MOP	SX	MOP
1	2.362	2.431	.1490	.1984	.751	.589	.738	.823	7.67	11.40
2	3.342	2.544	.2434	.1801	.707	.607	.823	.788	8.11	11.43
3	3.218	2.846	.2577	.2131	.664	.634	.955	.802	8.86	11.63
4	1.851	2.321	.1810	.2141	.512	.618	.807	.809	12.47	10.68
5	4.536	1.906	.2443	.1873	.805	.602	.877	.840	6.66	10.65
6	2.791	2.799	.2326	.2055	.719	.661	.905	.841	12.62	11.40
7	3.734	2.318	.2361	.3386	.762	.617	.831	.851	10.67	11.66
8	4.833	3.375	.5561	.2495	.740	.646	.979	.886	11.14	12.41
9	3.202	3.676	.3071	.2824	.724	.674	.880	.900	7.39	12.61
10	2.064	3.151	.1841	.2835	.657	.657	.914	.908	8.35	11.86
11	2.975	2.737	.2869	.2567	.656	.642	.900	.939	9.72	11.63
12	2.977	3.630	.2900	.2749	.675	.701	.979	.940	11.12	12.38
13	3.514	3.148	.2220	.4079	.826	.656	.810	.949	10.51	12.64
14	3.780	3.790	.3545	.2642	.694	.692	.908	.865	8.29	12.64
15	3.255	3.265	.2757	.2652	.714	.675	.936	.873	11.24	11.89
16	3.362	2.850	.2530	.2384	.726	.660	.940	.904	10.33	11.66
17	2.780	3.743	.2098	.2566	.611	.719	.910	.905	9.15	12.41
18	3.960	3.262	.3014	.3897	.705	.674	.923	.914	11.57	12.67
19	3.266	3.566	.4368	.2982	.715	.703	.958	.887	10.63	12.09
20	3.864	3.152	.3344	.2714	.691	.687	.934	.918	11.71	11.86
21	2.611	4.045	.2559	.2896	.635	.746	.833	.919	8.65	12.61
22	4.650	3.563	.3547	.4226	.755	.702	.920	.928	7.66	12.87
23	3.168	2.267	.3875	.2724	.669	.671	.933	.925	10.03	11.11
24	1.701	3.520	.2615	.2906	.512	.730	.925	.926	9.51	11.86
25	3.926	3,038	.3543	.4237	.760	.685	.950	.936	8.48	12.12

Continued

Appendix Table 2--Continued.

Identification number	CO_2 evolved per 25-seed		CO_2 evolved per mg of seed		RQ per 25-seed		RQ per mg of seed		Seedling vigor index	
	SX	MOP	SX	MOP	SX	MOP	SX	MOP	SX	MOP
26	2.106	3.105	.2751	.2638	.549	.714	.891	.957	11.51	11.64
27	2.363	2.624	.2119	.3969	.618	.670	.877	.967	9.33	11.89
28	3.677	3.517	.2698	.4151	.691	.729	.950	.968	10.29	12.64
Average	3.209	3.091	.2847	.2750	.687	.670	.899	.895	9.77	11.82
$s_{\bar{x}}$	.5153		.0159		.0218		.0158		.1824	
C.V.	22.70%		25.01%		14.18%		7.84%		2.64%	
					TX Progeny					
29	2.985		.2798		.640		.954		10.90	
30	2.957		.2130		.651		.839		11.88	
31	3.369		.2445		.698		.809		11.19	
32	2.262		.1813		.603		.761		10.28	
33	2.755		.1407		.646		.630		11.36	
Average	2.865		.2184		.647		.799		11.12	
					OP Progeny					
51	1.600		.1290		.549		.724		10.42	
52	3.261		.2677		.628		.921		12.38	
53	3.488		.2312		.664		.851		12.42	
54	4.091		.2971		.719		.879		12.84	
55	3.042		.2992		.686		.894		11.34	
56	2.212		.2456		.655		.956		10.87	
57	3.998		.2820		.773		.958		12.38	
58	3.035		.5481		.684		.977		12.89	
Average	3.091		.2750		.669		.895		11.82	

Continued

Appendix Table 2--Continued.

Identification number	CO_2 evolved per 25-seed	CO_2 evolved per mg of seed	RQ per 25-seed	RQ per mg of seed	Seedling vigor index
	SX MOP	SX MOP	SX MOP	SX MOP	SX MOP
			Checks		
59	1.354	.1805	.535	.953	7.64
34	3.152	.4259	.766	.983	6.26
35	.841	.1012	.407	.915	5.26
36	1.649	.2050	.542	.949	7.75
Average	1.745	.2281	.563	.950	6.73
Grand mean	3.0201	.2698	.669	.892	10.00
$s\bar{x}$	.5186	.0144	.0212	.0469	.4224
C.V.	24.28%	23.83%	14.16%	7.46%	5.96%

* Identification number in Table 1.

Appendix Table 3. Means, standard errors of the mean ($s\bar{x}$) and coefficients of variation (C. V.) for six characteristics of white clover. (Corvallis, Oregon. 1972)

Identification number*	Stolon number at 50 days		Stolon number at 70 days		Stolon number growth rate		Stolon length at 50 days		Stolon length at 70 days		Stolon Length growth rate	
	SX Progeny and Mid-Parent											
	SX	MP	SX	MP	SX	MP	SX	MP	SX	MP	SX	MP
1	2.20	1.48	5.00	3.58	2.7	2.1	6.07	3.82	26.68	16.18	20.60	12.37
2	1.75	1.25	4.25	3.25	2.5	2.0	3.37	4.95	20.18	22.05	16.88	17.10
3	2.45	1.18	4.65	2.75	2.2	1.6	6.08	3.30	30.23	13.09	24.15	9.79
4	2.25	1.15	4.60	2.88	2.4	1.7	5.88	3.19	30.75	12.55	24.88	9.39
5	1.90	1.23	4.68	2.77	2.8	1.5	5.71	3.32	34.48	12.19	28.78	8.87
6	1.55	1.25	4.60	2.48	3.1	1.2	2.99	3.51	26.05	11.98	23.05	8.45
7	2.45	1.25	5.03	2.85	2.6	1.6	5.90	3.87	36.35	15.90	30.45	11.99
8	2.35	1.48	4.88	3.83	2.5	2.4	5.88	3.67	32.08	21.63	26.20	17.92
9	1.65	1.40	4.85	3.33	3.2	1.9	3.43	2.02	27.33	12.42	23.90	10.42
10	1.60	1.38	4.30	3.45	2.7	2.1	2.91	1.97	20.43	16.88	17.53	10.01
11	1.95	1.45	4.25	3.34	2.3	1.9	4.45	2.04	28.08	11.52	23.63	9.48
12	2.15	1.48	4.35	3.05	2.2	1.6	4.17	2.22	31.18	11.30	27.00	9.07
13	1.95	1.48	4.45	3.43	2.5	2.0	2.74	2.58	20.10	15.23	17.38	12.61
14	2.65	1.18	5.10	3.00	2.5	1.8	9.08	3.15	39.40	18.54	30.33	15.14
15	1.90	1.15	4.50	3.13	2.6	2.0	3.40	3.04	27.73	17.75	24.33	14.75
16	2.35	1.23	5.50	3.02	3.2	1.8	5.55	3.17	32.33	17.39	26.78	14.22
17	2.00	1.25	4.85	2.73	2.9	1.5	7.03	3.36	40.63	17.18	33.60	13.80
18	2.10	1.25	4.85	3.10	2.8	1.9	7.98	3.72	44.25	21.10	36.28	17.34
19	1.10	1.08	4.00	2.63	2.9	1.6	2.28	1.39	24.10	8.79	21.83	7.43
20	2.05	1.15	5.10	2.52	3.1	1.4	4.98	1.52	33.00	8.43	28.30	6.91
21	1.95	1.18	4.75	2.23	2.8	1.1	3.95	1.71	32.10	8.22	28.15	6.49
22	1.65	1.18	4.78	2.60	2.9	1.4	2.89	2.07	28.98	12.14	26.10	10.03
23	1.85	1.13	5.08	2.64	3.2	1.5	3.14	1.41	33.18	7.89	29.45	6.48
24	1.40	1.15	4.13	2.35	2.8	1.2	2.40	1.60	30.70	7.68	28.30	6.09
25	2.10	1.15	4.60	2.73	2.5	1.6	4.55	1.96	34.30	11.60	29.75	9.63

Continued

Appendix Table 3--Continued.

Identification number	Stolon number at 50 days		Stolon number at 70 days		Stolon number growth rate		Stolon length at 50 days		Stolon length at 70 days		Stolon growth	Length rate
	SX	MP	SX	MP	SX	MP	SX	MP	SX	MP	SX	MP
26	1.65	1.23	4.85	2.24	3.2	1.0	3.53	1.78	25.70	7.32	22.18	5.57
27	1.05	1.23	4.20	2.62	3.2	1.4	1.80	2.09	19.28	11.24	17.48	9.11
28	1.65	1.25	4.58	2.33	2.9	1.1	3.75	2.27	32.13	11.04	27.63	8.69
Average	1.92	1.26	4.67	2.88	2.7	1.6	4.51	2.68	30.06	13.34	25.53	10.67
$s\bar{x}$	.3213		.2434		.2595		.9211		4.0292		3.5808	
C.V.	33.50%		10.43%		18.93%		40.80%		26.80%		28.05%	
					TX Progeny							
29	1.80		4.65		2.85		3.55		21.83		18.28	
30	1.95		4.10		2.15		4.25		21.08		16.83	
31	1.85		4.30		2.45		3.20		21.90		18.73	
32	1.30		4.15		2.85		2.33		20.98		18.65	
33	1.90		4.68		2.78		3.33		27.75		24.43	
Average	1.76		4.38		2.62		3.33		27.71		19.38	
					Checks							
34	1.40		3.90		2.75		2.70		17.20		14.50	
35	1.75		4.85		3.10		4.83		36.55		31.73	
36	1.50		4.15		2.65		2.58		16.88		14.30	
Average	1.55		4.30		2.83		3.37		23.54		20.18	
					Parents of SX							
37	1.25		3.00		1.75		5.10		16.85		11.75	
38	1.70		4.15		2.45		2.53		15.50		12.88	
39	1.25		3.50		2.25		4.80		27.25		22.45	
40	1.10		2.50		1.40		1.50		9.33		7.83	

Continued

Appendix Table 3--Continued.

Identification number	Stolon number at 50 days	Stolon number at 70 days	Stolon number growth rate	Stolon length at 50 days	Stolon length at 70 days	Stolon growth Length rate
	SX MP	SX MP	SX MP	SX MP	SX MP	SX MP
41	1.05	2.75	1.70	1.28	8.25	7.03
42	1.20	2.53	1.33	1.54	7.53	5.98
43	1.25	1.95	.70	1.91	7.10	5.15
44	1.25	2.70	1.45	2.63	14.95	12.23
Average	1.26	2.88	1.63	2.68	13.34	10.67
			Parents of TX			
45	1.00	1.95	.95	1.20	6.73	5.53
46	1.10	2.15	1.05	1.40	5.88	4.48
47	1.00	2.50	1.50	1.80	10.03	8.23
48	1.15	2.45	1.30	2.53	14.50	11.98
49	1.35	3.35	2.10	2.00	13.30	11.30
50	1.55	3.75	2.20	3.70	19.90	16.20
Average	1.19	2.69	1.52	2.10	11.72	9.62
Grand mean	1.68	4.09	2.41	3.74	24.06	20.31
$s\bar{x}$	.2727	.2637	.2819	.7871	3.4204	3.0141
C.V.	32.35%	12.88%	23.40%	42.10%	28.43%	30.93%

* Identification number in Table 1.

Appendix Table 4. Means, standard errors of the mean ($s\bar{x}$) and coefficients of variation (C. V.) for five characteristics of white clover. (Corvallis, Oregon. 1972)

Identification number *	Stolon diameter		Internode length		Petiole length		Petiole diameter		Number of leaves per plant	
	SX Progeny and Mid-Parent									
	SX	MP	SX	MP	SX	MP	SX	MP	SX	MP
1	2.17	2.29	1.64	1.40	12.93	11.32	1.40	1.40	25.25	15.03
2	2.03	2.26	1.46	1.76	11.00	13.11	1.27	1.47	21.65	14.08
3	2.16	2.17	1.64	1.38	11.75	11.19	1.41	1.34	27.25	11.68
4	2.35	2.29	1.94	1.56	13.25	10.86	1.46	1.44	24.90	11.35
5	2.31	2.21	1.95	1.53	13.15	10.68	1.40	1.40	23.35	11.88
6	2.19	2.28	1.77	1.50	10.20	11.61	1.31	1.51	20.95	10.63
7	2.22	2.24	1.90	1.69	12.70	11.67	1.30	1.37	26.70	11.90
8	2.05	2.22	1.83	1.47	12.25	11.39	1.39	1.41	25.75	15.05
9	2.16	2.13	1.67	1.08	11.40	9.48	1.22	1.28	22.65	12.65
10	2.12	2.25	1.65	1.26	10.95	9.14	1.26	1.28	19.85	12.33
11	2.24	2.22	1.61	1.24	11.70	8.97	1.39	1.34	25.35	12.85
12	2.30	2.24	1.59	1.21	11.75	9.89	1.37	1.45	23.10	11.60
13	2.32	2.20	1.59	1.40	12.23	9.95	1.43	1.31	20.55	12.88
14	2.13	2.10	1.60	1.45	12.70	11.27	1.36	1.35	31.75	11.70
15	2.31	2.22	1.77	1.63	13.13	10.93	1.42	1.45	21.65	11.38
16	2.19	2.19	1.48	1.60	12.15	10.76	1.30	1.40	29.25	11.90
17	2.34	2.21	1.87	1.57	12.90	11.68	1.39	1.51	28.55	10.65
18	2.26	2.17	1.91	1.76	13.10	11.74	1.28	1.38	23.80	11.93
19	1.98	2.13	1.65	1.24	10.65	9.02	1.32	1.32	17.45	8.98
20	2.03	2.10	1.72	1.22	11.68	8.84	1.20	1.28	29.80	9.50
21	2.04	2.12	1.93	1.19	12.13	9.77	1.32	1.39	25.20	8.25
22	1.99	2.12	1.94	1.38	11.95	9.83	1.23	1.25	20.00	9.53
23	2.25	2.22	1.84	1.40	12.08	8.51	1.36	1.38	26.10	9.18
24	2.19	2.24	1.92	1.37	11.48	9.43	1.39	1.49	20.00	7.93
25	2.23	2.20	1.82	1.56	12.15	9.49	1.31	1.35	23.90	9.20

Continued

Appendix Table 4--Continued.

Identification number	Stolon diameter		Internode length		Petiole length		Petiole diameter		Number of leaves per plant	
	SX	MP	SX	MP	SX	MP	SX	MP	SX	MP
26	2.16	2.21	1.68	-1.34	9.95	9.26	1.30	1.44	25.20	8.45
27	2.15	2.17	1.79	1.53	11.36	9.32	1.33	1.31	18.30	9.73
28	2.08	2.37	1.78	1.50	11.38	10.24	1.35	1.42	25.25	8.48
Average	2.17	2.21	1.75	1.44	11.93	10.33	1.34	1.38	23.98	11.10
$s_{\bar{x}}$	.0602		.1139		.5233		.05153		1.7977	
C.V.	5.55%		12.75%		8.77%		7.71%		14.99%	
					TX Progeny					
29	2.73		1.39		13.10		1.44		21.80	
30	2.39		1.53		14.83		1.52		21.05	
31	2.43		1.62		14.38		1.45		20.85	
32	2.34		1.77		12.48		1.35		15.85	
33	2.40		1.79		12.65		1.37		22.20	
Average	2.38		1.62		13.48		1.42		22.35	
					Checks					
34	2.54		1.62		11.25		1.35		18.23	
35	1.96		1.91		12.25		1.22		21.85	
36	2.54		1.49		12.90		1.54		19.45	
Average	2.35		1.67		12.13		1.37		16.17	
					Parents of SX					
37	2.33		1.69		13.03		1.46		14.05	
38	2.25		1.10		9.60		1.34		10.00	
39	2.19		1.83		13.18		1.47		14.10	
40	2.00		1.06		9.35		1.22		9.30	

Continued

Appendix Table 4--Continued.

Identification number	Stolon diameter	Internode length	Petiole length	Petiole diameter	Number of leaves per plant
	SX MP	SX MP	SX MP	SX MP	SX MP
41	2.25	1.42	8.68	1.42	8.65
42	2.19	1.37	8.33	1.33	9.70
43	2.23	1.31	10.18	1.55	7.20
44	2.14	1.69	10.30	1.28	9.75
Average	2.20	1.43	10.33	1.38	11.09
			Parents of TX		
45	2.70	1.61	13.35	1.93	6.20
46	2.85	1.27	13.63	2.05	7.50
47	2.48	1.49	13.83	1.63	8.55
48	2.75	1.94	12.48	1.77	10.35
49	2.66	1.20	12.68	1.62	16.60
50	2.02	1.34	9.60	1.27	15.80
Average	2.58	1.47	12.59	1.71	10.83
Grand mean	2.26	1.65	11.92	1.40	19.73
$\bar{sx}$	.0582	.1269	.0071	.0642	1.8867
C.V.	5.16%	15.42%	10.19%	9.18%	19.12%

* Identification number in Table 1.

Appendix Table 5. Means, standard errors of the mean ($s\bar{x}$) and coefficients of variation (C. V.) for six characteristics of white clover. (Corvallis, Oregon. 1972)

Identification number *	Leaf width		Leaf length		Leaf ratio		Area per leaf		Dry weight per leaf		Specific leaf weight (SLW)	
					Six Progeny and Mid-Parent							
	SX	MP	SX	MP	SX	MP	SX	MP	SX	MP	SX	MP
1	1.72	1.61	1.86	1.77	1.08	1.11	7.50	6.89	16.27	15.95	2.16	2.32
2	1.49	1.65	1.63	1.90	1.09	1.16	6.30	7.43	13.52	18.03	2.13	2.44
3	1.49	1.51	1.65	1.65	1.11	1.10	6.51	5.97	15.32	13.90	2.33	2.32
4	2.70	1.59	1.91	1.73	1.13	1.10	7.41	6.63	17.84	15.03	2.41	2.26
5	1.66	1.55	1.82	1.75	1.10	1.12	7.22	6.28	15.83	13.76	2.23	2.20
6	1.57	1.69	1.84	1.96	1.18	1.17	7.00	7.12	14.95	17.67	2.13	2.31
7	1.51	1.63	1.65	1.75	1.09	1.08	6.76	6.59	15.07	16.11	2.25	2.42
8	1.61	1.61	1.81	1.84	1.12	1.15	7.30	7.02	15.10	16.49	2.10	2.36
9	1.50	1.47	1.62	1.59	1.08	1.09	5.69	5.56	11.58	12.36	2.03	2.23
10	1.62	1.55	1.81	1.67	1.12	1.08	6.89	6.22	14.80	13.50	2.14	2.18
11	1.67	1.51	1.78	1.69	1.07	1.11	6.75	5.85	13.75	12.22	2.04	2.11
12	1.62	1.65	1.93	1.90	1.20	1.16	7.17	6.71	14.60	16.13	2.03	2.23
13	1.73	1.59	1.79	1.69	1.04	1.07	6.70	6.18	13.78	14.57	2.06	2.34
14	1.56	1.52	1.80	1.72	1.16	1.14	5.94	6.10	13.59	14.45	2.30	2.35
15	1.72	1.59	1.94	1.80	1.13	1.14	7.89	6.76	16.39	15.58	2.10	2.30
16	1.63	1.55	1.80	1.82	1.10	1.16	6.73	6.41	13.62	14.31	2.02	2.23
17	1.64	1.69	1.98	2.03	1.21	1.21	8.07	7.25	17.56	18.22	2.18	2.35
18	1.69	1.63	1.81	1.82	1.08	1.12	6.90	6.72	15.54	16.65	2.25	2.45
19	1.57	1.45	1.79	1.55	1.15	1.08	6.01	5.30	12.01	11.45	2.02	2.18
20	1.52	1.41	1.61	1.57	1.06	1.10	5.53	4.95	11.32	10.18	2.05	2.11
21	1.53	1.55	1.82	1.78	1.19	1.15	6.82	5.79	13.71	14.09	2.01	2.23
22	1.55	1.49	1.69	1.57	1.09	1.06	5.46	5.26	11.66	12.52	2.14	2.33
23	1.59	1.49	1.69	1.64	1.07	1.10	6.96	5.61	14.06	11.31	2.02	2.05
24	1.60	1.63	1.82	1.86	1.15	1.15	7.22	6.45	14.99	15.22	2.08	2.17
25	1.71	1.57	1.88	1.65	1.10	1.06	7.07	5.92	15.06	13.65	2.14	2.28

Continued

Appendix Table 5--Continued.

Identification number *	Leaf width		Leaf length		Leaf ratio		Area per leaf		Dry Weight per leaf		Specific leaf weight (SLW)	
	SX	MP	SX	MP	SX	MP	SX	MP	SX	MP	SX	MP
26	1.53	1.59	1.67	1.88	1.09	1.17	5.92	6.10	12.16	13.95	2.04	2.10
27	1.58	1.53	1.56	1.67	.99	1.08	5.82	5.57	11.13	12.38	1.92	2.21
28	1.53	1.67	1.85	1.88	1.21	1.13	6.49	6.41	14.31	16.29	2.20	2.33
Average	1.50	1.57	1.78	1.75	1.11	1.12	6.71	6.25	14.27	14.50	2.13	2.26
$s_{\bar{x}}$	.0274		.0171		.0253		.3015		.8269		.0239	
C.V.	34.37%		4.30%		3.22%		8.98%		11.67%		7.10%	
TX Progeny												
29	1.59		1.69		1.06		7.40		14.60		1.97	
30	1.89		2.30		1.22		9.08		18.68		2.06	
31	1.83		2.09		1.15		8.93		19.04		2.14	
32	1.69		1.83		1.08		7.29		15.58		2.13	
33	1.77		1.95		1.11		7.76		15.76		2.06	
Average	1.75		1.97		1.12		8.09		16.73		2.07	
Checks												
34	1.69		2.13		.127		5.99		16.48		2.05	
35	1.68		1.77		1.06		6.69		13.00		1.95	
36	1.85		2.18		1.19		9.51		20.28		2.16	
Average	1.74		2.03		1.17		8.08		16.58		2.05	
Parents of SX												
37	1.64		1.83		1.12		7.30		17.49		2.40	
38	1.57		1.71		1.09		6.48		14.41		2.23	
39	1.65		1.97		1.20		7.56		18.58		2.48	

Continued

Appendix Table 5--Continued.

Identification number *	Leaf width	Leaf length	Leaf ratio	Area per leaf	Dry weight per leaf	Specific leaf weight (SLW)
	SX MP	SX MP	SX MP	SX MP	SX MP	SX MP
40	1.37	1.47	1.08	4.64	10.32	2.23
41	1.53	1.62	1.07	5.96	12.58	2.12
42	1.45	1.66	1.12	5.25	10.04	1.99
43	1.73	2.09	1.22	6.95	17.86	2.22
44	1.61	1.67	1.04	5.88	14.73	2.43
Average	1.57	1.75	1.12	6.25	14.50	2.26
			Parents of TX			
45	1.81	2.58	1.44	10.23	20.91	2.05
46	2.10	2.96	1.42	12.53	27.43	2.23
47	1.99	2.26	1.14	10.15	19.95	1.99
48	2.13	2.46	1.16	11.27	26.74	2.39
49	1.74	2.15	1.22	9.07	19.51	2.15
50	1.39	1.65	1.19	5.10	10.97	2.15
Average	1.86	2.34	1.26	9.73	20.92	2.15
Grand mean	1.65	1.87	1.13	7.22	15.49	2.14
$s_{\bar{x}}$	.0751	.1177	.0127	.4373	.9724	.0782
C.V.	6.44%	8.88%	4.98%	12.11%	12.56%	7.30%

* Identification number in Table 1.

Appendix Table 6. Means, standard errors of the mean ($s\bar{x}$) and coefficients of variation (C.V.) for six characteristics of white clover. (Corvallis, Oregon. 1972)

Identification number *	Total leaf area		Leaf area ratio (LAR)		Diurnal ratio in SLW (AM/Noon)		Diurnal ratio in SLW (Noon/PM)		Diurnal ratio in SLW (AM/PM)		Forage yield	
	SX Progeny and Mid-Parent											
	SX	MP	SX	MP	SX	MP	SX	MP	SX	MP	SX	MP
1	189.69	103.69	120.27	117.96	.997	1.027	.874	.972	.864	.993	1.57	.89
2	136.03	104.71	142.96	115.67	.966	.971	.961	.978	.925	.944	.97	.92
3	179.56	73.08	125.30	126.02	.996	.975	.960	.998	.954	.964	1.43	.61
4	184.62	77.35	117.34	118.51	.899	.991	1.305	.948	.928	.937	1.58	.66
5	169.71	77.25	124.61	151.60	.994	.967	.933	.982	.927	.944	1.37	.58
6	145.73	76.05	122.79	133.54	.953	.958	.893	.946	.850	.964	1.21	.60
7	180.59	80.28	127.16	111.09	.982	1.013	.926	.951	.907	.959	1.41	.72
8	187.99	105.20	131.40	114.17	.996	.963	.934	.984	.930	.945	1.48	.95
9	128.91	73.58	117.14	124.52	.918	.967	.972	1.004	.892	.965	1.11	.64
10	135.77	77.85	123.77	117.01	1.051	.983	.903	.954	.948	.938	1.10	.69
11	169.85	77.74	140.06	150.09	.943	.959	.940	.988	.884	.945	1.24	.61
12	165.08	76.54	129.97	132.03	.923	.950	.965	.952	.891	.905	1.28	.63
13	135.92	80.78	127.61	109.58	.972	1.005	.947	.957	.920	.960	1.07	.75
14	188.81	74.60	119.96	122.23	.943	.910	1.023	1.010	.965	.915	1.60	.67
15	170.43	78.87	122.60	114.72	.994	.927	.891	.960	.883	.888	1.40	.72
16	196.69	78.76	132.46	147.81	.911	.903	1.000	.994	.912	.895	1.49	.63
17	232.84	77.56	138.50	129.75	.945	.894	1.020	.958	.963	.856	1.67	.66
18	163.01	81.80	122.90	107.30	.939	.948	.940	.962	.880	.910	1.31	.78
19	105.33	47.24	117.51	125.07	.961	.931	.921	.980	.887	.908	.94	.41
20	165.47	47.14	132.01	158.16	.998	.907	.952	1.014	.949	.915	1.25	.33
21	172.30	45.94	133.69	140.10	.955	.898	.909	.978	.864	.876	1.29	.35
22	108.50	50.17	117.11	117.65	.937	.952	.919	.983	.860	.930	.96	.47
23	179.87	51.41	144.57	150.65	.999	.923	.950	.964	.949	.880	1.27	.38
24	145.08	50.21	124.08	132.59	.981	.914	.924	.928	.906	.849	1.15	.40
25	170.96	54.44	124.77	110.14	.955	.969	.973	.933	.929	.903	1.37	.52

Continued

Appendix Table 6--Continued.

Identification number *	Total leaf area		Leaf area ratio (LAR)		Diurnal ratio in SLW (AM/Noon)		Diurnal ratio in SLW (Noon/PM)		Diurnal ratio in SLW (AM/PM)		Forage yield	
	SX	MP	SX	MP	SX	MP	SX	MP	SX	MP	SX	MP
26	149.87	50.10	122.26	165.67	.924	.890	1.024	.962	.945	.856	1.25	.32
27	106.90	54.34	139.97	143.22	.991	.945	.930	.967	.919	.910	.79	.39
28	151.38	53.14	133.61	125.16	.936	.935	.988	.931	.925	.871	1.15	.46
Average	161.32	70.71	127.73	129.00	.963	.949	.950	.969	.913	.919	1.27	.60
$s_{\bar{x}}$	18.0331		8.1655		.0406		.0406		.0394		.1344	
C.V.	22.36%		12.79%		5.96%		6.04%		6.10%		21.12%	
					TX Progeny							
29	104.09		137.60		.914		1,014		.926		1.20	
30	191.44		143.07		.966		.973		.939		1.34	
31	185.59		142.00		.950		.952		.903		1.31	
32	118.03		123.69		.892		.976		.807		.93	
33	169.44		140.21		.951		.992		.943		1.21	
Average	165.72		137.31		.934		.981		.916		1.20	
					Checks							
34	145.67		130.06		.937		.969		.905		1.15	
35	144.66		128.15		.953		.954		.909		1.15	
36	183.61		163.77		.833		1.071		.879		1.15	
Average	157.98		140.66		.907		.998		.898		1.15	
					Parents of SX							
37	103.19		119.46		1.035		.966		.992		.86	
38	104.18		116.45		1.019		.978		.994		.92	

Continued

Appendix Table 6--Continued.

Identification number *	Total leaf area	Leaf area ratio (LAR)	Diurnal ratio in SLW (AM/Noon)	Diurnal ratio in SLW (Noon/PM)	Diurnal ratio in SLW (AM/PM)	Forage yield
	SX MP	SX MP	SX MP	SX MP	SX MP	SX MP
39	106.22	111.88	.906	.989	.895	.97
40	42.97	132.58	.914	1.030	.935	.36
41	51.51	117.56	.947	.930	.881	.46
42	51.30	183.73	.899	.998	.895	.29
43	48.90	147.61	.881	.926	.816	.34
44	57.37	102.71	.990	.935	.925	.58
Average	70.70	129.00	.949	.969	.916	.32
			Parents of TX			
45	63.21	209.47	.954	.929	.886	.36
46	94.47	146.89	.910	.959	.874	.66
47	86.47	147.99	.874	.919	.800	.59
48	117.35	134.46	.922	.964	.888	.87
49	151.65	136.90	.951	1.009	.960	1.12
50	80.82	108.72	.934	.964	.891	.75
Average	98.99	147.40	.924	.957	.884	.72
Grand mean	139.58	132.03	.950	.960	.909	1.08
$s\bar{x}$	16.2310	11.8434	.0367	.0480	.0367	.1213
C.V.	7.29%	17.94%	5.47%	7.06%	5.72%	22.41%

* Identification number in Table 1.