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Genotypic Variability in Yorkshire Fog Grass
(*Holcus lanatus* **L.**)

A thesis
presented in partial fulfilment of the requirements
for the degree of
Master of Agricultural Science
in Agronomy
at
Massey University

Muangthong Thuantavee
1989

ABSTRACT

Plant to plant genotypic variation in New-Zealand Yorkshire-Fog grass was examined in order to quantify the relative importance of average gene effects, dominance, epistasis and environment. The plant variability was contrasted also against topodeme variation.

Plants were grown under glasshouse conditions (20° - 25°C), using vernalization and sixteen hour daylight to encourage growth and flowering. The confounding effect of bench position was removed by regression adjustment.

Fifty half-sib lines representing ten diverse New Zealand topodemes were examined in a one-way mating design, laid out as a randomized complete block experiment.

In general, half-sib and plant variances were much larger than the topodeme variance. This supports earlier findings that there are no major topodeme differences in New Zealand Yorkshire Fog grass germplasm.

The broad-sense heritability estimates which indicated total genotypic contribution varied from low to high. Most botanical, flowering and tillering characters had a medium to high values while the agronomic characters had medium to low estimates.

The attributes with medium to high narrow-sense heritability are several measures of leaf size, tiller development, purple colour, plant height and erectness, flavanols and panicle width. Breeding methods, such as mass selection, line selection, line breeding or simple recurrent selection should ,therefore, be appropriate for these.

The attributes with medium to high heterotic-sense heritability are leaf tensile strength, leaf hairiness, old disease (rust), flowering period, panicle length and compactness and several aspects of tiller production. Breeding methods, such as recurrent selection with progeny testing or top cross progeny tests for high specific combining ability should be useful, including synthetic cultivars and some kinds of recurrent bulks.

Of particular interest was the finding that there was more genetic variability for the duration of tillering and flowering periods than for tiller numbers or flower initiation. There was also evidence that the genetic activity controlling tiller number changed as the tillers aged.

ACKNOWLEDGEMENT

I am deeply indebted to my supervisor, Dr I.L.Gordon, for his excellent guidance and assistance.

I wish to thank Mr A.G. Robertson of Agronomy Department and Dr M.J. Hill of Seed Technology Centre for their advice in grass physiology, Mr D.C. Havell of D.S.I.R. Grassland Division for the assistance on leaf tensile strength measurement, Mr D.T. Sollitt of Agronomy Department for his general technical assistance.

Thanks to Professor J. Hodgson and all the staff members of Agronomy Department for their advice and encouragement.

My special gratitude is to my dad and mum in Thailand who always give me a great support.

The awards of Helen E. Akers and D.J. McGowen scholarships to partially finance my study are gratefully acknowledged.

Lastly, my great appreciation is to my wonderful wife for her patience and invaluable help.

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INTRODUCTION

Yorkshire Fog grass has been judged as one of the significant grasses for farm productivity (Basnyat, 1957; Munro, 1961). It has always been valuable as a pioneer grass in drained peat swamp areas (Basnyat, 1957). It is also useful in infertile, unstable, poorly drained soil (Munro, 1961; Davies *et al.*, 1971; Morrison and Idle, 1972; Rumball, 1983). It is capable of establishing well in humid hill county, and on unploughable steep hills (Basnyat, 1957; Hughes and Nicholson, 1961;). On such area, *H. lanatus* is one of the earliest grasses to start growth in the spring and its subsequent growth was also notable (Herriot, 1975). It has been proposed as a 'nurse' species for sown *L. perenne* and *Trifolium rapens*, for which it would consolidate the soil, protect over grazing, and speed up the fertility cycle (Thomas, 1936; Davies, 1940). Furthermore, its good persistence has been used to control erosion (Dunbar, 1974; Hornung, 1976).

Yorkshire Fog grass is more suitable for less intensive farming system, typically dairy pasture and upland sheep farms (Munro, 1961). Its growth habit and vegetative-reproductive cycle make it a good candidate for a lenient system of defoliation (Levy, 1955; Beddows, 1961). Its grazing tolerance lies between perennial ryegrass and cocksfoot (Mitchell, 1956). In mixed swards and under infrequent grazing regime, *H. lanatus* dominated *L.perenne* (Watt, 1987) and its ground cover over 4 year in Oxford has increased from 18% to 43% (Haggars and Ellliot, 1978).

Yorkshire Fog grass is believed to have been introduced into New Zealand either as a seed impurity or a hay grass in eighteenth century (Cheeseman, 1923), and since then as a volunteer, it contributed much of New Zealand's pasture production (Munro, 1961). Massey University has been interested in Yorkshire Fog grass since 1950 (Basnyat, 1957). The first synthetic variety "Massey Basyn" was released and proved to be prominent in several areas (Robinson *et al.*, 1980; McAdam, 1984; Watt, 1987). Evaluation on Yorkshire Fog grass germplasm of New Zealand collection was carried on by Teow (1978). In addition, factors involving sheep palatability were determined by Cameron (1979). The broad-sense heritability estimates were also initially figured out pertinent to topodeme basis.

Following previous studies, this investigation has been set up to increase the genetical knowledge of Yorkshire Fog grass. An attempt has been made to unravel the heritabilities pertinent to individual plant basis. Comparison between plant variation and topodeme variation was also carried out.

CHAPTER 1

LITERATURE REVIEWS

1.1 Yorkshire Fog Grass

1.1.1 Agro-botany and Agronomy

Yorkshire Fog grass or velvet grass *(Holcus lanatus)* is probably a native of the Iberian Peninsular (Spain and Portugal) (Vinal and Hein, 1937). It is a tufted, softly hairy perennial which can adapt to a wide range of environmental conditions, but predominates in moist and low-fertility soil (Hubbard, 1968). *H. lanatus* is widespread in the temperate region around the world from the limits of Northern Scandinavia and Iceland to the Caucasus mountains, North and West Africa, North America, South America, Australia, New Zealand and several sub-antarctic islands (Hulten, 1950; Bocher and Larsen, 1958; Beddows, 1961; Munro, 1961; Watton, 1975).

Although its distribution is by accident rather than design, and has caused certain weed problems (Harkess and Hope, 1974), several workers have claimed its considerable contribution to fodder production; for example, in England and Wales (Forbes *et al.*, 1980; Watt, 1987), in Scotland (Swift, *et al.*, 1983), in Chile, Southern Brazil, and Hawaii (Whyte, Moir and Cooper, 1959), and in Falkland Islands (Davies, *et al.*, 1971).

H. lanatus can germinate over a wide range of soil temperature (Watt, 1976). Seedling emergence, however, is progressively delayed in accordance with decrease in mean soil temperature (Hart, 1961). It germinates well either at 22 ^{O}C. under continuous light or in diurnal fluctuating temperature (10 ^{O}C and 20 ^{O}C) under dark condition (Thompson, Grime and Mason, 1977). It also germinates readily in the light at normal room temperature (Grime and Jarvis, 1975). Moist soil condition is indispensable for optimum germination (Watt, 1976). Most freshly collected seeds germinate rapidly in moist conditions (Watt, 1977).

H. lanatus thrives well at temperature between 12.8 ^{o}C and 29.4 ^{o}C (Mitchell and Lucanus, 1962). However, growth is poor at 35 ^{o}C (Mitchell, 1956) and leafy shoot ceases development at 5 ^{o}C (Beddows, 1961). Because it grows relatively well at low temperature, many workers regard it as a good winter grower (Munro, 1961; Hubbard, 1945; Watkin and Robinson, 1974). It is able to establish over a wide altitude range (Basnyat, 1957) and spread evenly over altitudes up to 400 m. and on all slopes up to 50^{o} (Watt, 1976).

It can inhabit on a wide light regime ranging from dense shade to open and sunny (Levy, 1970). The broader leaves are likely to intercept more light per unit area than *L. perenne* (Riveros, 1963) and also are more efficient than *D. glomerata* (Remison, 1976).

Yorkshire Fog grass can grow in most soil types, from heavy loams to sands (Hubbards, 1945). Its optimum soil pH is 5.0 to 7.5 (Davies, 1944; Watt, 1977; Kruijne and de Vries, 1963). However, it also becomes prevalent in acidic soil (Davies, 1944; Hart and McGuire, 1963). It requires a moderate to low fertility. At low nitrogen level, it has yielded equally to *L. perenne* under cutting regimes (Haggars, 1976; Hayes, 1976; Haggars and Standell, 1982). The application of phosphorus did not change the amount of *H. lanatus* presence in a mixed sward in Oregon (Hart and McGuire, 1963). It tends to perform best on soil low in potassium, as noted in a survey in the Netherlands (Kruije and de Vries, 1963) and in United Kingdom (Castle and Holmes, 1960). The capability to grow in such poor nutrient conditions has been ascribed to various properties. One of these is its cation exchange capacity of the root systems, which provides it with an advantage over other grasses during a resource constraint (Jackman, 1960). Also, it has been noted that the root system absorbs nutrients in the surface layers of soil (Boggie *et al.*, 1958; Beddows, 1961). Lastly, a symbiosis of endotrophic mycorrhiza in the root has been described (Hatch, 1937; Nye, 1966).

Its growth becomes prevalent where the soil moisture content is adequate. *H.lanatus* seems to tolerate wet soil conditions, commonly appearing in swamp, flooded or waterlogged areas (Basnyat, 1957 ; Morrison and Idles, 1972; Watt and Haggars, 1980), but it cannot tolerate a moderately dry or dry soil (Levy, 1970). The flooding tolerant feature is possibly attributable to the anatomy of the root, which incorporates a radial cortex and many small irregular air spaces, thereby increasing the respiratory efficiency in low aeration (Soper, 1959; Jacques and Munro, 1963). Under such conditions, the plant also tends to produce more fine roots at soil surfaces and more adventitious roots around the edge of its clump (Watt, 1977).

Growth of Yorkshire Fog grass is centered on leaf expansion on a moderate number of large tillers (Munro, 1961). According to Protich (1977), formation of tillers in *Holcus lanatus* can be subdivided into the following four periods: (a) "one-stem plant- formation period", when a plant is in the form of a covered bud from the time of development of first green leaf to the initiation of first of the lateral buds in the tillering zone; (b) "tillering period", when tillers of the second, third and fourth order are formed; (c) the "spring development and inflorescence period", when tillering ceases and the apical buds rapidly enter into the inflorescence period and the successive ontogenetic stages (d) "spring tillering period" when formation of inflorescences on the first, second and third tillers are completed and enlargement of internodes begins; new tillers of third and fourth orders and buds of the third, fourth and fifth order are formed.

Equivalent growth is yielded from 50 tillers of Yorkshire Fog grass or cocksfoot, 80 tillers of short rotation ryegrass, 100 tillers of perennial ryegrass, or 350 tillers of browntop, at temperature 65 ^{O}F (Munro, 1961). Tiller number and shoot dry-weight in *H. lanatus* grown at 7 - 35 ^{O}C. followed a course similar to that in *L. perenne* and *D. glomerata* (Mitchell and Lucanus, 1962). However, *H.lanatus* can give greater yield of shoot dry weight in early spring than does *L.perenne* (cv. S23) (Haggar, 1976). This is possibly due to its early growth at low temperature (Watt, 1983). Comparison among weed grasses, i.e. rough stalked meadow grass, *Agrotis* spp. and *H. lanatus* with ryegrass, they were lower yielding than the best ryegrass line. However, there was one exceptional population of Yorkshire Fog (BS 3639) which showed higher mass than ryegrass (Twigg, 1978).

Yorkshire Fog grass is useful in infertile, unstable, poorly drained soil (Munro, 1961; Davies *et al.*, 1971; Morrison and Idle, 1972; Rumball, 1983). It is capable of establishing well in humid hill county, and on unploughable steep hills

(Basn~~s~~yat, 1957; Hughes and Nicholson, 1961). Despite some of its usefulness, several drawbacks have limited its generalized utilization in pasture production. These include the low palatiblity commonly attributed to excessive flower heads, basal dead matter~~s~~, rust infestation, hairiness (Munro, 1961; Rumball, 1983). However, Cameron (1979) had pointed out that hairiness was considered an unimportant factor determining sheep preference. It is very susceptible to damage by tramping and treading (Brown and Evans, 1973; Watt, 1977). *H. lanatus* also restricted the establishment of sown *T. repens* more than did *L. perenne* (Jacques, 1974; Smith and Allcolk, 1985), and the clover transplants grew twice as much in ryegrass swards as in Yorkshire Fog swards (Turkington *et al.*, 1979). This is possibly due to either its greater shading (Jaques, 1974), the allelopathic effects from its root leachates towards its neighbouring plants (Newman and Rovira, 1975), or its aggressive root competition (Remison, 1976).

The onset of numerous flower heads have caused a rapid decline in acceptability (Cowlishaw & Alder, 1960; Garner, 1963; Jacques, 1974). The density of inflorescences was one of the most important factors determining lack of sheep acceptability (Cameron, 1979).

1.1.2 Plant Breeding

To improve the grass, Massey Agricultural college initiated its improvement project in 1953 with collection of 151 seed samples from most districts of New Zealand (Basnyat, 1957). Spaced plants underwent evaluation for two years combined with selection to improve utilization and palatability. The criteria used were: habit of growth, the extent of leaf pubescence, the propagation of dead basal tissue, resistance to crown rust, competitivity with legumes in the sward (Jaques, 1962; Munro, 1961).

A group of promising plants were selected for progeny testing by the polycross techniques in 1959 - 1960 resulting in selection of 10 lines showing high general combining ability in term of maintained production, adaptability to three different soil type, limited heading and rust resistance (Basnyat, 1957; Munro, 1961). The performance of elite line was tested against ryegrass showing that its winter yield sustained vigour throughout the year, and a high tolerance to crown rust (Munro, 1961). The cultivar was released as " Massey Basyn " in 1977 (Rumball, 1983)

Massey Basyn performance was evaluated in several temperate countries. At Glen Innes, Australia, comparison with *P. aquatica* cv.Sirosa, cv.Commercial and *Festuca arundina* cv.Demeter under mixed sward with white clover, showed that mean pasture availability was greatest initially on Massey Basyn but finally on Commercial *Phalaris* (Robinson, May and Scarsbrick, 1980). It established and grew well by direct drilling following burning of native grassland in the Falkland Islands (McAdam, 1984). In the uplands of Britain, Massey Basyn with 130 kg.N/ha showed similar dry matter yields to that of *L. perenne* (Smith and Allcock, 1985). However, *L. perenne* responded better than *L. lanatus* to high levels of nitrogen fertilizer (200-250 kg.N/h annually) (Watt, 1984). Similar results was affirmed at the Oxford University Field Station and additionally indicated that Massey Basyn and German Commercial had no difference in terms of yield but Massey Basyn was affected less by rust infection (Watt, 1987).

1.1.3 Germplasm Variability

An outcrossing species Yorkshire Fog grass may be subjected to a wide range of adaptive pressures. Its large phenotypic variability in New Zealand has been described as a secondary centre of diversity for the species (Munro, 1961; Jacques, 1962; 1974). A cluster analysis study of the phenotypic variability in several characters was conducted by Teow (1978). Based on Ward's clustering method, the 161 local populations (topodemes) were grouped into five distinct clusters.

1.1.4 Phenotypic and Genotypic Variability

Phenotypic variation of some characters (related to sheep acceptability) was estimated by Cameron (1979). The investigation was based on topodeme level. It is also notable that a high degree of plant variation within the topodeme prevails (the residuals of the previous two studies).

Besides the topodeme variability just discussed, several workers have made observation on specific characters in *Holcus lanatus*.

Phenotypic variation in leaf pubescence, in terms of hair density and hair length, is apparent. The inheritance of this character was believed to be quantitative by Beddows (1961). The genetic variation relative to phenotypic variation was low (0.2) (Cameron, 1979).

Plant form is variable in Yorkshire Fog grass. Commonly, Yorkshire Fog grass plants have an extremely prostrate growth habit (Jacques, 1974). However, it tends to grow in clumps in established swards (Beddows, 1961; Hubbard, 1968; Turkington and Harper, 1979). Its growth habit can be due to the formation of decumbent tillers in the late summer which subsequently produce roots and shoots at the nodes (Watt, 1983) Conversely, predominantly erect and semi-erect plants were available in the early selection program (Munro, 1961). Clump erectness was found to be one of most discriminating characters among groups in clustering analysis (Teow, 1978). However, the genetic variation relative to phenotypic variation was very low (0.1) (Cameron, 1979).

The major disease is crown rust (*Puccinia coronata* var.*holci*) which commonly infests old leaves during summer (Corkill, 1956; Jacques & Munro, 1963). The phenotypic variation on disease appearance was high both among and within population (Munro, 1961). The genetic variation relative to phenotypic variation was low (0.1 - 0.3) (Cameron, 1979).

Panicle variation is observable. Panicle shapes are varied from lanceolate to oblong or ovate, very dense to rather loose, erect and nodding , whitish, pale green, pinkish or with a tinge of purple. The panicle size ranges from 3 to 20 cm.(Hubbard, 1968).

Yorkshire Fog grass tends to develop its maximum number of panicles during summer (October - November) in New Zealand. Flowering duration is about 3 months and varies widely over the groups of plants (Basnyat, 1957). However, time of flowering is also influenced by micrograzing pressure, soil moisture, exposure and the recurrence of annual period of moisture stress (McMillan, 1959; Cooper, 1954). The flowering date was also one of the most discriminating characters amongst groups in the clustering study (Teow, 1978). The genotypic variation relative to phenotypic variation of flowering day was medium (0.3) (Cameron, 1979).

Yorkshire Fog grass can attain the height of 20 - 100 cm.(Hubbard, 1968). The genetic variation relative to phenotypic variation in clump height was very low (0.004 - 0.03) (Cameron, 1979).

1.1.5 Heritability

Until recently, the relative contribution of genetics and environments to this variability were estimated. The heritability estimates were presented by Cameron (1979), using the split-plot-in-time model. These estimates on some of botanic and flowering characters are shown in Table 1.1. These estimates are for topodeme differences, not plant variation.

Heritability estimates based on plant to plant variation were studied recently on two adjacent populations in North Wales. Billington *et al.* (1988) revealed the heritability of several morphological and tillering characters (see Table 4.2). Two different quantitative genetic methods were employed in the study using maximum-likelihood technique. The populations were derived from fields with different management backgrounds. The improved field was also applied with fertilizer preceding the hay cut while the traditional field was not fertilized.

1.2 Quantitative Genetics

Quantitative genetics is the inheritance of those phenotypic characters between individuals that are continuously variable (quantitative) rather than due to simple segregating major gene system (qualitative) (Falconer, 1981) The same genetic principles underlie these attributes, but many genes are involved (polygenic) and the role of environment is much more pronounced. East (1910) was one of the early workers to demonstrate the relationship between classical genetics and quantitative variation. The procedures need some modified terminology and more biometrics than classical "segregating" genetic (Sprague, 1966).

Table 1.1 Broad-sense heritability estimates from split-plot-in-time model (Cameron,1979)

Characters	Single harvest		Pooled harvest	
	h^2	se.	h^2	se.
Leaf tensile strength	0.04	(0.07)	0.01	(0.01)
Leaf pubescence	0.20	(0.08)	-	
Leaf flavanols	0.01	(0.08)	-	
Leaf width	0.08	(0.04)	-	
Clump erectness	-		0.10	(0.05)
Clump height	-		0.004	(0.006)
Clump diameter	-		0.06	(0.03)
Clump rust	0.10	(0.08)	-	
Green material	-		0.02	(0.02)
Flowering date	0.34	(0.09)	-	

Table 1.2 Heritability estimates from polycross data and the North Carolina model-2 experiment, both using REML (Billington, *et al.* 1988)

Characters	Polycross		North Carolina 2	
	Impr Fld.	Trd Fld.	Impr Fld.	Trd Fld.
Tiller number	0.08	-0.17	0.03	-
Tiller dryweight (gm)	0.19	0.19	0.01	0.24
Stolon number	-0.29	0.28	-0.10	0.17
Stolon dryweight (gm)	-0.16	0.23	-0.22	0.15
Leaf width (mm)	-0.27	-0.29	0.10	0.17
Leaf length (mm)	0.17	-	-	-
Plant height (mm)	0.18	-	-	-
Plant diameter (mm)	-0.20	0.18	-	-
Tiller number after cut	0.22	0.19	-	-
Flowering time (days)	0.24	0.14	0.23	0.10
Inflorescence number	0.01	0.19	0.14	0.18
Panicle length(mm)	0.27	0.01	-	-
Flag-leaf length (mm)	0.04	0.11	-	-

Impr Fld. = Improved Field
Trd Fld. = Traditional Field

1.2.1 Partitioning Genetic Variance

The phenotypic value of a character for an individual can be partitioned into two main components that due to the genetic effect and that to the environmental effect (Mather and Jink, 1971; Falconer, 1981; Becker, 1984; Baker, 1986).

$$P = G + E$$

where: P is the phenotypic value
G is the genotypic value
E is the environmental effect

The genotypic value can be partitioned into three components, i.e.

$$G = A + D + I$$

where: A is the average allele effect ("additive")
D is the heterozygote effect ("dominance")
I is the interaction between A and D ("epistasis")

The average effect is the sum of the "additive" (average) effects of alleles across all their backgrounds (Falconer, 1981).

The dominant effect or intra-locus effect is the sum, across loci, of heterozygote deviates within each locus (Falconer, 1981).

The epistatic effect or inter-locus effect or non-allelic effect, is the sum of main gene-effect inconsistencies among the loci (Falconer, 1981). It can be partitioned further into three parts, as follows:

$$I = AA + AD + DD$$

where: AA is the additive x additive interaction
AD is the additive x dominant interaction
DD is the dominant x dominant interaction

The environmental variance can also be partitioned according to the experimental model and assumptions (Cockerham, 1954). For example, in Randomized Complete Block design, the environmental variance is partitioned into the block variance and the residual (error) variance.

1.2.2 Genetic Experimental Designs

The experimental designs mostly employed to estimate genetical components are generations mean analysis and mating designs for variance component analysis (Spragues, 1966).

The basic generation mean model comprises P_1, P_2, F_1, F_2, BC to P_1 (BC_1), and BC to P_2 (BC_2) generation (Hayman, 1958 a; b). Other models have been developed to suit the nature of crop and decrease workloads. For example, model comprising P_1, P_2, F_2, F_3, BC_1S_1, BC_2S_1 generation is rather convenient for self-pollinated crop with a small amount of seed production (Hayman 1958b; Snape, 1987). The utilisation of generation mean analysis permits direct estimation of all epistatic parameters, but preparation of crosses usually limits the breadth of germplasm which can be studied.

The mating designs for variance component analysis are generally used much more than the former. The foundation of this procedure is due to Fisher (1918). The advancement in this area was developed by Wright (1921), Comstock and Robinson (1948) and Mather and Jink (1971), Hayman (1958a; b), Kempthorne (1957) ,Becker (1984) and Baker (1986).

Any models developed for the estimation of genetic variances involve a series of biological assumptions. The common ones are: normal diploid behaviour at meiosis; no maternal or cytoplasmic effects; no multiple alleles; linkage equilibrium; no selection; no epistasis.

Under some conditions, however, one or some of these assumptions can be exempted; but these may not be any needs to suppose relation of these assumptions, as they may be reasonable under population equilibria conditions.

The simplest mating designs are biparental mating design (BIP) and one-way mating design. The former involves crossing parents pairwise to produce full-sib family (Kearsey, 1965). And the latter involves crossing of one parent with an unknown parent to produce half-sib families (Becker, 1964). Both designs are confined to only two kinds of relationship among progenies, either sibling (full-sib / half-sib) or unrelated. However, under proper experimental design and appropriate assumptions, it can supply well-defined genetical variance components. An example of one-way mating design was showed in studying genetic components of morphological variation in *Salix repens* (Fowler *et al.*, 1983).

Other designs utilize both half-sib and full-sib relationships. These are hierarchical design (North Carolina I) and factorial design (North Carolina II) (Comstock and Robinson, 1948). In the hierarchical design, each of a series of random males *(m)* is mated to each of *f* random females. The offsprings of the *mf* matings comprise the relationship of half-sib (Vm) and full-sib - half-sib ($Vf_{(m)}$) and the unrelated (V_e) (comstock and Robinson, 1948; 1952).

For the factorial design, each of a different series of males (*m*) and females (*f*) are mated to each other. The offsprings of *mf* are related in the form of half-sib to males (Vm), half-sib to females (Vf), full-sib - both half-sibs, and the related (V_e) (Comstock and Robinson 1948; 1952).

One of modifications of factorial designs which is popular and mostly applied in plant genetical analysis is diallel analysis (Cockerham, 1963; Kempthorne, 1957). The design involves the same series of males and females mating to one another. Due to its use of common parent group, the design can be modified further to several types (Griffings, 1956a; b).

1. Full diallel, offsprings derived from all full combinations of parents.
2. Partial diallels, offsprings derived from incomplete combinations which can be with or without parents and with or without reciprocal. They are used to overcome constraints from a large numbers of crosses. (Gilberts, 1958; Kempthorne and Curnow, 1961; Curnow, 1963; England, 1974).
3. Triallels (Rawlings and Cockerham, 1962a).
4. Partial triallels (Hinkelmann, 1965).

5. Tetra-allele cross designs (Rawlings and Cockerham, 1962b).

1.2.3 Heritability and Its Standard Error Estimates

Heritability is defined as proportion of genotypic variance to phenotypic variance (Falconer, 1981).

$$h^2 = V_G/V_P$$

where: V_G is genotypic variannce
V_P is phenotypic variance

One basic method to determine the heritability is the linear regression of genotypic values on phenotypic values (Baker, 1986). By definition;

$$b_{GP} = V_{GP}/ V_P$$

where: V_{GP} is the covariance between genotypic and phenotypic value
V_P is the phenotypic variance

Since, $P = G + E$

$$V_{GP} = V_{(G)(G+E)} = V_G + V_{GE}$$

If G and E are independent, $V_{GE} = 0$, $V_{GP} = V_G$

Hence;

$$b_{GP} = V_G/ V_P$$

Based on similar concept, parent-offspring relationship is also used to estimate the heritability. In this case, the phenotypic value of progeny (P_i) is one-half maternal genetic value (G_i), one-half paternal genetic value (G_j) and an environmental deviation (E_i);

$$P_i = 0.5\,G_i + 0.5\,G_j + E_i$$

Under random mating situation, G_i and G_j will be uncorrelated. Hence;

$$V_{GP} = V_{Gi(0.5\,Gi + 0.5\,Gj + Ei)} = 0.5\ V_G$$
$$h^2 = 0.5\ V_G / V_P$$

Furthermore, there is another viewpoint on heritability by considering the coefficient of determination of the regression of genotypic value on phenotypic value.

If $P_i = G_i + E_i$ and $(G_i - \bar{G}) = b_{GP}\,(P_i - \bar{P})$,

The coefficient of determination for the regression of genotypic value is ;

$$r^2 = V_{GP}/\,V_G.V_P = V_G\,/V_G.V_P = V_G/\,V_P = h^2$$

Heritability can be also estimated indirectly from differences between phenotypic and environmental variances or from the covariances between relatives. Partitioning genotypic variances into additive and non-additive portions can yield at least two common kinds of heritabilities. The broad-sense heritability considers total genetic variability in relation to the phenotypic variability (V_G/V_P) while the narrow-sense considers only the additive portion of the genetic variability in relation to phenotypic variation (V_A/V_P)(Hanson, 1963; Falconer, 1981). The proper application of these estimates in plant breeding exercise depends on mating practice. The former is appropriate for the inbred or clonal genotypes while latter is more appropriate in random mating population (Baker, 1986).

Its precision is indicated by its standard error (Falconer, 1981). A conventional way to derive the standard error of heritability is using the intra-class correlation coefficient (Robertson and Lerner, 1949). For a one-way mating design, Becker (1984) has described it as:

$$se.h^2 = 4\sqrt{\frac{2(1-t)^2\,[\,1+(k-1)t\,]^2}{k(k-1)\,(s-1)}}$$

where: t is the intra-class correlation

k is the coefficient of variance component being estimated

In addition, standard error of heritability can also be derived from the variance of a ratio, using ratios of variance components (Osborne and Paterson, 1952) This procedure can be used with phenotypic and genotypic variances from any experimental models. Solutions for more complicated models were demonstrated by Gordon, *et al.* (1972) and Gordon (1979).

CHAPTER 2

MATERIALS AND METHODS

2.1 Objectives

1. Partition genetic variance and estimate heritability.
2. Estimate the plant genetic variance and compare with topodeme variance.
3. Describe the species variation, identify those characters useful in selection and also develop guidelines for future plant breeding.
4. Elaborate tiller development and growth from the genetic point of view.

2.2 Source of Materials

Seeds of each line were collected from individual mother plants in an open-pollination field. The offsprings of each plant therefore have one common parent (female) and many different male parents, making them half-sibs. Observations on an individual plant basis from these sibling groups make it possible to study the underlying genetic components. These lines will be called 'half-sib families' in this study.

Furthermore, the half-sib mother-plants were random individuals from several wild populations (topodemes) which previously had been grouped into clusters (Teow, 1978). This knowledge was used to define stratified samples, representing the phenotypic variation throughout New Zealand Yorkshire Fog grass. Stratified random sampling provided fifty half-sib families, five from each of ten topodemes, two of which came from each of the five clusters of Teow (see Fig.2.1). Comparison between the topodeme variation and half-sib family variation could therefore be done, in addition to the half-sib genetic analysis referred to earlier.

2.3 Experimental Design and Bench Layout

The experimental design was a grouped treatment Randomized Complete Block design. Nine individual plants from each half-sib family were used, arranged in three blocks, with three plants per experimental unit.

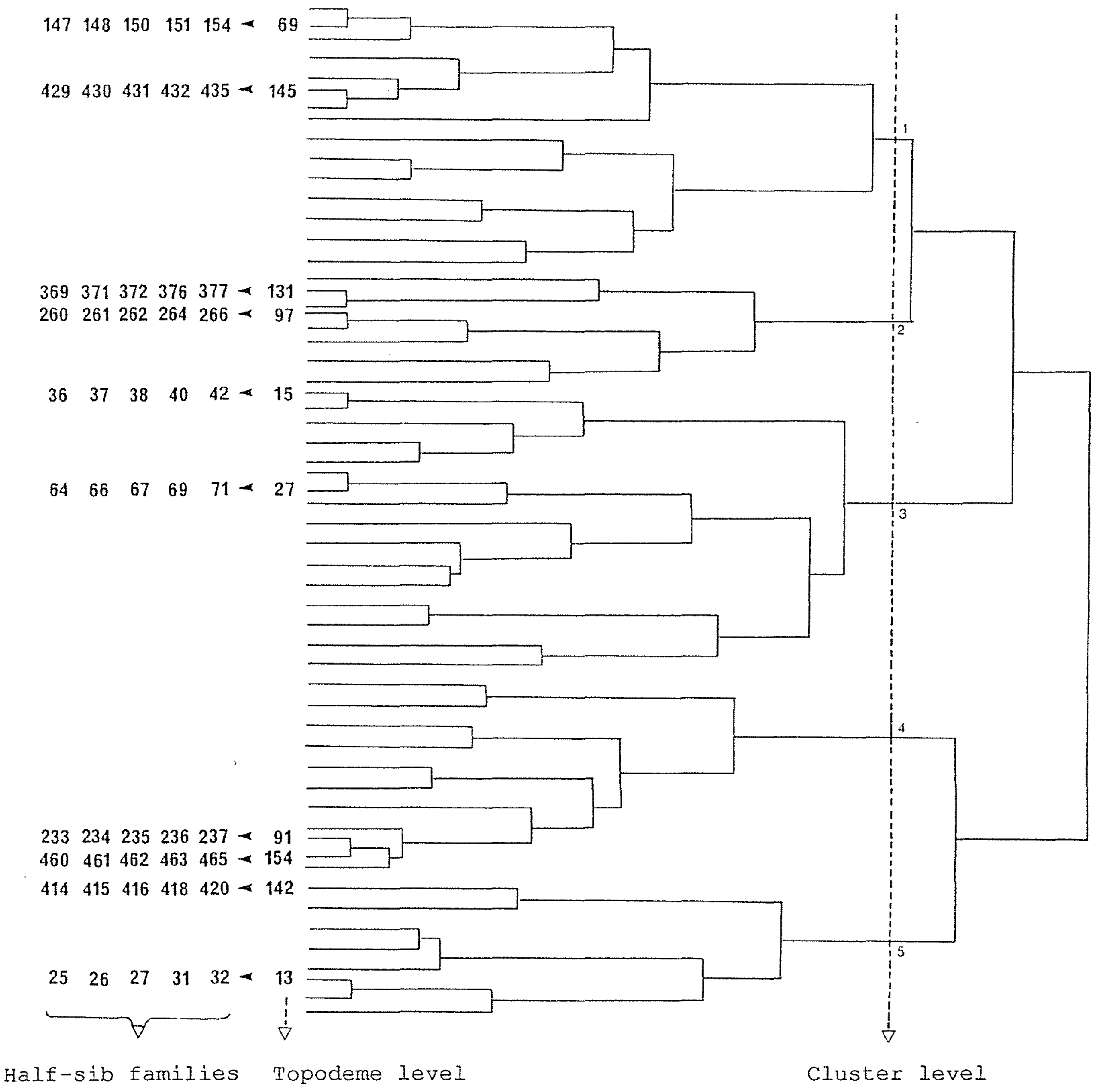

Figure 2.1 Origins of the 50 half-sib families from the 10 topodemes in 5 clusters defined by Teow (1978), the numbers refer to the seed catalogue

The experiment was set up in a glasshouse. Plants were placed in a fixed position across benches, without relocation. In this way, it was intended to used "position" as a concomitant variable in order to remove and quantify any position effect (e.g. from shading, etc.).(see Fig.2.2 and plate 2.1)

2.4 Experimental Crop Management

Seeds were sown in autumn (early April 1988). They were germinated in fluctuating temperature (8 hrs. in 10^{o}C and 16 hrs.in 20^{o}C) and under continuous light conditions in a germinator. After 5 to 7 days, seedlings were removed to the glasshouse and transplanted into plastic planter bags (1.6 litres). The media used was sand and peat at the ratio of 3:1 with 250 g. of 3-month Osmocote-^{R} for every 70 litres of mixed media.

At the early stages of vegetative growth, starting from the 4-5 leaf stage, plants were subjected to the ambient winter temperature of Palmerston North (heating unit was switched off) for almost 6 weeks (6-th May to 17-th June), in case vernalization was required. Previous studies and speculations indicated that low temperature in winter and long-day photoperiod may be a requirement for flower induction of Yorkshire Fog grass (Hill, 1988; Robertson, 1988 *pers.comm.*). Flowering induction and initiation were chiefly determined by a photoperiod more than 15.5 hours (Montaldo and Paredes, 1981) or between 1430 and 1845 hours (Prokudin; Kalenichenko; Mamro, 1983). Subsequently, plants were provided with artificial photosynthetic light to extend the active daylength to 16 hours a day starting from 0400 to 2000 hrs. Temperature in the glasshouse was controlled between 20 - 25 ^{O}C. The aim was to provide a semblance of spring/ summer in the out-of-season glasshouse. The vernalizing treatments seemed to be effective, as the plants started their booting and heading on the first and second weeks of July.

Plants were watered by drip irrigation onto bench mats twice a day with each watering lasting about 30 minutes. Few aphids appeared, but were kept in check by pyrethroid chemical (rate 0.02%) when necessary. Caging of individual plants with chicken-wire columns was practiced to hold up the plants because of the limited space in the glasshouse (Plate 2.3).

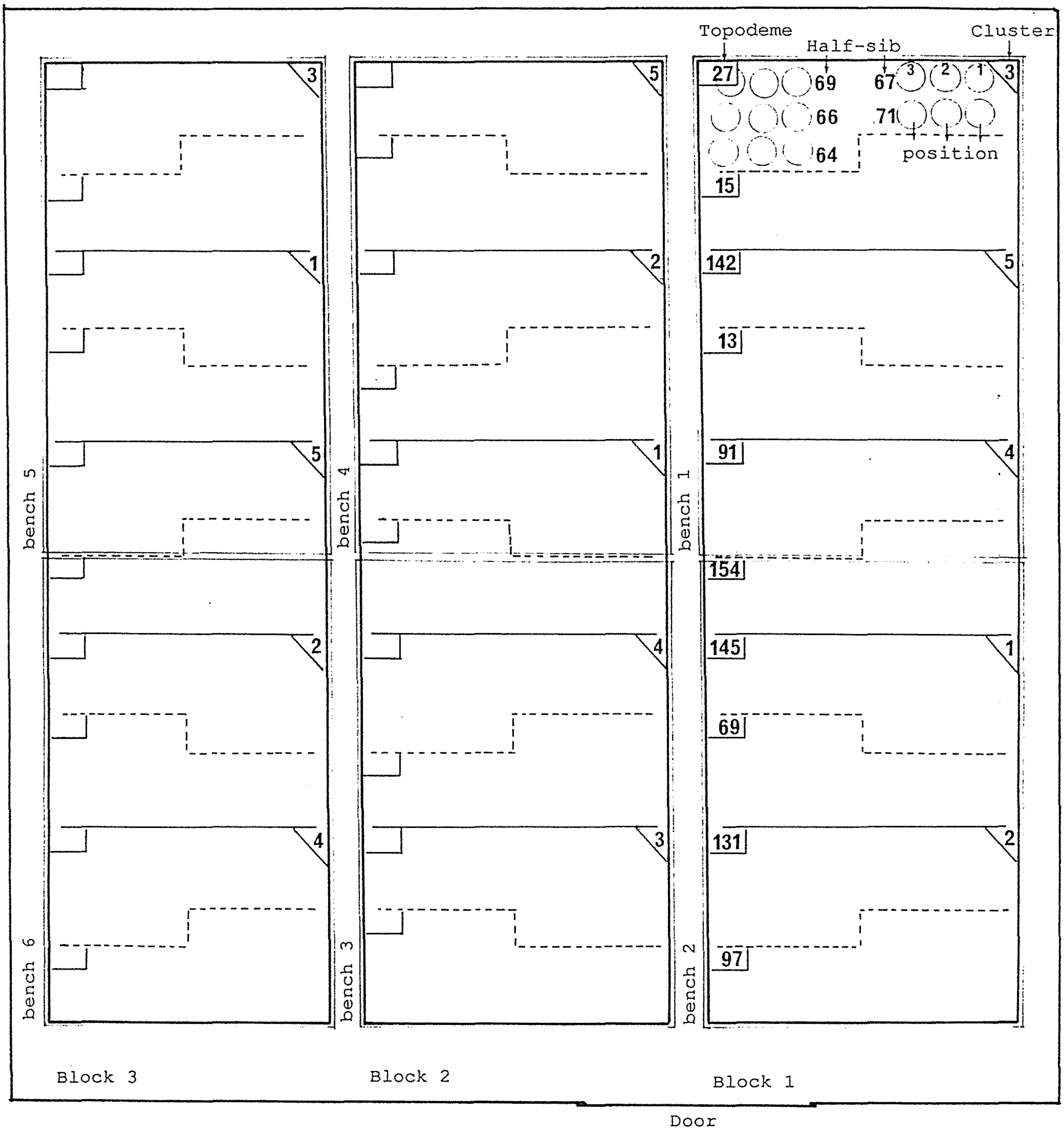

Figure 2.2 Experimental layout in the glasshouse

Plate 2.1 Experimental layout at 4-th week (above) and at 7-th week (below).

2.5 Data Collection and Measurement

2.5.1 Leaf Blade Attributes

Seedling leaf blade width and seedling leaf blade length of the 2-nd and 3-rd leaves from the ground level were measured (in millimetres) on the vegetative seedling (about one month from sowing). The leaf blade width was measured at the widest part of the leaf blade. Length was measured from the ligule to the tip. Most plants had 4 - 5 leaves at this stage.

Mature leaf blade width was measured (in millimetres) on the 3-th and the 4-th leaf blade from the top at two different growth stages. Firstly, at the stem elongation stage (about 15-16 weeks after sowing), being the same time as leaf tensile strength, was measured; and secondly, at post-ripe-seed stage of the first tiller (about 30-35 weeks and also being the end of the experiment). The latter measurement virtually coincided with the stem elongation stage of the secondary tillers. Three samples per plant were recorded in the first occasion, and only one sample per plant was recorded in the second measurement.

2.5.2 Tiller Numbers

Total tiller numbers of individual plant were counted every 7-10 days for two months, during vegetative stages from seedling to stem elongation (from 4-th wk. to 11-th wk. after sowing) (Plate 2.2).

At the end of experiment, tillers were classified into four groups namely: (1) dead tillers (post-flowering main tillers) (2) green tillers (secondary and tertiary tillers) (3) young tillers under 15 cm. tall and (4) aerial tiller (see Plate 2.3 and Fig 4.1 in Discussion).

After counting, each group of tillers was dried out in oven (at 75^{o}C) for 3 days and weighed separately giving tiller mass (in grams) for each group of tillers for each plant.

Plate 2.2 Stage of seedlings when the tiller counting started

Plate 2.3 Green tillers and aerial tillers

2.5.3 Leaf Sheath Purple Colour

Degrees of purple colour at the leaf sheath were scored three times : (1) at the vegetative stage of older plant just prior to stem elongation (about 12 wks. from sowing), (2) at stem elongation stage (about 14 wks. from sowing), and at stem elongation stage of the secondary tiller (about 33 wks. from sowing). Standard colour specimens were established, and an ordinal score from 1 to 5 was based on these scores (increasing with the increasing purple colour) (Plate 2.4). Increment of half-scores were used for border-line assessments.

2.5.4 Leaf Favanol and Tannin Content

The flavanoid precursors of condensed tannins in the leaf sheath were evaluated semi-quantitatively by Burn's spot test, based on the vanillin-hydrochloric acid method. The procedure, described extensively by Burn's (1963) and Jones *et al.* (1973) was relatively rapid and inexpensive. The test was carried out twice at the early stem elongation stage (firstly about 13 wks. and secondly about 15 wks. from sowing). An approximate 5 cm. piece of the outermost part of the leaf sheath was sampled from each plant. The sample was squeezed between two layers of Whatman^{R} No.1 filter papers. The plant residual was discarded and its imprint on the paper was wetted with a few drops of test reagent. The reagent comprised two volumes of 10% w/v vanillin in ethanol mixed with one volume of concentrated hydrochloric acid. The reagent was normally kept on ice to keep it cool. The reaction paper was left for drying under ambient temperature (15^{o}-$20\ ^{o}C$) inside a dark chamber for about 30 - 40 minutes. Development of a red to violet colour was scored against standards on a photograph (Plate 2.5). Ordinal scores of 1 to 5 (increasing with degree of red / violet) with half increments were based on these standards. The imprints with red and violet indicated the presence of flavan materials, while blue or green spots indicated lack of them.

2.5.5 Leaf Tensile Strength

Leaf tensile strength was tested during the middle-stem elongation stage (about 15 -16 wks. of sowing) on the third and fourth leaf blade from the top. The

score = 1

score = 2

score = 3

score = 4

score = 5

Plate 2.4 Leaf sheath colour score standard

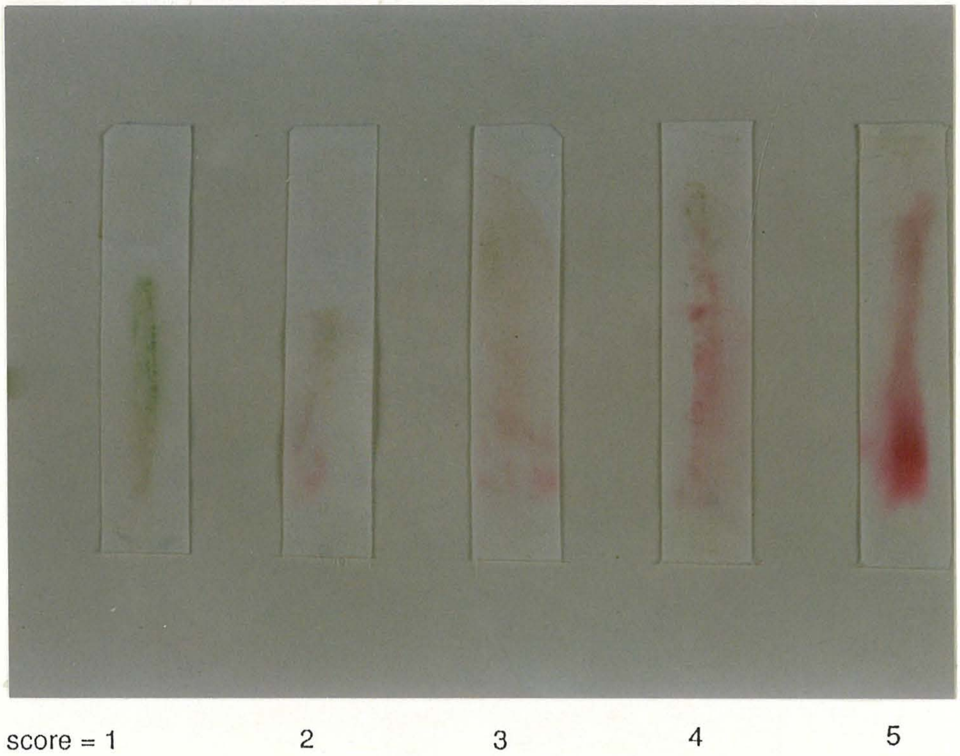

Plate 2.5 Burn's spot test on flavanol standard machine and technique were developed by Evans (1967 a; b). Three mature leaf blades were sampled from each plant during the morning. Water-soaked cotton wool was wrapped over the cut-end, and the leaves were put into a moist plastic bag until the testing period in the afternoon and evening. A 5 cm. piece was cut from about the middle of the lamina. This was inserted and held between two clamps. A motor-driven spring applied load to a beam until the leaf specimens broke. A calibrated dial converted the breaking load into grams, using the regression equation of $Y= -92.5 + 5.5 X$ ($R^2 = 97.2\ \%$), where Y = estimate of breaking load (gms.), X = dial reading (Evans, 1964). The dry weight (mg.) of the tested specimens, (found after drying for 3 days at 70°C) was also recorded after the break. The index of strength was estimated as:

$$\text{Index of Strength} = \frac{\text{breaking load (gms.)}}{\text{dry weight (mg.)}} \quad \text{(Evans, 1964)}$$

2.5.6 Leaf Hair

A mature leaf blade sampled at the stem elongation stage of the secondary tiller (about 30 - 35 wks. from sowing) was chosen randomly to examine the degree of hair intensity under a stereo-microscope. Ordinal scores 1 to 5 with a half increments were applied using the standard of Cameron(1979) (Plate 2.6).

2.5.7 Clump Erectness

Plant erectness scores were recorded at the older vegetative stage (about 7 wks. of sowing), this being prior to stem elongation for flowering. Ordinal scores of 1 to 5 with half increments were applied using the following definitions of angles from horizontals: (1) 0^o - 15^o ; (2) 15^o - 30^o ; (3) 30^o - 45^o ; (4) 45^o - 68^o ; (5) 68^o - 90^o. In allotting these scores, the general impression of the leaf-sheath angles of the plant were used.

Figure 2.3 Leaf hair standards for ordinal score (Cameron, 1979)

2.5.8 Flowering Day

Peeping day, the first anthesis day, the last flowering day were recorded (in number of days from sowing) on individual plant basis.

The peeping day was the first day when the terminal leaf-sheath showed a longitudinal split because of an enlarging inflorescence.

The first anthesis day was the first day when the first flower started to anthise.

And the last flowering day was the day when the last anthesis occurred.

The day lying half-way between the first anthesis day and the last flowering day was estimated also as the median flowering day.

2.5.9 Anthesis Time and Position

Anthesis time of day and anthesis position in the inflorescence on the first panicle have been recorded by ordinal scores, at the first anthesis day. For anthesis time, the scores of 1 to 4 were allocated for the time periods of 0400 - 0900 ; 0900 - 1200 ; 1200 - 1400 ; 1400 - 1600 hours , respectively. For anthesis position, the scores 1 to 3 were assigned to: top end portion, mid portion and bottom portion, respectively. Increments of half were used, also, for intermediate positions.

2.5.10 Panicle Size and Compactness

Panicle width and length were measured on a fully dehiscing inflorescence at the main anthesis stage (about 20 wks. from sowing). The degree of compactness was rated against ordinated standard specimens (Plate 2.7). The scores were 1 to 5 from dense to loose, with half increments.

score = 1

score = 2

score = 3

score = 4

score = 5

Plate 2.6 Panicle compactness standard

2.5.11 Plant Height

Plant height was measured (in centimetres) from the soil level to top-end of panicle at late milk stage of the seed (about 25 wks. from sowing).

2.6 Statistical Analyses

2.6.1 Regression Analysis of Tiller Development

The functional relationship between tiller numbers and days was examined for each individual plant, using the "Sigmoid 2 Program" (Smith, unpubl.). The logistic function provided consistently the best fit (The other function examined was gompert). Best-fit was judged by high coefficient of determination, and by inspection of the fitted plots). Several estimates were obtained from the logistic fits namely : number of tillers at 5% , 50% , 95% of the upper asymptote , and at flowering time ; also the number of days to attain 5% , 50% , 95% of upper asymptote of tiller number; the relative growth rate of tiller numbers at 5% , 50% , 95% of the upper asymptote. These calculations were assisted by an auxiliary program "Sigfits" (Smith, unpubl.). These estimates were used as data in ANOVA. These estimates provide data on first-tiller development, being estimated separately for each observational unit (plant).

2.6.2 Analysis of Variance

Due to some experimental units having one or two missing plants, the analysis of variance was carried out by generalized linear model procedure. The ANOVA was based on the following two models :

Model 1 (for Topodeme/Sib Families comparisons)

$$X_{ijkl} = \mu + T_i + B_j + TB_{ij} + H_{k(i)} + HB_{k(i)j} + \varepsilon_{ijkl}$$

where: X_{ijkl} = *the ijkl-th phenotypic variate of individual plant.*

$i = 1, \ldots t$ (no.of topodemes).
$j = 1, \ldots b$ (no.of blocks).
$k = 1, \ldots h$ (no.of half-sib families)
$l = 1, \ldots p$ (no. of plants)

μ = *the grand mean;*
T_i = *the i-th topodeme effect;*
B_j = *the j-th block effect;*
$H_{k(i)}$ = *the k-th halfsib effect, nested within topodemes(error (a));*
TB_{ij} = *the interaction between topodeme and block effect;*
$HB_{k(i)j}$ = *the interaction between half-sib and block effect(error(b));*
ε_{ijkl} = *the residual variation associated with the ijkl-th plant.*

This is a grouped treatment Randomized Complete Block design, which is analogous to a split-block design in its definition of error terms (Gomez and Gomez, 1984). Its main purpose was to compare the relative sizes of the three genotypic partitions: topodeme, half sib family and individual plant (Table 2.1).

Model 2 (for genetic analysis)

$$X_{ijk} = \mu + H_i + B_i + HB_{ij} + \varepsilon_{ijk}$$

where: X_{ijk} = *the ijk-th phenotypic variate of individual plant;*

$i = 1, \ldots h$ (no.of half-sib families);
$j = 1, \ldots b$ (no.of blocks);
$k = 1, \ldots p$ (no.of plants);

μ = *the grand mean;*
H_i = *the i-th halfsib genotype effect;*
B_j = *the j-th block effect;*
HB_{ij} = *the interaction between half-sib and block (experimental error);*
ε_{ijk} = *the residual variation associated with the ijk-th plant.*

This is an Randomized Complete Block design, with plant subsamples, intended to give a pooled genetic analysis (Table 2.2).

Both analyses of variance have been adjusted with the concomitant variable of plant bench-position to eliminate possible confounded effects due to plant position (such as shading, disease incidence, etc.). The plants of each half-sib were coded from one to three, starting from the outer edge towards the middle of the bench. These codes provided the concomitant variable.

F-tests for significance were constructed in the usual manner using random-effect expectations of Mean Squares (Steel and Torrie, 1981; Crump, 1951; Satterthwaite, 1946).

Variance components for each effect were estimated together with their standard errors, using the program "Thwaite" (Gordon, unpubl.).

The estimator for the standard errors of the component 's estimates (s^2) was

$$\widehat{Var}(s^2) = 2\,\Sigma a_i^2 M_i^2/(f_i+2)$$

where: a_i's are the linear mean-square coefficients used in computing s^2;
M_i's are the mean squares used in estimating s^2;
f_i's are the degrees of freedom of those mean-squares.
(Anderson and Bancroft, 1952 ; Crump, 1951).

Program "Thwaite" (Gordon, unpubl.) was used to effect these estimates.

2.6.3 Estimation of Genetic Variance

The biometrical variance estimates and the genetic variances were interrelated via the intra-class correlation (Falconer, 1981). The present experiment represents a one-way mating design (Falconer, 1981), and relates the model-2 experimental (biometrical) variances to the covariance between individuals within a progeny group (Baker, 1984; Falconer, 1981). As these progeny individuals were half-sibs, the

Table 2.1 Expected Mean Squares (EMS) (Model 1)

Source	EMS	
Block	$V_w + \tilde{p}V_{HB} + \tilde{p}hV_{TB} + \tilde{p}hT_{VB}$	MS6
Topodeme	$V_w + \tilde{p}V_{HB} + \tilde{p}hV_{TB} + \tilde{p}hbV_T$	MS5
Topodeme x Block	$V_w + \tilde{p}V_{HB} + \tilde{p}V_{HB} + \tilde{p}hV_{TB}$	MS4
Half-sib(Topodeme)	$V_w + \tilde{p}V_{HB} + \tilde{p}bV_{H(T)}$	MS3
Half-sib(Topodeme) x Block	$V_w + \tilde{p}V_{HB}$	MS2
Residual (Within Plot)	V_w	MS1

Table 2.2 Expected Mean Squares (EMS) (Model 2)

Source	EMS	
Block	$V_w + \tilde{p}V_{HB} + \tilde{p}gV_B$	MS4
Half-sib	$V_w + \tilde{p}V_{HB} + \tilde{p}bV_H$	MS3
Block x Half-sib	$V_w + \tilde{p}V_{HB}$	MS2
Residual (Within Plot)	V_w	MS1

These are the balanced expectation ($\tilde{p} = c_1\ c_2\ c_3$ etc.)

variance amongst progeny group is equivalent to covariance between half-sib individuals.

Therefore,the genetical model in this one-way mating design is as follows :

$V_H = \text{cov.(HS)} = 1/4\ V_A + 1/16\ V_{AA}$ ....(1)
$V_W = V_{Tot.} - \text{cov.(HS)} = 3/4V_A + V_D + 15/16V_{AA} + V_{AD} + V_{DD} + V_e$..(2)
(Baker, 1984)

where: V_A = "additive" variance (average allele effect variance);
V_D = "dominance" variance (heterozygote variance);
V_{AA} = "additive x additive" variance (epistatic inconsistencies across genes when additive effects are combined);
V_{AD} = "additive x dominant" variance (epistatic inconsistencies from additive x dominance combination);
V_{DD} = "dominant x dominant" variance (epistatic inconsistencies from dominance x dominance combination);
V_e = "environmental" variance.

The model 2 plot residual ($V_{BH} = V_{EXG}$) represents an "environmental" variance for experimental-units, each consisting of (notionally) three plants (the harmonic mean of actual plants per plot, after allowing for misses, was used in some characters). Therefore, on an individual plant basis,

$$V_{BH} = V_{\bar{x}(plt.)}$$
$$= V_e / p$$

From which V_e = $p\ V_{BH}$.....................(3)
= environmental variance for plant within plots

This assumption of homogeneity of environmental variances has made it possible to remove the environmental confounding within V_W.

The links between the biometrical variance components and the genetic variance components were as followed:

$$V_H = (MS3 - MS2)/pb$$

(From 1) $= 1/4\ V_A + 1/16\ V_{AA}$

$$4V_H = V_A + 1/4\ V_{AA} \ \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

and $3V_H = 3/4\ V_A + 3/16\ V_{AA} \ \ldots\ldots\ldots\ldots\ldots\ldots (5)$

The phenotypic variance was defined as:

$$
\begin{aligned}
V_p' &= V_H + V_w \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)\\
&= V_H + V_g + V_e\\
&= V_G + V_e\\
&= V_A + V_{AA} + V_D + V_{AD} + V_{DD} + V_e \ \ldots\ldots (7)
\end{aligned}
$$

The within- family genetic variance is, using (2) and (3),

$$V_g = V_w - V_e \qquad \ldots\ldots\ldots\ldots\ldots\ldots (8)$$

From V_w and (5),

$$V_w - 3V_H = V_D + 3/4V_{AA} + V_{AD} + V_{DD} + Ve \ \ldots\ldots\ldots (9)$$

and (9)-(3),

$$V_h = V_D + 3/4\ V_{AA} + V_{AD} + V_{DD} \ \ldots\ldots\ldots\ldots (10)$$

2.6.4 Heritability

Various heritability estimates were made, following standard principles (Falconer, 1981; Comstock, 1952). The definitions used were as follows.

h^2 (broad sense) = heritability of all gene effects (genotype);
$= (V_H + V_g) / (V_H + V_w)$
$= (V_A + V_D + V_{AA} + V_{AD} + V_{DD}) / V_P$,

h^2 (narrow sense) = heritability of average allele effects;
$= 4\ V_H / (V_H + V_w)$
$= (V_A + 1/4\ V_{AA}) / V_P$,

h_2 (heterotic sense)= heritability of non-average allele effects;
$= (V_w - 3\ V_H) / (V_H + V_w)$
$= (V_D + 3/4 V_{AA} + V_{AD} + V_{DD}) / V_P$,

CHAPTER 3

RESULTS

There were forty seven characters under investigation in this experiment. They were divided into three main categories: botanical characters, agronomic characters and tillering characters. The model 1 analysis (see methods) was used to compare the magnitude in variation between topodemes and half-sib families. The model 2 analysis was the basis for the plant genetic analyses, from which the heritability estimates were obtained.

The general value of each attribute is indicated by the grand means given in the Table 3.1. This table also summarized the overall variability in two ways: the coefficient of variation and the range (minimum and maximum). Several attributes have a high level of the coefficient of variation. These include 12 wks. and 15 wks. leaf sheath purple, anthesis time, anthesis position, panicle width and compactness, clump erectness, old disease and new disease, flavanoid at leaf sheath and almost all attributes of tillering except for the number of days to tillering. Mean differences among the fifty half-sib families accounting for each attribute are exhibited in Appendix I.

3.1 Topodeme, Half-sib and Plant Variance Analysis

The environmental variance, including block variance (V_B), error (a) variance or topodeme by block interaction (V_{TB}) and error (b) variance or half-sib by block interaction (V_{HB}) is shown in Table 3.2. Most attributes was significantly influenced to some degrees by the environmental effects. The attributes which show significance on those three environmental effects simultaneously include 15 wks. leaf sheath purple, flowering peeping day, first anthesis day, median flowering day, clump erectness, flavanoid at leaf sheath, tillering number at 5% tillering, numbers of dead tillers, and numbers of days for 50%, 95% tillering.

Table 3.1 The grand means, their coefficients of variation and maxima and minima over all half-sib families

CHARACTERS	unit	$\bar{x}$	c.v.	min.	max.
Botanic characters					
1. Juvenile leaf width	mm	25.51	14.12	21.9	32.1
2. Juvenile leaf length	mm	72.83	15.94	59.4	92.9
3. Mature leaf width (15 wks)	mm	10.31	11.13	9.1	11.5
4. Mature leaf width (33 wks)	mm	9.49	11.75	8.5	10.7
5. Leaf sheath purple (12 wks)	score	6.20	22.53	4.2	7.8
6. Leaf sheath purple (15 wks)	score	4.32	35.14	3.0	6.7
7. Leaf sheath purple (33 wks)	score	9.07	15.19	7.4	10.0
8. Plant height	cm	107.82	9.47	97.6	121.4
Flowering characters					
9. Flower peeping day	days	112.83	3.53	108.44	122.00
10. First anthesis day	days	120.58	3.55	115.22	129.60
11. Median flowering day	days	134.16	7.07	128.21	145.31
12. Last flowering day	days	147.75	12.40	135.71	169.63
13. Anthesis time	score	2.18	100.86	1.00	4.00
14. Anthesis position	score	3.78	33.88	2.78	4.89
15. Panicle width	cm.	55.75	31.79	37.68	80.68
16. Panicle length	cm.	134.03	18.96	107.79	157.42
17. Panicle compactness	score	5.36	34.86	3.75	6.80
Agronomic characters					
18. Clump erectness	score	4.33	35.15	2.1	5.9
19. Old diseases	score	7.12	22.87	5.1	8.5
20. New diseases	score	4.21	40.89	1.9	6.6
21. Leaf hairiness	score	8.76	12.10	7.6	9.6
22. Leaf tensile strength	mm.	95.70	15.13	80.5	115.7
23. Flavanoid at leaf sheath	score	4.62	37.07	2.7	21.02

Table 3.1 (continued)

CHARACTERS	unit	$\bar{x}$	c.v.	min.	max.
Tillering characters					
24. Tiller No.at 5% tillering	no.	2.34	99.72	1.40	10.18
25. Tiller No.at 50% tillering	no.	21.44	63.58	13.91	48.81
26. Tiller No.at 95% tillering	no.	41.46	67.33	28.03	102.56
27. Tiller No.at flowering time	no.	41.86	34.91	29.88	62.75
28. No.of dead tillers at end	no.	18.08	46.00	8.67	30.56
29. No.of green tillers at end	no.	28.18	53.83	18.00	41.25
30. No.of young tillers at end	no.	11.37	86.59	2.44	26.83
31. No.of aerial tilllers at end	no.	73.77	47.24	49.89	108.11
32. No.of total tillers at end	no.	132.65	33.62	101.89	117.14
33. No.of base tillers at end	no.	57.67	40.31	34.67	91.22
34. No.of base green tiller	no.	39.53	50.78	21.33	64.86
35. Dead tiller dry weight	gm.	8.83	64.80	2.80	15.06
36. Green tiller dryweight	gm.	19.43	66.94	11.66	35.67
37. Young tiller dryweight	gm.	1.33	106.22	0.24	3.62
38. Aerial tiller dryweight	gm.	27.92	53.07	15.84	45.37
39. Total tiller dryweight	gm.	56.81	44.99	38.10	78.24
40. Base tiller dryweight	gm.	55.94	44.31	17.93	46.51
41. Base green tiller dry weight	gm.	20.82	64.76	12.61	35.91
42. No.of days for 5% tillering	days	28.98	14.49	24.16	34.88
43. No.of days for 50% tillering	days	63.63	11.78	54.39	77.56
44. No.of days for 95% tillering	days	98.49	12.74	83.85	120.63
45. RGR at 5% tillering	-	35.94	162.34	-21.68	246.12
46. RGR at 50% tillering	-	87.34	74.67	69.13	284.41
47. RGR at 95% tillering	-	91.10	78.58	70.58	286.40

* Significant at 5% probability level

** Significant at 1% probability level

Table 3.2 Block, Error(a), Error(b) variance components and their standard error and F-significance, together with position F-significance (model 1)

Characters	Block		Error(a)		Error(b)		Position
	Var. (se.)	F-sig.	Var. (se.)	F-sig.	Var. (se.)	F-sig.	F-sig.
Botanic characters							
1. Juvenile leaf width	0.07 (0.12)	ns	0.02 (0.33)	ns	0.26 (0.81)	ns	ns
2. Juvenile leaf length	0.26 (0.79)	ns	2.48 (3.57)	ns	-4.76 (7.32)	ns	ns
3. Mature leaf width (15 wks)	-0.004 (0.004)	ns	0.02 (0.03)	ns	-0.06 (0.08)	ns	ns
4. Mature leaf width (33 wks)	0.35 (0.26)	**	-0.01 (0.04)	ns	0.16 (0.10)	*	ns
5. Leaf sheath purple(12 wks)	0.05 (0.05)	**	0.04 (0.05)	*	-0.15 (0.10)	ns	ns
6. Leaf sheath purple(15 wks)	0.05 (0.05)	**	0.08 (0.11)	**	0.45 (0.20)	**	**
7. Leaf sheath purple(33 wks)	0.29 (0.22)	**	-0.04 (0.06)	ns	0.35 (0.17)	**	ns
8. Plant height	9.35 (7.47)	**	10.92 (6.72)	**	11.32 (8.27)	ns	ns
Flower characters							
9. Flower peeping day	1.26 (1.02)	**	1.72 (1.06)	**	1.93 (1.29)	*	ns
10. First anthesis day	1.32 (1.13)	**	2.40 (1.50)	**	4.48 (1.82)	**	ns
11. Median flowering day	3.49 (3.06)	**	6.08 (4.38)	**	4.04 (6.33)	**	**
12. Last flowering day	5.63 (6.09)	*	19.14 (14.99)	*	11.36 (23.08)	ns	**
13. Anthesis time	-0.03 (0.01)	ns	-0.17 (0.10)	ns	0.36 (0.36)	ns	ns
14. Anthesis position	0.03 (0.03)	*	0.004 (0.05)	ns	0.09 (0.12)	ns	ns
15. Panicle width	1.80 (3.78)	ns	-2.43 (12.15)	ns	68.61 (30.05)	**	**
16. Panicle length	83.17 (62.12)	**	14.92 (19.67)	ns	-17.47 (39.49)	ns	**
17. Panicle compactness	-0.03 (0.01)	ns	-0.06 (0.12)	ns	0.73 (0.33)	**	ns

Table 3.2 (continued)

Characters	Block		Error(a)		Error(b)		Position
	Var. (se.)	F-sig.	Var. (se.)	F-sig.	Var. (se.)	F-sig.	F-sig.
Agronomic characters							
18. Clump erectness	0.19 (0.15)	**	0.24 (0.15)	**	0.29 (0.18)	*	**
19. Old diseases	-0.02 (0.01)	ns	0.21 (0.16)	**	0.38 (0.22)	*	ns
20. New diseases	0.38 (0.29)	ns	0.33 (0.21)	**	0.54 (0.26)	**	ns
21. Leaf hairiness	8.11 (0.08)	**	-0.04 (0.03)	ns	0.20 (0.10)	**	ns
22. Leaf tensile strength	34.52 (26.11)	**	-6.44 (7.22)	ns	50.20 (21.03)	**	ns
23. Flavanoid at leaf sheath	0.25 (0.20)	**	0.05 (0.14)	**	0.72 (0.28)	**	**
Tillering characters							
24. Tiller No.at 5% tillering	-0.03 (0.06)	ns	0.15 (0.04)	**	3.13 (0.81)	**	**
25. Tiller No.at 50% tillering	4.0 (3.88)	*	-1.33 (4.90)	ns	9.54 (12.89)	ns	**
26. Tiller No.at 95% tillering	14.88 (14.92)	*	-13.28 (18.85)	ns	46.00 (54.90)	ns	**
27. Tiller No.at flowering time	0.81 (1.92)	ns	3.84 (7.46)	ns	15.05 (15.40)	ns	**
28. No.of dead tillers at end	1.39 (1.53)	**	2.95 (3.36)	**	3.56 (1.97)	*	**
29. No.of green tillers at end	33.89 (25.50)	**	31.90 (15.33)	**	1.93 (14.24)	ns	**
30. No.of young tillers at end	10.48 (8.06)	**	5.27 (4.44)	**	-5.19 (5.17)	ns	**
31. No.of aerial tilllers at end	60.59 (48.09)	**	46.21 (36.90)	ns	-83.72 (61.72)	ns	**
32. No.of total tillers at end	76.61 (65.26)	**	156.72 (92.31)	**	-51.91 (115.96)	ns	**
33. No.of base tillers at end	1.81 (5.23)	ns	68.25 (35.73)	**	22.08 (37.14)	ns	**
34. No.of base green tiller at end	7.08 (7.91)	*	60.83 (29.15)	**	7.83 (26.49)	ns	**
35. Dead tiller dryweight at end	1.48 (1.28)	**	4.08 (2.12)	**	7.57 (2.16)	ns	**
36. Green tiller dryweight at end	38.07 (27.73)	**	4.38 (5.12)	ns	-3.94 (9.79)	ns	**

Table 3.2 (continued)

Characters	Block		Error(a)		Error(b)		Position
	Var. (se.)	F-sig.	Var. (se.)	F-sig.	Var. (se.)	F-sig.	F-sig.
Tillering characters							
37. Young tiller dry weight	0.17 (0.13)	**	0.06 (0.08)	*	0.17 (0.15)	ns	**
38. Aerial tiller dry weight	-0.85 (0.56)	ns	6.90 (7.01)	ns	-7.47 (12.83)	ns	**
39. Total tiller dry weight	18.03 (16.78)	**	22.71 (20.21)	ns	-40.80 (35.86)	ns	**
40. Base tiller dry weight	21.87 (16.78)	**	12.49 (9.52)	*	1.50 (14.64)	ns	**
41. Base green tiller dryweight	35.56 (26.05)	**	6.28 (6.04)	ns	-5.06 (10.80)	ns	**
42. No.of days for 5% tillering	0.14 (0.19)	ns	0.29 (0.50)	ns	-0.22 (1.07)	ns	**
43. No.of days for 50% tillering	4.18 (3.37)	**	1.39 (2.34)	*	7.81 (4.60)	*	**
44. No.of days for 95% tillering	18.52 (14.18)	**	3.45 (6.14)	*	17.69 (12.30)	*	**
45. RGR at 5% tillering	-33.59 (22.50)	ns	-95.43 (199.12)	**	2005.46 (509.82)	**	**
46. RGR at 50% tillering	-43.51 (17.15)	ns	103.74 (245.58)	**	1565.67 (493.79)	**	ns
47. RGR at 95% tillering	-52.11 (15.74)	ns	167.65 (277.71)	**	1450.78 (529.38)	**	ns

* Significant at 5% probability level
** Significant at 1% probability level

The significance of the position effect is also shown in Table 3.2. Position effects were not significant in about half of the attributes, namely juvenile leaf width and leaf length, mature leaf width, leaf tensile strength, 12 wks. and 33 wks. leaf sheath purple, plant height, flower peeping day, first anthesis day, anthesis time, anthesis position, panicle compactness, old disease, new disease and leaf hairiness. Surprisingly, plant height was not affected by position in this study. It was noteworthy that nearly all tiller attributes were affected.

The half-sib family variance had more characters with significant variance than the topodeme component (in ratio of 5 to 4). This indicated that more variability existed at the half-sib family level. Comparison of the topodeme and half-sib variances and also within plot variance can be made directly in Table 3.3. The half-sib variances had a higher value than the topodeme variances in almost all the characters, except in 33 wks. mature leaf width, 15 wks. leaf sheath purple, flavanoid at leaf sheath and panicle compactness. In addition, the within plot variance has the higher value than the half sib variance in every characters. This indicated that variability level of plant to plant variation within half sib lines was also predominant.

3.2 Genotypic Variance Analysis and Heritability Estimation

From model 2 analysis, the overall genotypic variances (half-sib families or lines) are given in Table 3.4. The block and within-plot variances are the same as in the model 1. The biometrical variance was subsequently repartitioned into genetic variances. The plot variance (V_{HB}) and within plot variance (V_w) are also presented in the same table. Most of the half-sib variance were significant (39 out of 47) except in median and last flowering days, anthesis time and anthesis position, numbers of green tillers and total tillers. However, the plot variance showed less numbers of significant attributes (27 out of 47).

The genotypic variance was repartitioned into additive variance (V_A) and heterotic variance (V_h). The phenotypic was also obtained from the overall genotypic variance and environmental variance combination. These estimates are shown in Table 3.5. About half of total characters had higher value of additive variance than heterotic variance and *vice versa*.

Table 3.3 Topodeme, half-sib, within-plot variance component with their standard error and the F-significance (Model 1)

	Characters	Topodeme		Half-sib		Within-plot
		Var. (se.)	F-sig.	Var. (se.)	F-sig.	Var. (se.)
	Botanic characters					
1.	Juvenile leaf width	0.99	**	3.37	**	12.96
		(0.56)		(1.10)		(10.58)
2.	Juvenile leaf length	8.04	**	29.67	**	134.76
		(0.54)		(9.65)		(110.03)
3.	Mature leaf width (15 wks)	0.04	*	0.20	**	1.32
		(0.03)		(0.08)		(0.12)
4.	Mature leaf width (33 wks)	0.07	**	0.05	**	1.24
		(0.05)		(0.06)		(1.01)
5.	Leaf sheath purple (12 wks)	0.07	**	0.41	**	1.95
		(0.05)		(0.13)		(1.59)
6.	Leaf sheath purple (15 wks)	0.34	**	0.18	**	2.30
		(0.19)		(0.14)		(1.88)
7.	Leaf sheath purple (33 wks)	0.03	ns	0.07	ns	1.90
		(0.04)		(0.11)		(1.55)
8.	Plant height	1.18	**	12.15	**	104.27
		(4.08)		(6.70)		(85.14)
	Flower characters					
9.	Flower peeping day	0.59	**	0.84	**	15.90
		(0.79)		(0.84)		(12.98)
10.	First anthesis day	-0.30	**	1.10	**	18.36
		(0.72)		(1.20)		(14.99)
11.	Median flowering day	-2.52	ns	-0.43	ns	90.00
		(1.63)		(3.18)		(73.48)
12.	Last flowering day	-7.00	ns	-0.34	ns	335.78
		(5.94)		(11.76)		(28.74)
13.	Anthesis time	0.03	ns	-0.18	ns	4.83
		(0.05)		(0.16)		(3.94)
14.	Anthesis position	0.01	ns	-0.03	ns	1.64
		(0.03)		(0.06)		(1.34)
15.	Panicle width	10.59	ns	19.05	**	314.03
		(10.01)		(19.81)		(256.40)
16.	Panicle length	-9.92	ns	76.87	**	645.54
		(7.38)		(34.49)		(527.08)
17.	Panicle compactness	0.08	**	0.06	**	3.49
		(0.09)		(0.19)		(2.85)

Table 3.3 (continued)

	Characters	Topodeme		Half-sib		Within-plot
		Var. (se.)	F-sig.	Var. (se.)	F-sig.	Var. (se.)
	Agronomic characters					
18.	Clump erectness	0.08 (0.11)	**	0.35 (0.16)	**	2.13 (0.19)
19.	Old diseases	0.03 (0.09)	**	0.05 (0.13)	*	2.65 (0.22)
20.	New diseases	0.30 (0.23)	**	-0.06 (0.13)	ns	2.96 (2.42)
21.	Leaf hairiness	0.02 (0.02)	ns	0.005 (0.05)	*	1.12 (0.91)
22.	Leaf tensile strength	-3.33 (2.39)	ns	15.55 (14.30)	**	209.46 (18.34)
23.	Flavanoid at leaf sheath	0.31 (0.19)	**	0.09 (0.17)	**	2.94 (2.40)
	Tillering characters					
24.	Tiller No.at 5% tillering	-0.11 (0.17)	*	0.12 (0.47)	**	5.46 (0.46)
25.	Tiller No.at 50% tillering	2.21 (2.05)	ns	14.08 (9.36)	**	185.81 (15.59)
26.	Tiller No.at 95% tillering	15.18 (14.67)	ns	42.26 (36.46)	**	779.09 (636.12)
27.	Tiller No.at flowering time	4.16 (5.39)	**	39.73 (15.92)	**	213.65 (17.93)
28.	No.of dead tillers at end	2.74 (2.80)	**	13.74 (5.87)	**	69.98 (5.91)
29.	No.of green tillers at end	-8.20 (6.03)	ns	-1.49 (6.86)	ns	230.13 (19.55)
30.	No.of young tillers at end	1.00 (2.73)	**	11.90 (5.96)	**	96.91 (79.13)
31.	No.of aerial tilllers at end	31.32 (31.58)	**	55.73 (39.98)	ns	1214.34 (100.33)
32.	No.of total tillers at end	-19.62 (43.99)	ns	54.05 (67.30)	ns	1989.22 (1677.82)
33.	No.of base tillers at end	-6.21 (17.58)	**	33.99 (25.51)	**	540.38 (45.92)
34.	No.of base green tillers at end	-13.13 (12.18)	ns	17.31 (16.70)	*	402.96 (329.02)
35.	Dead tiller dryweight at end	-0.58 (0.98)	*	4.68 (2.04)	**	30.57 (24.96)
36.	Green tiller dryweight at end	1.46 (3.22)	ns	11.64 (7.09)	*	169.17 (138.13)

Table 3.3 (continued)

Characters	Topodeme		Half-sib		Within-plot
	Var. (se.)	F-sig.	Var. (se.)	F-sig.	Var. (se.)
Tillering characters					
37. Young tiller dryweight at end	-0.02 (0.04)	ns	0.28 (0.13)	**	2.00 (0.17)
38. Aerial tiller dryweight at end	-0.08 (3.69)	ns	10.19 (8.23)	ns	219.53 (14.09)
39. Total tiller dryweight at end	-9.17 (8.01)	ns	15.17 (19.93)	ns	653.09 (55.49)
40. Base tiller dryweight at end	-5.52 (7.91)	ns	17.24 (10.66)	**	228.33 (19.65)
41. Base green tiller dryweight at end	1.04 (3.59)	ns	11.92 (7.58)	*	181.84 (15.56)
42. No.of days for 5% tillering	0.70 (0.53)	**	2.46 (1.02)	**	17.64 (1.49)
43. No.of days for 50% tillering	2.21 (2.05)	**	4.22 (3.26)	**	56.16 (45.85)
44. No.of days for 95% tillering	9.20 (6.76)	**	10.53 (8.50)	**	157.50 (128.60)
45. RGR at 5% tillering	-18.38 (90.19)	*	210.62 (324.72)	**	3404.53 (287.22)
46. RGR at 50% tillering	-1.23 (126.18)	**	56.49 (283.68)	**	4254.19 (357.00)
47. RGR at 95% tillering	-5.03 (142.94)	**	54.08 (300.30)	**	5124.98 (430.08)

* Significant at 5% probability level
** Significant at 1% probability level

Table 3.4 Genotypic variance from half-sib (V_H) and Plot variance (V_{HB}) with their standard errors (Model 2)

Characters	Half-sib V_H (se.)	Half-sib F-sig.	Plot V_{HB} (se.)	Plot F-sig.
Botanic characters				
1. Juvenile leaf width	3.63 (1.05)	**	0.28 (0.75)	ns
2. Juvenile leaf length	30.95 (9.17)	**	-2.62 (7.07)	ns
3. Mature leaf width (15 wks)	0.20 (0.07)	**	-0.06 (0.07)	ns
4. Mature leaf width (33 wks)	0.12 (0.07)	**	0.15 (0.09)	*
5. Leaf sheath purple (12 wks)	0.40 (0.12)	**	-0.11 (0.09)	ns
6. Leaf sheath purple (15 wks)	0.46 (0.19)	**	0.53 (0.19)	**
7. Leaf sheath purple (33 wks)	0.09 (0.09)	**	0.31 (0.15)	**
8. Plant height	10.58 (6.71)	**	22.86 (9.12)	**
Flower characters				
9. Flower peeping day	0.99 (0.92)	**	3.59 (1.40)	**
10. First anthesis day	0.42 (1.15)	**	6.74 (1.97)	**
11. Median flowering day	-2.60 (2.98)	ns	9.39 (6.52)	ns
12. Last flowering day	-6.50 (11.02)	ns	27.87 (23.43)	ns
13. Anthesis time	-0.13 (0.38)	ns	0.21 (0.31)	ns
14. Anthesis position	-0.02 (0.05)	ns	0.10 (0.11)	ns
15. Panicle width	23.17 (18.12)	**	61.81 (26.63)	**
16. Panicle length	49.54 (27.66)	**	0.79 (38.96)	ns
17. Panicle compactness	0.13 (0.18)	**	0.67 (0.29)	**

Table 3.4 (continued)

	Characters	Half-sib		Plot	
		V_H (se.)	F-sig.	V_{HB} (se.)	F-sig.
	Agronomic characters				
18.	Clump erectness	0.36 (0.17)	**	0.50 (0.19)	**
19.	Old diseases	0.70 (0.13)	**	0.56 (0.23)	**
20.	New diseases	0.23 (0.19)	**	0.83 (0.28)	**
21.	Leaf hairiness	0.01 (0.05)	*	0.17 (0.09)	**
22.	Leaf tensile strength	10.46 (11.48)	**	42.58 (18.30)	**
23.	Flavanoid at leaf sheath	0.36 (0.20)	**	0.77 (0.26)	**
	Tillering characters				
24.	Tiller No.at 5% tillering	-0.01 (0.42)	**	3.33 (0.76)	**
25.	Tiller No.at 50% tillering	14.21 (8.45)	**	8.74 (11.80)	ns
26.	Tiller No.at 95% tillering	49.69 (33.57)	**	35.72 (49.37)	ns
27.	Tiller No.at flowering time	36.07 (14.04)	**	18.77 (14.67)	ns
28.	No.of dead tillers at end	13.35 (5.46)	**	13.43 (5.79)	**
29.	No.of green tillers at end	-8.75 (7.45)	ns	26.59 (16.80)	*
30.	No.of young tillers at end	10.59 (5.52)	**	12.14 (6.98)	*
31.	No.of aerial tilllers at end	76.45 (43.27)	*	-43.04 (62.47)	ns
32.	No.of total tillers at end	32.07 (68.67)	ns	87.67 (124.95)	ns
33.	No.of base tillers at end	22.16 (25.99)	**	82.91 (42.10)	**
34.	No.of base green tillers at end	2.53 (16.97)	*	60.96 (31.28)	**
35.	Dead tiller dryweight at end	3.30 (1.87)	**	5.17 (2.46)	**
36.	Green tiller dryweight at end	11.25 (6.59)	**	-0.98 (9.46)	ns

Table 3.4 (continued)

Characters	Half-sib V_H (se.)	Half-sib F-sig.	Plot V_{HB} (se.)	Plot F-sig.
Tillering characters				
37. Young tiller dryweight at end	0.21 (0.11)	**	0.22 (0.14)	*
38. Aerial tiller dryweight at end	8.12 (7.78)	ns	0.90 (13.00)	ns
39. Total tiller dryweight at end	3.52 (18.08)	ns	-16.54 (36.36)	ns
40. Base tiller dryweight at end	14.59 (10.03)	**	11.08 (14.85)	ns
41. Base green tiller dryweight	11.21 (7.14)	*	-0.25 (10.63)	ns
42. No.of days for 5% tillering	2.61 (0.98)	*	0.42 (1.01)	ns
43. No.of days for 50% tillering	5.89 (3.37)	**	9.30 (4.42)	**
44. No.of days for 95% tillering	17.95 (9.33)	**	21.27 (11.78)	*
45. Relative growth rate at 5% tillering	155.42 (280.41)	**	1942.37 (455.59)	**
46. Relative growth rate at 50% tillering	42.63 (266.84)	**	1711.72 (470.17)	**
47. Relative growth rate at 95% tillering	33.04 (287.16)	**	1676.03 (513.99)	**

* Significant at 5% probability level
** Significant at 1% probability level

Table 3.5 Genetic Variance components repartitioned into additive variance (V_A) and heterotic variance (V_h), together with phenotypic-variance ($V_{P'}$)

	Characters	V_A	V_h	$V_{P'}$
	Botanic characters			
1.	Juvenile leaf width	14.5	21.23	16.59
2.	Juvenile leaf length	123.80	49.72	165.71
3.	Mature leaf width (15 wks)	0.80	0.88	1.52
4.	Mature leaf width (33 wks)	0.44	-1.91	-1.04
5.	Leaf sheath purple (12 wks)	1.60	1.08	2.35
6.	Leaf sheath purple (15 wks)	1.84	-0.65	2.76
7.	Leaf sheath purple (33 wks)	0.36	0.74	1.99
8.	Plant height	42.32	8.98	114.85
	Flowering characters			
9.	Flower peeping day	3.96	2.97	16.89
10.	First anthesis day	1.68	-0.95	18.78
11.	Median flowering day	-10.40	71.71	87.40
12.	Last flowering day	26.00	277.80	329.28
13.	Anthesis time	0.52	4.64	4.70
14.	Anthesis position	-0.08	1.42	1.62
15.	Panicle width	92.68	73.29	337.20
16.	Panicle length	198.16	494.73	695.08
17.	Panicle compactness	0.52	1.24	3.62
	Agronomic characters			
18.	Clump erectness	1.44	-0.26	2.67
19.	Old diseases	0.28	0.87	2.72
20.	New diseases	0.92	-0.06	3.19
21.	Leaf Hair	0.04	0.61	1.13
22.	Leaf tensile strength	41.84	63.12	219.92
23.	Flavanoid at leaf sheath	1.44	-0.42	3.30

Table 3.5 (continued)

	Characters	V_A	V_h	$V_{P'}$
	Tillering characters			
24.	Tiller No.at 5% tillering	-0.04	-3.37	5.45
25.	Tiller No.at 50% tillering	56.84	118.27	200.02
26.	Tiller No.at 95% tillering	198.76	528.22	828.78
27.	Tiller No.at flowering time	144.28	51.95	249.72
28.	No.of dead tillers at end	53.40	-8.07	83.33
29.	No.of green tillers at end	-35.00	181.40	221.38
30.	No.of young tillers at end	42.36	29.70	107.50
31.	No.of aerial tilllers at end	305.80	1111.52	1290.79
32.	No.of total tillers at end	128.28	1641.41	2021.29
33.	No.of base tillers	88.64	240.09	562.54
34.	No.of base green tillers	10.12	223.46	405.49
35.	Dead tiller dry weight at end	13.20	6.19	33.87
36.	Green tiller dryweight at end	45.00	138.25	180.42
37.	Young tiller dryweight at end	0.84	0.76	2.21
38.	Aerial tiller dryweight at end	32.48	192.63	227.67
39.	Total tiller dryweight at end	14.08	689.02	656.61
40.	Base tiller dryweight	58.36	151.28	242.92
41.	Base green tiller dry weight	44.84	148.91	193.05
42.	No.of days for 5% tillering	10.40	8.65	20.24
43.	No.of days for 50% tillering	23.56	11.98	62.05
44.	No.of days for 95% tillering	71.80	43.02	175.45
45.	RGR at 5% tillering	621.68	-2578.06	3559.95
46.	RGR at 50% tillering	170.52	-752.10	4296.82
47.	RGR at 95% tillering	132.16	249.17	5158.02

* Significant at 5% probability level

** Significant at 1% probability level

The relative contribution of genetic variance to the phenotypic variance was viewed in the forms of narrow-sense heritability (average allele), heterotic-sense heritability (non-additive) and broad-sense heritability, (general genotypic) respectively. The comparison among these three estimates can be done in Table 3.6. The characters which have high narrow-sense heritability include juvenile leaf width and length, 12 wks. and 15 wks. leaf sheath purple, tiller numbers at flowering and numbers of dead tillers. The high heterotic heritability estimates include 15 wks. and 33 wks. mature leaf width, median and last flowering day, anthesis time and position, panicle length, tiller numbers at 95%, numbers of green tiller, numbers of aerial tiller, and numbers of total tiller, green tiller dry-weight, aerial tiller dry-weight, base tiller dry-weight and total tiller dry-weight. Finally, the broad-sense heritability estimates are high in most characters especially in flowering and tillering characters.

Table 3.6 Heritability estimates for narrow sense (h^2_N), heterotic sense (h^2_h) and broad sense (h^2_B)

	Characters	h^2_N	h^2_h	h^2_B
	Botanic characters			
1.	Juvenile leaf width	0.88	0.07	0.95
2.	Juvenile leaf length	0.75	0.30	1.05
3.	Mature leaf width (15 wks)	0.53	0.58	1.11
4.	Mature leaf width (33 wks)	-0.42	1.84	1.41
5.	Leaf sheath purple (12 wks)	0.68	0.46	1.14
6.	Leaf sheath purple (15 wks)	0.66	-0.24	0.43
7.	Leaf sheath purple (33 wks)	0.18	0.37	0.55
8.	Plant height	0.37	0.08	0.45
	Flowering characters			
9.	Flower peeping day	0.23	0.18	0.41
10.	First anthesis day	0.09	-0.05	0.04
11.	Median flowering day	-0.12	0.82	0.70
12.	Last flowering day	-0.08	0.84	0.76
13.	Anthesis time	0.11	0.98	0.88
14.	Anthesis position	-0.05	0.88	0.83
15.	Panicle width	0.27	0.22	0.49
16.	Panicle length	0.29	0.71	1.00
17.	Panicle compactness	0.14	0.34	0.49
	Agronomic characters			
18.	Clump erectness	0.54	-0.10	0.44
19.	Old diseases (Rust)	0.10	0.32	0.42
20.	New diseases (other)	0.29	-0.02	0.27
21.	Leaf hairiness	0.04	0.54	0.58
22.	Leaf tensile strength	0.19	0.29	0.48
23.	Flavanoid at leaf sheath	0.44	-0.13	0.31

Table 3.6 (continued)

	Characters	h^2_N	h^2_h	h^2_B
	Tillering characters			
24.	Tiller No.at 5% tillering	-0.007	-0.62	-0.63
25.	Tiller No.at 50% tillering	0.28	0.59	0.88
26.	Tiller No.at 95% tillering	0.24	0.64	0.88
27.	Tiller No.at flowering time	0.58	0.21	0.79
28.	No.of dead tillers at end	0.64	-0.10	0.54
29.	No.of green tillers at end	-0.16	0.82	0.66
30.	No.of young tillers at end	0.39	0.28	0.67
31.	No.of aerial tilllers at end	0.24	0.86	1.10
32.	No.of total tillers at end	0.06	0.81	0.88
33.	No.of base tillers at end	0.16	0.43	0.58
34.	No.of base green tiller at end	0.03	0.55	0.58
35.	Dead tiller dry weight at end	0.39	0.18	0.57
36.	Green tiller dryweight at end	0.25	0.77	1.02
37.	Young tiller dryweight at end	0.38	0.34	0.72
38.	Aerial tiller dryweight at end	0.14	0.85	0.99
39.	Total tiller dryweight at end	0.13	1.07	1.21
40.	Base tiller dryweight at end	0.24	0.62	0.86
41.	Base green tiller dry weight	0.23	0.77	1.00
42.	No.of days for 5% tillering	0.51	0.43	0.94
43.	No.of days for 50% tillering	0.38	0.19	0.57
44.	No.of days for 95% tillering	0.41	0.25	0.65
45.	RGR at 5% tillering	0.17	-0.72	-0.55
46.	RGR at 50% tillering	0.04	-0.18	-0.14
47.	RGR at 95% tillering	0.03	0.05	0.07

* Significant at 5% probability level

** Significant at 1% probability level

CHAPTER 4

DISCUSSION

4.1 Comparison Among Topodeme, Half-sib and Plant Variations

The topodeme variation is derived from the differentiation among means of local populations, the open-pollinated seeds were collected from several locations throughout New Zealand. Whereas the half sib variation is confined to among plants within each topodeme. In the other word, the half sib variation is the allele effects amongst single plants within topodemes originally used as self mother plants. The within plot variation is the plant to plant variation within half sib families or lines. Hence, the total plant to plant variation within topodemes is the half sib variance and within variance combined.

In this study, the half-sib family variance has a higher value than topodeme variance in most characters (39 out of 47 characters) The exception were: 33 wks. mature leaf blade width, 15 wks. leaf sheath purple ,flavanoid, anthesis time, anthesis position, panicle compactness, new disease and leaf hairiness. And plant-to-plant within half sib variance has a higher value than topodeme variance in every character. This has affirmed the speculation from the previous work conducted by Cameron (1979)

It is of some interest to compare this result with those from other species. The within-population of *Trifolium repens* from a uniform pasture found a great deal of variation in several characters; and even as great as that between populations from different environments in some cases (Burdon and Harper, 1980). The breeding system of a species could affect on the amount of genetic variation within and between populations (Levin, 1978). The population of cross-fertilizng species was less differentiated *inter se* than the population of self-fertilizing species. In *Trifolium* spp., outbreeders had more within population heterogeneity for quantitative characters and less between-population heterogeneity than inbreeder (Katznelson,1969 cited from

Levin,1978). However, other workers found a great deal variation in predominantly selfing-species and concluded that patterns of variation was not confined to one group of species or the others (Allard 1975; Jain, 1976).

In practice, selection could be more effective on the half-sib family level than the topodeme level. The germplasm collection and maintenance would be more benefitial to pay attention on subsamples within topodemes or half-sib families than among samples of topodemes.

The ecotypes of *Holcus* spp. in New Zealand was proposed by earlier workers (Munro, 1961). The high level of half-sib and plant variations (and much higher than the topodeme in some traits) in the present finding may suggest that there are no ecotype nor major topodeme differences in New Zealand. The situation was quite similar to *Phalaris tuberosa* in Australia where Trumble and Cashmore (1934) found no evidence of ecotypic differentiation among samples from various parts of Australia, despite the fact that the species had at that time been established in relatively small but widespread areas for long time.

4.2 Genetic Variance and Heritability

Significant genetic variation is detected among half sib progenies for numerous Yorkshire Fog grass characteristics. These results concur with earlier reports in Yorkshire Fog grass for several characters (Cameron,1979; Billington *et al.*,1988).

In the analysis of quantitative variability and heritability in predominantly cross-fertilized forage species, it is convenient to make use of family groups produced by natural crossing. The offspring is often derived from the ovules of a maternal plant which has been pollinated without control of male parentage (pollen), and these form half-sib progenies or lines. For the analysis, it is assumed that the offspring were produced under random mating (no inbreeding). However, some traits may be also under the influence of maternal effect and phenotypic assortive mating. The maternal effect might cause bias estimates of heritability if they were ignored. From such fact, the use of field collected maternal sibships needs to be cautious. Paternal analysis indicated that these progeny were not likely to be half-sibs (Ellstrand,1984), which could cause overestimates of heritability.

Some estimates of phenotypic and genotypic variances are negative. And they, in turn, have caused the inflated or negative heritability estimates in some attributes. This is possible because of the sampling distribution of trivial parameters or non-random sampling of genotypes from the natural population (Falconer,1981) It is also possible that estimates of narrow-sense heritabilities may be biased by the confounding of nonadditive genetic variance (Mitchell-Olds and Rutledge, 1986).

These heritability estimates are on an individual plant basis, and vary from low to high. The broad-sense heritability estimates are low (0.04) for the first day of anthesis to very high (1.0) for juvenile leaf-width, mature leaf width at 15 and 30 weeks, the panicle length and purple leaf sheath at 12 weeks. The narrow-sense heritability estimates are relatively high to medium in most of the botanical and tillering attributes. But most of agronomic traits showed medium to low narrow-sense heritability. Although, Moll and Stuber (1974) concluded that the genetic variability of many important agronomic traits of forage crops had been found to be predominantly additive.

4.2.1 Botanical Characters

The heritability estimates for the most botanical characters are similar to those of other workers with other grasses. The broad-sense and narrow-sense heritability estimates for juvenile leaf width and leaf length of Yorkshire Fog grass are relatively high while the heritability estimates of Italian ryegrass seedlings for leaf width and leaf length were medium, (0.38 and 0.42, respectively)(Cooper and Edwards, 1961).

The broad-sense heritability estimates of mature leaf blade width both at 15 and 30 weeks are high and the narrow-sense one is medium at 15 weeks and high at 30 weeks. Similar result was shown in Bermudagrass (*Cynodon dactylon*) whose broad-sense and narrow-sense heritability estimates of leaf blade width were high and medium (0.83 and 0.62, respectively). However, Cameron (1979) and Billington (1988) had found that the broad-sense and narrow-sense heritability for this attributes was relatively low (0.08 and 0.17,respectively). Furthermore, the leaf width mean tended to change with time. This study has unraveled some genetic variance pattern on it. At 15 weeks, there are almost half additive variance and heterotic variance, but at 30 weeks, it alters to become all heterotic. The leaf-width grand mean towards the narrowness indicates that the leaf narrowness is under the heterotic heritability.

There are some contrasting patterns in broad-sense and narrow-sense heritabilities for leaf sheath purple of different time periods. The difference possibly indicates that there has been a trigger, or change of genetic control. A possible external trigger may have been the caging, which occurred between the two measuring periods. Further research should resolve this issue.

The broad-sense and narrow-sense heritability estimates of plant height in Yorkshire Fog grass are medium and low in value, respectively. The pattern was very similar to other grasses. In the following examples, the broad-sense heritability estimates were ranged from 0.4 - 0.6 namely: for Nebraska populations Indiangrass (*Sorghastrum nutans*) was 0.4 (Vogel,*et al.*, 1980), for reed canarygrass (*Phalaris arundizacea*) in Eastern Canada population was 0.54 (Sachs and Coulman, 1983), for sand bluestem (*Andropogon halhi*) was 0.62 (Riley,1982), for Rhodes grass (*Chloris gayana*) was 0.66 (Quesenberry *et al.*,1978). The narrow-sense heritability was also very similar to guineagrass (*Panicum maximum*) which was rather low (0.2) (Usberti and Jain, 1978).

4.2.2 Flowering Characters

Most of these flowering characters have medium to high broad-sense heritability with heterotic variances prevailing. There are some variations amongst different flowering measurements. The first day and the median day of flowering may be under different sets of gene control. The first anthesis day has very small additive genetic variance, only 4 percent and very large environmental variance, about 96 percent. This suggests an invariant mechanism for flowering initiation. In contrast, later flowering controls have stronger genetic variability. Both the median flowering day and last flowering have a very high genetic variance and all of which is heterotic. (as shown by h^2_h). But they have fewer environmental variance, only about 30 percent.

It shows the same trend in this study. Billington (1988) found that the narrow-sense heritability of flowering time in Yorkshire Fog grass was relatively low in traditional field and medium in improved field population, respectively. In general, the heritability estimates for median flowering or heading day are quite similar to other grasses. In Indiangrass (*Sorghastrum nutans*) of Nebraska populations was 0.5-0.7 (Vogel, *et al.*,1980), in (*Lolium perenne*) was 0.94, in canarygrass (*Phalaris arundizacea*) was 0.94 (Sachs and Coulman, 1983) and in sand bluestem was 0.73 (Riley,1982).

The panicle length had nearly the same amount of narrow-sense heritability as Billington (1988) had found, but the broad-sense heritability was considerably larger.

4.2.2 Agronomic Characters

For agronomic characters, most have a medium broad-sense heritability and low to medium for broad-sense heritability.

Clump erectness at vegetative stage, just prior to stem elongation, had a relatively medium (0.44) estimate for narrow-sense heritability. This was different to a previous study by Cameron (1979) which reported a low estimate (0.10). The differences in the two results arise from this: Cameron's material was a different sample from the same germplasm but it could also be due to scoring at different stages of growth.

Sheep performance has been associated with leaf cellulose content which may be positively correlated with leaf tensile strength in ryegrass (*Lolium* spp.). Weight gains have been reported highest on the grasses with the lowest strengths (Wilson,1965; Evan,1967b). The present study reveals significant genetic differences in leaf tensile strength. This has been reported also amongst lines of weeping lovegrass (*Eragrostis curvala*) and amongst clones of Bermudagrass (*Cynodon dactylon*), sideoats grama (*Bouteloua curtipendula*) and sand bluestem (*Andropogon hallii*) (Kneebone,1960). In this study, a medium level of broad-sense heritabilty was found which was different from Cameron's result which showed a very low value (0.01-0.04). It was also different from other grasses. The broad-sense heritability estimates for leaf tensile strength in tall fescue (*Festuca arundinacea*) were relatively high, ranking from 0.83 in June to 0.93 in August to 0.85 in October. The narrow-sense heritability estimates were also high (0.7-0.8) (Nguyen,*et al.*,1982). The genetic control mechanism might change according to the seasonal cycle or growth stages. Further investigation is needed to resolve the issue.

The flavanol level had a relatively medium narrow-sense heritability. The pattern was rather similar to leaf sheath purple at 12 weeks. It has been summarized that the purple colour is flavanoid in nature and the similarity of the two heritabilities may support this possibility.

Leaf hair has both high broad-sense and narrow-sense heritability. It contrasted to Cameron's (1979) result which indicated a low broad-sense heritability (0.2). The result was similar to that for *Medicago* where the narrow-sense heritability of hair density was medium (0.55)(Kitch, *et al.*,1985).

Leaf diseases are categorized into old disease,i.e. mostly rust, and new diseases, i.e. leaf spot (symptom similar to Helminthosporium leaf spot). Both have relatively low to medium broad-sense heritabilities and low narrow-sense heritabilities. These results are similar to those of other grasses. The realized heritabilities for rust resistance on eight cultivars of tall fescue (*Festuca arundinacea*) ranked from 0.07, 0.08, 0.16, 0.18, 0.36, 0.45, 0.49 and 0.52, respectively. It was concluded that there might be different gene system for rust resistance in different population. Also, the low heritability one might be the result of some non-additive gene action for rust resistance (Wofford and Watson, 1982). In this study, plants have a low narrow-sense heritability on rust resistance, while the heterotic variance is three time higher than the additive variance. The high non-additive variance indicated it might not be easy to select for in traditional selection nursery methods. This contrasted to Munro's (1961) recommendation for rust resistance relating to easily selected major genes. In case of leaf spot, in meadow fescue (*Festuca pratensis*), the narrow-sense heritability for *Helminthosporium* was medim (0.49) (Frandsen *et al.*,1981). This indicated that it might be easier to select for leaf spot disease resistance in the traditional selection nursery methods.

4.3 Genetic Variance on Tiller Development

Tiller development starting from sowing till flowering observed by tiller numbers has expressed virtually in a logistic function (Fig.4.1). Growth analysis of a permanent pasture in Normandy in spring revealed that *Holcus lanatus* growth followed a sigmoid curve (Lemaire, *et al.*,1982). In *Lolium*, however, the tiller number in the early stage were increasing exponentially (Cooper and Edwards, 1961). It is interesting to note that the lower half of a logistic is exponential (Causton, 1977)

Grasses are likely to developed the tillers successively and continuously without any distinct termination of the whole tillering process. This complies very well to Protich's (1977) descriptive work. Although flowering tillers died soon after seed maturity, the new young tillers emerged from the ground thereafter. During the heading and seed development periods, grasses had possessed a great number of elongated green tillers and aerial tillers directly from their green tillers.

For tiller number, the broad-sense heritability estimates across time are from zero to very high (0.88). The narrow-sense estimates are from zero to medium (0.28) and then low (0.07)(Fig.4.1 and Fig.4.2). Billigton *et al.* (1988) unraveled the same pattern of medium broad-sense heritability and low narrow-sense heritability for ten week growth of Yorkshire Fog grass. Similar trend also occurs in the other grasses. The broad-sense heritability estimates of tillers on two month-old *Lolium* from sowing were medium to high (0.4 - 0.8) (Cooper and Edwards, 1961). In reed canary grass, both broad-sense and narrow-sense heritability were high for tiller number (Casler, 1984). In guineagrass, heritability estimates based on parent-offspring regression for total tiller number were relatively low to medium (0.3) (Usberti and Jain, 1978). In maize, however, the genetic component of variation for tillering was believed due to general combining ability (Rood and Major, 1981)

Both broad-sense and narrow-sense heritabilities for flowering tillers are high and medium, respectively. This was somewhat comparable to what Billington *et al.* (1988) finding which revealed a medium to low heritabilities for both improved-field and traditional field population. The young tillers which have emerged after flower tiller died, show the same pattern of genetic and environment variation. This might indicate the recycle of genetic control in Yorkshire Fog grass.

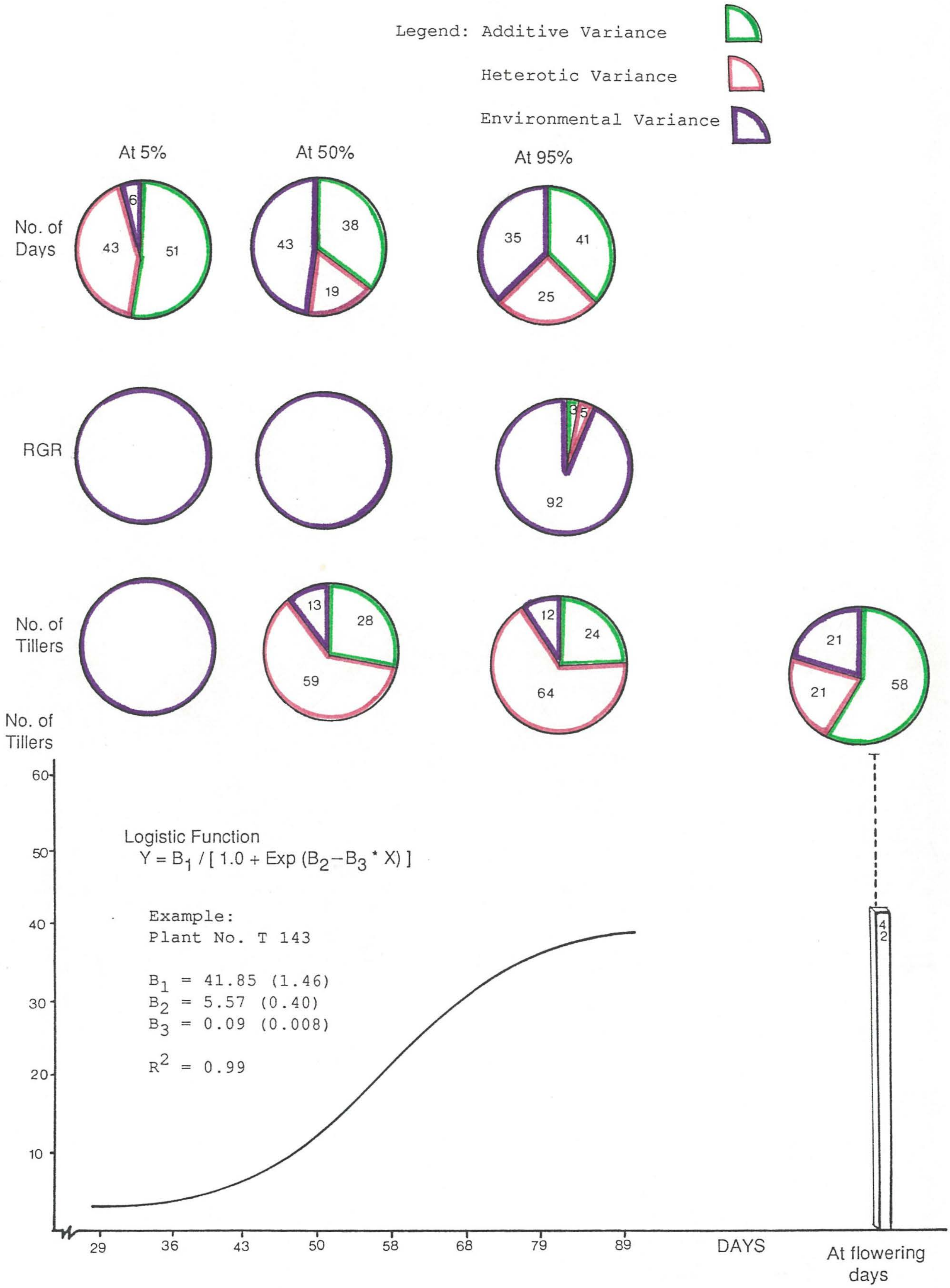

Figure 4.1 Genotypic variance of tiller number development from sowing to flowering stage

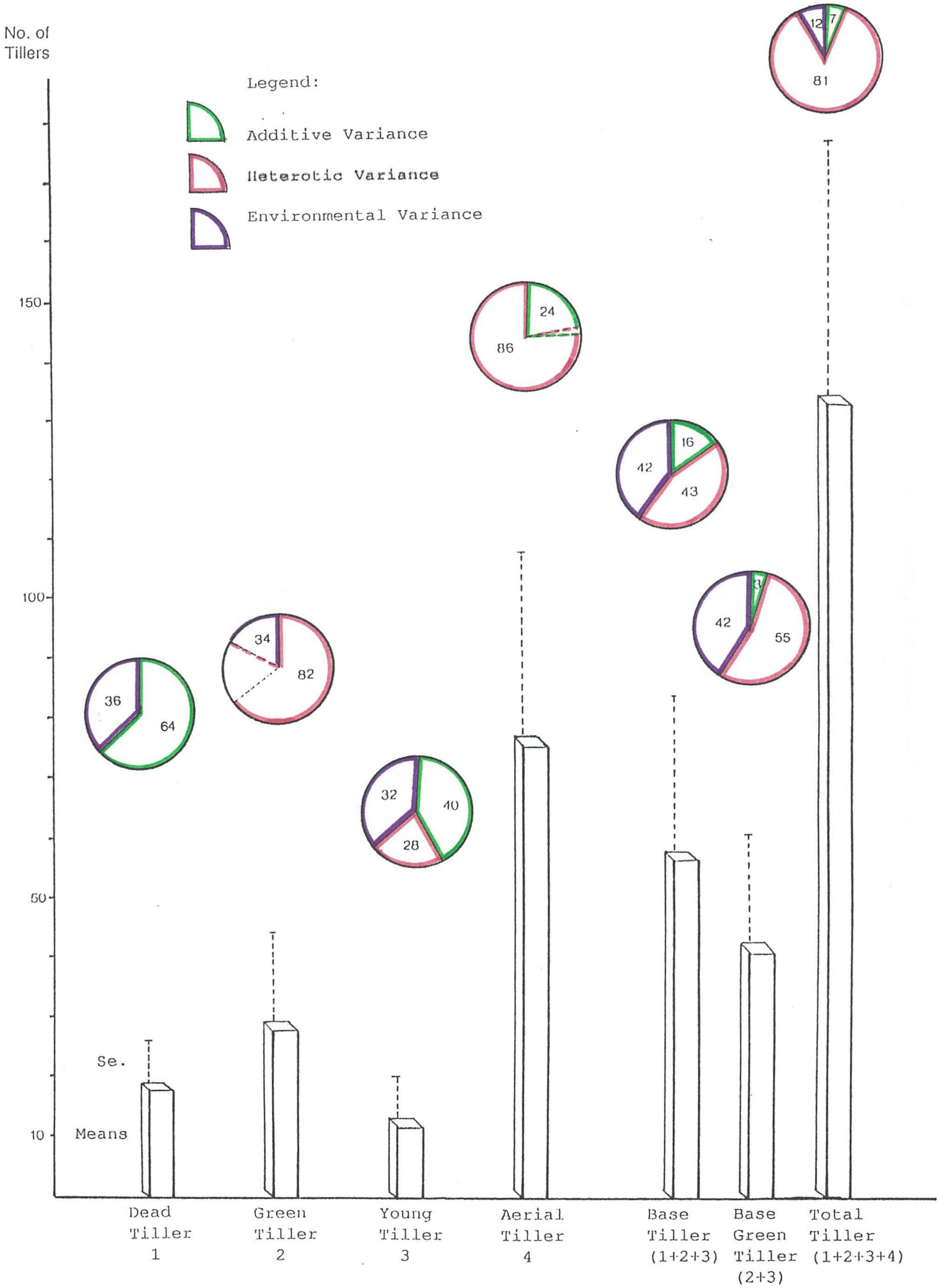

Figure 4.2 Genotypic variance of tiller number after main tiller flowering stage (33 weeks)

For dry matter, a high broad-sense and medium to low narrow-sense heritabilities are obtained for every type of tiller at old plant stage (33 wks.)(Fig.4.3). That basal tiller mass (which included dead (post-flowering) tillers, green tillers and young tillers) represents the mass in pasture, and is of particular interest. It has a medium broad-sense heritability (0.43) and low narrow-sense heritability (0.16), which are somewhat comparable to other grass species. The broad-sense heritability of mass (yield) in several grasses was medium to low (Clements,1969; Marum *et al*,1979; Oram, *et al.*,1974, Shenk and Westerhaus,1982). Dry matter/plant in *Lolium multiforum* had medium broad-sense heritability (0.48)(Bugge,1984). Also, in reed canary grass, for the tiller dry weight per plant, broad-sense heritabilities were relatively medium (0.3-0.6) (Casler, 1981); as it was in *Lolium perenne* (0.53) (Utz and Oettler, 1978).

Similar results of heritability estimates for dry matter with respect to variability within established genotypes of crossed fertilized species have been drawn by Cooper(1959) on *Lolium*, Gardner (1963) on yield of maize and by Kehr and Gardner (1960) on forage yield in lucern

The relative growth rate at 5% , 50 % and 95 % asymptote show quite a similar patterns in their variance components (Fig.4.1). At very young stages, the plant has only environmental variances in action. The 95% stage has 92 percent of environmental variance with only 3 percent additive and 5 percent heterotic variance. The timing to reach 5% ,50% ,and 95% of growth have results very different to those of relative growth rate and tiller numbers. These generally are high and medium broad-sense heritabilities and relatively medium narrow-sense heritabilities. This showed, clearly, the different genetic perspectives represented by growth rate and timings. As for the flowering attributes, the duration of events was shown to have greater genetic variabilities than either their initiation (for flowering) or the rates of change (for tillering).

4.4 Implication for plant breeding

The detailed genetic analysis of a locally populations is of practical interest in setting up a effective plant breeding programme. The initial step in any of them is the

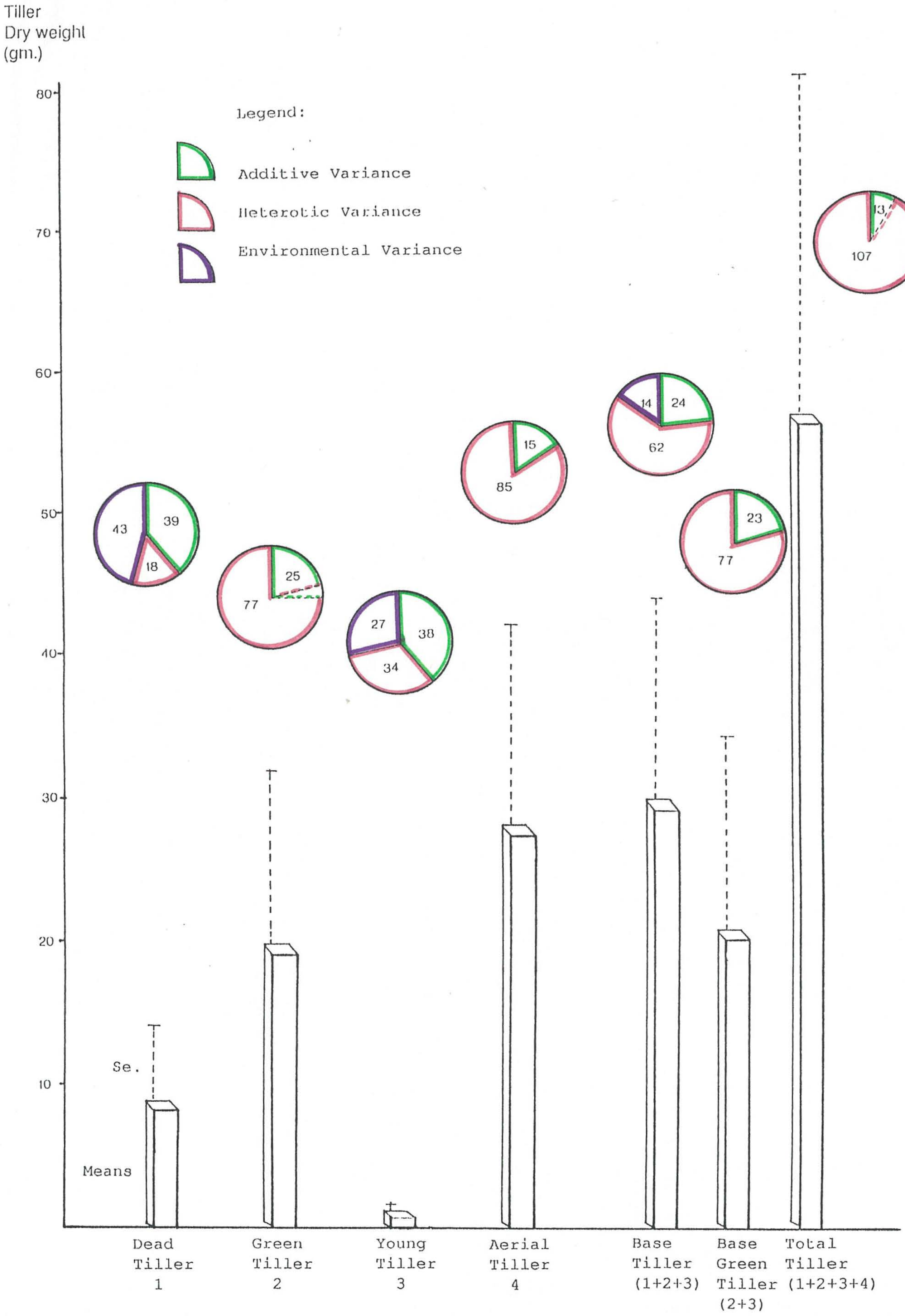

Figure 4.3 Genotypic variance of tiller dry matter after main tiller flowering stage (33 weeks)

choice of a suitable base population. The alternatives, in the case of cross-fertilized species, will often include:

1. the improvement of an established populations by intra-population selection, or

2. the formation of a more widely based genetic population by the incorporation of introduced materials (wide crosses).

The useful genetic variation presented in the local New Zealand populations of *Holcus* has been found to be quite appreciable for most of the characters studied. The genetic advance under selection for these characters depends on the amount of genetic variation available and on its heritability.

These results indicate that genetic advance for the characters: juvenile leaf blade width and length, 15 weeks mature leaf blade width, purple leaf sheath, plant height, clump erectness, flavanol, panicle width, number of dead tillers and young tillers, dead tiller mass, young tiller mass, number of days to reach 5%, 50% and 95% of growth stage should be possible using breeding methods which utilize additive genetic variation. The traditional breeding methods such as mass selection, line selection, line breeding or simple recurrent selection should be efficient methods for the improvement of these attributes.

Many characters exhibit low narrow-sense heritability but high heterotic heritability, are included : 30 wks. mature leaf blade width , leaf tensile strength, leaf hair, old disease, median and last flowering day, panicle length and compactness, total tiller number, green tiller number, number of tiller at 50% and 95% of growth stage, basal tiller number , total tiller mass, basal tiller mass and green tiller mass. These require some combination of progeny testing and recurrent selection or top cross progeny tests for high specific combining ability for development of synthetic cultivars or special forms of recurrent selection bulks.

Some further research would be desirable. For example, estimates of correlation was needed because it would assist in estimating the relative efficiency of direct and indirect selection for characters which were easier to evaluate than others.

For instance, a high total genetic contribution in juvenile leaf size criteria might be used as indirect selection for some other high genetic correlated responses.

For those characters which had different genotypic variances across time (eg. purple leaf sheath, flowering day and tiller number development), it would be good practice to select at the period with a higher level of genotypic variance. For instance, amongst the flowering characters, selection would be more effective on the median flowering day, than on the first day of flowering. Also, the number of tillers would best be selected in the later stages of development (50% and 95% of growth stages).

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APPENDIX 1

Duncan's multiple range test for juvenile leaf blade width

No.	Clus	Topo	Half-sib	Means	
1	1	69	147	24.9	defghijk
2			148	24.3	defghijk
3			150	22.5	ijk
4			151	24.9	defghijk
5			154	21.9	k
6		145	429	26.2	cdefghijk
7			430	25.2	defghijk
8			431	32.1	a
9			432	26.8	cdefghi
10			435	28.2	bcde
11	2	97	260	25.9	defghijk
12			261	26.1	cdefghijk
13			262	26.7	cdefghij
14			264	27.9	bcdef
15			266	26.9	cdefghi
16		131	369	21.9	k
17			371	27.2	bcdefgh
18			372	27.3	bcdefg
19			376	22.9	hijk
20			377	25.4	defghi
21	3	15	36	27.6	bcdef
22			37	27.4	bcdefg
23			38	23.9	efghijk
24			40	25.7	defghijk
25			42	24.4	defghijk
26		27	64	26.9	cdefghi
27			66	22.3	jk
28			67	25.2	defghijk
29			69	23.2	ghijk
30			71	23.6	fghijk
31	4	91	233	24.0	defghijk
32			234	31.3	ab
33			235	22.8	ijk
*34			236	23.9	defghijk
35			237	25.4	defghijk
36		154	460	23.6	fghijk
37			461	30.3	abc
38			462	25.1	defghijk
39			463	23.6	fghijk
40			465	25.6	defghijk
41	5	13	25	26.3	cdefghijk
42			26	22.1	k
43			27	26.8	cdefghi
44			31	25.9	defghijk
45			32	24.8	defghijk
46		142	414	26.1	cdefghijk
47			415	23.0	ghijk
48			416	24.0	defghijk
49			418	28.3	abcd
50			420	26.8	cdefghi

Means with the same letter are not significantly different at 5%

```
Duncan's multiple range test for juvenile leaf blade length

No.Clus Topo Half-sib             Means
 1  1   69    147                 64.2             jkl
 2            148                 75.5     bcdefghijk
 3            150                 59.4               l
 4            151                 72.2     bcdefghijkl
 5            154                 65.3           hijkl
 6     145    429                 67.9         fghijkl
 7            430                 70.5      cdefghijkl
 8            431                 81.3     bcde
 9            432                 77.8      cdefghi
10            435                 71.9      cdefghijkl
   ------------------------------------------------------------
11  2   97    260                 85.3    ab
12            261                 77.5     bcdefghi
13            262                 71.7      cdefghijkl
14            264                 78.6      cdefgh
15            266                 74.5     bcdefghijk
16     131    369                 62.7              kl
17            371                 69.8      cdefghijkl
18            372                 65.7           hijkl
19            376                 67.2         fghijkl
20            377                 69.3        efghijkl
   -------------------------------------------------------------
21  3   15     36                 81.9    abcd
22             37                 71.2      cdefghijkl
23             38                 69.4       defghijkl
24             40                 75.4     bcdefghijk
25             42                 73.3     bcdefghijk
26     27      64                 77.4     bcdefghij
27             66                 69.0       defghijkl
28             67                 81.9    abcd
29             69                 66.3          ghijkl
30             71                 75.1     bcdefghijk
  ---------------------------------------------------------------
31  4  91     233                 71.3      cdefghijkl
32            234                 92.9    a
33            235                 63.2               lk
34            236                 71.6      cdefghijkl
35            237                 77.2     bcdefg
36    154     460                 67.8          ghijkl
37            461                 82.9    abc
38            462                 73.4      cdefghijk
39            463                 64.6            ijkl
40            465                 73.2     bcdefghijk
  ---------------------------------------------------------------
41  5  13      25                 79.1     bcdefg
42             26                 66.8         fghijkl
43             27                 79.9     bcdef
44             31                 74.6     bcdefgh
45             32                 72.3     bcdefghijkl
46    142     414                 79.1     bcdefg
47            415                 59.6               l
48            416                 62.8        efghijk
49            418                 79.4     bcdefg
50            420                 73.8     bcdefghijk
----------------------------------------------------------------------
Means with the same letter are not significantly different at 5%
```

```
Duncan's multiple range test for mature leaf blade width at 15 weeks

No.Clus Topo Half-sib            Means
 1  1    69    147                 9.6       efgh
 2             148                10.8   abcdef
 3             150                10.7   abcdef
 4             151                10.4   abcdefgh
 5             154                10.0      defgh
 6      145    429                10.0      defgh
 7             430                11.5   ab
 8             431                10.9   abcde
 9             432                10.4   abcdefgh
10             435                10.9   abcde
   -------------------------------------------------------
11  2    97    260                 9.6       efgh
12             261                 9.8      defgh
13             262                10.7   abcdef
14             264                10.2   abcdefgh
15             266                10.1    bcdefgh
16      131    369                 9.1          h
17             371                10.4   abcdefgh
18             372                10.6   abcdef
19             376                 9.9      defgh
20             377                10.5   abcdefg
   -------------------------------------------------------
21  3    15     36                10.7   abcdef
22              37                11.1   abcd
23              38                11.3   abc
24              40                10.7   abcdef
25              42                 9.8      defgh
26       27     64                11.3   abc
27              66                10.5   abcdef
28              67                10.4   abcdefgh
29              69                 9.7       efgh
30              71                10.5   abcdef
   -------------------------------------------------------
31  4   91     233                 9.5        fgh
32             234                10.7   abcdef
33             235                10.2    bcdefgh
34             236                 9.5        fgh
35             237                10.4   abcdefgh
36     154     460                10.5   abcdef
37             461                10.0      defgh
38             462                10.4   abcdefg
39             463                 9.9      defgh
40             465                10.0     cdefgh
   -------------------------------------------------------
41  5   13      25                10.6   abcdef
42              26                10.6   abcdef
43              27                 9.9      defgh
44              31                10.0      defgh
45              32                 9.9      defgh
46     142     414                 9.4        fgh
47             415                10.2   abcdefgh
48             416                 9.2         gh
49             418                11.5   a
50             420                10.9   abcde
   -------------------------------------------------------
Means with the same letter are not significantly different at 5%
```

Duncan's multiple range test for mature leaf blade width at 33 weeks

No.	Clus	Topo	Half-sib	Means	
1	1	69	147	9.4	abcdef
2			148	10.3	abc
3			150	10.7	a
4			151	8.9	cdef
5			154	10.1	abcde
6		145	429	9.9	abcdef
7			430	10.3	abc
8			431	10.0	abcdef
9			432	8.8	cdef
10			435	10.2	abcd
11	2	97	260	9.6	abcdef
12			261	9.4	abcdef
13			262	8.8	cdef
14			264	8.5	f
15			266	8.6	ef
16		131	369	9.0	bcdef
17			371	10.1	abcde
18			372	9.7	abcdef
19			376	8.9	cdef
20			377	10.2	abcd
21	3	15	36	9.6	abcdef
22			37	9.7	abcdef
23			38	9.7	abcdef
24			40	9.4	abcdef
25			42	10.0	abcdef
26		27	64	9.0	bcdef
27			66	9.6	abcdef
28			67	9.1	abcdef
29			69	9.4	abcdef
30			71	9.7	abcdef
31	4	91	233	8.6	ef
32			234	9.3	abcdef
33			235	8.5	f
34			236	9.6	abcdef
35			237	9.3	abcdef
36		154	460	9.6	abcdef
37			461	9.6	abcdef
38			462	10.0	abcdef
39			463	9.3	abcdef
40			465	10.0	abcdef
41	5	13	25	9.4	abcdef
42			26	10.6	ab
43			27	9.8	abcdef
44			31	9.7	abcdef
45			32	9.6	abcdef
46		142	414	8.6	ef
47			415	9.7	abcdef
48			416	9.3	abcdef
49			418	8.7	def
50			420	9.6	abcdef

Means with the same letter are not significantly different at 5%

Duncan's multiple range test for leaf sheath purple at 12 weeks

No.	Clus	Topo	Half-sib	Means	
1	1	69	147	6.8	abcde
2			148	6.3	abcdefgh
3			150	5.6	defghijk
4			151	4.2	k
5			154	5.9	cdefghij
6		145	429	6.3	abcdefgh
7			430	6.2	bcdefg
8			431	6.2	bcdefg
9			432	6.1	bcdefghi
10			435	6.6	abcdefg
11	2	97	260	6.8	abcde
12			261	6.1	bcdefghi
13			262	6.4	abcdefgh
14			264	5.9	cdefghi
15			266	7.0	abcd
16		131	369	6.6	abcdefg
17			371	5.9	cdefghi
18			372	6.9	abcd
19			376	5.8	cdefghi
20			377	6.7	abcdef
21	3	15	36	4.7	ijk
22			37	6.2	bcdefgh
23			38	7.1	abc
24			40	6.8	abcde
25			42	7.1	abc
26		27	64	7.1	abc
27			66	5.2	fghijk
28			67	5.3	fghijk
29			69	6.3	abcdefgh
30			71	6.6	abcdefg
31	4	91	233	6.1	bcdefghi
32			234	6.6	abcdefg
33			235	5.3	efghijk
34			236	5.0	ijkh
35			237	6.3	abcdefgh
36		154	460	4.7	ijk
37			461	7.4	ab
38			462	5.9	cdefghij
39			463	6.4	abcdefgh
40			465	7.8	a
41	5	13	25	6.1	bcdefghi
42			26	5.0	hijk
43			27	6.7	abcdef
44			31	7.2	abc
45			32	5.9	cdefghij
46		142	414	6.4	abcdefgh
47			415	4.6	jk
48			416	5.1	ghijk
49			418	6.7	abcdef
50			420	5.8	cdefghij

Means with the same letter are not significantly different at 5%

Duncan's multiple range test for leaf sheath purple at 15 weeks

No.	Clus	Topo	Half-sib	Means	
1	1	69	147	4.6	abcdef
2			148	4.0	cdef
3			150	3.9	cdef
4			151	3.0	f
5			154	4.2	bcdef
6		145	429	3.3	def
7			430	3.9	cdef
8			431	3.4	def
9			432	3.2	ef
10			435	4.2	bcdef
11	2	97	260	5.9	abc
12			261	4.4	abcdef
13			262	5.1	abcdef
14			264	3.4	def
15			266	5.4	abcdef
16		131	369	5.0	abcdef
17			371	4.1	cdef
18			372	5.3	abcdef
19			376	3.3	def
20			377	4.9	abcdef
21	3	15	36	5.7	abcd
22			37	5.7	abcd
23			38	5.0	abcdef
24			40	4.4	abcdef
25			42	6.6	a
26		27	64	4.6	abcdef
27			66	3.8	cdef
28			67	4.4	abcdef
29			69	5.2	abcdef
30			71	4.4	abcdef
31	4	91	233	4.0	cdef
32			234	4.2	bcdef
33			235	3.7	cdef
34			236	3.1	ef
35			237	3.7	cdef
36		154	460	3.2	ef
37			461	6.7	a
38			462	4.2	bcdef
39			463	4.9	abcdef
40			465	6.4	ab
41	5	13	25	3.7	cdef
42			26	3.3	def
43			27	4.1	cdef
44			31	3.9	cdef
45			32	3.4	def
46		142	414	3.9	cdef
47			415	4.2	bcdef
48			416	3.1	ef
49			418	4.2	bcdef
50			420	3.0	f

Means with the same letter are not significantly different at 5%

Duncan's multiple range test for leaf sheath purple at 33 weeks

No.	Clus	Topo	Half-sib	Means	
1	1	69	147	8.3	abc
2			148	9.0	abc
3			150	9.2	abc
4			151	8.9	abc
5			154	9.9	ab
6		145	429	9.4	abc
7			430	8.9	abc
8			431	9.4	abc
9			432	9.6	ab
10			435	9.0	abc
11	2	97	260	9.4	abc
12			261	9.0	abc
13			262	9.8	ab
14			264	9.0	ab
15			266	10.0	a
16		131	369	7.4	bc
17			371	8.0	abc
18			372	9.6	ab
19			376	9.1	abc
20			377	9.4	abc
21	3	15	36	9.7	ab
22			37	9.9	ab
23			38	8.2	abc
24			40	9.0	abc
25			42	9.6	ab
26		27	64	9.3	abc
27			66	8.1	abc
28			67	8.5	abc
29			69	8.9	abc
30			71	9.8	ab
31	4	91	233	8.4	abc
32			234	8.9	abc
33			235	8.9	abc
34			236	7.9	bc
35			237	9.0	abc
36		154	460	7.9	bc
37			461	9.7	ab
38			462	9.6	ab
39			463	9.6	ab
40			465	10.0	a
41	5	13	25	9.3	abc
42			26	8.4	abc
43			27	8.4	abc
44			31	9.6	abc
45			32	9.2	abc
46		142	414	7.9	bc
47			415	9.6	ab
48			416	8.9	abc
49			418	9.7	ab
50			420	8.9	abc

Means with the same letter are not significantly different at 5%

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Duncan's multiple range test for plant height

No.Clus Topo Half-sib          Means
 1  1    69    147             105.6   abcdefg
 2             148             109.2   abcdefg
 3             150             110.7   abcdefg
 4             151             109.6   abcdefg
 5             154             113.9   abcdef
 6     145     429              98.9       efg
 7             430             107.9   abcdefg
 8             431             112.3   abcdefg
 9             432             114.6   abcde
10             435             105.8   abcdefg
   -------------------------------------------------
11  2    97    260             104.2    bcdefg
12             261             107.7   abcdefg
13             262             121.4   a
14             264             114.6   abcde
15             266             111.9   abcdefg
16     131     369              98.5        fg
17             371             110.6   abcdefg
18             372             114.8   abcde
19             376             106.9   abcdefg
20             377             108.3   abcdefg
   -------------------------------------------------
21  3    15     36             117.5   ab
22              37             111.5   abcdefg
23              38             104.7    bcdefg
24              40             101.4     cdefg
25              42             106.7   abcdefg
26      27      64             108.6   abcdefg
27              66             102.4    bcdef
28              67              97.6         g
29              69             104.4    bcdefg
30              71             107.1   abcdefg
   -------------------------------------------------
31  4   91     233             116.0   abcd
32             234             116.9   abc
33             235             104.6    bcdefg
34             236             106.3   abcdefg
35             237             114.1   abcdef
36    154      460             100.2      defg
37             461             100.8      defg
38             462             108.0   abcdefg
39             463             101.4     cdefg
40             465             113.5   abcdefg
   -------------------------------------------------
41  5   13      25             106.8   abcdefg
42              26             105.8   abcdefg
43              27             112.5   abcdefg
44              31             109.4   abcdefg
45              32             100.0      defg
46    142      414             106.8   abcdefg
47             415             101.6     cdefg
48             416             100.6      defg
49             418             107.4   abcdefg
50             420             108.5   abcdefg
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Means with the same letter are not significantly different at 5%
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Duncan's multiple range test for peeping day

No.Clus Topo Half-sib             Means
 1  1   69    147                 113.8     bcde
 2            148                 112.5     bcde
 3            150                 122.0    a
 4            151                 113.1     bcde
 5            154                 113.2     bcde
 6     145    429                 111.2     bcde
 7            430                 110.4     bcde
 8            431                 114.5     bcde
 9            432                 113.8     bcde
10            435                 114.0     bcde
 ---------------------------------------------------------
11  2   97    260                 111.9     bcde
12            261                 113.8     bcde
13            262                 111.7     bcde
14            264                 109.3       de
15            266                 113.9     bcde
16     131    369                 111.6     bcde
17            371                 112.3     bcde
18            372                 111.9     bcde
19            376                 111.9     bcde
20            377                 108.4        e
 ---------------------------------------------------------
21  3   15     36                 112.3     bcde
22             37                 115.9     bc
23             38                 114.3     bcde
24             40                 112.6     bcde
25             42                 114.2     bcde
26     27      64                 114.0     bcde
27             66                 114.7     bcde
28             67                 113.8     bcde
29             69                 112.6     bcde
30             71                 114.9     bcde
 ---------------------------------------------------------
31  4  91     233                 113.8     bcde
32            234                 111.6     bcde
33            235                 111.8     bcde
34            236                 109.7      cde
35            237                 110.8     bcde
36    154     460                 110.9     bcde
37            461                 109.3       de
38            462                 113.4     bcde
39            463                 114.9     bcde
40            465                 111.2     bcde
 ---------------------------------------------------------
41  5  13      25                 113.3     bcde
42             26                 115.7     bc
43             27                 111.9     bcde
44             31                 113.0     bcde
45             32                 115.1     bcd
46    142     414                 112.1     bcde
47            415                 116.1     b
48            416                 112.3     bcde
49            418                 113.6     bcde
50            420                 112.9     bcde
-------------------------------------------------------------
Means with the same letter are not significantly different at 5%
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Duncan's multiple range test for anthesis day

No.Clus Topo Half-sib          Means
 1  1    69    147             139.2   ab
 2             148             130.4    b
 3             150             138.1   ab
 4             151             136.1   ab
 5             154             137.1   ab
 6      145    429             131.2    b
 7             430             128.4    b
 8             431             137.6   ab
 9             432             129.9    b
10             435             129.9    b
   ---------------------------------------------------------
11  2    97    260             132.1    b
12             261             145.3   a
13             262             136.9   ab
14             264             131.6    b
15             266             135.4   ab
16      131    369             130.8    b
17             371             135.8   ab
18             372             136.6   ab
19             376             133.1   ab
20             377             136.4   ab
   ----------------------------------------------------------
21  3    15     36             139.2   ab
22              37             133.4   ab
23              38             134.3   ab
24              40             128.2    b
25              42             136.5   ab
26      27      64             131.3    b
27              66             129.2    b
28              67             134.8   ab
29              69             132.9   ab
30              71             135.1   ab
   -----------------------------------------------------------
31  4   91     233             137.6   ab
32             234             130.4    b
33             235             130.9    b
34             236             135.0   ab
35             237             133.8   ab
36     154     460             130.8    b
37             461             131.8    b
38             462             138.0   ab
39             463             137.1   ab
40             465             134.8   ab
   --------------------------------------------------------
41  5   13      25             132.3   ab
42              26             136.3   ab
43              27             128.6    b
44              31             139.2   ab
45              32             135.3   ab
46     142     414             134.0   ab
47             415             137.4   ab
48             416             134.3   ab
49             418             131.8    b
50             420             132.2   ab
------------------------------------------------------------
Means with the same letter are not significantly different at 5%
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Duncan's multiple range test for the median flowering day

No.	Clus	Topo	Half-sib	Means	
1	1	69	147	139.2	b
2			148	130.4	b
3			150	138.1	ab
4			151	136.1	ab
5			154	137.1	ab
6		145	429	131.2	b
7			430	128.4	b
8			431	137.6	ab
9			432	129.9	b
10			435	129.9	b
11	2	97	260	132.1	b
12			261	145.3	a
13			262	136.9	ab
14			264	131.6	b
15			266	135.4	ab
16		131	369	130.8	b
17			371	135.8	ab
18			372	136.6	ab
19			376	133.1	ab
20			377	136.4	ab
21	3	15	36	139.2	ab
22			37	133.4	ab
23			38	134.3	ab
24			40	128.2	b
25			42	136.5	ab
26		27	64	131.3	b
27			66	129.2	b
28			67	134.8	ab
29			69	132.9	ab
30			71	135.1	ab
31	4	91	233	137.6	ab
32			234	130.4	b
33			235	130.9	b
34			236	135.0	ab
35			237	133.8	ab
36		154	460	130.8	b
37			461	131.8	b
38			462	138.0	ab
39			463	137.1	ab
40			465	134.8	ab
41	5	13	25	132.3	ab
42			26	136.3	ab
43			27	128.6	b
44			31	139.2	ab
45			32	135.3	ab
46		142	414	134.0	ab
47			415	137.4	ab
48			416	134.3	ab
49			418	131.8	b
50			420	132.2	ab

Means with the same letter are not significantly different at 5%

Duncan's multiple range test for the last day of flowering

No.	Clus	Topo	Half-sib	Means	
1	1	69	147	155.8	ab
2			148	141.1	b
3			150	146.6	ab
4			151	151.4	ab
5			154	153.6	ab
6		145	429	144.2	b
7			430	138.8	b
8			431	152.6	ab
9			432	138.3	b
10			435	137.9	b
11	2	97	260	145.0	ab
12			261	169.6	a
13			262	154.8	ab
14			264	145.6	ab
15			266	149.2	ab
16		131	369	141.8	b
17			371	150.4	ab
18			372	153.7	ab
19			376	146.0	ab
20			377	157.6	ab
21	3	15	36	158.6	ab
22			37	143.9	b
23			38	144.8	ab
24			40	136.1	b
25			42	152.4	ab
26		27	64	140.4	b
27			66	135.7	b
28			67	149.2	ab
29			69	146.2	ab
30			71	147.6	ab
31	4	91	233	152.2	ab
32			234	141.8	b
33			235	142.9	b
34			236	151.6	ab
35			237	149.2	ab
36		154	460	142.4	b
37			461	146.4	ab
38			462	154.4	ab
39			463	146.8	ab
40			465	151.3	ab
41	5	13	25	143.7	b
42			26	151.3	ab
43			27	137.8	b
44			31	157.0	ab
45			32	147.8	ab
46		142	414	146.3	ab
47			415	152.9	ab
48			416	148.9	ab
49			418	143.2	b
50			420	144.3	b

Means with the same letter are not significantly different at 5%

Duncan's multiple range test for anthesis time

No.	Clus	Topo	Half-sib	Means	
1	1	69	147	2.4	ab
2			148	1.3	ab
3			150	1.0	b
4			151	2.9	ab
5			154	1.4	ab
6		145	429	1.4	ab
7			430	1.0	b
8			431	1.4	ab
9			432	2.3	ab
10			435	3.1	ab
11	2	97	260	1.4	ab
12			261	3.1	ab
13			262	2.0	ab
14			264	1.7	ab
15			266	2.2	ab
16		131	369	3.6	ab
17			371	2.0	ab
18			372	2.1	ab
19			376	2.2	ab
20			377	1.7	ab
21	3	15	36	1.8	ab
22			37	2.0	ab
23			38	1.1	b
24			40	1.6	ab
25			42	3.2	ab
26		27	64	2.8	ab
27			66	1.0	b
28			67	2.2	ab
29			69	3.0	ab
30			71	1.8	ab
31	4	91	233	2.9	ab
32			234	2.3	ab
33			235	2.9	ab
34			236	3.2	ab
35			237	3.4	ab
36		154	460	2.0	ab
37			461	2.7	ab
38			462	1.7	ab
39			463	1.9	ab
40			465	2.8	ab
41	5	13	25	2.0	ab
42			26	2.3	ab
43			27	2.1	ab
44			31	2.2	ab
45			32	4.0	a
46		142	414	2.0	ab
47			415	1.7	ab
48			416	1.6	ab
49			418	2.2	ab
50			420	1.9	ab

Means with the same letter are not significantly different at 5%

Duncan's multiple range test for anthesis position

No.	Clus	Topo	Half-sib	Means	
1	1	69	147	3.9	abc
2			148	3.4	abc
3			150	3.4	abc
4			151	3.4	abc
5			154	4.0	abc
6		145	429	4.3	abc
7			430	4.3	abc
8			431	3.6	abc
9			432	3.7	abc
10			435	3.6	abc
11	2	97	260	3.9	abc
12			261	4.3	abc
13			262	4.7	ab
14			264	3.3	abc
15			266	3.4	abc
16		131	369	4.3	abc
17			371	4.3	abc
18			372	4.2	abc
19			376	3.6	abc
20			377	3.3	abc
21	3	15	36	3.2	abc
22			37	3.9	abc
23			38	4.1	abc
24			40	3.0	bc
25			42	3.8	abc
26		27	64	3.8	abc
27			66	3.7	abc
28			67	3.3	abc
29			69	3.6	abc
30			71	4.9	a
31	4	91	233	3.3	abc
32			234	3.6	abc
33			235	3.3	abc
34			236	2.8	c
35			237	3.8	abc
36		154	460	3.6	abc
37			461	3.7	abc
38			462	3.8	abc
39			463	3.8	abc
40			465	3.3	abc
41	5	13	25	4.0	abc
42			26	4.0	abc
43			27	4.0	abc
44			31	4.3	abc
45			32	3.8	abc
46		142	414	3.8	abc
47			415	3.2	abc
48			416	4.4	abc
49			418	4.1	abc
50			420	4.4	abc

Means with the same letter are not significantly different at 5%

Duncan's multiple range test for panicle width

No.	Clus	Topo	Half-sib	Means	
1	1	69	147	54.7	abcdef
2			148	66.2	abcd
3			150	61.9	abcdef
4			151	65.0	abcde
5			154	44.8	bcdef
6		145	429	47.2	bcdef
7			430	61.2	abcdef
8			431	59.9	abcdef
9			432	57.2	abcdef
10			435	54.9	abcdef
11	2	97	260	49.7	bcdef
12			261	56.2	abcdef
13			262	61.0	abcdef
14			264	46.6	bcdef
15			266	38.7	ef
16		131	369	66.3	abcd
17			371	68.6	abc
18			372	37.7	f
19			376	50.2	bcdef
20			377	41.0	def
21	3	15	36	54.3	abcdef
22			37	61.5	abcdef
23			38	56.6	abcdef
24			40	56.4	abcdef
25			42	64.7	abcdef
26		27	64	71.8	ab
27			66	66.1	abcd
28			67	52.8	bcdef
29			69	48.1	bcdef
30			71	66.7	abcd
31	4	91	233	52.5	bcdef
32			234	48.3	bcdef
33			235	42.9	cdef
34			236	46.8	bcdef
35			237	56.6	abcdef
36		154	460	61.7	abcdef
37			461	56.0	abcdef
38			462	55.6	abcdef
39			463	53.2	bcdef
40			465	41.1	def
41	5	13	25	59.9	abcdef
42			26	86.7	a
43			27	60.9	abcdef
44			31	62.0	abcdef
45			32	49.3	bcdef
46		142	414	59.3	abcdef
47			415	58.4	abcdef
48			416	52.1	bcdef
49			418	62.8	abcdef
50			420	56.3	abcdef

Means with the same letter are not significantly different at 5%

Duncan's multiple range test for panicle length

No.	Clus	Topo	Half-sib	Means	
1	1	69	147	132.4	abcdef
2			148	138.9	abcdef
3			150	126.2	abcdef
4			151	155.5	ab
5			154	107.8	f
6		145	429	120.3	cdef
7			430	150.3	abcd
8			431	133.6	abcdef
9			432	146.1	abcde
10			435	132.8	abcdef
11	2	97	260	118.8	def
12			261	134.8	abcdef
13			262	149.2	abcdef
14			264	134.5	abcdef
15			266	136.4	abcdef
16		131	369	125.6	bcdef
17			371	130.3	abcdef
18			372	134.3	abcdef
19			376	135.2	abcdef
20			377	124.8	bcdef
21	3	15	36	128.9	abcdef
22			37	138.8	abcdef
23			38	145.0	abcdef
24			40	128.1	abcdef
25			42	142.7	abcde
26		27	64	155.6	ab
27			66	151.0	abc
28			67	124.6	bcdef
29			69	117.9	ef
30			71	135.2	abcdef
31	4	91	233	144.7	abcdef
32			234	147.9	abcdef
33			235	125.0	bcdef
34			236	118.1	ef
35			237	132.8	abcdef
36		154	460	150.4	abc
37			461	122.4	cdef
38			462	124.4	bcdef
39			463	138.3	abcdef
40			465	130.7	abcdef
41	5	13	25	134.3	abcdef
42			26	157.4	a
43			27	131.3	abcdef
44			31	128.2	abcdef
45			32	130.6	abcdef
46		142	414	124.1	bcdef
47			415	139.9	abcdef
48			416	126.4	abcdef
49			418	134.3	abcdef
50			420	136.6	abcdef

Means with the same letter are not significantly different at 5%

```
Duncan's multiple range test for panicle compactness

No.Clus Topo Half-sib            Means
 1  1    69    147               6.4    abc
 2             148               5.9    abc
 3             150               6.8    a
 4             151               6.3    abc
 5             154               3.9     bc
 6      145    429               5.1    abc
 7             430               4.1    abc
 8             431               6.4    abc
 9             432               6.0    abc
10             435               6.0    abc
   -------------------------------------------------------
11  2    97    260               4.7    abc
12             261               5.6    abc
13             262               5.4    abc
14             264               4.9    abc
15             266               3.9     bc
16      131    369               6.3    abc
17             371               4.8    abc
18             372               3.8      c
19             376               4.8    abc
20             377               4.0    abc
   -------------------------------------------------------
21  3    15     36               4.8    abc
22              37               6.1    abc
23              38               6.7    ab
24              40               5.3    abc
25              42               6.1    abc
26       27     64               6.0    abc
27              66               4.6    abc
28              67               5.9    abc
29              69               3.9     bc
30              71               5.5    abc
   ------------------------------------------------------
31  4   91     233               4.4    abc
32             234               6.0    abc
33             235               3.8      c
34             236               6.5    abc
35             237               4.6    abc
36     154     460               6.2    abc
37             461               4.8    abc
38             462               5.3    abc
39             463               5.3    abc
40             465               4.3    abc
   ------------------------------------------------------
41  5   13      25               6.2    abc
42              26               6.2    abc
43              27               6.3    abc
44              31               6.4    abc
45              32               5.0    abc
46     142     414               6.3    abc
47             415               4.9    abc
48             416               5.4    abc
49             418               6.2    abc
50             420               5.3    abc
---------------------------------------------------------
Means with the same letter are not significantly different at 5%
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Duncan's multiple range test for clump erectness

No.Clus Topo Half-sib              Means
 1  1    69    147                 4.3   abcdef
 2             148                 5.0   abcd
 3             150                 5.1   abcd
 4             151                 5.4   abcd
 5             154                 4.9   abcd
 6      145    429                 4.3   abcdef
 7             430                 5.6   abc
 8             431                 5.6   abc
 9             432                 4.0   abcdef
10             435                 3.6    bcdef
   ---------------------------------------------------------
11  2    97    260                 4.0   abcdef
12             261                 5.6   abc
13             262                 3.4    bcdef
14             264                 2.6       ef
15             266                 3.2      def
16      131    369                 4.3   abcdef
17             371                 4.9   abcd
18             372                 5.3   abcd
19             376                 3.6    bcdef
20             377                 3.7   abcdef
   ---------------------------------------------------------
21  3    15     36                 4.8   abcdef
22              37                 4.1   abcdef
23              38                 4.2   abcdef
24              40                 5.9   a
25              42                 3.3     cdef
26      27      64                 4.2   abcdef
27              66                 3.9   abcdef
28              67                 4.4   abcdef
29              69                 4.3   abcdef
30              71                 4.2   abcdef
   ---------------------------------------------------------
31  4   91     233                 3.2      def
32             234                 4.6   abcdef
33             235                 4.1   abcdef
34             236                 4.3   abcdef
35             237                 4.0   abcdef
36     154     460                 3.9   abcdef
37             461                 2.1        f
38             462                 4.6   abcde
39             463                 2.1        f
40             465                 4.4   abcde
   ---------------------------------------------------------
41  5  13       25                 5.0   abcd
42              26                 5.6   abc
43              27                 5.7   ab
44              31                 3.2      def
45              32                 4.1   abcdef
46     142     414                 3.8   abcdef
47             415                 5.1   abcd
48             416                 5.0   abcd
49             418                 5.0   abcd
50             420                 5.0   abcd
-------------------------------------------------------------
Means with the same letter are not significantly different at 5%
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Duncan's multiple range test for old disease

No.	Clus	Topo	Half-sib	Means	
1	1	69	147	6.7	abc
2			148	8.3	a
3			150	7.8	ab
4			151	7.6	abc
5			154	6.7	abc
6		145	429	8.5	a
7			430	7.8	ab
8			431	7.1	abc
9			432	8.0	ab
10			435	8.3	a
11	2	97	260	7.0	abc
12			261	6.4	abc
13			262	6.2	abc
14			264	8.3	a
15			266	7.3	abc
16		131	369	7.2	abc
17			371	8.0	ab
18			372	8.3	a
19			376	6.4	abc
20			377	6.1	abc
21	3	15	36	6.3	abc
22			37	7.2	abc
23			38	7.0	abc
24			40	7.1	abc
25			42	7.9	ab
26		27	64	7.1	abc
27			66	7.0	abc
28			67	8.0	ab
29			69	6.3	abc
30			71	7.3	abc
31	4	91	233	5.6	bc
32			234	5.1	c
33			235	6.5	abc
34			236	7.3	abc
35			237	6.2	abc
36		154	460	7.6	abc
37			461	7.2	abc
38			462	6.5	abc
39			463	6.9	abc
40			465	7.0	abc
41	5	13	25	7.2	abc
42			26	8.1	a
43			27	7.0	abc
44			31	6.8	abc
45			32	7.0	abc
46		142	414	7.0	abc
47			415	7.8	ab
48			416	6.7	abc
49			418	6.2	abc
50			420	7.3	abc

Means with the same letter are not significantly different at 5%

Duncan's multiple range test for new diseases

No.	Clus	Topo	Half-sib	Means	
1	1	69	147	3.6	bcde
2			148	4.2	abcde
3			150	4.8	abcd
4			151	4.3	abcde
5			154	3.4	bcde
6		145	429	4.4	abcde
7			430	4.6	abcde
8			431	3.9	abcde
9			432	4.9	abcd
10			435	4.3	abcde
11	2	97	260	3.1	cde
12			261	3.4	bcde
13			262	3.3	bcde
14			264	4.0	abcde
15			266	4.2	abcde
16		131	369	4.0	abcde
17			371	4.4	abcde
18			372	4.1	abcde
19			376	3.4	bcde
20			377	3.2	bcde
21	3	15	36	5.3	abcd
22			37	5.2	abcd
23			38	6.0	ab
24			40	5.2	abcd
25			42	6.6	a
26		27	64	3.9	abcde
27			66	3.7	bcde
28			67	4.4	abcde
29			69	4.5	abcde
30			71	3.8	bcde
31	4	91	233	2.9	cde
32			234	1.9	e
33			235	3.5	bcde
34			236	4.2	abcde
35			237	3.7	bcde
36		154	460	4.4	bcde
37			461	3.4	bcde
38			462	2.9	cde
39			463	5.0	abcd
40			465	2.6	de
41	5	13	25	5.0	abcd
42			26	5.6	abc
43			27	4.8	abcd
44			31	3.3	bcde
45			32	5.0	abcd
46		142	414	4.8	abcd
47			415	5.3	abcd
48			416	4.9	abcd
49			418	3.7	bcde
50			420	5.0	abcd

Means with the same letter are not significantly different at 5%

Duncan's multiple range test for leaf hair

No.	Clus	Topo	Half-sib	Means	
1	1	69	147	9.1	abc
2			148	8.8	abcd
3			150	8.2	abcd
4			151	8.9	abcd
5			154	8.3	abcd
6		145	429	9.1	abcd
7			430	8.8	abcd
8			431	9.2	abc
9			432	8.6	abcd
10			435	8.3	abcd
11	2	97	260	9.1	abcd
12			261	8.9	abcd
13			262	8.9	abcd
14			264	9.6	a
15			266	9.6	ab
16		131	369	8.8	abcd
17			371	8.8	abcd
18			372	8.7	abcd
19			376	9.0	abcd
20			377	9.4	abc
21	3	15	36	8.6	abcd
22			37	7.9	cd
23			38	8.7	abcd
24			40	9.3	abc
25			42	8.4	abcd
26		27	64	8.8	abcd
27			66	9.1	abcd
28			67	8.9	abcd
29			69	9.3	abc
30			71	7.6	d
31	4	91	233	8.3	abcd
32			234	8.3	abcd
33			235	8.8	abcd
34			236	9.0	abcd
35			237	9.4	abc
36		154	460	8.4	abcd
37			461	8.7	abcd
38			462	9.1	abcd
39			463	8.0	bcd
40			465	8.6	abcd
41	5	13	25	9.1	abcd
42			26	8.7	abcd
43			27	8.4	abcd
44			31	8.2	abcd
45			32	8.3	abcd
46		142	414	8.4	abcd
47			415	8.8	abcd
48			416	8.3	abcd
49			418	8.9	abcd
50			420	8.4	abcd

Means with the same letter are not significantly different at 5%

Duncan's multiple range test for tensile leaf blade strength

No.	Clus	Topo	Half-sib	Means	
1	1	69	147	102.5	abcdefg
2			148	81.1	fg
3			150	93.4	bcdefg
4			151	94.1	abcdefg
5			154	93.2	bcdefg
6		145	429	94.3	abcdefg
7			430	93.9	abcdefg
8			431	93.8	abcdefg
9			432	109.2	abc
10			435	93.5	abcdefg
11	2	97	260	80.5	g
12			261	96.3	abcdefg
13			262	97.6	abcdefg
14			264	103.6	abcdef
15			266	97.3	abcdefg
16		131	369	90.9	bcdefg
17			371	92.5	bcdefg
18			372	90.3	bcdefg
19			376	110.1	ab
20			377	105.5	abcde
21	3	15	36	92.4	bcdefg
22			37	115.7	a
23			38	107.8	abcd
24			40	93.8	abcdefg
25			42	84.0	efg
26		27	64	100.9	abcdefg
27			66	107.6	abcd
28			67	85.3	defg
29			69	91.8	bcdefg
30			71	89.1	bcdefg
31	4	91	233	94.3	abcdefg
32			234	90.7	bcdefg
33			235	92.2	bcdefg
34			236	93.7	abcdefg
35			237	98.1	abcdefg
36		154	460	96.1	abcdefg
37			461	91.6	bcdefg
38			462	97.2	abcdefg
39			463	90.9	bcdefg
40			465	104.7	abcde
41	5	13	25	96.5	abcdefg
42			26	103.8	abcde
43			27	90.6	bcdefg
44			31	95.4	abcdefg
45			32	87.4	cdefg
46		142	414	96.6	abcdefg
47			415	102.3	abcdefg
48			416	91.8	bcdefg
49			418	106.6	abcde
50			420	88.8	bcdefg

Means with the same letter are not significantly different at 5%

Duncan's multiple range test for flavanoid leaf sheath

No.	Clus	Topo	Half-sib	Means	
1	1	69	147	5.2	abcdef
2			148	4.6	abcdef
3			150	5.3	abcdef
4			151	3.3	def
5			154	4.4	abcdef
6		145	429	4.4	abcdef
7			430	4.2	abcdef
8			431	3.9	bcdef
9			432	4.0	bcdef
10			435	3.8	cdef
11	2	97	260	5.7	abcde
12			261	4.4	abcdef
13			262	4.6	abcdef
14			264	3.4	def
15			266	6.2	abc
16		131	369	5.8	abcd
17			371	4.7	abcdef
18			372	5.6	abcdef
19			376	3.7	cdef
20			377	4.6	abcdef
21	3	15	36	7.0	a
22			37	5.6	abcdef
23			38	5.3	abcdef
24			40	5.3	abcdef
25			42	6.2	abc
26		27	64	5.4	abcde
27			66	4.0	bcdef
28			67	5.0	abcdef
29			69	6.6	ab
30			71	5.1	abcdef
31	4	91	233	4.9	abcdef
32			234	4.3	abcdef
33			235	3.9	bcdef
34			236	3.0	ef
35			237	4.4	abcdef
36		154	460	3.6	cdef
37			461	6.2	abc
38			462	3.8	cdef
39			463	5.1	abcdef
40			465	5.7	abcde
41	5	13	25	4.7	abcdef
42			26	3.3	def
43			27	4.8	abcdef
44			31	4.2	bcdef
45			32	4.1	bcdef
46		142	414	3.9	bcdef
47			415	3.7	cdef
48			416	2.7	f
49			418	4.4	abcdef
50			420	3.3	def

Means with the same letter are not significantly different at 5%

Duncan's multiple range test for tiller number at 5% asymptote

No.	Clus	Topo	Half-sib	Means	
1	1	69	147	1.8	b
2			148	1.8	b
3			150	2.0	b
4			151	3.3	b
5			154	1.7	b
6		145	429	2.2	b
7			430	1.6	b
8			431	2.3	b
9			432	2.8	b
10			435	2.1	b
11	2	97	260	2.0	b
12			261	2.5	b
13			262	1.7	b
14			264	2.6	b
15			266	2.5	b
16		131	369	2.1	b
17			371	1.6	b
18			372	1.8	b
19			376	1.5	b
20			377	2.1	b
21	3	15	36	5.0	b
22			37	2.9	b
23			38	1.7	b
24			40	1.5	b
25			42	2.6	b
26		27	64	1.5	b
27			66	1.4	b
28			67	2.8	b
29			69	2.9	b
30			71	2.3	b
31	4	91	233	2.2	b
32			234	2.5	b
33			235	1.6	b
34			236	1.5	b
35			237	10.2	a
36		154	460	1.9	b
37			461	2.4	b
38			462	2.5	b
39			463	1.9	b
40			465	2.4	b
41	5	13	25	2.1	b
42			26	1.5	b
43			27	1.7	b
44			31	1.9	b
45			32	1.8	b
46		142	414	1.9	b
47			415	1.9	b
48			416	2.6	b
49			418	2.9	b
50			420	2.6	b

Means with the same letter are not significantly different at 5%

Duncan's multiple range test for tiller number at 50% upper asymptote

No.	Clus	Topo	Half-sib	Means	
1	1	69	147	17.2	bc
2			148	16.0	bc
3			150	19.8	bc
4			151	19.8	bc
5			154	16.5	bc
6		145	429	21.8	bc
7			430	15.6	bc
8			431	23.1	bc
9			432	28.0	bc
10			435	20.5	bc
11	2	97	260	20.3	bc
12			261	24.4	bc
13			262	16.7	bc
14			264	25.9	bc
15			266	24.8	bc
16		131	369	17.8	bc
17			371	17.5	bc
18			372	17.5	bc
19			376	14.7	c
20			377	20.7	bc
21	3	15	36	48.8	a
22			37	28.4	bc
23			38	17.1	bc
24			40	14.6	c
25			42	25.6	bc
26		27	64	15.3	c
27			66	13.9	c
28			67	27.6	bc
29			69	28.9	bc
30			71	22.6	bc
31	4	91	233	22.5	bc
32			234	24.9	bc
33			235	16.2	bc
34			236	14.4	c
35			237	23.0	bc
36		154	460	18.8	bc
37			461	23.6	bc
38			462	24.4	bc
39			463	19.5	bc
40			465	24.0	bc
41	5	13	25	21.0	bc
42			26	14.8	c
43			27	17.0	bc
44			31	19.7	bc
45			32	17.8	bc
46		142	414	17.4	bc
47			415	16.6	bc
48			416	25.7	bc
49			418	28.8	bc
50			420	26.4	bc

Means with the same letter are not significantly different at 5%

Duncan’s multiple range test for tiller number at 95% asymptote

No.	Clus	Topo	Half-sib	Means	
1	1	69	147	33.7	b
2			148	31.4	b
3			150	37.5	b
4			151	61.6	b
5			154	33.1	b
6		145	429	42.0	b
7			430	30.7	b
8			431	46.0	b
9			432	51.8	b
10			435	38.5	b
11	2	97	260	38.6	b
12			261	48.0	b
13			262	33.9	b
14			264	49.3	b
15			266	48.6	b
16		131	369	32.3	b
17			371	31.1	b
18			372	35.2	b
19			376	31.0	b
20			377	41.3	b
21	3	15	36	102.6	a
22			37	57.0	b
23			38	33.6	b
24			40	29.0	b
25			42	48.8	b
26		27	64	30.5	b
27			66	28.0	b
28			67	53.9	b
29			69	51.3	b
30			71	45.3	b
31	4	91	233	43.7	b
32			234	49.5	b
33			235	31.0	b
34			236	31.3	b
35			237	35.8	b
36		154	460	36.6	b
37			461	43.8	b
38			462	44.8	b
39			463	36.1	b
40			465	44.9	b
41	5	13	25	40.8	b
42			26	29.0	b
43			27	33.3	b
44			31	38.9	b
45			32	34.8	b
46		142	414	34.8	b
47			415	33.4	b
48			416	48.2	b
49			418	52.1	b
50			420	50.6	b

Means with the same letter are not significantly different at 5%

Duncan's multiple range test for tiller number at flowering

No.	Clus	Topo	Half-sib	Means	
1	1	69	147	34.7	defgh
2			148	32.9	efgh
3			150	40.3	bcdefgh
4			151	62.8	a
5			154	36.2	cdefgh
6		145	429	43.8	abcdefgh
7			430	32.1	gh
8			431	47.2	abcdefgh
9			432	52.8	abcde
10			435	39.9	bcdefgh
11	2	97	260	39.8	bcdefgh
12			261	44.0	abcdefgh
13			262	38.0	cdefgh
14			264	51.7	abcdefgh
15			266	50.4	abcdefgh
16		131	369	33.6	defgh
17			371	32.0	fgh
18			372	37.1	cdefgh
19			376	33.3	defgh
20			377	43.0	bcdefgh
21	3	15	36	44.7	abcdefgh
22			37	35.7	cdefgh
23			38	35.7	cdefgh
24			40	30.4	h
25			42	49.4	abcdefgh
26		27	64	32.4	fgh
27			66	30.5	h
28			67	55.8	abc
29			69	51.0	abcdefg
30			71	46.4	abcdefgh
31	4	91	233	46.1	abcdefgh
32			234	52.3	abcdef
33			235	32.4	fgh
34			236	34.7	defgh
35			237	35.6	defgh
36		154	460	36.0	cdefgh
37			461	43.6	abcdefgh
38			462	46.4	abcdefgh
39			463	37.0	cdefgh
40			465	45.9	abcdefgh
41	5	13	25	43.0	bcdefgh
42			26	29.9	h
43			27	35.2	defgh
44			31	41.7	bcdefgh
45			32	36.7	cdefgh
46		142	414	44.3	abcdefgh
47			415	35.0	defgh
48			416	49.1	abcdefgh
49			418	53.1	abcd
50			420	52.6	abcde

Means with the same letter are not significantly different at 5%

Duncan's multiple range test for dead tiller number

No.	Clus	Topo	Half-sib	Means	
1	1	69	147	10.1	efghi
2			148	15.3	cdefgh
3			150	9.0	gh
4			151	14.7	cdefgh
5			154	25.1	abc
6		145	429	15.9	cdefgh
7			430	13.6	cdefgh
8			431	20.2	abcdefgh
9			432	17.9	bcdefgh
10			435	16.3	cdefgh
11	2	97	260	16.8	cdefgh
12			261	24.3	abcd
13			262	23.8	abcd
14			264	22.9	abcd
15			266	23.4	abcd
16		131	369	14.8	cdefgh
17			371	16.1	cdefgh
18			372	23.6	abcd
19			376	13.9	cdefgh
20			377	23.2	abcd
21	3	15	36	29.7	ab
22			37	13.9	cdefgh
23			38	16.8	cdefgh
24			40	12.2	defgh
25			42	30.6	a
26		27	64	13.3	cdefgh
27			66	9.3	fgh
28			67	18.7	abcdefgh
29			69	22.6	abcde
30			71	21.6	abcdefg
31	4	91	233	20.0	abcdefgh
32			234	19.7	abcdefgh
33			235	18.5	abcdefgh
34			236	16.2	cdefgh
35			237	20.4	abcdefgh
36		154	460	15.0	cdefgh
37			461	21.7	abcdef
38			462	17.8	bcdefgh
39			463	17.9	bcdefgh
40			465	24.1	abcd
41	5	13	25	15.0	cdefgh
42			26	8.7	h
43			27	15.6	cdefgh
44			31	20.0	abcdefgh
45			32	11.6	defgh
46		142	414	13.4	cdefgh
47			415	14.3	cdefgh
48			416	17.3	bcdefgh
49			418	23.9	abcd
50			420	20.3	abcdefgh

Means with the same letter are not significantly different at 5%

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Duncan's multiple range test for green tiller number

No.Clus Topo Half-sib             Means
 1  1    69    147                30.3   ab
 2             148                22.8   ab
 3             150                32.7   ab
 4             151                27.4   ab
 5             154                25.3   ab
 6      145    429                20.6   ab
 7             430                29.7   ab
 8             431                24.1   ab
 9             432                33.1   ab
10             435                19.5    b
   ----------------------------------------------------
11  2    97    260                27.3   ab
12             261                26.9   ab
13             262                22.2   ab
14             264                31.0   ab
15             266                26.7   ab
16      131    369                21.2   ab
17             371                30.1   ab
18             372                30.8   ab
19             376                26.4   ab
20             377                26.7   ab
   ----------------------------------------------------
21  3    15     36                34.4   ab
22              37                36.3   ab
23              38                33.0   ab
24              40                22.2   ab
25              42                36.3   ab
26       27     64                18.0    b
27              66                26.7   ab
28              67                35.8   ab
29              69                27.1   ab
30              71                25.1   ab
   ----------------------------------------------------
31  4   91     233                28.2   ab
32             234                33.2   ab
33             235                41.3   a
34             236                28.8   ab
35             237                25.4   ab
36     154     460                28.3   ab
37             461                32.0   ab
38             462                21.0   ab
39             463                27.4   ab
40             465                35.1   ab
   ----------------------------------------------------
41  5   13      25                20.2   ab
42              26                31.8   ab
43              27                26.4   ab
44              31                20.8   ab
45              32                28.9   ab
46     142     414                26.6   ab
47             415                36.9   ab
48             416                36.3   ab
49             418                22.9   ab
50             420                32.1   ab
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Means with the same letter are not significantly different at 5%
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Duncan's multiple range test for young tiller number

No.	Clus	Topo	Half-sib	Means	
1	1	69	147	12.6	bcdefg
2			148	9.8	defg
3			150	26.8	a
4			151	3.7	fg
5			154	17.6	abcde
6		145	429	8.6	defg
7			430	8.7	defg
8			431	7.4	defg
9			432	9.4	defg
10			435	10.0	defg
11	2	97	260	10.9	cdefg
12			261	8.5	defg
13			262	8.0	defg
14			264	6.6	defg
15			266	6.2	defg
16		131	369	11.1	bcdefg
17			371	18.0	abcd
18			372	10.9	cdefg
19			376	9.4	defg
20			377	7.8	defg
21	3	15	36	17.8	abcd
22			37	2.4	g
23			38	14.0	abcdefg
24			40	13.4	bcdefg
25			42	24.3	abc
26		27	64	3.3	fg
27			66	9.3	defg
28			67	19.6	abcd
29			69	13.7	abcdefg
30			71	16.3	abcdefg
31	4	91	233	9.6	defg
32			234	11.4	bcdefg
33			235	16.6	abcdefg
34			236	12.4	bcdefg
35			237	8.9	defg
36		154	460	12.1	bcdefg
37			461	9.4	defg
38			462	10.6	defg
39			463	16.9	abcdef
40			465	24.6	ab
41	5	13	25	8.3	defg
42			26	11.0	cdefg
43			27	6.8	defg
44			31	6.8	defg
45			32	14.6	abcdefg
46		142	414	11.3	bcdefg
47			415	16.6	abcdef
48			416	10.4	defg
49			418	3.9	efg
50			420	6.8	defg

Means with the same letter are not significantly different at 5%

Duncan's multiple range test for aerial tiller number

No.	Clus	Topo	Half-sib	Means	
1	1	69	147	61.1	bcde
2			148	55.9	cde
3			150	80.2	abcde
4			151	71.9	abcde
5			154	66.2	bcde
6		145	429	64.6	bcde
7			430	64.2	bcde
8			431	65.2	bcde
9			432	76.8	abcde
10			435	64.6	bcde
11	2	97	260	70.5	abcde
12			261	52.9	cde
13			262	65.8	bcde
14			264	75.6	abcde
15			266	76.3	abcde
16		131	369	97.3	ab
17			371	66.0	bcde
18			372	70.8	abcde
19			376	69.4	abcde
20			377	83.8	abcde
21	3	15	36	66.4	bcde
22			37	62.6	bcde
23			38	108.1	a
24			40	68.6	bcde
25			42	77.7	abcde
26		27	64	93.7	abc
27			66	68.4	bcde
28			67	95.0	abc
29			69	80.2	abcde
30			71	83.5	abcde
31	4	91	233	100.0	ab
32			234	98.8	ab
33			235	56.6	cde
34			236	65.9	bcde
35			237	87.3	abcde
36		154	460	50.6	e
37			461	62.3	bcde
38			462	49.9	e
39			463	57.4	cde
40			465	71.4	abcde
41	5	13	25	77.0	abcde
42			26	50.4	e
43			27	91.2	abcd
44			31	95.0	abc
45			32	76.1	abcde
46		142	414	65.2	bcde
47			415	88.9	abcde
48			416	77.3	abcde
49			418	91.3	abcd
50			420	73.6	abcde

Means with the same letter are not significantly different at 5%

Duncan's multiple range test for base tiller number

No.	Clus	Topo	Half-sib	Means	
1	1	69	147	53.4	cde
2			148	47.9	cde
3			150	68.5	abcde
4			151	45.8	de
5			154	68.0	abcde
6		145	429	44.5	de
7			430	51.9	cde
8			431	51.8	cde
9			432	60.4	abcde
10			435	45.8	de
11	2	97	260	54.9	cde
12			261	59.6	abcde
13			262	54.0	cde
14			264	60.0	abcde
15			266	56.3	cde
16		131	369	47.1	de
17			371	64.2	abcde
18			372	65.2	abcde
19			376	49.8	cde
20			377	57.7	bcde
21	3	15	36	81.9	abc
22			37	52.7	cde
23			38	63.8	abcde
24			40	47.9	cde
25			42	91.2	a
26		27	64	34.7	e
27			66	45.3	de
28			67	74.1	abcde
29			69	63.9	abcde
30			71	64.9	abcde
31	4	91	233	57.8	bcde
32			234	64.3	abcde
33			235	76.4	abcd
34			236	57.4	bcde
35			237	54.8	cde
36		154	460	55.1	cde
37			461	63.1	abcde
38			462	49.4	cde
39			463	62.0	abcde
40			465	89.0	ab
41	5	13	25	43.6	de
42			26	51.4	cde
43			27	48.8	cde
44			31	47.6	de
45			32	55.0	cde
46		142	414	53.8	cde
47			415	67.8	abcde
48			416	61.4	abcde
49			418	50.7	cde
50			420	59.2	abcde

Means with the same letter are not significantly different at 5%

Duncan's multiple range test for base green tiller number

No.	Clus	Topo	Half-sib	Means	
1	1	69	147	43.3	abcdef
2			148	32.6	bcdef
3			150	59.5	abc
4			151	31.1	cdef
5			154	42.9	abcdef
6		145	429	28.6	def
7			430	38.3	abcdef
8			431	31.6	bcdef
9			432	42.6	abcdef
10			435	29.5	def
11	2	97	260	38.1	abcdef
12			261	35.4	bcdef
13			262	30.2	cdef
14			264	37.1	abcdef
15			266	32.9	bcdef
16		131	369	32.3	bcdef
17			371	48.1	abcdef
18			372	41.7	abcdef
19			376	35.9	abcdef
20			377	34.4	bcdef
21	3	15	36	52.2	abcdef
22			37	38.8	abcdef
23			38	47.0	abcdef
24			40	35.7	abcdef
25			42	60.7	ab
26		27	64	21.3	f
27			66	36.0	abcdef
28			67	55.4	abcdef
29			69	41.3	abcdef
30			71	41.4	abcdef
31	4	91	233	37.8	abcdef
32			234	44.7	abcdef
33			235	57.9	abcd
34			236	41.2	abcdef
35			237	34.3	bcdef
36		154	460	40.1	abcdef
37			461	41.4	abcdef
38			462	31.6	bcdef
39			463	44.1	abcdef
40			465	64.9	a
41	5	13	25	28.6	def
42			26	42.8	abcdef
43			27	33.2	bcdef
44			31	27.6	ef
45			32	43.4	abcdef
46		142	414	39.4	abcdef
47			415	53.4	abcdef
48			416	44.1	abcdef
49			418	26.8	ef
50			420	38.9	abcdef

Means with the same letter are not significantly different at 5%

Duncan's multiple range test for total tiller number

No.	Clus	Topo	Half-sib	Means	
1	1	69	147	129.9	abcd
2			148	103.8	d
3			150	148.7	abcd
4			151	117.7	bcd
5			154	134.2	abcd
6		145	429	115.1	bcd
7			430	116.1	bcd
8			431	117.0	bcd
9			432	137.2	abcd
10			435	117.4	bcd
11	2	97	260	125.4	abcd
12			261	112.5	cd
13			262	119.8	abcd
14			264	143.5	abcd
15			266	132.7	abcd
16		131	369	144.4	abcd
17			371	130.2	abcd
18			372	136.0	abcd
19			376	119.2	bcd
20			377	141.4	abcd
21	3	15	36	148.3	abcd
22			37	115.2	bcd
23			38	171.9	ab
24			40	116.4	bcd
25			42	168.9	abc
26		27	64	128.3	abcd
27			66	113.8	cd
28			67	152.3	abcd
29			69	135.2	abcd
30			71	132.6	abcd
31	4	91	233	157.8	abcd
32			234	163.1	abc
33			235	132.9	abcd
34			236	123.3	abcd
35			237	142.1	abcd
36		154	460	118.1	bcd
37			461	125.4	abcd
38			462	103.0	d
39			463	132.7	abcd
40			465	177.1	a
41	5	13	25	120.6	abcd
42			26	101.9	d
43			27	140.0	abcd
44			31	142.6	abcd
45			32	131.1	abcd
46		142	414	113.6	cd
47			415	156.7	abcd
48			416	158.9	abcd
49			418	142.0	abcd
50			420	132.8	abcd

Means with the same letter are not significantly different at 5%

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Duncan's multiple range test for dead tiller dry weight

No.Clus Topo Half-sib           Means
 1  1   69    147                2.8          g
 2            148                7.3   abcdefg
 3            150                5.1      defg
 4            151                7.1   abcdefg
 5            154               10.5   abcdefg
 6     145    429                6.9   abcdefg
 7            430                6.0     cdefg
 8            431                9.0   abcdefg
 9            432                8.1   abcdefg
10            435                6.7     cdefg
  --------------------------------------------------------
11  2   97    260                5.2      defg
12            261               14.2   abc
13            262               11.6   abcdef
14            264                9.7   abcdefg
15            266                9.7   abcdefg
16     131    369                5.3      defg
17            371                8.1   abcdefg
18            372               12.6   abcde
19            376                6.5     cdefg
20            377               11.8   abcdef
  --------------------------------------------------------
21  3   15     36               14.5   ab
22             37                7.2   abcdefg
23             38                7.3   abcdefg
24             40                5.2      defg
25             42               12.0   abcdef
26     27      64                7.3   abcdefg
27             66                4.5       efg
28             67                9.0   abcdefg
29             69               13.2   abcd
30             71               12.9   abcd
  --------------------------------------------------------
31  4  91     233                8.1   abcdefg
32            234                8.6   abcdefg
33            235                8.0   abcdefg
34            236                6.1     cdefg
35            237                8.6   abcdefg
36    154     460                6.3     cdefg
37            461               15.1   a
38            462                8.4   abcdefg
39            463                7.9   abcdefg
40            465               12.4   abcde
  --------------------------------------------------------
41  5  13      25                7.1   abcdefg
42             26                4.0        fg
43             27                7.7   abcdefg
44             31                9.9   abcdefg
45             32                5.7      defg
46    142     414                5.0      defg
47            415                8.5   abcdefg
48            416                9.3   abcdefg
49            418               10.6   abcdefg
50            420               10.0   abcdefg
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Means with the same letter are not significantly different at 5%
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Duncan's multiple range test for green tiller dry weight

No.	Clus	Topo	Half-sib	Means	
1	1	69	147	18.5	bcdef
2			148	17.6	bcdef
3			150	19.5	bcdef
4			151	12.5	f
5			154	18.1	bcdef
6		145	429	15.1	def
7			430	17.4	bcdef
8			431	15.7	cdef
9			432	20.8	abcdef
10			435	13.6	f
11	2	97	260	13.9	ef
12			261	21.3	abcdef
13			262	13.3	f
14			264	19.1	bcdef
15			266	16.1	bcdef
16		131	369	11.7	f
17			371	20.7	bcdef
18			372	20.0	bcdef
19			376	18.1	bcdef
20			377	24.8	abcdef
21	3	15	36	30.0	abcd
22			37	35.7	a
23			38	20.0	bcdef
24			40	15.9	bcdef
25			42	21.1	abcdef
26		27	64	15.7	cdef
27			66	22.1	abcdef
28			67	18.6	bcdef
29			69	20.2	bcdef
30			71	16.8	bcdef
31	4	91	233	16.3	bcdef
32			234	21.0	abcdef
33			235	31.0	abc
34			236	20.0	bcdef
35			237	13.7	ef
36		154	460	15.4	def
37			461	19.9	bcdef
38			462	13.7	ef
39			463	31.4	ab
40			465	29.3	abcde
41	5	13	25	14.0	ef
42			26	26.8	abcdef
43			27	19.0	bcdef
44			31	16.5	bcdef
45			32	20.6	bcdef
46		142	414	12.1	f
47			415	29.3	abcde
48			416	21.3	abcdef
49			418	16.1	bcdef
50			420	20.8	abcdef

Means with the same letter are not significantly different at 5%

Duncan's multiple range test for young tiller dry weight

No.	Clus	Topo	Half-sib	Means	
1	1	69	147	0.9	cdefg
2			148	1.4	bcdefg
3			150	2.2	abcdefg
4			151	0.3	g
5			154	2.2	abcdefg
6		145	429	0.9	cdef
7			430	0.8	defg
8			431	1.0	bcdefg
9			432	1.4	bcdefg
10			435	1.4	bcdefg
11	2	97	260	0.9	cdefg
12			261	0.9	cdefg
13			262	1.0	bcdefg
14			264	0.7	defg
15			266	0.9	cdefg
16		131	369	0.9	cdefg
17			371	2.3	abcde
18			372	1.6	bcdefg
19			376	0.7	defg
20			377	0.7	efg
21	3	15	36	2.0	abcdefg
22			37	0.2	g
23			38	1.2	bcdefg
24			40	1.6	bcdefg
25			42	3.6	a
26		27	64	0.3	fg
27			66	0.9	cdefg
28			67	2.9	ab
29			69	1.9	abcdefg
30			71	2.0	abcdefg
31	4	91	233	1.7	bcdefg
32			234	1.4	bcdefg
33			235	2.7	abcde
34			236	1.0	bcdefg
35			237	0.9	cdefg
36		154	460	1.2	bcdefg
37			461	0.9	cdefg
38			462	1.1	bcdefg
39			463	2.8	abc
40			465	1.5	bcdefg
41	5	13	25	0.9	cdef
42			26	1.3	bcdef
43			27	0.7	def
44			31	0.9	cdef
45			32	2.3	abcdef
46		142	414	1.2	bcdef
47			415	2.7	abcd
48			416	0.6	efg
49			418	0.5	efg
50			420	0.8	cdefg

Means with the same letter are not significantly different at 5%

Duncan’s multiple range test for base green tiller dryweight

No.	Clus	Topo	Half-sib	Means	
1	1	69	147	21.5	abcdef
2			148	19.0	bcdef
3			150	25.6	abcdef
4			151	12.8	f
5			154	20.3	abcdef
6		145	429	14.3	ef
7			430	18.2	cdef
8			431	16.7	def
9			432	22.2	abcdef
10			435	16.1	def
11	2	97	260	14.9	ef
12			261	22.2	abcdef
13			262	14.3	ef
14			264	19.5	bcdef
15			266	17.0	def
16		131	369	12.6	f
17			371	23.0	abcdef
18			372	21.6	abcdef
19			376	18.9	bcdef
20			377	25.5	abcdef
21	3	15	36	32.1	abcd
22			37	35.9	a
23			38	21.2	abcdef
24			40	17.4	cdef
25			42	24.7	abcdef
26		27	64	16.0	def
27			66	23.2	abcdef
28			67	21.6	abcdef
29			69	22.3	abcdef
30			71	18.8	bcdef
31	4	91	233	18.3	cdef
32			234	22.4	abcdef
33			235	33.7	abc
34			236	22.8	abcdef
35			237	13.5	f
36		154	460	15.3	ef
37			461	20.8	abcdef
38			462	14.0	f
39			463	35.0	ab
40			465	30.8	abcde
41	5	13	25	14.8	ef
42			26	28.1	abcdef
43			27	19.7	abcdef
44			31	17.4	cdef
45			32	22.9	abcdef
46		142	414	13.3	f
47			415	32.0	abcdef
48			416	20.2	abcdef
49			418	16.6	def
50			420	21.7	abcdef

Duncan's multiple range test for aerial tiller dry weight

No.	Clus	Topo	Half-sib	Means	
1	1	69	147	21.3	bcde
2			148	21.6	cde
3			150	33.3	abcde
4			151	26.2	bcde
5			154	26.0	bcde
6		145	429	29.1	abcde
7			430	26.7	bcde
8			431	24.6	bcde
9			432	33.7	abcde
10			435	27.5	abcde
11	2	97	260	18.0	de
12			261	22.4	bcde
13			262	28.3	abcde
14			264	29.7	abcde
15			266	27.0	bcde
16		131	369	28.1	abcde
17			371	26.2	bcde
18			372	26.9	bcde
19			376	30.4	abcde
20			377	33.6	abcde
21	3	15	36	23.7	bcde
22			37	23.7	bcde
23			38	28.6	abcde
24			40	21.7	bcde
25			42	29.4	abcde
26		27	64	36.9	abc
27			66	32.5	abcde
28			67	26.4	bcde
29			69	26.3	bcde
30			71	36.3	abcd
31	4	91	233	29.7	abcde
32			234	38.1	ab
33			235	20.3	bcde
34			236	15.8	e
35			237	32.8	abcde
36		154	460	23.5	bcde
37			461	23.1	bcde
38			462	26.8	bcde
39			463	26.4	bcde
40			465	26.0	bcde
41	5	13	25	33.7	abcde
42			26	18.8	cde
43			27	29.0	abcde
44			31	35.0	abcd
45			32	35.8	abcd
46		142	414	21.5	bcde
47			415	31.0	abcde
48			416	21.0	bcde
49			418	45.4	a
50			420	30.8	abcde

Means with the same letter are not significantly different at 5%

Duncan's multiple range test for base tiller dry weight

No.	Clus	Topo	Half-sib	Means	
1	1	69	147	24.3	cdef
2			148	22.2	def
3			150	30.7	abcdef
4			151	19.9	def
5			154	30.8	abcdef
6		145	429	21.1	def
7			430	24.1	cdef
8			431	25.7	cdef
9			432	30.3	abcdef
10			435	22.8	def
11	2	97	260	20.1	def
12			261	46.4	abcdef
13			262	26.0	cdef
14			264	29.2	abcdef
15			266	26.6	bcdef
16		131	369	17.9	def
17			371	31.1	abcdef
18			372	34.2	abcdef
19			376	25.3	cdef
20			377	37.3	abcdef
21	3	15	36	46.5	a
22			37	43.1	abc
23			38	28.5	abcdef
24			40	22.6	def
25			42	36.7	abcdef
26		27	64	23.3	cdef
27			66	28.2	abcdef
28			67	30.6	abcdef
29			69	35.5	abcdef
30			71	31.7	abcdef
31	4	91	233	26.9	abcdef
32			234	31.1	abcdef
33			235	41.6	abcd
34			236	29.3	abcdef
35			237	20.9	def
36		154	460	21.6	def
37			461	35.8	abcdef
38			462	22.3	def
39			463	42.9	abc
40			465	46.2	ab
41	5	13	25	21.9	def
42			26	32.1	abcdef
43			27	27.4	abcdef
44			31	27.3	abcdef
45			32	28.6	abcdef
46		142	414	18.3	def
47			415	40.5	abcde
48			416	29.9	abcdef
49			418	27.3	abcdef
50			420	31.6	abcdef

Means with the same letter are not significantly different at 5%

Duncan's multiple range test for total tiller dry weight

No.	Clus	Topo	Half-sib	Means	
1	1	69	147	45.6	bcd
2			148	47.0	bcd
3			150	64.0	abcd
4			151	46.0	bcd
5			154	56.8	abcd
6		145	429	50.2	abcd
7			430	50.8	abcd
8			431	50.2	abcd
9			432	64.0	abcd
10			435	50.4	abcd
11	2	97	260	38.1	d
12			261	58.8	abcd
13			262	54.2	abcd
14			264	58.9	abcd
15			266	53.6	abcd
16		131	369	46.1	bcd
17			371	57.3	abcd
18			372	61.1	abcd
19			376	55.7	abcd
20			377	70.9	ab
21	3	15	36	70.2	ab
22			37	66.9	abcd
23			38	57.1	abcd
24			40	44.3	bcd
25			42	66.1	abcd
26		27	64	60.3	abcd
27			66	51.2	abcd
28			67	52.2	abcd
29			69	54.9	abcd
30			71	60.9	abcd
31	4	91	233	56.6	abcd
32			234	69.2	abc
33			235	62.0	abcd
34			236	42.7	bcd
35			237	55.8	abcd
36		154	460	45.1	bcd
37			461	58.9	abcd
38			462	49.2	abcd
39			463	69.2	abc
40			465	78.2	a
41	5	13	25	55.6	abcd
42			26	50.9	abcd
43			27	56.4	abcd
44			31	62.3	abcd
45			32	64.4	abcd
46		142	414	38.8	cd
47			415	71.4	ab
48			416	50.8	abcd
49			418	72.7	ab
50			420	62.5	abcd

Means with the same letter are not significantly different at 5%

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Duncan's multiple range test for number of days to reach 5% asymptote

No.Clus Topo Half-sib          Means
 1  1    69    147              26.2        fghi
 2             148              28.7     bcdefghi
 3             150              34.9    a
 4             151              28.3     bcdefghi
 5             154              32.2    abcd
 6      145    429              27.9     bcdefghi
 7             430              26.3        fghi
 8             431              27.9     bcdefghi
 9             432              27.4      cdefghi
10             435              24.2            i
  --------------------------------------------------------
11  2    97    260              27.9     bcdefghi
12             261              29.2     bcdefghi
13             262              30.4    abcdefg
14             264              25.9          ghi
15             266              27.5      cdefghi
16      131    369              29.9     bcdefg
17             371              32.0    abcde
18             372              31.7    abcdef
19             376              29.4     bcdefgh
20             377              28.3     bcdefghi
  --------------------------------------------------------
21  3    15     36              32.0    abcde
22              37              31.7    abcde
23              38              27.5      cdefghi
24              40              25.4          ghi
25              42              28.9     bcdefghi
26       27     64              27.3       defghi
27              66              29.7     bcdefg
28              67              32.5    abc
29              69              29.1     bcdefghi
30              71              31.1    abcdef
  --------------------------------------------------------
31  4    91    233              29.0     bcdefghi
32             234              29.9     bcdefg
33             235              28.7     bcdefghi
34             236              28.3     bcdefghi
35             237              29.2     bcdefghi
36      154    460              32.0    abcde
37             461              29.8     bcdefg
38             462              29.1     bcdefghi
39             463              27.9     bcdefghi
40             465              28.5     bcdefghi
  --------------------------------------------------------
41  5    13     25              27.0         efghi
42              26              28.5     bcdefghi
43              27              29.3     bcdefgh
44              31              27.7     bcdefghi
45              32              26.4        fghi
46      142    414              24.5           hi
47             415              32.8    ab
48             416              29.6     bcdefgh
49             418              30.1    abcdefg
50             420              29.7     bcdefgh
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Means with the same letter are not significantly different at 5%
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Duncan's multiple range test for number of days to reach 50% upper asymptote

No.Clus Topo Half-sib        Means
 1  1   69    147             61.6    bcde
 2            148             54.4       e
 3            150             67.1    bc
 4            151             65.4    bcde
 5            154             62.2    bcde
 6     145    429             62.8    bcde
 7            430             59.3     cde
 8            431             66.2    bcd
 9            432             65.6    bcd
10            435             60.0     cde
  -----------------------------------------------
11  2   97    260             63.1    bcde
12            261             69.4   abc
13            262             64.5    bcde
14            264             66.6    bc
15            266             64.5    bcde
16     131    369             61.8    bcde
17            371             63.5    bcde
18            372             64.1    bcde
19            376             60.3    bcde
20            377             62.6    bcde
  -----------------------------------------------
21  3   15     36             77.8   a
22             37             69.0   abc
23             38             61.5    bcde
24             40             60.9    bcde
25             42             67.7    bc
26      27     64             59.6     cde
27             66             60.9    bcde
28             67             68.7   abc
29             69             67.3    bc
30             71             67.7    bc
  -----------------------------------------------
31  4  91     233             60.4    bcde
32            234             63.6    bcde
33            235             61.4    bcde
34            236             61.3    bcde
35            237             61.0    bcde
36    154     460             64.8    bcde
37            461             71.3   ab
38            462             64.1    bcde
39            463             65.2    bcde
40            465             65.1    bcde
  -----------------------------------------------
41  5  13      25             62.2    bcde
42             26             62.2    bcde
43             27             61.4    bcde
44             31             60.2     cde
45             32             61.1    bcde
46    142     414             55.5      de
47            415             58.5     cde
48            416             65.8    bcd
49            418             65.1    bcde
50            420             66.2    bcd
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Means with the same letter are not significantly different at 5%
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Duncan's multiple range test for number of days to reach 95 % upper asymptote

No.Clus Topo Half-sib          Means
 1  1    69    147             97.5    bcdef
 2             148             83.9        f
 3             150             99.3    bcdef
 4             151            102.5    bcde
 5             154             92.2     cdef
 6      145    429             97.8    bcdef
 7             430             92.3     cdef
 8             431            104.5   abcde
 9             432            103.8   abcde
10             435             96.0    bcdef
   -------------------------------------------------------
11  2    97    260             98.4    bcdef
12             261            109.7   abc
13             262             98.6    bcdef
14             264            105.1   abcde
15             266            101.6    bcdef
16      131    369             93.7     cdef
17             371             94.9     cdef
18             372             97.0    bcdef
19             376             91.3      def
20             377             96.8    bcdef
   -------------------------------------------------------
21  3    15     36            120.6   a
22              37            106.3   abcd
23              38             95.5    bcdef
24              40             96.4    bcdef
25              42            106.6   abcd
26       27     64             91.9     cdef
27              66             92.1     cdef
28              67            105.0   abcde
29              69            105.5   abcde
30              71            104.3   abcde
   -------------------------------------------------------
31  4   91     233             91.7     cdef
32             234             97.4    bcdef
33             235             94.2     cdef
34             236             94.3     cdef
35             237             92.8     cdef
36     154     460             97.6    bcdef
37             461            112.9   ab
38             462             98.7    bcdef
39             463            102.5    bcde
40             465            102.3    bcde
   -------------------------------------------------------
41  5   13      25             97.4    bcdef
42              26             95.9    bcdef
43              27             93.5     cdef
44              31             92.7     cdef
45              32             95.7    bcdef
46     142     414             90.3      def
47             415             88.0       ef
48             416            101.9    bcde
49             418            100.2    bcdef
50             420            102.7    bcde
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Means with the same letter are not significantly different at 5%
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Duncan's multiple range test for relative growth rate on 5% upper asymptote

No.	Clus	Topo	Half-sib	Means	
1	1	69	147	31.5	b
2			148	30.8	b
3			150	12.5	b
4			151	46.1	b
5			154	-8.9	b
6		145	429	43.0	b
7			430	30.2	b
8			431	39.3	b
9			432	49.7	b
10			435	37.5	b
11	2	97	260	35.9	b
12			261	37.3	b
13			262	26.7	b
14			264	42.0	b
15			266	41.2	b
16		131	369	42.3	b
17			371	24.6	b
18			372	26.6	b
19			376	23.8	b
20			377	37.5	b
21	3	15	36	41.9	b
22			37	44.4	b
23			38	35.0	b
24			40	21.0	b
25			42	34.8	b
26		27	64	25.6	b
27			66	1.5	b
28			67	48.5	b
29			69	46.2	b
30			71	12.6	b
31	4	91	233	35.1	b
32			234	39.7	b
33			235	14.0	b
34			236	4.4	b
35			237	246.1	a
36		154	460	-21.7	b
37			461	40.4	b
38			462	36.4	b
39			463	32.6	b
40			465	45.1	b
41	5	13	25	36.6	b
42			26	-0.5	b
43			27	26.9	b
44			31	38.0	b
45			32	33.1	b
46		142	414	34.7	b
47			415	36.5	b
48			416	40.3	b
49			418	48.8	b
50			420	47.9	b

Means with the same letter are not significantly different at 5%

Duncan's multiple range test for relative growth rate at 50% upper asymptote

No.	Clus	Topo	Half-sib	Means	
1	1	69	147	76.7	b
2			148	150.9	b
3			150	81.8	b
4			151	77.7	b
5			154	82.1	b
6		145	429	80.3	b
7			430	82.9	b
8			431	72.9	b
9			432	77.0	b
10			435	77.9	b
11	2	97	260	80.1	b
12			261	72.3	b
13			262	80.0	b
14			264	69.1	b
15			266	76.0	b
16		131	369	94.5	b
17			371	86.7	b
18			372	82.5	b
19			376	85.2	b
20			377	80.6	b
21	3	15	36	69.2	b
22			37	75.4	b
23			38	81.4	b
24			40	76.3	b
25			42	72.4	b
26		27	64	83.5	b
27			66	82.6	b
28			67	77.8	b
29			69	77.6	b
30			71	74.2	b
31	4	91	233	87.5	b
32			234	81.4	b
33			235	81.9	b
34			236	76.7	b
35			237	284.4	a
36		154	460	76.2	b
37			461	70.1	b
38			462	81.2	b
39			463	77.3	b
40			465	78.5	b
41	5	13	25	80.0	b
42			26	77.9	b
43			27	84.6	b
44			31	84.5	b
45			32	80.2	b
46		142	414	155.4	b
47			415	126.1	b
48			416	80.0	b
49			418	82.9	b
50			420	77.9	b

Means with the same letter are not significantly different at 5%

Duncan's multiple range test for relative growth rate at 95% upper asymptote

No.	Clus	Topo	Half-sib	Means	
1	1	69	147	79.5	b
2			148	170.5	b
3			150	87.0	b
4			151	79.4	b
5			154	89.6	b
6		145	429	82.3	b
7			430	85.9	b
8			431	74.8	b
9			432	78.4	b
10			435	80.1	b
11	2	97	260	82.4	b
12			261	74.2	b
13			262	82.7	b
14			264	70.6	b
15			266	78.0	b
16		131	369	97.4	b
17			371	90.2	b
18			372	85.9	b
19			376	89.0	b
20			377	83.3	b
21	3	15	36	70.6	b
22			37	77.2	b
23			38	84.0	b
24			40	79.3	b
25			42	74.5	b
26		27	64	86.9	b
27			66	88.7	b
28			67	79.4	b
29			69	79.2	b
30			71	79.4	b
31	4	91	233	90.6	b
32			234	84.2	b
33			235	86.5	b
34			236	82.4	b
35			237	286.4	a
36		154	460	84.7	b
37			461	71.5	b
38			462	83.6	b
39			463	79.6	b
40			465	80.2	b
41	5	13	25	82.1	b
42			26	83.7	b
43			27	88.0	b
44			31	87.6	b
45			32	82.9	b
46		142	414	157.8	b
47			415	152.3	b
48			416	82.1	b
49			418	84.7	b
50			420	79.5	b

Means with the same letter are not significantly different at 5%