A STUDY OF THE GERMINATION AND ESTABLISHMENT OF LUCERNE (*MEDICAGO SATIVA* L.) OVERSOWN ON AN UNCULTIVATED GRASS SWARD

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ABSTRACT

In this study on the oversowing of lucerne on an uncultivated sward at Massey, three trials were conducted, two in the field and one box trial under glasshouse conditions during the summer of 1975/76 and the autumn and early winter of 1976. The trials compared the effects of two lengths of ground cover, untreated, suppressed for a longer or shorter period with herbicides and burnt on the early establishment of lucerne sown as bare or pelleted seed.

It was found that small amounts of cover at sowing encouraged lucerne germination under high moisture conditions. Subsequent establishment and early survival was best on the burnt and chemically desiccated plots. The cover was most useful where it was short (8 cm) and desiccated by long term paraquat or glyphosate treatments. Dense live cover was harmful to lucerne seedlings and smothered them within 5 weeks after sowing. Where recovery of the resident vegetation and weeds was rapid, as on the burnt and short term herbicide plots, lucerne establishment and survival was poor and surviving plants were small and weak.

Weed infestation was heavy both on burnt and herbicide treated plots, pointing to the need to introduce an early weed control programme with oversowing. Weeds were found to respond in a similar manner to lucerne to grass competition.

In the autumn and early winter trials, slug damage was observed and this problem appeared to be of major importance under wet conditions. The effects of slugs were found to be most damaging during the first 4-5 weeks after sowing. Metaldehyde slug bait pellets were effective in reducing slug damage if applied at least twice during the establishment period of lucerne.

The implications of these findings are reported and discussed with particular reference to the possibilities of oversowing under East African conditions.

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1. INTRODUCTION

1.1 Grasslands

Grasslands or pastures are communities of plants usually consisting of two or more species in association which can be utilized for grazing by livestock. In these associations, plants of the grass and legume families are the most commonly dominant; and the species interact causing the community to be in a dynamic equilibrium. Grasslands may be either natural, semi-natural or artificial. Natural grasslands are a result of natural succession leading to a climatic climax vegetation in equilibrium with the environment. Semi-natural grasslands are also called sub-climax grasslands as they owe their existence to biotic factors such as grazing animals. Artificial grasslands are sown pastures (Odum, 1971; Semple, 1972; Spedding, 1971).

1.1.1 Natural Grasslands

These grasslands depend principally upon differences in moisture and temperature. Secondary factors are elevation, latitude, length of day and light intensity (Semple, 1972). Natural treeless grasslands are restricted to the arid regions of the world, elsewhere, grasslands are either treeless or wooded because of some other factors which influence tree growth (see Mbuga grasslands). Natural grasslands include the grass steppe, alpine grasslands and desert steppe which have been caused by low temperatures and rainfalls that range from 250mm - 760mm annually. Desert scrub and savanna grasslands are a result of moisture restrictions although they may get 1000mm - 1500mm rainfall annually, this being a result of prolonged dry seasons (Odum, 1971).

1.1.1.1 Mbuga Grasslands

Throughout the woodlands, thornbush and thickets in Tanzania are found the mbuga grasslands. They are nearly pure grasslands that are subject to seasonal flooding and impeded drainage (Heady, 1960). Mbugas are usually long and narrow, on both sides of rivers, with little chance of flood waters to escape. The seasonal flooding and drying leads to the development of treeless grasslands in these situations.

1.1.2 Sub-climax Grasslands

These grasslands comprise the majority of the world's grasslands and they owe their existence to biotic factors such as grazing animals (wild or domesticated) and fire, including fires started by natural means (such as lightning or volcanic action) and fires resulting from human activities (either deliberate or accidental). It is suggested, for example, that almost all the grasslands of America and Africa are a result of burning; other factors also being of importance, namely soils, topography, and biotic factors (Thomas, 1960).

1.1.3 Artificial Grasslands

In many parts of Europe, Australia and New Zealand, grasslands have been developed from climax forests by clearing and burning followed by sowing of desired pasture species with or without cultivation. (Semple, 1972). At present pastoral farming, particularly in developed countries, involves the development of pastures through cultivation and sowing of grass and legume species of high quality. These pastures can either be permanent or temporary and fitted into a rotation that includes cropping (Semple, 1972; Levy, 1970).

1.2 Importance of Grasslands

Grasslands have been of very great importance to man throughout his evolution. First as a food-gatherer and hunter, then as a nomadic herder, and later as a cultivator, mankind has been dependent on grasslands for his food and other products obtained from forage-consuming animals. Today grasslands are still important, particularly in areas unsuitable for crop production because of inadequate moisture or too short a growing season. Here annual or perennial grasses grow together with shrubs and herbs that support a variety of livestock. In more favourable parts of the world, pastures are part of mixed farming systems and grass is regarded as a valuable crop.

1.3 Grassland Development

From the above, it is evident that grasslands are an important part of the world of farming. The development of grasslands has been a result of either the effects of the environment or the biotic factors in which mankind was and is most active. Pasture development from forest, bush or unimproved grasslands of natural species involves a number of operations including clearing, burning, ploughing, cultivation and finally sowing desired pasture species. The pre-sowing operations are aimed at removing or reducing the competition exerted by the resident vegetation against the sown species. These activities comprise seed-bed preparation and may vary from the conventional cultivation involving a sequence of tillage operations to zero cultivation.

Conventional cultivation techniques in pasture development are limited by their high cost. Marshall (1972) pointed out that, in New Zealand a saving of $32 to $44/ha could be realized when oversowing techniques were used instead of the conventional cultivations for improvement of pastures. Other limitations to conventional cultivation which apply in particular to developing countries are the lack of machinery and technical expertise and the inaccessibility of many grassland areas to machinery. Surface sowing thus is a potential tool for pasture development in such areas in that it offers low cost techniques that can be employed in the improvement of natural grasslands and rangelands. For this reason, it is evident that there is a need to carry out thorough studies on surface sowing techniques so as to make surface sowing reliable. In New Zealand, Cullen (1966, 1970, 1971), Janson (1970, 1975), White 1970, 1973b), Suckling (1959, 1966, 1975) and many other workers (see section 2) have reported the possibility of successful surface sowing for pasture improvement on hill country. In Australia, Campbell (1968, 1973, 1974, 1976), Campbell and Swain (1973a, 1973b) report oversowing successes where soil moisture was adequate, competition from existing vegetation was eliminated or reduced, legume seeds were inoculated and coated and where there was provision of an inert vegetative ground cover to act as a buffer to soil moisture fluctuations, in particular where soil moisture was limiting. Possibilities include the use of desiccants, burning, grazing techniques and a combination of the above as seedbed preparation operations.

The aim of the present study was to investigate the effects of different ground cover treatments on the success of surface sowing technique in introducing a pasture legume, Medicago sativa L. (Var. Hunter River) into an existing grass sward. In preparing the experimental area, efforts were made to simulate natural grassland conditions found in the country of origin of the writer, Tanzania. This was not easy to achieve because of the vast differences between these countries, however, the wet summer of 1975/76 proved useful in providing conditions that were comparable to a tropical rainy season (see table 9 in Chapter 4).

The following table below is a comparison of rainfall (mm), humidity (%) and temperature (°C) of two selected areas of Tanzania, Dodoma and Dar-Es-Salaam with those at Massey University in the Manawatu. Dodoma is found in

Central Tanzania and has a savanna type climate while Dar-Es-Salaam is on the coast and its climate is of tropical forest type (Berry, 1971).

Table I: Rainfall, Humidity and Temperature of two Selected Areas in Tanzania Compared to Those of New Zealand, Massey University. (Compiled from Kongwa Pasture Research Station Notes; Tanzania in Maps by L. Berry (1971) and N.Z. Meteorological Observations (1972).

Month	Rainfall (mm)			Humidity (%)					Temperature (°C)					
	Dodoma	Dar-Es-Salaam	Massey	Dodoma		Dar-Es-Salaam		Massey	Dodoma		Dar-Es-Salaam		Massey	
				9 a.m	3 p.m	6 a.m	12 p.m	9 a.m	Max	Min	Max	Min	Max	Min
January	88	60	60	80	41	94	65	66	30.7	16.8	29.0	24.0	21.4	12.8
February	143	74	47	95	60	95	65	68	28.3	17.2	29.5	25.0	21.5	11.4
March	66	122	135	88	51	96	68	76	29.3	16.3	30.1	24.0	21.1	13.5
April	28	264	70	83	49	97	74	78	29.6	15.8	31.0	24.0	18.1	9.3
May	25	228	111	80	43	96	67	82	28.7	15.4	30.2	23.3	14.5	6.3
June	-	34	39	66	35	97	60	83	28.9	12.1	29.7	20.1	11.1	2.2
July	-	22	101	69	36	97	50	85	27.9	12.6	29.0	19.2	12.8	5.3
August	-	25	78	64	35	96	54	79	28.6	13.2	28.0	19.0	12.1	3.6
September	3	27	55	63	35	96	55	77	30.3	14.9	28.5	20.0	14.8	7.8
October	11	48	65	66	38	97	58	75	30.9	17.2	29.0	21.5	16.5	9.2
November	75	63	30	65	39	97	64	74	31.9	18.4	30.0	23.2	19.9	11.5
December	120	74	40	79	43	95	66	69	30.6	18.7	30.0	25.1	19.2	10.2
	559	1041	831						29.6	15.7	29.5	22.7	16.9	8.6
		TOTALS									MEANS			

Dodoma shows arid conditions while Dar-Es-Salaam has a wetter climate. In the former area, moisture is the most limiting factor for cropping and pasture production and such areas are called rangelands, whose development would best be achieved using low cost methods such as surface sowing techniques.

Ground cover treatments were done in such a way as to simulate grazed or ungrazed conditions of natural grasslands in the tropics during the rainy season or at the end of a dry season by application of herbicides as explained in Section 3.2.2.

2. LITERATURE REVIEW

2.1 Pasture Development

Pasture development may take place on forest, bush, scrub or natural grasslands. In the case of the development of pasture from natural grasslands, the aim is to introduce grass and legume species that will lead to increased dry matter production and quality of the herbage. Careful selection of the species and their successful introduction may lead to the provision of growth curves complementary to those of the native pasture species, thus narrowing the gaps of low pasture yield and quality normally associated with natural grasslands particularly under tropical conditions (Mannetje, 1967; Semple, 1972).

When developing a pasture the primary aim is generally to create an environment that will favour the germination, development and establishment of the sown species and their subsequent survival. This involves the destruction of the existing vegetation to remove or minimize competition for light, water and nutrients. The operation comprises the process of seedbed preparation which ranges from conventional cultivation to varying forms of minimum cultivation involving overdrilling after herbicide application. In its extreme form, zero cultivation may be practiced and this involves surface sowing by air or ground equipment, usually on non-arable land (White, 1973a, 1973b). The choice of technique for seedbed preparation will depend on such factors as the type of vegetation present (species, height, density and resistance to the available means of destruction), the soil conditions (soil type and depth), the general topography (slope, roughness, and presence of stones) and the economics of the operation in relation to the actual production potential of the land (McColly and Martin, 1955; White, 1973a). In the most difficult situations vegetation destruction may be restricted to the killing or at least reduction in vigour of the resident species, so as to allow access to the area by stock, followed by seeding after "tooth and hoof" treatment (Levy, 1970; Suckling 1951, 1966).

2.2 Pasture Development Techniques

Under this heading, three techniques will be discussed; namely conventional seedbed preparation by cultivation, reduced cultivation and zero-cultivation.

2.2.1 Conventional Seedbed Preparation by Cultivation

With this technique, the final objective is to produce a well-drained, weedfree, fine, firm, moist and level seedbed and root bed (Slipher, 1956; White, 1973a). The seedbed must provide physical conditions optimum for the germination of the seed and development of the seedling; the rootbed must provide a zone having physical properties favourable for root growth and must also sustain a healthy and vigorous root system throughout the intended life of the pasture. An ideal seedbed for small seeded grasses and legumes should have the following characteristics:-

(a) There should be ample moisture in the surface layer and in the sub soil,

(b) the surface soil in which the seeds are to be sown should be reasonably fine and granular but not excessively fine and pulverized,

(c) the soil should be firm beneath the depth at which the seeds are to be sown and

(d) the ploughed layer of soil should be in direct contact with the layer below in order to allow an uninterrupted upward movement of soil moisture and nutrients (Ahlgren, 1945).

Additional desirable characteristics of a seedbed are freedom from weeds, adequate aeration and adequate consolidation and a sufficient supply of nutrients. To achieve these properties the operations of tillage, levelling and consolidation are carried out.

2.2.1.1 Tillage

This includes ploughing, cultivating, harrowing, hoeing and other operations that affect the availability of soil moisture and oxygen, the soil temperature, the size of soil aggregates, the presence of restrictive pans (affecting root penetration) or soil crusts (affecting emergence), the degree of soil fertility and the degree of competition from unsown species. Tillage controls established weeds by a combination of mechanical damage and burial. It also loosens the surface of the soil, so facilitating the operation of sowing or planting equipment. Other important objectives of tillage may include the improvement of such soil properties as aeration, and thermal properties (due to mulching of the surface) (Bainer, et al, 1963; Cross, 1959; Charles, 1962; Davies, 1960 and Sears, 1951, 1952). The main reasons for tillage are thus the control of weeds and the production of favourable physical, chemical and biological conditions for the germination, emergence, establishment and growth of the sown plants (Carter, 1969).

2.2.1.2 Levelling

The levelling of ploughed surfaces helps to reduce irregularities in the field. Such irregularities are undesirable as crests tend to dry out rapidly and hollows to become water-logged and frequently infested with weeds or species of poor productivity (Levy, 1970). A level surface will facilitate uniform utilization by grazing animals and also simplify later mechanical operations such as mowing or haymaking (Cross, 1959 and Levy, 1970).

2.2.1.3 Consolidation

Adequate consolidation is one of the most important factors in seedbed preparation and every effort should be made to achieve a sufficient degree of firmness (Cross, 1956, 1957, 1959; Levy 1970). Consolidation encourages upward capillary movement of water from the subsoil (Cross, 1959; Baker, 1969, 1970) and seed bed preparation operations should be aimed at achieving the following:-

(a) firming the soil below the seed level,
(b) pressing the seeds into the compacted soil and
(c) covering the seeds with loose soil (Anon 1966; Arndt, 1965a, 1965b; Baker, 1969; Blackmore, 1960; Cross 1959 and Levy 1970).

2.2.1.4 Additional Effects

Intensive seedbed preparation has other advantages in addition to those given above. Cultivation is reported to reduce the population of many undesirable insects, slugs and other soil organisms that may damage the developing seedling. The reduction of soil pest populations is thought to be due to mechanical damage, exposure to the air (resulting in desiccation) and exposure to preying animals and birds (Runham and Hunter, 1970; Suckling, 1951). Without cultivation, slugs, for example, have been recorded to cause up to 100% loss of Trifolium spp. (Clovers) with surface sowing (Suckling, 1951).

2.2.2 Reduced Cultivation

The concept of tillage requirements for establishing crops or pastures is changing rapidly, in that short cuts are now being employed with encouraging success (Baeumer and Bakermans, 1973). These short cuts involve the substitution of light working of the soil, namely discing and harrowing, for the deeper working of conventional tillage. The advantages of such techniques are that light working has a lower energy requirement, time is saved and costs are lower. Seed sowing by direct drilling following herbicide application also falls into this category (Baker, 1969, 1970; Baumer and Bakermans, 1973; White, 1973a and 1973b). With minimum tillage techniques, competition from the resident species and soil moisture are two of the major limiting factors. Drilling of seed after manipulating the vegetation by hard grazing, burning and/or herbicide application has been reported to yield good establishment of pasture species. In New Zealand, the following workers have worked in this field and have reported encouraging results. Baker (1969, 1970); Blackmore (1954, 1957, 1958a, 1958b, 1962, 1965); Cross (1959); Cullen, (1971); Janson and White (1971); Ludecke (1962); White (1970, 1973a and 1973b). In Australia, Carter, (1969); Carter and Saunders, (1969); Decker, et al, (1969) report the wide use of the technique in non-arable lands. Allen (1967) reports the use of paraquat in conjunction with drilling for grassland renewal in Britain and Baeumer and Bakermans (1973) report on the results of minimum tillage with pasture and crop species under American conditions. In East Africa, Kenya, Keya and Kalangi (1973) have obtained encouraging results with oversowing in natural grasslands.

2.2.3 Zero Cultivation

Early demonstration of the essential features of zero-cultivation, i.e. establishing a crop by oversowing on the surface without disturbing the soil is reported by Graber (1927). This work reports the successful oversowing of a legume, Melilotus alba (Sweet-clover) into an unproductive grass sod, Poa spp (Blue grass) without tillage, using such techniques as close grazing or burning combined with heavy seed rates. Such methods allowed the sown species to compete successfully with the old sward but needed to be combined with careful livestock management as the action of the grazing animals was necessary to bring the seeds into close contact with the soil. Significant advances in zero-cultivation techniques were realized in the 1950's when chemicals such as dalapon and amitrole were introduced. These herbicides were able to destroy the existing vegetation but had relatively short or no residual effects on the crop species being established (Baeumer and Bakermans, 1973).

Zero cultivation techniques are particularly appropriate for establishing improved pasture species on sites unsuitable for cultivation. Various broadcast sowing techniques with ground machinery or aircraft, with or without the assistance of grazing, hoof-cultivation, burning or herbicides, have been employed with varying degrees of success, particularly in cool, temperate regions of the world (Levy, 1970; Semple, 1972). In New Zealand, early pasture development was achieved by clearing and burning the forest followed by the sowing of seed in the ash (Levy, 1970). More recently in the past 20 years or so, extensive use has been made of aerial oversowing for the improvement of non-arable hill country, establishment of clovers having been found to increase production (Cullen, 1971; Suckling 1966, 1975). The commonest practice in hill country development, in New Zealand, has been first to oversow a mixture of clovers and, later, to introduce improved grass species. The grasses have been omitted from the first sown seed mixtures for the following reasons:-

(a) Grass establishment was often unsuccessful.
(b) As only low stocking rates were possible, it was not considered economical to sow expensive grass seeds.
(c) On low fertility soils the common view was that soil fertility had to be built up by clovers and topdressing before high producing grasses could be introduced (Cullen, 1971; Suckling 1966; 1975).

However, the above view was contradicted by results obtained by Cullen and McLeod (1962) who found that grass established most successfully if it was included in the initial sowing mixture and germinated when competition from the existing vegetation was at a minimum. Despite low fertility and very low nitrogen levels, grasses survived and ultimately thrived as the nitrogen status improved.

Success in the oversowing technique is dependent on achieving close contact between seed and soil, on correct timing to ensure adequate soil moisture and on suitable rainfall conditions after sowing (Cullen, 1971; Campbell 1973; 1974a; Nixon, 1971).

2.3 Pasture Development by Oversowing

As shown in the previous section the oversowing technique has opened up new avenues in the field of pasture development and in this section the factors involved will be reviewed. As already mentioned, pasture development is best achieved by using the conventional cultivation technique where this is possible (Cullen, 1971; Gillard, 1974; Baker 1970 and White 1973a). However, this technique is limited by the high costs involved (Baeumer and Bakermans, 1973; Marshall, 1972). In New Zealand, Marshall (1972) reported a saving of $32 to $44/ha when surface sowing techniques were used instead of cultivation for pasture development. On land unsuited to cultivation, oversowing seems to be the only feasible method of introducing improved pasture species. Particularly in developing countries where there is often a lack of machinery and technical know-how and where many pasture areas are inaccessible to machinery. Surface sowing techniques may be the key to pasture improvement in many of these areas.

Both grasses and legumes have been used in oversowing experiments and varying degrees of success have been achieved. In New Zealand, Cullen (1971) and Suckling (1966, 1975) report that better establishment was achieved if legumes were introduced first followed by grass species later (see section 2.2.3). In Australia, Campbell (1967, 1968, 1973, 1974a) and Campbell and Swain (1973a, 1973b) report success with oversowing grasses and legumes together provided the effects of limiting factors were minimized. For the purpose of this review emphasis will be laid on legume introduction.

It is estimated that, under New Zealand conditions, the pasture nutrient requirements for the production of 11360 kg/ha dry matter, are roughly equivalent to the nitrogen in 2163 kg of sulphate of ammonia, the potassium in 890.6 kg of muriate of potash, the phosphorus and sulphur in 254.5 kg of superphosphate and the magnesium in 254.5 kg magnesium sulphate, Ball (1969). This means that the soil must provide relatively large quantities of nitrogen for vigorous pasture growth and that inputs of nitrogen either from fertilizers or from fixation by legumes are essential. The fundamental importance of nitrogen for plant nutrition has long been appreciated. Mishustin (1970) dates this appreciation as early as 1838. The same author points out that nitrogeneous fertilizer production has increased at a greater pace than that of other fertilizers. Nevertheless, although 254-279 million tonnes of nitrogen are removed from the soil annually by farm products, only 38 million tonnes are returned in the form of artificial fertilizers. The deficit has to come from other sources, including organic fertilizers in which the process of biological nitrogen fixation is especially important. In the pasture situation the legume component of grasslands has a fundamental role in agricultural production because of the ability of its associated root-nodule bacteria (Rhizobium spp.) to fix atmospheric nitrogen. The nitrogen fixed in the nodules is available immediately to the host legume and subsequently, to the associated grass species (Ball, 1969; O'Connor, 1966; Sears, 1960; Walker, 1956, 1962; Wilson, 1968).

In Britain there has been a shift in emphasis from pasture legumes towards the use of fertilizer nitrogen in the past 10 years. This trend, however, is now being re-assessed because of soaring fertilizer prices and also because of the improvements in legumes through plant breeding and through increased knowledge in the management of pasture mixtures (Aldrich, 1974). In New Zealand, nitrogen fixation by legumes is undoubtedly the most important method of adding nitrogen to the soil-plant-animal system (Ball, 1969; Levy, 1970; Semple, 1972; Spedding, 1971). Temperate pasture legumes have been reported to fix 227-682 kg/ha nitrogen annually (Ball, 1969; Wilson, 1968). Tropical pasture legumes have not been recorded as fixing nitrogen in these quantities although their contribution to the soil-plant-animal system is still substantial (Thomas, 1973; Semple, 1972; Spedding, 1971; McIlroy, 1964; Wilson, 1968).

Apart from the fixation of nitrogen, legumes in pastures have other benefits namely, increasing the nutritive value of the herbage through increased protein and mineral contents (During, 1972; Semple, 1972; Smetham, 1973). Also drought resistant perennial legumes, such as, Medicago sativa L. (Lucerne), Stylosanthes spp. (Stylo) and Macroptilium atropurpureum (Siratro) subsequently increase the productivity of pastures in semi-arid regions of the world by maintaining production into the dry season when other species have stopped producing or have died back (Mannetje, 1967; Gillard, 1974; Semple, 1972).

In the more densely populated ares of the tropics where labour is cheap, if moisture conditions are suitable, pastures are often developed on highly intensive systems such as heavily fertilized Pennisetum purpureum L. (elephant grass) which is cut and carted to the animals. Such a system may be suitable in a place where land is at a premium and a market exists for relatively high priced animal products (Roberts, 1974). On the other hand, there are vast tropical areas such as the savannah grasslands of Tanzania and other parts of Africa which are better suited to extensive grazing systems. Such areas consist mainly of more or less natural grasslands dominated by native grasses and poor in native legumes where the establishment of introduced legumes could have very beneficial effects (Thomas, 1973; Semple, 1972).

Pasture development by oversowing normally employs a combination of grazing, burning or herbicide treatment for the preparation of a seedbed with the aim of removing or reducing the competitive effects of the existing vegetation with other agronomic practices such as proper timing of sowing, a high seed rate and early weed control.

2.3.1 Grazing

This has long been used as a method for the destruction, removal or reduction of existing vegetation before seeding. The animals graze down the pasture resulting in a reduction of competition and the trampling produces hoof marks that create suitable microsites for seed germination (Suckling, 1951, 1975). Also in some cases, mob stocking is used after seed sowing to bury the seed by the action of hooves; hence the term "hoof-cultivation". This practice checks regrowth of resident vegetation and results in better germination and development of the introduced species (Cullen, 1971; Douglas, 1967). These authors agree with Campbell (1969, 1972) and Suckling 1966, 1975) that close grazing encourages the establishment of introduced species under dense cover, where competition for light, water and nutrients is most severe; but under sparse cover, lax grazing is recommended so as to leave adequate foliage to act as a mulch. Suckling (1951, 1959, 1975) points out that to reduce losses in seedling establishment through damage by insects, such as porina, or slugs, close grazing before sowing reduces the protective cover for pests thus encouraging a higher level of control by birds or desiccation due to exposure. However, close grazing also reduces the mulching effect of the cover and under some conditions has been found to reduce germination and establishment of surface sown pasture species (Campbell, 1973; Campbell and Swain 1973a, 1973b; Cullen 1966, 1971; Janson and White, 1971; Hely, 1965). Campbell and Swain (1973a, 1973b) summarised the functions of cover as follows:-

(a) Cover increases the heterogeneity of the soil surface which in turn leads to better radicle entry of the oversown species.

(b) Cover reduces temperature extremes.

(c) Cover reduces frost lift.

(d) Cover reduces the rate at which the soil surface hardens when drying after rain, thus facilitating radicle entry.

However, the benefits of cover are better achieved when the vegetation does not offer severe competition to the introduced species, as in the case of the dead cover produced by desiccant herbicides; and where the cover is not so dense as to offer physical impedance to the seedlings (Haggar, et al. 1976; Squires and Elliott, 1975). See Section 2.3.3.

2.3.2 Burning

As mentioned earlier, many existing natural grasslands are a result of biotic factors in which fire has played and still plays the major role (Semple, 1972; McIlroy, 1964). In humid climates, pastures have generally been developed from forest through clearing and burning followed by oversowing in the ash as reported in New Zealand by Levy (1970). However, the results have usually been poor where rainfall was unreliable and high seed rates have been necessary to boost establishment (Campbell 1969, 1973, 1974a; Cullen, 1971; Suckling 1966, 1975). The most frequent causes of failure under temperate conditions, have been losses of young seedlings due to desiccation because of lack of a mulch. In the tropics a frequent cause of failure is the activity of harvester ants which eat the seed or otherwise prevent seedling development (Campbell, 1972, 1973; Campbell and Swain, 1973b; Johns and Greenup, 1976a, 1976b; Russell, et al. 1967). In Australia, Campbell (1969) obtained successful establishment of *Stylosanthes* Sp. (Stylo) using a wet season burn treatment. This involved burning the vegetation with enough fuel to scorch and kill the foliage but to leave behind some form of protection for the seeds and seedlings. Campbell concludes that, except in special cases (i.e. where there is adequate available moisture), the reduction in competition from existing vegetation caused by burning was far less beneficial to the introduced species than where the process was carried out by application of a desiccant.

Under rangeland conditions in the tropics and the subtropics, planned firing is aimed at achieving the following:-

(a) The removal of any unpalatable growth left over from previous seasons that tends to form a mat of dead tissue, creating poor conditions for seed germination and development.

(b) To stimulate regrowth.

(c) To destroy parasites and insects.

(d) To control encroachment of undesirable perennial plants

(e) To prepare a seedbed for natural or artificial seeding of desired species.

(f) To stimulate seed production.

(g) To encourage the growth of native legumes (Adegbola and Onayinka, 1976; Coaldrake and Russell, 1969; Tothill, 1971a, 1971b; West, 1965).

The relative importance of the above functions will obviously vary according to the type of grassland and seasonal climatic conditions. The effects of fire are also modified by grazing. Van Rensburg (1972), for example, reports that there was a strong interaction between the intensity of grazing and the efficiency of fires in controlling the encroachment of woody and other weeds. Bently (1963), Coaldrake and Russell (1969), Danbenmire (1968), Harrington (1974), Innes (1971), Ivens (1970), Thomas and Pratt (1967), Tothill (1971a, 1971b) and West (1965) all point out that burning at the end of the dry season will provide an effective control over woody weeds, namely Acacia spp. However, a wet season burn produces better conditions for oversowing under tropical and subtropical conditions where moisture stress is the main limiting factor for germination and development of surface sown species.

2.3.3 Herbicides

The use of herbicides in place of cultivation for the removal of competition from existing vegetation has been studied by many workers in various parts of the world. The results show that herbicides can be an effective way of controlling the growth of resident vegetation and thus promoting the establishment and survival of introduced species (Baeumer and Bakermans, 1973; Allen 1967; Campbell, 1972, 1973, 1974a, 1974b, 1976; Cullen 1966, 1970, 1971; Janson and White 1971; White 1970, 1973b). The advantage of chemicals is that they kill off the vegetation and remove competition and yet leave a cover behind to supply the benefits detailed in section 2.3.1 and summarised by Campbell and Swain (1973a, 1973b). Evans and Young (1970) point out that plant litter covering the soil surface acts as an insulating layer which moderates temperature and moisture fluctuations and creates favourable microsites (niches) for seed germination. In rangeland communities, therefore, litter cover is an important factor in the succession among annual species. Similarly, these benefits would also apply to oversown species (Janson and White, 1971; White 1970, 1973b). Cullen, (1971) reported more successful use of paraquat on dense swards than on sparse swards as surface drying was accentuated with the sparse cover desiccated by paraquat spraying. Janson and White (1971) report that herbicide treatment could be used to overcome the allelopathic activity of Notodanthonia spp. which hinders establishment of oversown lucerne.

2.3.3.1 Types of Herbicides Used

Dalapon, amitrole, paraquat, diquat and more recently glyphosate, have been the materials most widely used in chemical cultivation. Of the above herbicides, paraquat has been used the most widely. Allen (1967) cites the following properties of paraquat that make it particularly suitable for chemical cultivation:-

(a) Its rapid absorption into foliage, which imparts rainfastness.
(b) Its high level of effectiveness against grasses of many types.
(c) Its almost instantaneous inactivation on all except the very lightest of mineral soils.

This combination of properties makes paraquat particularly suitable as a substitute for cultivation in seedbed preparation and there are numerous reports of successful trials of surface sowing and sod seeding with the aid of this chemical (Appleby and Brenchley, 1968; Blackmore, 1965; Cullen, 1970, 1971; Campbell, 1969; Lee, 1965). Dalapon and glyphosate have also been used but require more care in avoiding residual effects on germinating seedlings. Campbell (1974b, 1976) suggests that a period of up to three to four weeks may be needed between glyphosate spraying and sowing to allow the residues to dissipate. The effect may also vary with species, i.e. 10 days for grasses, 20 days for lucerne and over 20 days for subterranean clover. Residues of glyphosate, says Campbell (1974b), had no effects on germination but reduced establishment, particularly of legumes. Dalapon at 8.7kg a.e./ha is reported to have residual effects for 4-8 weeks (Campbell 1976).

Appleby and Brenchly (1968) noted residual effects from paraquat caused by residues in the dead herbage cover rather than in the soil. They went on to say that paraquat could be absorbed from dead plant material on the soil surface by emerging seedlings. Grass seeds, in the early stages of germination may also absorb toxic levels of paraquat from surrounding dead plant material if they came into contact with it. Paraquat residual effects in cover are overcome by sowing 1-2 weeks after spraying (Campbell and Swain, 1973b).

2.3.4 Factors Causing Losses

2.3.4.1. Loss of Seeds

This problem has been noted in tropical and other parts of Australia where ants may remove large numbers of oversown seeds (Campbell, 1968, 1969, 1973, 1974a; Campbell and Swain, 1973a, 1973b; Russell, *et al*, 1967). Harvesting of oversown seed by ants was found to vary with season and lighter seeds were preferred to heavier seeds. Seed harvesting is also noted to increase if surface sowing is followed by dry conditions. Johns and Greenup (1976a, 1976b) report that, in New South Wales, theft of pasture seed by ants was 1-25% in winter and 40-90% in summer. Coated seed was also harvested. Campbell and Swain (1973b) observed the following with oversown seed and ant theft:-

In winter, 29% of the seed was taken within 33 days from sowing; 42% was taken within 24 days from sowing in spring, and in summer, 33% seed was taken within 18 days from sowing. In all situations and seasons, harvesting of seed by ants ceased when seeds germinated.

2.3.4.2 Loss During Germination

Germination of seed sown on the soil surface depended on the moisture relations in the seed, the soil and the atmosphere (Harper and Banton, 1966). In Australia, Campbell and Swain (1973b) found that germination of *Medicago sativa* L. (lucerne), *Trifolium subterraneum* L. (Subterranean clover), *Lolium perenne* L. (Ruanui perennial ryegrass) and *Phalaris tuberosa* L. (Australian phalaris) in winter was higher because of lower moisture losses from the seed and soil than in summer. Summer germination has been shown to be improved where an inert plant cover was present to reduce moisture losses (Campbell, 1973; Campbell and Swain, 1973b). Causes of germination failure are given as moisture stress, insect damage, poor seed/soil contact, the radicle becoming caught in the seed coat, and fungus damage. The first of these causes is considered to be the most important (Campbell 1968, 1969, 1973; Cullen 1966, 1970, 1971; Janson, 1970, 1975; White 1970, 1973b; McWilliam and Dowling, 1970; Clifford, 1975).

2.3.4.3 Loss While Radicle Penetrating Soil

Loss of germinating seeds may occur because the radicle is either unable to exert sufficient force to deform and penetrate the soil surface or cannot find pores of a suitable size to allow entry. Failure to enter the soil leads to subsequent desiccation. Under relatively high evaporative conditions in summer, an inert cover over the soil surface has proved more effective than irrigation in allowing the radicle to penetrate the soil as reported by Campbell and Swain (1973b). Evans and Young (1970) also observed that cover increased the relative humidity at the soil surface and decreased the rate at which the surface dried out. This reduced the danger of desiccation and allowed a longer period for radicle penetration. In their study, Campbell and Swain (1973b), working with phalaris, ryegrass, lucerne and subterranneum clover found the grasses and legumes to require 2 and 5 days respectively for 50% of the radicles to enter the soil. The legume radicles were thicker and appeared to have greater difficulty in entering the soil, hence being more subject to losses resulting from desiccation and damage by soil fauna (Campbell, 1973). Factors other than desiccation including obstruction, disturbance, insect damage and malformed radicles, reduced percentage soil penetration by 4-11% as observed by Campbell and Swain (1973b).

2.3.4.4 Loss During Establishment

Heavy losses of seedlings at this stage are mainly due to moisture stress and may occur at any season (Campbell, 1973, 1974a; Cullen 1970, 1971; Janson, 1970; White, 1970, 1973b; Marshall, 1972; McWilliam and Dowling, 1970). The losses may occur as a result of desiccation even after the tip of the radicle has entered the soil. In addition to moisture stress, losses due to soil fauna are reported by various workers. In Australia, Campbell and Swain(1973b) found slugs (Milax gagates Draparhand) to be a common cause of damage to seedlings in summer where ground cover was present. Slugs and insect larvae were active in winter and legumes appeared to be eaten in preference to grasses. Similar observations with regards to insect and slug damage are reported by Suckling (1951, 1975); Charlton, (1977) and Sims (1977) (personal comm.) in New Zealand with surface sowing for pasture development.

In Britain, Haggar and Squires (1976) report slug problems with oversowing. For slug control, grazing prior to sowing and application of mulluscicides are suggested by Suckling (1951). The former treatment, of course, negates the advantage of cover. Sims (1977 personal comm.) says that results with oversowing are improved by sowing the seed with mulluscicides in the Manawatu. Charlton (1977 personal comm.) has observed that slugs are the main cause of seedling loss following oversowing of legumes (clovers and lotus) and that most of the damage is done during the first four weeks after oversowing under favourable germination and establishment conditions. Campbell and Swain also observed seedling loss due to residual herbicides in the dead herbage cover.

2.3.4.5 Loss of Establishing Seedlings

Losses occuring after establishment are mainly due to competition from the regrowth of existing vegetation together with invasion by volunteer annuals (Campbell and Swain 1973b). These authors found that 80-98% reduction in light intensity at the soil surface could be caused by the vegetation being allowed to grow 15cm high. Grazing has been suggested before, during and after sowing to control this competition and to assist in the establishment and survival of pasture species (Suckling 1951, 1959, 1975; Cullen, 1970, 1971). Although grazing may cause the loss of some established plants, the losses incurred by not grazing might often be greater. Another method suggested for reducing competition from weeds is the application of selective herbicides (Allen, 1967; Haggar, et al, 1976; King, 1971). Most of the major losses of oversown species during establishment, due to theft by ants, poor germination, desiccation of the radicle, competition from weeds and moisture stress could apparently be alleviated by the provision of a dead plant cover. However, there appears to be a limit to the thickness of cover desirable that is determined by the availability of light and by the physical impedance of the layer (Campbell and Swain 1973a, 1973b; Haggar, et al, 1976). At present it appears that no treatment can be confidently recommended to avoid losses of young plants during periods of severe moisture stress.

2.3.5 Fertilizer Application

Most pastoral areas of New Zealand, Australia, Africa and elsewhere have been found to lack one or more of the major mineral nutrients needed for the proper growth of high-producing pasture species (Semple, 1972). In New Zealand, the oversowing with legumes and grasses of large areas of hill country has been successful in combination with topdressing of phosphatic fertilizers (Suckling 1966, 1975; White 1970, 1973b). Similar results have been reported in Australia by Campbell (1972), Dowling and Robinson (1976), Halse and Francis (1974), Wilson, (1968). Keya and Kalangi (1973) report successful oversowing of the legume Desmodium uncinatum (silver leaf desmodium) into uncultivated grasslands in Kenya dominated by Hyparrhenia spp. when superphosphate was applied at the rate of 500 kg/ha. This points to the need for correcting mineral nutrient deficiencies before successful introduction of high fertility pasture species becomes possible (see also During, 1972; Levy, 1970; White 1973a).

2.4 Surface Sowing of Lucerne

2.4.1 Lucerne as a Pasture Legume Species

Lucerne is the world's most important fodder legume (Halse and Francis,1974). It includes a wide range of cultivars from the species *Medicago sativa* L. and its hybrids with *M. falcata*. In New Zealand, varieties sown include Wairau, normally the first choice and Hunter River the second most popular (Langer, 1973; Leach, 1967; Janson, 1975). In Australia, Hunter River is the best known commercial variety, the others including Cancreep, African (or Paravivo), Siro Peruvian and Du Puits (Halse and Francis, 1974). Both the Wairau and Hunter River types are best suited for hay making. Grazing of these types is therefore best managed so as to simulate haymaking (Leach, 1968; Langer and Keeghan, 1970). The reason for this is that, unlike grasses, lucerne loses the growing points of the shoots on defoliation. Defoliation must therefore be timed so that buds and young basal shoots are present to replace the shoots removed (O'Connor, 1970; Othman, 1974; Smith, 1970). Correct timing of defoliation is very important for a high level of production and for persistence of the lucerne crop (Janson, 1975b). Under New Zealand conditions, lucerne has been found to be relatively resistant to damage by grass grub, except in the establishment phase (Langer, 1973). Another reason for careful timing of defoliation is to allow the lucerne plant to develop the deep root system, on which its drought resistance depends (Leach, 1967; Langer, 1973). In the tropics, e.g. in Tanzania, lucerne is grown as a fodder crop usually under conditions of irrigation, where the fodder is cut and fed to stock either green or as hay. It has been found to be a particularly valuable leguminous fodder because of its productivity during the dry season (McIlroy, 1964; Thomas, 1973; Semple, 1972).

2.4.2 Lucerne Establishment Requirements

2.4.2.1. Agronomy of Lucerne

As mentioned in section 2.4.1, lucerne grows under more diverse conditions than most perennial legumes (Halse and Francis, 1974; Jung and Larson, 1972). Leach (1967) says that environments suitable for lucerne may range from those of high latitude with low temperatures, wide annual range of photoperiod and relatively low light intensity, to subtropical environments where temperature fluctuations will depend largely upon altitude, photoperiod will have a small range and light intensity will be high. Superimposed upon this variation will be the range of precipitation. In addition irrigation may be used to supplement natural water supply in many arid areas. In general, higher air temperatures and light intensities promote both vegetative and reproductive growth, although many cultivars make less growth with temperatures exceeding about 25°C (Langer, 1973; Leach, 1967; Fields, et al. 1976). However, Aamodt (1941) reported that lucerne could survive temperatures as low as -64°C and as high as 49°C and may be found growing in areas with an annual precipitation of 250mm or less. The low temperature survival of lucerne is thought to be dependent on air and soil cooling rates, minimum temperature reached, warming rate and the cold tolerance of the cultivar involved (Jung and Larson, 1972). Too high temperatures also limit lucerne production and it has been shown that growth ceases at temperatures below those killing the plants (Wilsie, 1962; Levitt, 1969). Shaw (1952) has worked out the minimum, optimum and maximum temperatures for lucerne growth. This relationship is complex as not only does temperature affect most of the growth processes in the plant but there are also indirect effects due to the influence of temperature on soil organism activity in the rhizosphere and nodules and on pathogens and pests (Shaw, 1952; Hagar, 1967; Kramer, 1969; Levitt, 1972).

Soils suited for lucerne growth are those that are well-drained and of medium to high pH. Lucerne cannot tolerate "wet feet" (Halse and Francis, 1974). Where soils are acidic, liming is necessary to increase pH. The pH at which the crop grows best is 6.5 - 7.0 (Langer, 1973; Rogers, 1967).

2.4.2.2 Requirements for Germination and Emergence

Germination is that sequence of steps which causes a quiescent seed with a low water content to increase its general metabolic activity and initiate the formation of a seedling from the embryo (Mayer and Poljakoff-Mayber, 1963). Seedling emergence can be regarded as the first appearance of parts of the seedling above the soil surface. An ideal environment for these processes is a firm, fine, well-drained, weed-free seedbed, adequately supplied with nutrients and moisture (Brown, 1973; Halse and Francis, 1974; Langer, 1968, 1973). Bula and Massengale (1972) stress that temperature, age of seed and close contact between seed and soil are also important for good germination.

2.4.2.2a Soil Moisture

Soil moisture is a function of incoming water from rain, dew, irrigation and movement from a water table combined with losses due to evaporation, transpiration, drainage and runoff. The germination behaviour of lucerne appears to be controlled by two main soil moisture properties; the potential and the resistance to movement of moisture into the seed (Collis-George and Sands, 1959, 1962). Imbibition is governed by the degree of wetness of the soil around the seed and a wetter soil has a better ability to transmit water than a drier one. Under drier conditions soil compaction will improve imbibition and hence germination, by improving the contact between seed and soil, thus reducing the resistance to water movement (Peters and Runkles, 1967). Collis-George and Sands (1959, 1962) studying the influence of soil moisture on germination found that, with three Medicago spp., an increase in soil moisture tension produced a decrease in the rate of germination until at 10 atmospheres germination practically ceased.

2.4.2.2b Soil Temperature

Shaw (1952) claims that germination and emergence are intimately related to soil temperature. Bula and Massengale (1972) say that temperatures regulate speed of germination, primarily by regulating the metabolic process involved. Within limits a temperature increase generally increases the rate of germination and emergence. Fields et al. (1976) agree that many plant responses to temperature are mediated by the underlying metabolic reactions. Williams (1963) and Larsen (1967) quote 4-5°C as minimum, 25°C as optimum and 38°C as maximum temperatures for lucerne germination and emergence with only small differences in the 15° - 30°C range and with appreciable varietal differences. The acceleration of metabolic activity is reflected in the rate of growth and these reactions generally increase 2-3 fold for every 10°C rise in temperature over the range 5-35°C (Went 1961 - cited by Fields et al., 1976).

2.4.2.2c Seed Quality

Viability and vigour of seed are the two important qualities in determining a high level of emergence and subsequent establishment with all plants (Hill, 1974). Seeds can retain their viability and vigour for long periods provided that they are in a state of sufficient desiccation (Mayer and Poljakoff-Mayber, 1963). The duration of viability, however, is variable and depends both on storage conditions and the type of seed. Hard seeds usually have a long viability partly because their seed coats are impermeable to water and gases and partly by mechanically constraining the embryo,(Graber, 1922; Hill 1974; 1977 person. comm.). Graber found with hard lucerne seed that a reduction in germination from 94.5% to 47% occurred after storage in a cool place for 10-12 years. Delayed germination due to hard seed is one of the factors causing variations in plant vigour within a lucerne seedling population (Blair, 1971) so that, in addition to viability, seed hardness is an important factor in lucerne establishment through its effects on speed of germination and vigour.

2.4.2.2d Depth of Sowing

In general, as seed size decreases so also must the depth of coverage, probably because of decreasing cotyledonary food reserves and capacity to extension growth in the hypocotyl (Black, 1959; Brougham, 1969). Depth of sowing is thus a critical factor in the establishment of lucerne because of its small seed size and according to Langer (1973), the more shallowly the seed is sown the better. Sund, et al (1966) found that the best depth of sowing was 1.3 - 2.5 cm in loams and 1.3 cm or less in clay soils. The optimal sowing depth for sandy loams or silt loams was found to be 1.25 cm by Triplett and Tessar (1960). Seed sown on the surface has been noted to suffer from weathering with a consequent reduction in viability (Campbell and Swain, 1973b).

2.4.2.3 Requirements for Seedling Survival and Growth

Seedling vigour, growth and development are influenced by such factors as soil moisture availability, availability of nutrients, temperature, light, seed size and the conditions under which the seeds matured. Air temperature and soil moisture during the period of seed production have been found to affect not only seed weight and germination but also the subsequent growth of seedlings (Bula and Massengale, 1972; Hill, 1974; Walter and Jansen, 1970).

2.4.2.3a Soil Moisture

Readily available moisture is essential for the growth of lucerne seedlings particularly under surface sowing conditions (Campbell, 1973, 1974a; Janson, 1970, 1975; White, 1970). Bula and Massengale (1972) showed that a sufficient soil moisture supply was important for seedling growth but that excess moisture was detrimental due to reduced soil aeration. Excess water may thus cause the development of shallow root systems and plants with small crowns. In addition, excess moisture may cause loss of seedlings by damping-off pathogens (Halse and Francis, 1974).

The effect of water stress on growth is most pronounced in rapidly developing tissues such as those comprising the major part of the plant during the stages of germination, emergence and early seedling growth (Bula and Massengale, 1972).

Both the extent and depth of rooting of lucerne and the ratio of root to shoot are influenced directly by soil moisture conditions (Peters and Runkles, 1967). Under moisture stress the growth rate of the tops is usually reduced more than that of the roots (Peters and Runkles, 1967; Slatyer, 1967; Kramer, 1969). Campbell and Swain (1973b) also found that water stress was the major cause of seedling loss during establishment under an oversowing situation.

2.4.2.3b Light

Light duration, intensity and quality are determined by the latitude, time of the year, atmospheric conditions and elevation (Bula and Massengale, 1972). Using light intensities of up to 32,000 lux, Bula et al (1959) observed that total dry matter accumulation was essentially proportional to light intensity. Matches et al. (1962) similarly reports that lucerne seedlings are not tolerant of low light intensities, under which total dry matter, shoot and root weights were reduced. Root production was affected more than shoot production as light intensities decreased.

2.4.2.3c Temperature

Immediately following emergence, the growth of lucerne seedlings is favoured by high temperatures of 20-30°C which result in rapid leaf expansion (Garza et al. 1965; Pearson and Hunt, 1972a, 1972b). Six weeks after emergence, however, growth is favoured by lower temperatures in the range 15-20°C (Fields et al. 1976). Garza et al. (1965) report results indicating that night temperatures of 15° - 20°C are especially important for a high growth rate. This shift in optimum temperature probably corresponds with the development following establishment of a sufficiently large initial leaf area, and of a favourable balance between photosynthesis and respiration for long term dry matter accumulation (Fields et al. 1976).

Jansen, et al. (1967) reported that lucerne (var. Moapa) plants grown under a warm regime (33°day/17°C night) grew faster and reached 10% bloom in about half the time required by plants grown under a cooler regime (2°C/4°C). Further, dry matter yields were significantly lower when root temperatures were maintained at 9°C than at 16, 24 or 32°C. However, there were no significant differences in forage yields between plants grown at the three higher temperatures. In work by McElgunn and Heinrichs (1970) root and top growth of lucerne (vars. Rambler and Alfa) was found to be greater at a soil temperature of 20°C than at 10°C or 15°C. Brown (1973) also found that high temperatures near the surface of a sandy soil could cause substantial seedling mortality and that 45°C was lethal. The effect of light also interacts with that of temperature as shown in the table below which summarises the work of Gist and Mott (1957).

Table 2 : Top Dry Weight of Lucerne Seedlings, Var: Ranger (gm/plot) Grown at four air temperatures and three light intensities for 45 days.

LIGHT INTENSITY (F.C.)	TEMPERATURES			
	16°C	21.3°C	26.6°C	32°C
1200	1.655	1.521	1.079	0.688
600	0.942	0.991	0.887	0.449
200	0.152	0.135	0.127	0.125

Increasing temperature reduced growth of tops more at higher than at lower light intensities. For example, a rise in temperature from 16°C to 32°C at 1200 f.c. led to 58.4% reduction in growth as compared to 17.8% reduction in growth at 200 f.c. by raising temperatures from 16°C to 32°C. In the same experiment, Gist and Mott found that root growth responded in the same way as top growth to variations in light intensity and temperature.

Under surface sowing conditions temperature and light intensity will exert an especially important influence in determining the amount of cover desirable in seedbed preparation. The higher the temperatures and light intensities the thicker the ground cover required to buffer the adverse effects of light and temperature and so provide the optimum conditions for seedling growth and development (Campbell and Swain, 1973b; Janson and White, 1971).

2.4.2.3d Soil Fertility

The mineral elements reported by Bolton (1962) as necessary for growth of lucerne are: phosphorus, calcium, potassium, magnesium, sulphur, boron, iron, manganese, zinc, molybdenum, copper and chlorine; the last seven only being required in trace amounts. Calcium, phosphorus, and potassium are the most important elements for stand establishment and phosphorus is particularly important because of its role in root development (Tesar and Jackobs, 1972; Lathwell, 1966). Cowett and Spraque (1962) suggested that nutrient balance was more important than nutrient levels alone for the growth and basal shoot development of lucerne seedlings. In New Zealand, phosphorus, potassium, sulphur, molybdenum, copper, and boron are the elements to which lucerne has given the most positive responses (Dale, 1967; Langer 1968, 1973). In addition, responses to lime are important on acid soils. Calcium appears to be needed more for nodulation than for plant growth (Loneragan and Dowling, 1958; Andrew and Norris, 1961; Langer 1973; White, 1970) and large amounts of calcium are required for nitrogen fixation (Loneragan, 1959). White (1970) in a trial with lime pelleted lucerne oversown on an acid soil (pH 5.5) on tussock grasslands, found that increasing rates of lime up to 5022 kg/ha resulted in increased dry matter production, a function of the growth of more and longer effective nodules. In the same trial a heavy rate of lime broadcast over the surface of the whole plot generally proved superior to smaller amounts drilled near the sown seed, apparently by stimulating more widespread nodulation. An effect of lime in alleviating poor lucerne root development has been reported and attributed to the lowering of toxic levels of hydrogen ions (White, 1965), manganese (Schmel, et al. 1950) or aluminium (McLeod and Jackson, 1965) in the soil.

2.4.2.4 Lucerne Nodulation Requirements

2.4.2.4a The Process of Nodulation

In common with other legumes lucerne forms a symbiotic association with rhizobium bacteria which form nodules on the roots. The bacteria receive carbohydrates from the host plant and in return, fix atmospheric nitrogen from the soil air converting it into the readily available form of nitrate. Therefore, provided conditions are favourable for nodulation and nitrogen fixation, lucerne can be established and grown successfully in soils of low nitrogen status.

Nicol and Thornton (1941) reported that one of the earliest steps in nodulation was the production of a substance by actively growing leguminous roots which attracted rhizobia towards the root hairs. The formation of nodules is preceded by a proliferation of rhizobia and curling of root hairs but the precise mechanism of entry into the root hairs remains obscure (Burton, 1972). Probably 3-indolyl acetic acid is responsible for the curling of the root hairs (Rovira, 1956). Once curling has occurred, the host plant produces extra-cellularly the enzyme polygalacturonase in response to a stimulus by specific infective rhizobia (Burton, 1972). This enzyme is thought to increase the plasticity of the root hair wall, thus assisting infection by the bacteria. Nutman (1963) reports that after infection has taken place, the bacteria move upwards through the root hairs into the cortex in structures termed "infection threads". These penetrate the cortical cells where the bacteria are released to develop into bacteroids. The site of the bacteroids and the host-plant membrane surrounding them are believed to be the fixation sites. (Dart and Mercer, 1963). Accelerated division of cells surrounding the bacteroids results in the eventual formation of nodules (Nutman, 1963).

The process of nodulation is such that the rhizobia cannot invade the root hair for some time after germination (Nutman, 1958). The secretion of the rhizobial attractant by rootlets of lucerne does not occur until the first true leaf has opened (Thornton, 1929). Nutman (1958) and Rovira (1961) point out that, under normal conditions, the population of rhizobia in the root zone reaches approximately 10^6 organisms per gram of soil. Hence the importance of ensuring optimum conditions for growth of rhizobia during the period of seedling establishment.

2.4.2.4b <u>Factors Affecting Rhizobial Survival</u>

In New Zealand and Australia, the lucerne nodule organism <u>Rhizobium meliloti</u> is not indigenous so that inoculation of lucerne seed before sowing is a standard procedure (Vincent, 1958; Wilson, 1968; Greenwood, 1964; Langden, 1973). Where the legume is being sown for the first time inoculation is especially important (Semple, 1972) and failure of the rhizobia to survive on the seed or in the soil, may result in a failure of nodulation and subsequent plant death. The following are the main factors affecting survival of rhizobia.

(i) <u>Level of Inoculum</u>

Under optimum conditions, a concentration of about 1,000 rhizobia per seed is considered adequate for effective nodulation (Wilson, 1968).

However, under difficult conditions, higher levels of inoculum are needed for lucerne as recommended by Date, (1970) and Lowther et al. (1970). Both White (1966, 1967, 1970) and Janson (1970) report that increasing the level of inoculum on the seed improved nodulation on acid soils. White (1970) also found that increasing the inoculum gave a highly significant improvement in percentage nodulation and plant survival when seed was surface sown in South Island hill country. These findings suggest that a high mortality of rhizobia may result from exposure to heat and wind. Janson and White (1971) stress that high rhizobium numbers on lucerne seed ensure the prompt nodulation without which the chances of successful establishment in the field are reduced. Hely (1963) pointed out that the use of a high inoculum level was a relatively inexpensive method of improving the establishment of lucerne.

(ii) pH

Most strains of R. meliloti are unable to survive in conditions more acid than pH 5.4-5.5, or more alkaline than pH 8.5, the optimum range being pH 6.5-7.5 (Jensen, 1942; Langer, 1973). Jensen (1942) demonstrated a good correlation between optimum pH levels in culture solution and in the field. Parle (1967) reports overcoming the problem of lucerne nodulation in pumice soils of pH 5.6-5.7 by liming so as to raise the pH to the optimum range.

(iii) Moisture

All stages of nodulation from the pre-infection stage to effective nitrogen fixation are affected by the environment and in particular by moisture availability (Masterton and Sherwood, 1970; Lie, 1971; Wilson 1921; Spent, 1971). Adequate moisture is essential for the multiplication of rhizobia. Soulides and Allison (1961) showed, for example, that on air-drying the total viable rhizobial population of soil was reduced by 80% in extreme cases and more commonly by 50-60%. Parle (1967) likewise stated that drying conditions had very serious effects on soil rhizobium populations especially where these conditions were accompanied by high temperatures.

(iv) Temperatures

Fields, et al. (1972) in their review point out that nodulation of legumes proceeds over a broad temperature range, with a consistent reduction only at extremes. In general, favourable temperatures for growth of rhizobia coincide with the optimum range for the growth of the host plant. Shaw (1952) reported that Rhizobium meliloti stops growing at 41°C. Gibson (1971) noted that the number of nodules decreased on lucerne grown at temperatures above 33°C or below 18°C. Work on survival of R. meliloti at high temperatures by Bowen and Kennedy (1959) indicate that the maximum varied from 36.5° to 42.5°C. The organisms survived in sterile sand at 40°C for just 24 hours. In this connection, Parle (1967) measured surface temperatures of 48°C on bare pumice soils in north New Zealand but also noted a rapid decline with depth; for example, a maximum of 37°C at 2.5 cm and 25°C 5.1 cm below the surface. Under Western Australian conditions, reported by Marshal and Roberts (1963) and Marshal (1964), where soil temperatures in mid-summer reach 65°C in the top 2.5 cm, Rhizobium trifolii failed to survive. Parle (1967) reported that microorganisms are less sensitive to low temperatures and suggested that cold conditions in the field are unlikely to cause much damage.

(v) Light

Kelner (1949) and Salle (1961) reported that ultra-violet light was harmful to rhizobia, the effect ranging from a mere reduction in growth rate to complete destruction of the cells. The degree of injury depended on the intensity and wavelength of the radiation and the duration of exposure (Salle, 1961). According to Chatigny (1961) ultraviolet rays have little penetrating power and thin films of liquid or dust will nullify their effects on bacteria. On the other hand, Taylor and Lloyd (1968) showed marked decreases in rhizobial numbers with pelleted seed (and Alexander and Chamblee, 1965 with unpelleted seed) after exposure to bright sunlight. These effects suggest that the reduction in rhizobial numbers are largely due to destructive influences of desiccation and high temperatures on rhizobia.

(vi) Seed Pelleting

After seed has been inoculated, death of the rhizobia on the surface is thought to be fairly rapid (Vincent, 1958). Numerous investigations on incorporating rhizobia with various stickers and coating material into pelleted seed have been made and considerable benefits have been demonstrated with clovers and lucerne (White 1973b). Lime coating is reported to help establishment of clovers and lucerne where nodulation problems exist. In addition, the lime helps to protect the bacteria and allows storage of the inoculated seed for up to one week before sowing instead of having to sow on the same day that the seed is inoculated (Curnow, et al. 1972). Pelleting has the following effects: (a) it protects the bacteria from desiccation, both during storage and in the field following sowing (Brockwell and Whalley, 1962; Curnow et al. 1972; Goss and Shipton, 1965; Murguia and Date, 1965) (b) it protects from ultra-violet light (Taylor and Lloyd 1968) (c) it protects from seed coat inhibitors released through scarification during the pelleting process (Lobb, 1958; Thompson, 1961) (d) it protects against microbial antagonism (Bergersen, et al. 1958) and (e) against the effects of acid fertilizers (White 1973b).

Pelleting may also supply nutrients (Brockwell, 1963; Hastings and Drake, 1963). The main function of an alkaline pelleting material, however, appears to be its ability to raise the pH of the soil immediately adjacent to the seed, thus permitting better survival and multiplication of the rhizobia (Blair and Bennett, 1960; Hayman, 1964; White, 1965a, 1967, 1973).

Pelleting of inoculated legume seed has proved a very successful technique in Australia, for pasture legume establishment (Lowther, 1974). In New Zealand however, results have been variable due partly to poor inoculum quality (Lowther, et al. 1970). Cullen and Ludecke (1966), for example, found poor nodulation with white clover sown as pelleted seed and Lowther et al. (1970) attributed this to low rhizobium numbers on the seed at the time of sowing. Lowther (1974, 1975) reports more successful establishment of oversown clover using pelleted seed. However Musgrave (1976) in oversowing trials with lucerne at Tara Hills, reports that pelleting of inoculated seed was not sufficient to ensure nodulation and survival of the lucerne seedlings under unfavourable conditions.

(vii) Biological Antagonism

Some soil microorganisms have been shown to exert antagonistic effects against other soil organisms as reviewed by Parle (1967). Cases of suspected microbial antagonism preventing nodulation in the field are reported by Hely, et al. (1957) and Cass Smith & Holland (1958).

In the U.S.A., Rice (1964) reported that certain higher plants caused inhibition of rhizobial growth; and there is evidence that species of Notodanthonia produce toxins which destroy rhizobia in the soil (Parle, 1967). In New Zealand, Janson and White (1971) observed this allelopathic effect of Notodanthonia spp. on bacterial growth and survival and found that destruction of the plant with such herbicides as paraquat six weeks before sowing greatly improved the establishment and nodulation of lucerne.

2.4.3 Establishment Procedures

Conventional sowing methods for lucerne generally involve drilling inoculated seed into thoroughly cultivated and (except for neutral and alkaline sites) heavily limed seedbeds. In many areas these methods are too expensive for lucerne growing to be practicable so that there is considerable interest in cheaper establishment methods such as oversowing (reviewed in Section 2.3).

The different sowing methods have been studied in New Zealand by several workers investigating such factors as time of sowing, inoculation and pelleting and the causes of seedling loss. For example, Janson (1970) and Janson and White (1971) report the results of establishment following broadcasting or drilling after three sward treatments (burning, paraquat and dalapon/amitrole applications). Overdrilling was found to be greatly superior to broadcasting, irrespective of rainfall, vegetative cover or sward treatment. Janson (1975), Musgrave (1976), White (1970, 1973b) and Clifford (1975) report on the importance of adequate soil moisture at and after sowing for ensuring good establishment with oversowing techniques. Campbell (1968, 1969, 1972, 1973, 1974a, 1974b, 1976 and Campbell and Swain (1973a, 1973b) also discuss the requirements for establishment of lucerne and other species by surface sowing under Australian conditions.

All the work on surface sowing of lucerne points to the following factors being needed for successful establishment:-

(a) an adequate soil moisture supply before and after sowing,
(b) the need to eliminate or reduce competition from existing species,
(c) the inoculation and pelleting of the seed and
(d) the availability of an inert ground cover to act as a buffer to climatic fluctuations at the soil surface (Janson 1970, 1975; Campbell and Swain 1973a, 1973b; Musgrave, 1976).

The review has shown that the information available on lucerne oversowing is limited to reports on its introduction into unimproved country mostly under adverse conditions of low rainfall and low fertility. Since the techniques of surface sowing offer opportunities for establishing pastures at lower costs than the conventional methods, there is also a need to examine the techniques under the more favourable conditions of arable land. Oversowing offers particular advantages for low-cost pasture improvement in the tropics and in developing countries generally. The present study was conducted under Palmerston North conditions, with the hope of approaching as closely as possible conditions encountered in the tropics. The summer of 1975-76 was unusually wet and warm and thus simulated to some extent the conditions of a tropical rainy season.

In the following pages, three trials are reported designed to provide further information on lucerne establishment by surface sowing using different surface cover treatments under a variety of climatic conditions.

3. METHODS AND MATERIALS

This study consisted of three trials, two in the field and one in the glasshouse. The field trials were conducted in the summer of 1975/76 and autumn of 1976 (starting in September, 1975 and March, 1976 respectively) while the glasshouse trial was carried out during the late-autumn and early-winter period of 1976 (May to July). The aim of the glasshouse trial was to determine whether the trends observed in the field, particularly in the summer trial, would also occur under a controlled environment.

3.1 Preliminary Work

The experimental site was located at the Massey University Sheepfarm No. 1. The choice of the site was governed largely by accessibility, evenness of grass cover and the presence of a vigorous sward without a large proportion of clover.

An area of 0.2 ha ($\frac{1}{2}$ acre) was fenced off from the rest of the paddock, harrowed to spread dung and topdressed with urea (254.6 kg/ha) on the 19th September 1975 to boost grass growth as the area had been hard grazed by cattle. Dicamba was then sprayed at the rate of 0.43 kg a.i./ha to kill off the clover component of the sward thus ensuring minimum competition to the introduced legume from existing legumes. The site was then left ungrazed for about 2 months to allow the grass to grow. (See Plate 1).

3.2 Trial I.

3.2.1. Laying Down of Plots

The 0.2 ha was divided into equal 0.1 ha areas down the gradient; one half was allocated for the summer and the other for the autumn trial. The summer trial site was then trimmed around the edges using a tractor-mounted rotary mower after marking off the replicates. Four blocks were laid down with 4m paths between them. Each block was divided into 16 plots $9m^2$ (3 x 3m) in area and the pathways demarcated by a lawn-mower giving a cut 0.5m wide (see appendix I for experimental layout). After marking out the plots, treatments were applied as explained below:-

3.2.2. Treatments

3.2.2.1 Existing Vegetation Treatment (Seedbed preparation)

Existing vegetation treatments consisted of a control, short-term herbicide treatment, longer lasting herbicide application and burning.

3.2.2.1(a) Control

Long vegetation cover 15cm high was selected as being comparable to lax grazed or ungrazed natural grasslands in the writer's country of origin (see Introduction). Also a short vegetation cover 8cm high was selected and this simulated grazed natural grasslands during periods of active growth.

3.2.2.1(b) Short Term Herbicide

This was applied to knock back existing vegetation for a limited time, thus simulating natural grassland conditions at the end of a mild dry season where the vegetation was not severely dried up.

3.2.2.1(c) Longer Lasting Herbicide

This was applied to check regrowth for a longer time while the introduced species was establishing.

3.2.2.1(d) Burning

To simulate the planned or unplanned burning of natural grasslands during or at the end of a dry season. It was found that the only practicable way of applying the burning treatment was first to desiccate the grass by spraying with paraquat (0.5 kg a.i./ha) and then to burn with a kerosine operated flame-thrower after the grass had dried.

The longer lasting herbicide treatment involved spraying paraquat at the rate of 0.5 kg a.i./ha on first application and then 1.0 kg a.i./ha 15 days later when some recovery and regrowth was observed. The short term herbicide treatment involved spraying once only with paraquat at the rate of 1.5 kg a.i./ha. With the longer lasting herbicide treatment the grass was killed back for well over 65 days while the short term herbicide treatment knocked back the resident vegetation for about 45 days. In both cases, regrowth was mainly from germinating grass and weed seeds.

Trimming the appropriate plots to 15cm or 8cm was done using a tractor-mounted rotary mower for longer and a reciprocating mower for the shorter height. In allocating the treatments to plots, random numbers (Table A_1 Snedecor and Cochran, 1968) were used. The experimental design was a randomised complete block. The blocking was done so as to minimize slope effects which were in turn expected to affect soil moisture content. See appendix I and plate 2 .

Plate 1: Grass growth at the Experimental Site before the application of ground cover treatments for Trial 1.

Plate 2: General view of Experimental Site after application of ground cover treatments (5/12/1975).

Plate 3: Long cover + short term herbicide (Paraquat 2) plot 5 days before sowing (5/12/1975).

Plate 4: Short cover + long lasting herbicide (Paraquat 1) plot 5 days before sowing (5/12/1975).

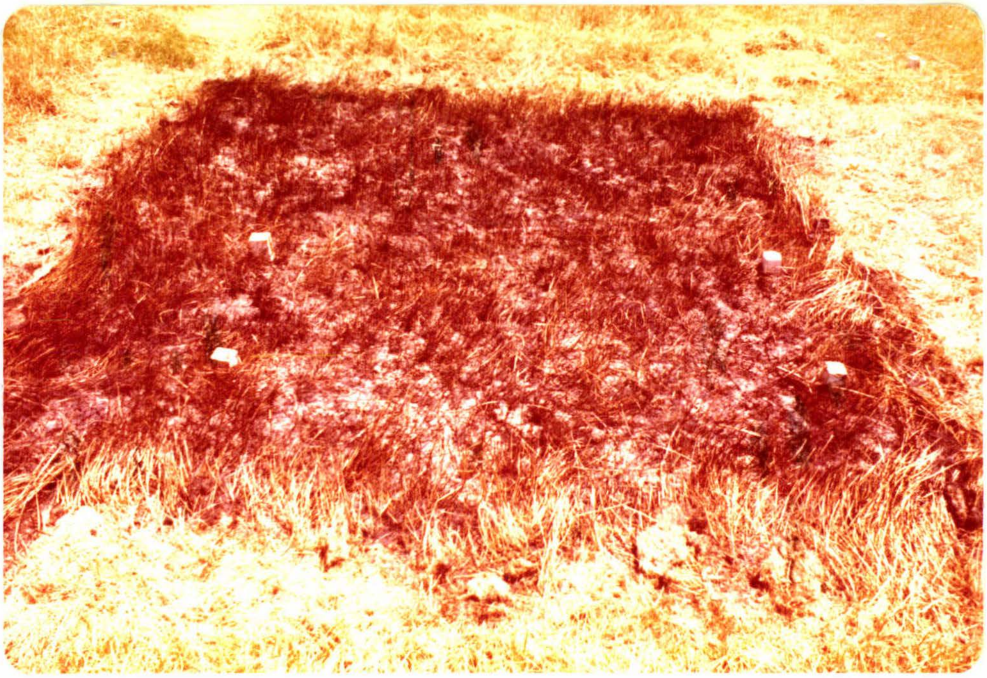


Plate 5: Paraquat 2+burning plot 5 days before sowing (5/12/1975).

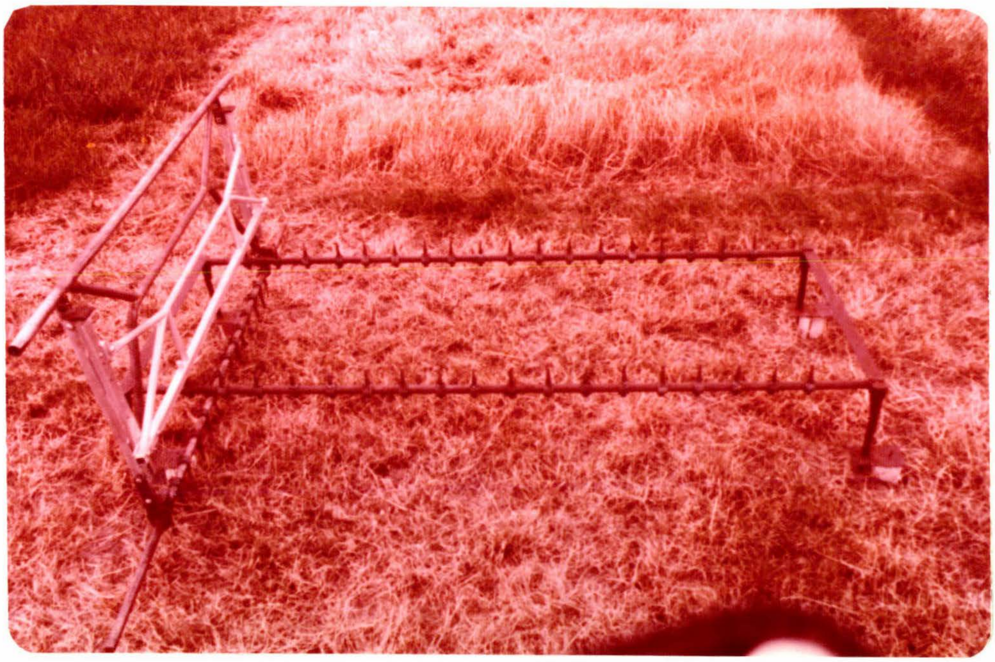


Plate 6: Frame used in the sowing operation resting on pegs of short cover + paraquat 2 plot. In the background long cover + paraquat 1 (5/12/1975).

3.2.2.2 Seed Treatment

Hunter river lucerne was used for both the pelleted and the bare seed. The coated seed was inoculated and pelleted commercially while the bare seed was inoculated in the laboratory before sowing using a generous quantity of inoculum for treatment. Prior to sowing, both coated and bare seed was tested for germination in the laboratory and the results were as follows:-

Table 3: Seed Germination Test Results

SEED	INTERIM COUNT (4 days)	FINAL COUNT (8 days)
COATED SEED	97%	97%
BARE SEED	61%	93%

Both seed types are seen to have had very high germination percentages.

3.2.3 Sowing

Accurate placement of every seed sown was achieved by using a modified Janson and White technique (1971). A rectangular frame was used that was fitted with a bar across the frame which could be placed in any of 18 positions, 7.6cm (3 in) apart down the length of the frame. Spaced across the bar were 14 points also 7.6 cm apart. This provided 252 points 7.6 cm apart to be located within the subplot formed by the frame. These points were accurately relocated at future dates i.e. at subsequent seedling counts. To relocate points accurately, the frame was placed on pegs that had been fitted with nails and the nails held the frame through holes that had been drilled through the feet of the frame. (See plate 6). One seed was placed on the ground/turf at the point indicated by the tip of each nail from the bar as the latter was progressively moved along the frame (252 seeds were sown per subplot of area 1.1 x 1.7 m). The rest of the 9 m^2 plot was reserved for herbage harvesting to indicate the rate of regrowth of the pasture and thus provide a measure of competition (See section 3.2.4.1). The placing of seed on the ground/turf was done using a pair of forceps.

3.2.4 Measurements (Observations)

3.2.4.1 Herbage Sampling

The amount of herbage cover in terms of dry matter was determined before sowing and at subsequent seedling counts. The harvesting of herbage was done on those parts of the plots outside the sown subplots by cutting one 250 cm^2 quadrat. The herbage was oven dried at 80^oC overnight for dry matter determination and the values converted into kg dm/ha. These dry matter figures may not have been representative of grass growth in the presence of lucerne because the grass outside the sown subplot never suffered competition from lucerne plants. Differences may have occurred as shown by botanical composition results, namely with vigorous lucerne growth grass growth was reduced.

3.2.4.2 Soil Moisture Content Determination

Sampling for soil moisture content determination was carried out using a standard soil core sampler. There was a need to determine the soil moisture level near the soil surface as the seeds were to be sown on the surface. To achieve this, 5.1 cm (2") of soil core was taken and the top 1.3cm ($\frac{1}{2}$") was cut off from the rest of the soil core and both samples put in containers. This was repeated for each plot and the soil samples were weighed and oven dried at 105^oC for about 24 hours. The soil moisture content was determined as a percentage of oven dried soil. For the first 2 weeks from sowing soil sampling was done at 5 day intervals, as this period was considered critical for soil surface moisture. As the trial progressed, the frequency of sampling was reduced, first to 7 day, then 10 day and finally 21 day intervals. This was also accompanied by a change in sampling technique; namely a 5.1cm soil core was taken from each plot and the level of moisture from 5.1 - 15cm was also determined for selected plots to indicate soil moisture at deeper levels.

3.2.4.3 Seedling Counting and Scoring

Counting of seedlings and scoring was done using the frame as explained in section 3.2.3, two weeks following sowing and fortnightly thereafter. Scoring of the stage of germination and development of the lucerne was done using the table below.

Table 4 : Lucerne Seed Germination and Development Score
(After Janson and White, 1971)

SYMBOL	MEANING
0	No sign of germination
00	Seed not seen
1	Germination commenced; radicle and/or epicotyl protruding
2	Two cotyledons visible
3	Two cotyledons and one primary leaf visible
1T	One true leaf visible
2T	Two true leaves visible
pL	Developing seedling/plant

The data obtained by counting were then used to give the seedling/plant count results which were expressed as percentages of seed sown. This provided an indication of germination level, and survival was determined by subsequent counting and scoring.

3.2.4.4 Botanical Composition

Before seedbed preparations were begun, the botanical composition of the sward was assessed visually. The resident vegetation was found to be about 98% grass (mainly ryegrass) and 2% other species mainly clover and weeds. According to the records of the paddock, the following pasture seed mixture was sown in 1960:-

11.4 kg/ha Certified Permanent Pasture Ryegrass (*Lolium perenne* L.
4.5 kg/ha Italian Ryegrass (*Lolium multiflorum* L.)
4.5 kg/ha N.Z. Cocksfoot (*Dactylis glomerata* L.)
4.5 kg/ha Certified Permanent Pasture White Clover (*Trifolium repens* L.)
1.1 kg/ha Crested Dogstail (*Cynosurus cristatus* L.)
2.3 kg/ha Timothy (*Phleum pratense* L.)
1.1 kg/ha Montgomery Red Clover (*Trifolium pratense* L.)
1.1 kg/ha Broad Red Clover (*Trifolium pratense* L.)
136 kg/ha Ryecorn

(Sheepfarm No. 1 Records 1960-1975)

Through the years the pasture seemed to have evolved into a ryegrass/white clover pasture instead of the original mixture. At the conclusion of the trial, botanical composition was determined both by visual assessment and dissection of cut herbage into component species.

3.2.4.4(a) Visual Assessment

A $0.1m^2$ quadrat was placed randomly on two positions in the sown subplot and the percentage composition of the various species assessed.

3.2.4.4(b) Herbage Dissection

Two $0.1m^2$ quadrats were cut from each plot. The herbage cuts for each plot were then bulked and dissected into component species, oven-dried and the dry matter determined. Percentage of total dry matter of each component species was obtained as a measure of botanical composition by weight. The aim of these measurements was to observe the changes in sward composition as a result of oversowing and the various seedbed preparation treatments.

3.2.4.5 Lucerne Growth

This parameter was observed at the conclusion of the trial. It involved the digging out of lucerne plants with as much of the root system as possible. The soil was washed off carefully from the roots and the nodules were counted. Where available, 10 plants per plot were dug out and the mean nodule number per plant, plant weight and top/root ratio determined. The last two parameters were obtained after oven-drying the samples.

3.2.4.6 Soil Analysis for Nutrient Status and pH Determination

According to sheepfarm No. 1 records, the paddock had received fertilizer treatments as shown below:-

1960	-	Topdressed with	254.5 kg/ha	superphosphate
1967	-	" "	381.7 kg/ha	"
	-	Limed "	2.54 tonnes/ha	Lime
1968	-	Topdressed with	254.5 kg/ha	superphosphate
1969	-	" "	254.5 kg/ha	"
1970	-	" "	254.5 kg/ha	"
1973	-	" "	254.5 kg/ha	"
1974	-	" "	254.5 kg/ha	"
1975	-	" "	254.5 kg/ha	"

Each topdressing or liming was done in the autumn. However soil samples were taken for nutrient status and pH determination in order to obtain a general indication of soil fertility at the experimental site. Because the site was part of a normal farm paddock used for grazing sheep and cattle its fertility was considerably higher than would be expected under unimproved natural grassland conditions. The results were obtained after sending the samples to Ruakura Agricultural Research Centre, Hamilton for quick testing. The quick test results are as shown in table 5 below:-

Table 5: Nutrient Status and pH Levels of Experimental Site (Depth of soil sampling = 8cm)

BLOCK	pH	Ca (ppm)	K (ppm)	P (ppm)	Mg (ppm)
1	6.4	1537.5	106	55.2	116.5
2	6.2	1412.5	80	52.0	136.5
3	6.5	1687.5	86	59.2	129.0
4	6.3	1500.0	90	39.2	130.0

Due to frequent topdressing, the nutrient status was fairly even and gradient seemed to have no profound effect except for the lower P level in block 4 at the bottom of the slope. However this lower P level could have been the result of the soil sample being taken from a dung patch because of the higher P-fixing characteristics of organic matter.

3.3 Trial 2.

This trial was a duplication of trial one carried out over the autumn period. A few modifications were made as explained below:-

3.3.1 Existing Vegetation Treatment

3.3.1.1 Short term herbicide treatment

Application of 1.0 kg a.i./ha paraquat was followed by a respraying, to kill numerous grass seedlings, at the rate of 0.5 kg a.i./ha paraquat 12 days later. Herbicide application was the same for plots selected for burning.

Plate 7: Long cover control plot of Trial 2 at sowing. (18/4/1976)

Plate 8: Short cover control plot of Trial 2 at sowing (18/4/1976).

Plate 9: Long cover + long lasting herbicide (Glyphosate) plot of Trial 2 at sowing (18/4/1976).

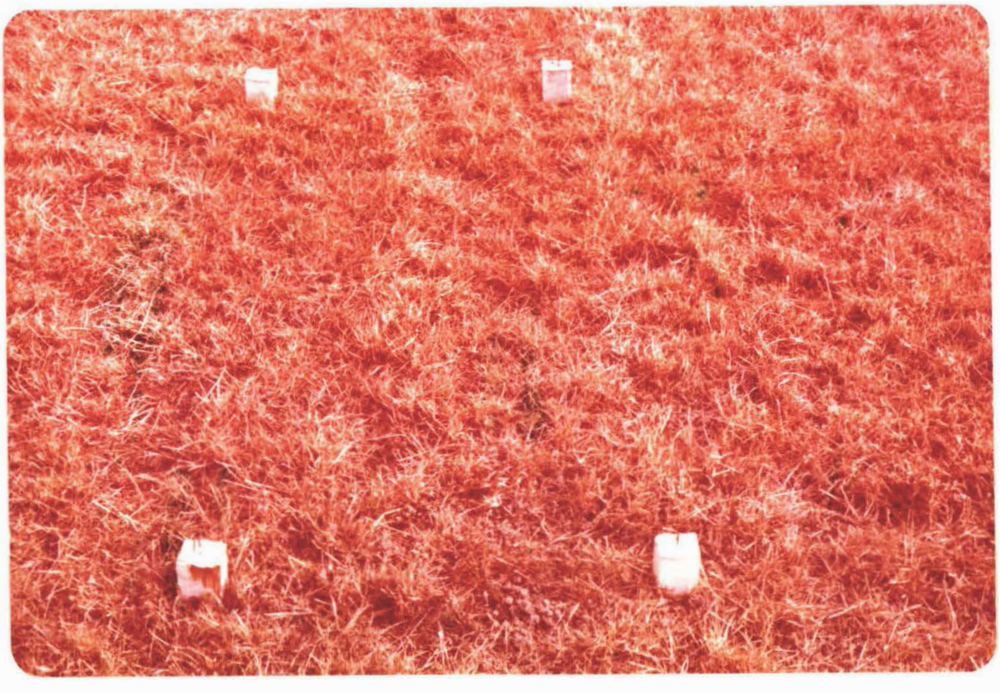


Plate 10: Short cover + short term herbicide (Paraquat) plot of Trial 2 at sowing (18/4/1976).

3.3.1.2 Long lasting herbicide treatment

Glyphosate at a rate of 2 kg/ha was sprayed and 12 days later 0.5 kg a.i./ha paraquat was applied to check germinating seedlings of the resident vegetation, mainly grass. Together with the paraquat 1.0 kg/ha carbetamide was used to check further grass seed germination. Glyphosate was chosen in this second trial because of its potential in chemical cultivation, see section 2, of literature review. See also appendix 1 and plate 9 for the experimental layout and ground cover treatments respectively.

3.3.2 Sowing

22 days after the first chemical application, lucerne was sown in the same way as in the earlier trial (see section 3.2.3). In addition seed was broadcast on the remainder of the plot outside the subplot to allow sampling for growth and nodule assessments at each seedling count. The seed germination tests of lucerne recorded 95% germination for both coated and bare seed.

3.3.3 Slug Counts

This assessment was introduced later during the experimental period to supply a measure of the relative population of slugs in the area as the slugs had detrimental effects on lucerne seedlings. Quadrats of 0.1 m^2 were cut from each plot and metaldehyde slug bait pellets sprinkled on the cut patches at a rate of 5 kg/ha. The slugs attracted to the pellets were collected and counted for each plot for three successive days and the total number of slugs per plot was taken as a measure of the slug population at that period, see section 2.2.3.

3.3.4 Botanical Composition

In addition to herbage dissection to obtain the botanical composition of the pasture, the weeds appearing were recorded to find which species were favoured by the various seedbed preparation techniques employed.

3.3.5 Soil Moisture Content Determination

Soil sampling for moisture determination was done at weekly intervals. A sampling depth of 5.1cm was chosen as it was shown in the earlier trial that differences between 0 - 1.3 and 1.3 - 5.1 cm layers were rarely significant, especially under wetter conditions.

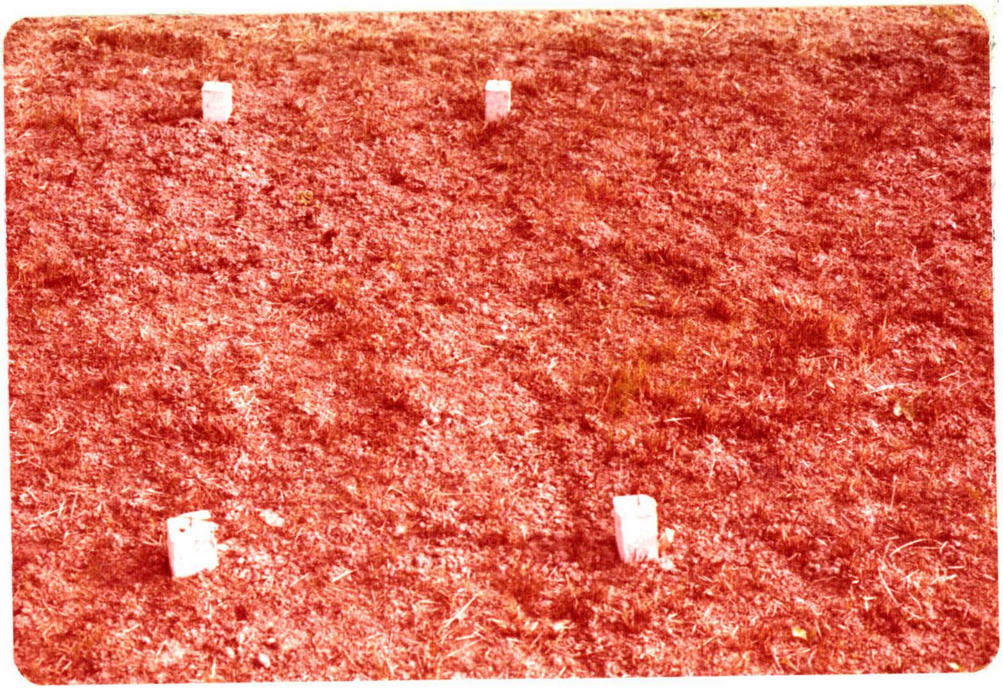


Plate 11: Paraquat + burn plot of trial 2 at sowing (18/4/1976).

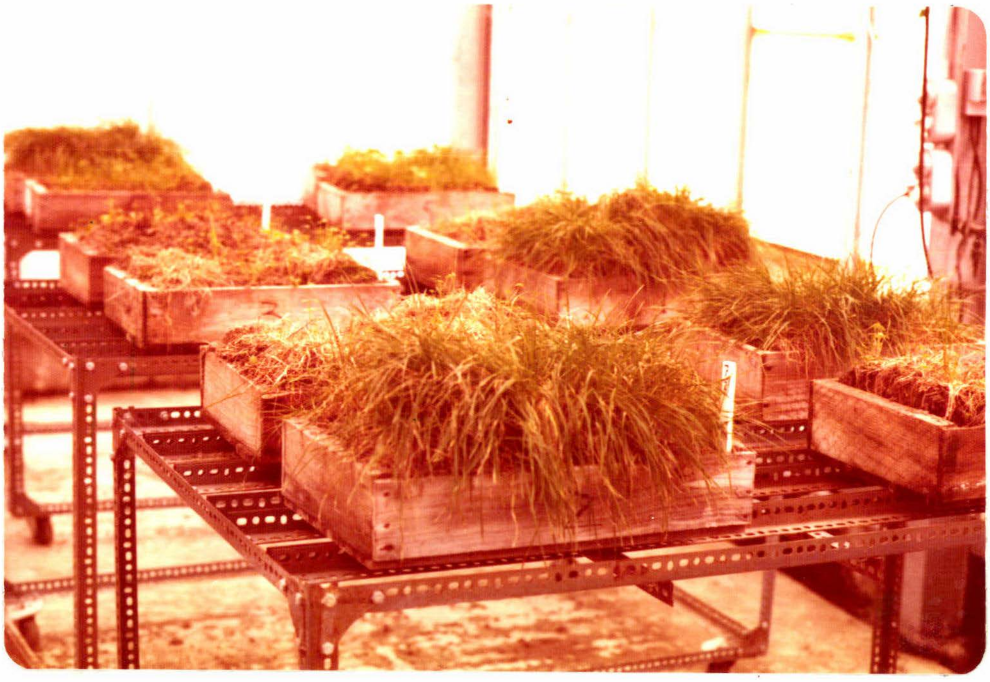


Plate 12: General arrangement of boxes in the glasshouse in Trial 3.

3.4 Trial 3.

Turf was dug from the field trial site from plots which had been sprayed with paraquat at the rate of 1.0 kg a.i./ha and from unsprayed plots. The turf was placed in boxes 45 x 30cm and 15cm deep. The turfs were cut with a spade to fit closely into the boxes. The cover on the turf was long (15cm). The boxes were carted to the glasshouse and left to dry for 14 days and then the treatments were applied as follows:-

3.4.1 Treatments

3.4.1.1 Vegetation

Boxes of live cover, paraquat treated turf and turf burnt after treatment with paraquat were arranged at random in 4 replicates. The burning was done using a gas-burner. See appendix 2 and plate 12 for experimental layout in the glasshouse.

3.4.1.2 Moisture Regime

Two moisture regimes were applied, moist conditions and drying conditions. Moist conditions involved wetting the turf to field capacity (F.C.) twice daily for the first 7 days after sowing and subsequently reducing the watering frequency to once every second day. For the drying regime, the boxes were watered to field capacity once every second day for the first 7 days and thereafter once every 7 days. Air temperature in the glasshouse fluctuated between 15 - 22°C .

3.4.1.3 Sowing

Lucerne seeds were sown as in the two field trials using an improvised structure of similar design to the frame described in section 3.2.3. The seed was inoculated in the laboratory before sowing and had a germination percentage of 95%. The spacing was 5 cm and each plot was sown with 54 seeds. Plate 15 shows the structure used for sowing and seedling counting.

3.4.1.4 Slug Bait Pellets

Slug activity was noticed in the boxes a week after sowing when the lucerne seedlings were mostly in the cotyledon and first primary leaf stages. Slug pellets, as used in trial 2, were sprinkled on the turf at a rate of 5 kg/ha and a week later the treatment was repeated.

3.4.2 Measurements

3.4.2.1 Seedling Counts and Scoring

The methods used were similar to those in the field trials except that counts were done every 7 days for the first 3 counts and 2 weeks elapsed between the 3rd and 4th (final) count. At each count the number of seedlings per box and their condition were recorded.

3.4.2.2 Slug Counts

Slugs attracted to the pellets were collected and counted each day until the conclusion of the trial. The total of these counts per box was taken as a measure of the population of slugs per box. See section 2.2.3.

3.4.2.3 Moisture Levels

Soil samples were taken for moisture determination for both phases of watering. Namely once during the more frequent watering period (first 7 days of the trial) and again during the less frequent watering period (7 days from sowing to conclusion of the trial). See section 3.4.1.2.

3.4.2.4 Growth and Development

At the conclusion of the trial, 10 seedlings were dug from each box. Nodules were counted and plant weights and top/root ratios determined after oven drying for 12 hours at 80°C.

3.4.2.5 Botanical Composition

Cut herbage was dissected into component species, dried in the oven at 80°C for 12 hours and the composition of each species by weight determined as a percentage of the total dry matter. The cut herbage was obtained from a 250 cm^2 quadrat in each box.

3.5 Analysis of Results

The results of all three trials were analysed statistically after the data had been transformed where necessary. Data expressed in percentages was transformed using the square root transformation ($\sqrt{X + \frac{1}{2}}$), (Little and Hill, 1972). Data obtained from counts, such as nodule and slug counts, was transformed by a centering transformation (X + 1), where some plots had zero counts (Gordon, 1976/77 - personal comm.). Analyses of variance were conducted on each set of observations using 3 and 2-Way Analysis of Variance Fortran Programmes developed by Chu (1976/77 - personal comm.). In the case of missing data, missing data calculations were done according to methods given by Steel and Torrie (1960).

Significant differences between treatments have been calculated by means of Duncan's Multiple Range Test. In the tables, means followed by the same letter in any column do not differ significantly and small and capital letters denote probability levels of 5 and 1% respectively. Little and Hill (1972) suggest that this is the most appropriate where several unrelated treatments are included in an experiment. Correlations between seedling counts, ground cover, dry matter and soil moisture were tested for by computing correlation coefficients using Programme-Correl developed by Gordon (1977 - personal comm.). The results are summarized in tables given in Chapter 4.

4 RESULTS

4.1 Trial 1

4.1.1 Germination and Establishment

Lucerne seedlings were counted and scored for stage of growth 15 days (2 weeks) after sowing by which time most seedlings were in the cotyledon stage and a few in the primary leaf stage. This count provided a measure of germination although it is possible that some seeds could have germinated and died by this time; the figures are given in table 6. Since there was no significant difference between coated and bare seeds, the means for the 7 ground cover treatments are used in the tables and figures. The highest germination took place on the burnt plots, i.e. an average of 78 seedlings per plot (31% germination) and the lowest occurred on the long cover control plots, i.e. 5 seedlings per plot (2% germination). Early establishment was assessed by the second count, 35 days (5 weeks) from sowing. Later counts were made for a further 8 weeks when the 5th and final assessment was made but, as shown in table 6, later counts showed no significant change from the second count (details of counts 3 and 4 are given in Appendix 4).

Table 6: Effects of ground cover treatments on lucerne germination and survival 15, 35 and 91 days after sowing. (Sowing Date:- 10-13/12/1975).

Seedling Counts	1			2			5		
Dates	26-29/12/1975			16-17/1/1976			12-13/3/1976		
Days from sowing	15 (2 weeks)			35 (5 weeks)			91 (13 weeks)		
Ground Cover	Seedling Numbers	% Germination Actual	% Germination Transformed	Seedling Numbers	% of Seed Sown Actual	% of Seed Sown Transformed	Seedling Numbers	% of Seed Sown Actual	% of Seed Sown Transformed
1. Long cover control	5	2	1.13 dC	0	0	0.71 dD	0	0	0.71 dD
2. Short cover control	40	16	3.81 bc AB	1	0.2	0.77 dD	0	0	0.71 dD
3. Long cover + long term paraquat treatment (Para 1*)	33	13	3.07 c BC	23	9	2.67 bc BC	20	8	2.61 bB
4. Long cover + short term paraquat treatment (Para 2*)	30	12	3.17 c BC	10	4	1.97 cC	8	3	1.82 cC
5. Short cover + long term paraquat treatment (para 1)	71	28	5.28 ab AB	66	26	5.07 a A	63	25	5.05 aA
6. Short cover + short term paraquat treatment (para 2)	60	23	4.60 abc AB	33	13	3.45 bB	30	12	3.30 bB
7. Paraquat + burning	78	31	5.52 Aa	60	23	4.77 aA	53	21	4.64 aA
LSD (0.05)			1.53			0.79			0.72
LSD (0.01)			2.04			1.05			0.96
Std. Error			0.76			0.39			0.36
Coeff. Var			39.8			28.0			26.5

* See Appendix IA.

The results of the first count show that higher percentage germination occurred on plots with smaller amounts of ground cover. The percentages were significantly higher with short cover compared with long cover ($P < 0.01$) and on paraquat sprayed compared with unsprayed plots ($P < 0.01$). The highest germination took place where the cover was burnt following desiccation with paraquat and the lowest on long cover control plots. The same trends persisted until the closure of the trial; lucerne survival was favoured by the seeds being oversown on burnt or desiccated plots where regrowth of the knocked-back resident species was slowest during the first 35 days after sowing (See figures 1, 2 and 3).

4.1.2 Ground Cover Dry Matter

4.1.2.1 Initial dry matter of cover and regrowth

Ground cover dry matter assessments expressed in kg/ha, are shown in table 7. As would be expected, the burnt plots had the lowest weights of cover on 5/12/1975 (5 days before sowing) followed by the short cover treatments, then the long cover plus paraquat. The long cover controls had the highest weights. This trend progressively changed as regrowth started until by the final harvest, 102 days (15 weeks) later, the burnt plots and long cover control plots had almost the same amount of dry matter.

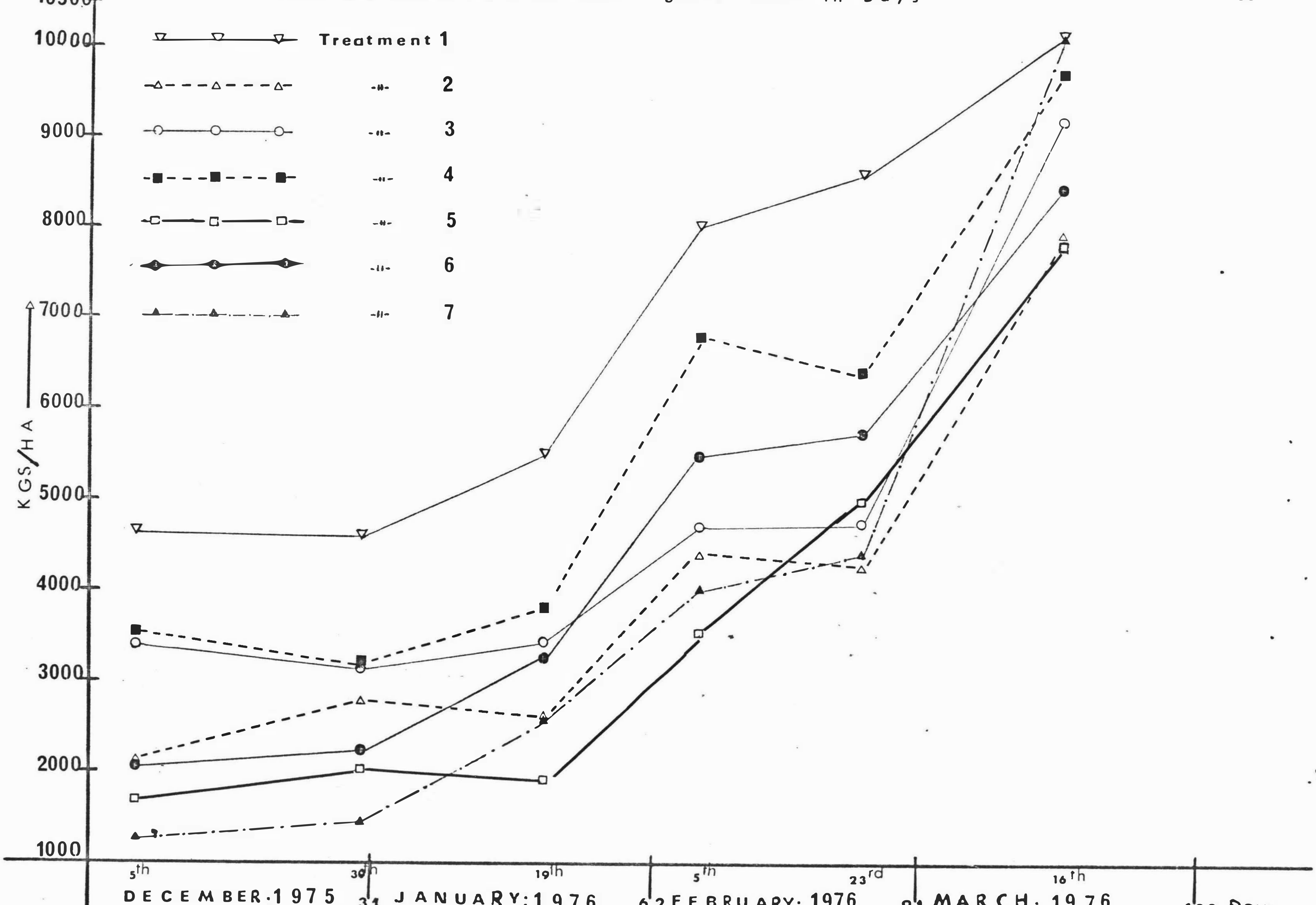
Table 7: Ground Cover Dry Matter (kg/ha) of Cuts Taken at Sowing and subsequent counting and scoring dates.

Cuts	1	2	3	4	5	6
Cutting Dates	5/12/1975	30/12/1975	19/1/1976	5/2/1976	23/2/1976	16/3/1976
1. Long cover control	4677aA	4614aA	5466aA	8008aA	8658aA	10254aA
2. Short cover control	2188cCD	2771bBC	2636cdCD	4381cdCD	4235cB	7992cB
3. Long cover + para 1*	3360bB	3091bB	3419bcBC	4664cdCD	4596cB	9150abcAB
4. Long cover + para 2*	3511bB	3099bB	3803bBC	6776bAB	6396bB	9703abA
5. Short cover + Para 1	1658cdCD	1993 dDE	1888dD	3527dD	4952bcB	7880cB
6. Short cover + para 2	2200cC	2277cdCD	3318bcBC	5494cBC	5708bcB	8400bcAB
7. Para 2+burn	1260dD	1432eE	2640cdCD	4025dCD	4417cB	10205aA
LSD (.05)	687	439	854	1177	1506	1297
LSD (.01)	919	588	1142	1575	2016	1735
Standard Error	340	217	422	582	745	642
Coeff. Var.	25.2	15.8	25.5	22.1	26.7	14.1

* Para 1 = long term paraquat treatment and Para 2 = short term paraquat treatment.

From Table 7 and Figure 1 it is clear that regrowth of the resident and volunteer pasture species and invasion by weeds was slowest in the longer term paraquat treatments; by the 4th harvest, the short cover plus long term paraquat treatments had the lowest amount of regrowth. Regrowth of cover on the burnt plots started slowly but became rapid from February onwards. On all chemically treated and burnt plots, regrowth was mainly from germinating grass, clover and weed seeds rather than from the desiccated or burnt grass stubble, except for the short term herbicide treatments (paraquat 2) where some stubble regrowth was observed from the 3rd cut onwards.

FIGURE 1: Ground Cover D.M. Against Time in Days



4.1.2.2 Relationships between lucerne seedling numbers and dry matter of cover during the first 5 weeks after sowing.

Figure 2 suggests that the denser the ground cover at sowing (i.e. the higher the dry matter) the lower the seedling numbers at the first count 15 days later. Statistical analysis shows a negative correlation, $r = -0.97$ ($P < 0.01$). Seedling numbers were also closely correlated $r = -0.98$ ($P < 0.01$) with cover dry matter as assessed at the second cut, 18 days after sowing. The negative correlation with the early ground cover dry matter figures was maintained at the subsequent counts, for example, seedling numbers obtained at the second count were negatively correlated with ground cover dry matter of cuts 2 and 3, $r = -0.81$ and $r = -0.78$ respectively ($P < 0.05$). See Figure 3. Also lucerne plant numbers obtained at the 5th and final count were negatively correlated with ground cover dry matter of counts 1, 2 and 3 at the 5% level of significance ($r = -0.78$, $r = -0.79$ and $r = -0.78$ respectively).

The effects of the short cover control treatment (treatment 2) however, were greatly increased, so that few or no seedlings survived after the first count with either the long or short cover controls. With the other treatments seedling numbers from 35 days onwards did not change appreciably up to the final count 56 days later. The only noticeable change was in the vigour and size of the seedlings; plants subjected to more intensive competition from regenerating cover making less growth (See section 4.1.5.2 - Table 12).

FIGURE 2: Relationships Between Seedling Count 1 and Ground Cover D.M. – Cut 1 & 2 15 Days After Sowing.

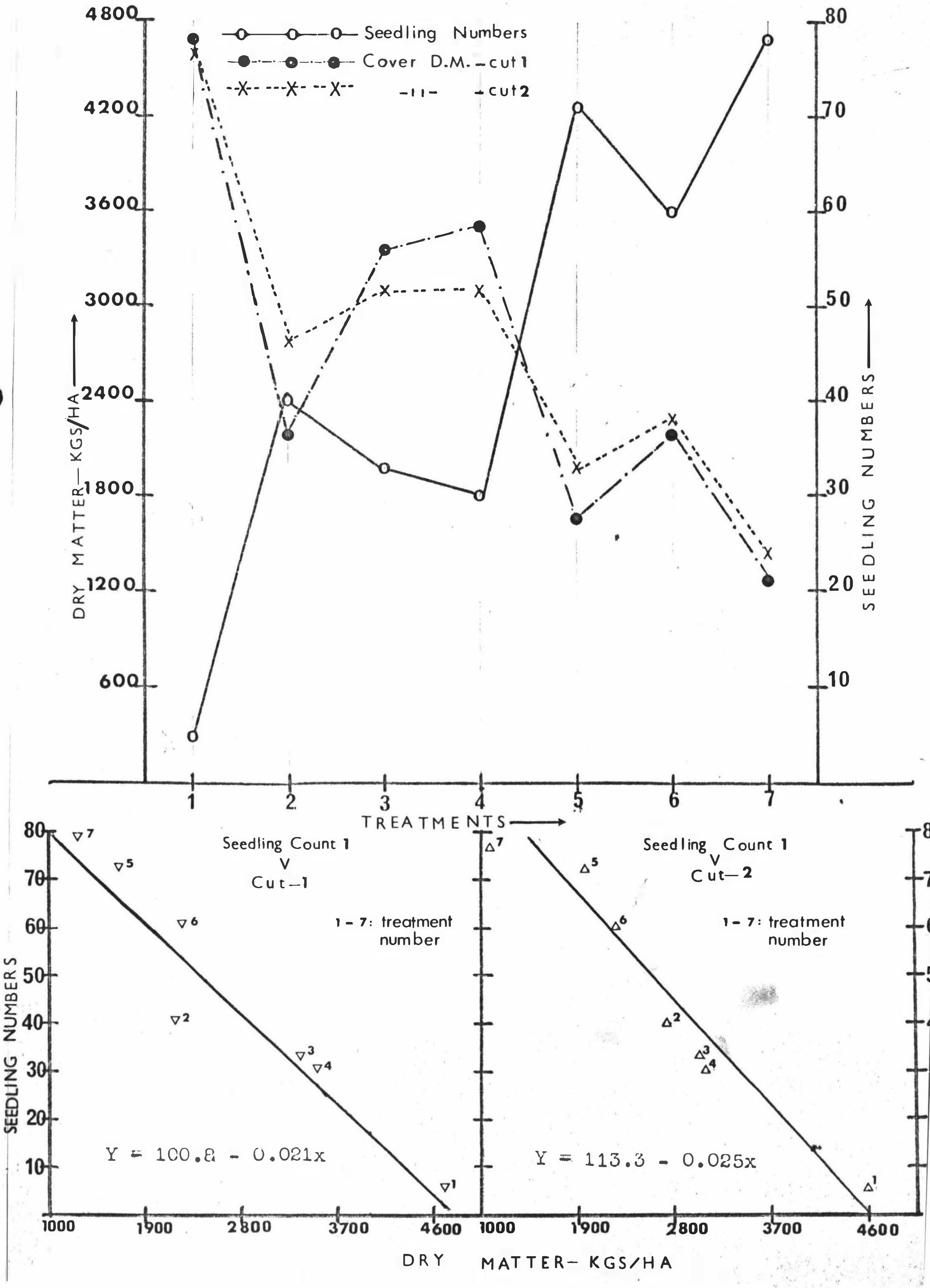
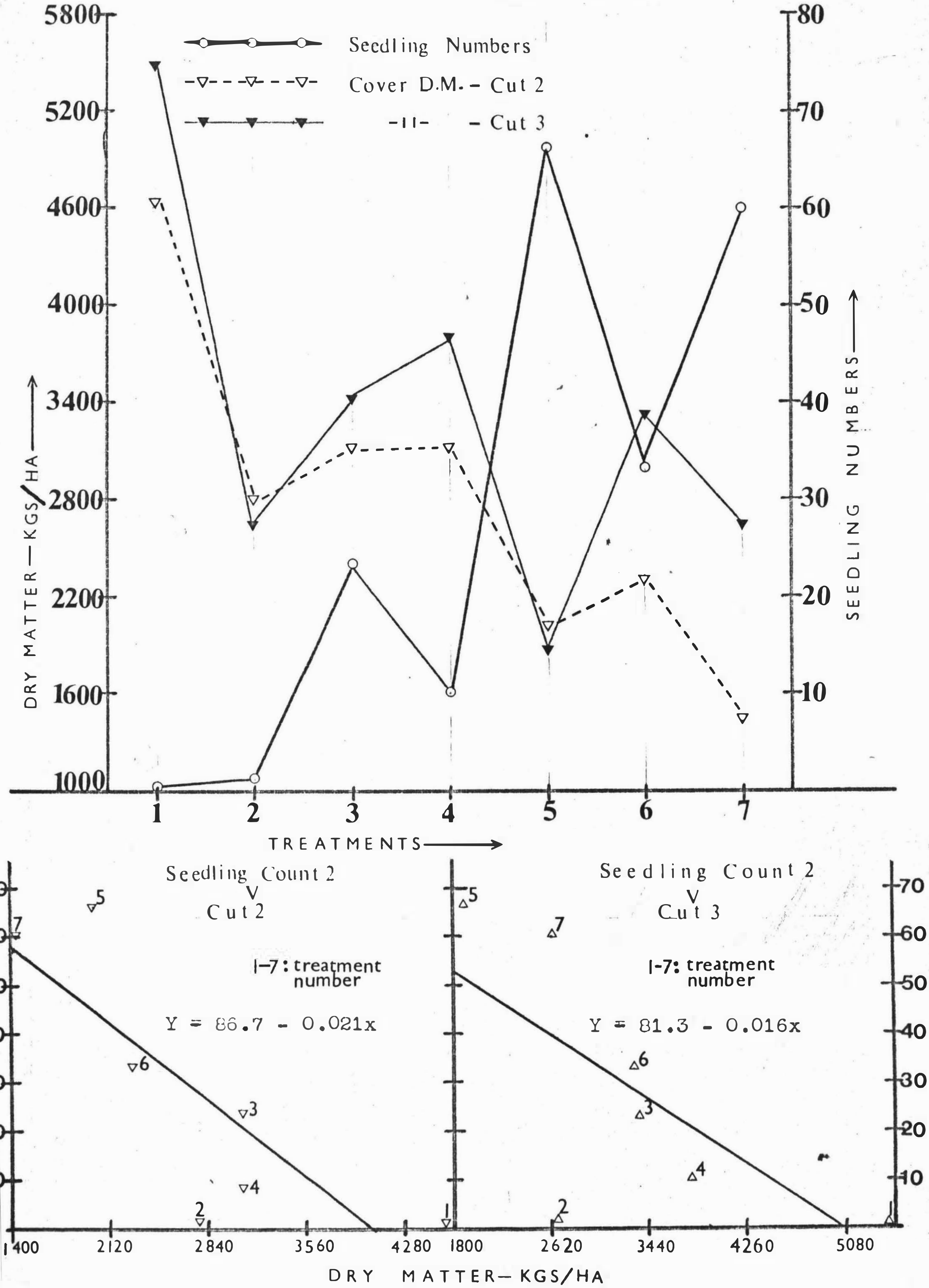


FIGURE 3: Relationships Between Seedling Count 2 and Ground Cover D.M. - Cut 2&3.



4.1.3 Soil Moisture and Rainfall

Soil moisture content was high throughout the trial period with a peak occuring in December, 1975. Gradually the soil moisture level declined, reaching its lowest in March, 1976 when the final soil samples were taken. This soil moisture pattern is closely related to the rainfall over the period (see tables 8 and 9 and figure 4). For example, from January through February and most of March, 1976 rainfall decreased. Figure 4 shows that the low soil moisture level on 23rd December, 1975 corresponded with 5 days without rain; also the high level of soil moisture on the 28th December, 1975 was connected with the 10.9mm rainfall recorded on that day. The graphical expression in Appendix 5 shows that the summer of 1975/76 was abnormally wet, particularly the months of November, December and January.

Soil samples taken from different layers, namely the top 1.3cm, 1.3 - 5.1 cm and 5.1 - 15.2 cm showed different responses to the rainfall pattern. The top layer became drier after a dry period and wetter soon after rain thus showing greater fluctuations. The 1.3 - 5.1 cm layer fluctuated with rainfall but not as rapidly as the top layer. The 5.1 - 15.2cm layer was drier than the surface layers when the average soil moisture was high but became wetter as the average moisture level declined with lower rainfall.

At the commencement of soil sampling, the long cover + paraquat plots had significantly higher moisture contents than short cover control plots ($P < 0.05$). The drier the soil the more the dead cover effects were shown. This trend was maintained, even though the differences were not significant statistically for many sampling dates. With live cover, where it was short, moisture was lost both from evaporation and transpiration, while on the short cover paraquat and burnt plots loss of moisture was mainly through evaporation. This probably accounts for the short cover control being significantly drier than treatment 3 and 4 at first soil sampling on 13/12/1975.

Table 8: Soil Moisture Content (%) From Samples Taken at Various Stages During Trial 1

Key: A = Top 1.3 cm; B = 1.3 - 5.1 cm layer and C = Top 5.1 cm.

Ground Cover Treatments

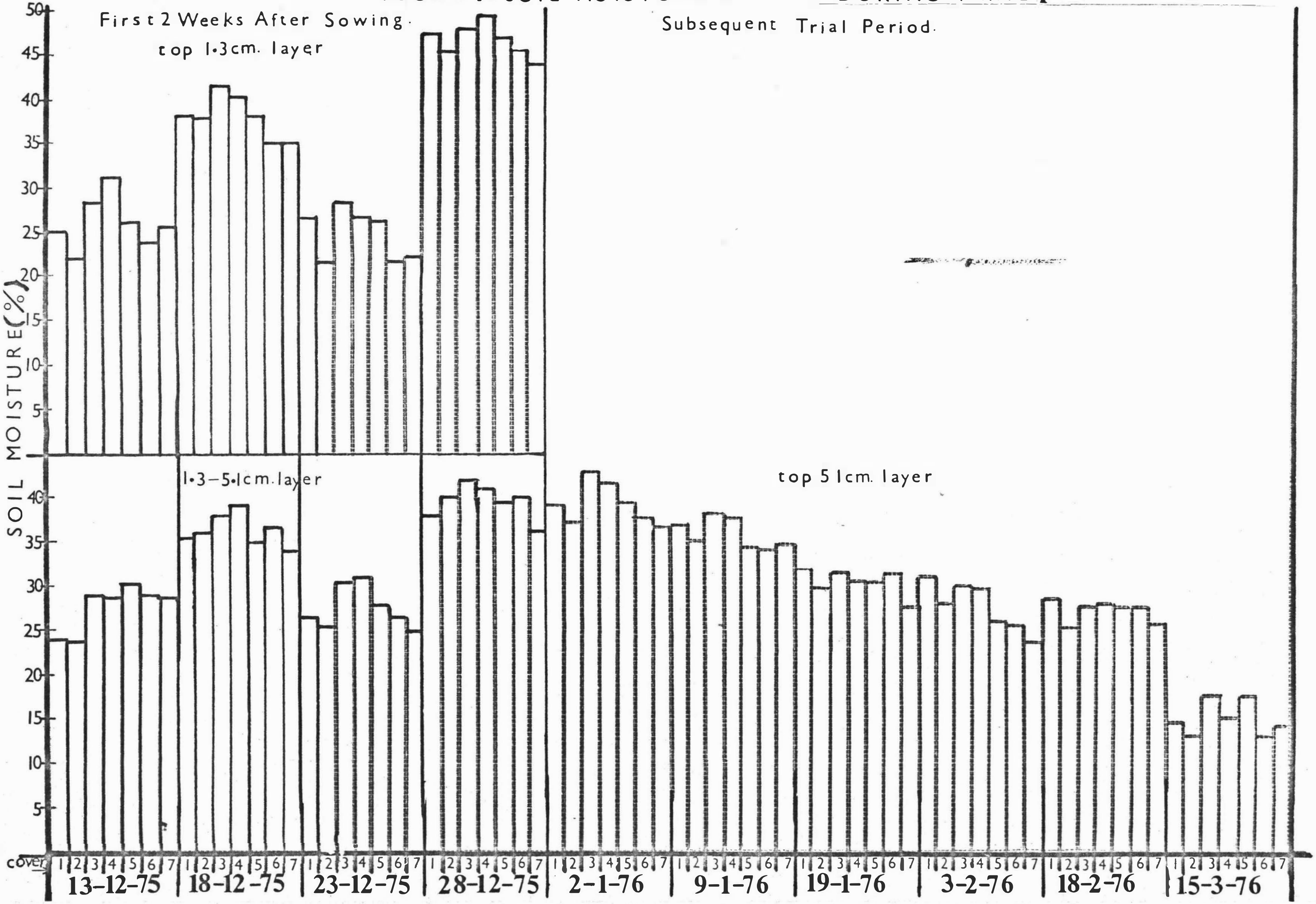
Date	1 13/12/1975		2 18/12/1975		3 23/12/1975		4 28/12/1975		5 2/1/76	6 9/1/76	7 19/1/76	8 3/2/76	9 18/2/76	10 15/3
Soil Layer	A	B	A	B	A	B	A	B	C	C	C	C	C	C
Long cover Control (1)	25.1bc	24.4bBC	38.3a	35.4bAB	26.5ab	26.6bAB	47.3a	37.9bcAB	39.0bcABC	36.7abc	32.0aA	31.0aA	28.5a	14.5
Short cover Control (2)	22.1c	24.0bC	37.9a	36.0bAB	21.6b	25.4 bB	45.3a	39.9abAB	37.2cBC	35.2abc	29.7abAB	27.9abcAB	25.3a	13.0
Long cover+ Paraquat* (3)	27.7ab	29.1aAB	41.4a	37.9aAB	28.4a	30.4aA	48.2a	41.7aA	42.7aA	38.2a	31.5aAB	30.0abA	27.6a	17.5
Long cover + Paraquat2* (4)	31.2a	28.8aAB	40.0a	39.3aA	26.5ab	30.8aA	49.5a	41.0aA	41.4abAB	37.7ab	30.5aAB	29.6abA	27.8a	15.0
Short cover + Paraquat 1 (5)	26.1abc	30.3aA	37.9a	34.9bB	25.9ab	27.8abAB	47.1a	39.6abAB	39.4bcABC	34.4bc	30.4aAB	26.1bcAB	27.4a	17.5
Short cover + Paraquat2 (6)	23.8bc	29.0aAB	34.9b	36.6aAB	21.4b	26.5bAB	45.6a	40.1abAB	37.3cBC	33.8c	31.4aAB	25.5cAB	27.6a	13.0
Paraquat + Burning (7)	25.5bc	28.8aAB	34.9b	34.3bB	22.3b	24.9bB	44.0a	36.3cB	36.6cC	34.5bc	27.5bB	23.5cB	25.5a	14.0
LSD(.05)	5.1	3.4	4.4	2.9	5.4	3.6	5.9	3.2	2.9	3.4	2.8	3.9	3.4	1.5
LSD(.01)	6.8	4.5	5.9	3.9	7.3	4.8	7.9	4.2	3.9	4.6	3.7	5.2	4.5	2.0
Standard Error	2.5	1.7	2.2	1.4	2.7	1.8	2.9	1.6	1.4	1.7	1.4	1.9	1.7	0.7
Coeff. Var.	19.5	12.1	11.6	7.9	21.8	12.9	12.4	7.9	7.3	9.4	9.1	13.9	12.3	10.0
									5.1 - 15.2cm Layer					
Treatment5(mean of 4 samples)									29.1	27.4	24.6	22.6	22.2	15.2

* Paraquat 1 = Long Term Paraquat Treatment
Paraquat 2 = Short Term Paraquat treatment

Table 9: Daily Rainfall (mm) for December 1975 Through to 31st March 1976

Date	December, 1975	January 1976,	February, 1976	March, 1976	
	Rainfall in Millimeters				
1	0.0	1.9	1.1	0.0	
2	1.3	5.2	0.0	0.0	
3	0.0	0.0	0.0	0.0	
4	0.0	0.0	0.0	0.0	
5	0.0	0.0	0.0	0.0	
6	0.0	0.0	22.8	0.0	
7	0.0	0.0	3.7	0.0	
8	0.0	0.0	0.0	3.0	
9	0.1	8.2	0.4	0.2	
10	11.2	3.2	22.1	0.0	
11	0.0	13.4	0.4	0.0	
12	0.0	4.0	0.0	0.0	
13	0.0	22.4	0.0	0.0	
14	0.0	4.1	0.0	0.0	
15	0.0	0.0	0.0	0.0	
16	34.4	3.7	0.0	0.0	
17	0.9	0.0	0.0	0.0	
18	15.1	0.0	0.0	0.0	
19	0.0	0.0	0.0	0.0	
20	0.0	0.0	0.4	0.0	
21	0.0	0.0	0.0	0.0	
22	0.0	3.0	0.0	0.5	
23	0.0	12.7	0.0	0.8	
24	15.9	0.0	0.0	0.0	
25	6.0	0.0	7.3	0.0	
26	0.0	3.1	2.2	0.0	
27	0.4	0.3	0.0	3.7	
28	10.9	3.4	0.0	36.0	
29	0.0	0.0	0.0	25.1	
30	0.3	0.4		8.2	
31	5.2	1.2		7.9	
Total	101.7	90.2	60.4	85.4	337.7

FIGURE 4: SOIL MOISTURE LEVELS DURING TRIAL 1



4.1.3.1 Seedling count and soil moisture relationships during the first 35 days of lucerne growth.

Figure 5 and 6 show that the seedling numbers assessed at the first two counts were not significantly correlated with soil moisture levels recorded at various times during the 18 days after sowing. This suggests that, although there were some significant differences in soil moisture level particularly at first sampling, between treatments ($P < 0.05$), this was not a factor limiting lucerne germination and establishment.

4.1.4 Relationships Between Germination/Establishment, Ground Cover Dry Matter and Soil Moisture.

Lucerne germination and establishment, expressed as percentage of seed sown were found to be negatively correlated with initial ground cover dry matter of cuts 1, 2 and 3 (see section 4.1.2.2). However soil moisture levels were not significantly correlated with seedling numbers although a positive correlation was shown ($r = 0.14$). Ground cover dry matter and soil moisture level were found to be positively correlated. For example, ground cover dry matter of cut 1 and soil moisture level from sample 1, taken on 13/12/1975 had a correlation coefficient $r = 0.73$ ($P < 0.10$) but as the soil moisture level increased with rainfall this correlation became less and less pronounced.

In general, the only meaningful correlations are those obtained for the relationships between seedling numbers and ground cover dry matter of cuts 1, 2 and 3.

FIG 5: RELATIONSHIPS BETWEEN SEEDLING COUNT 1 (26-29/12/75) AND SOIL MOISTURE MEASUREMENTS IN 0-1·3 cm LAYER (SM I - SM4)

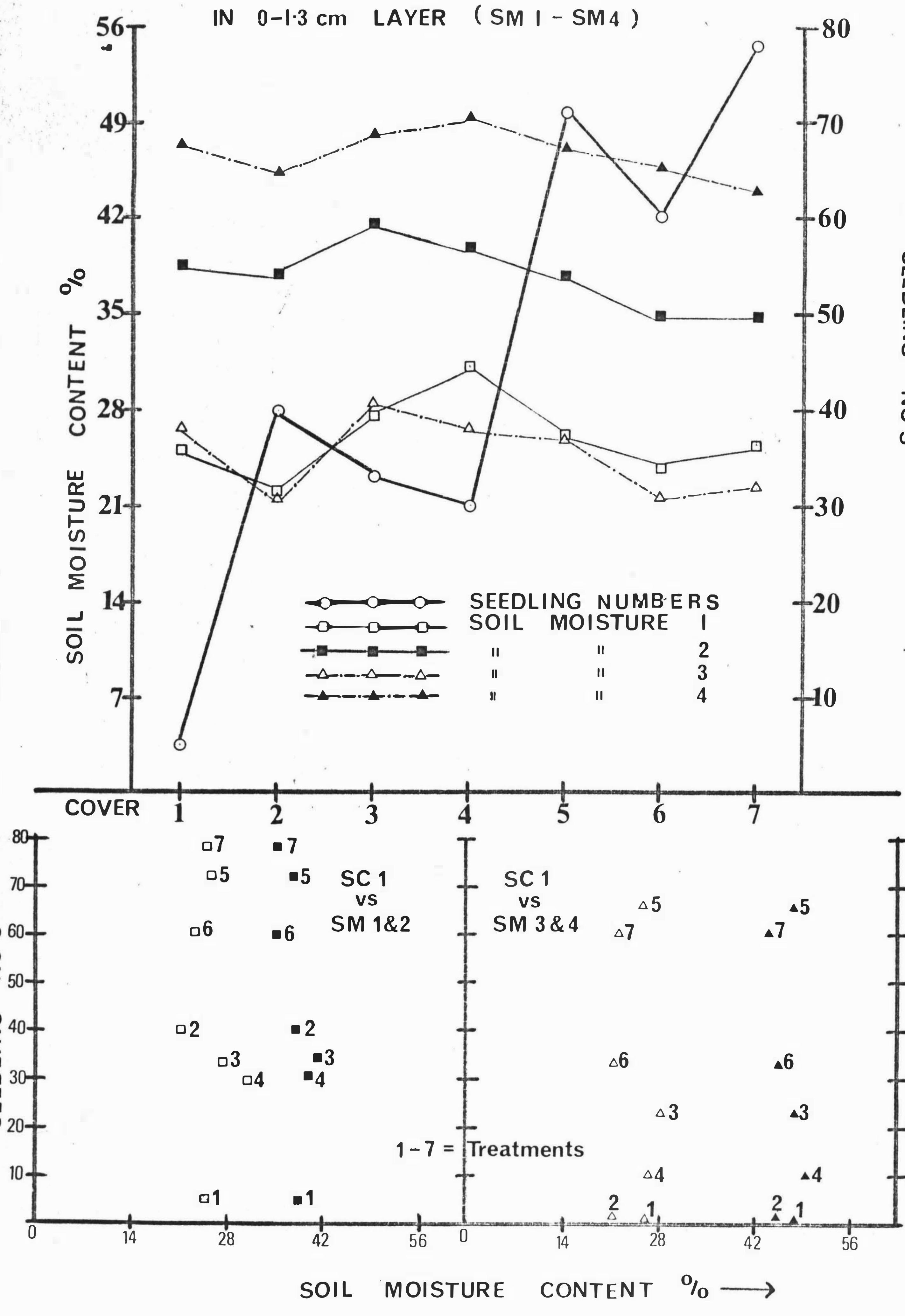
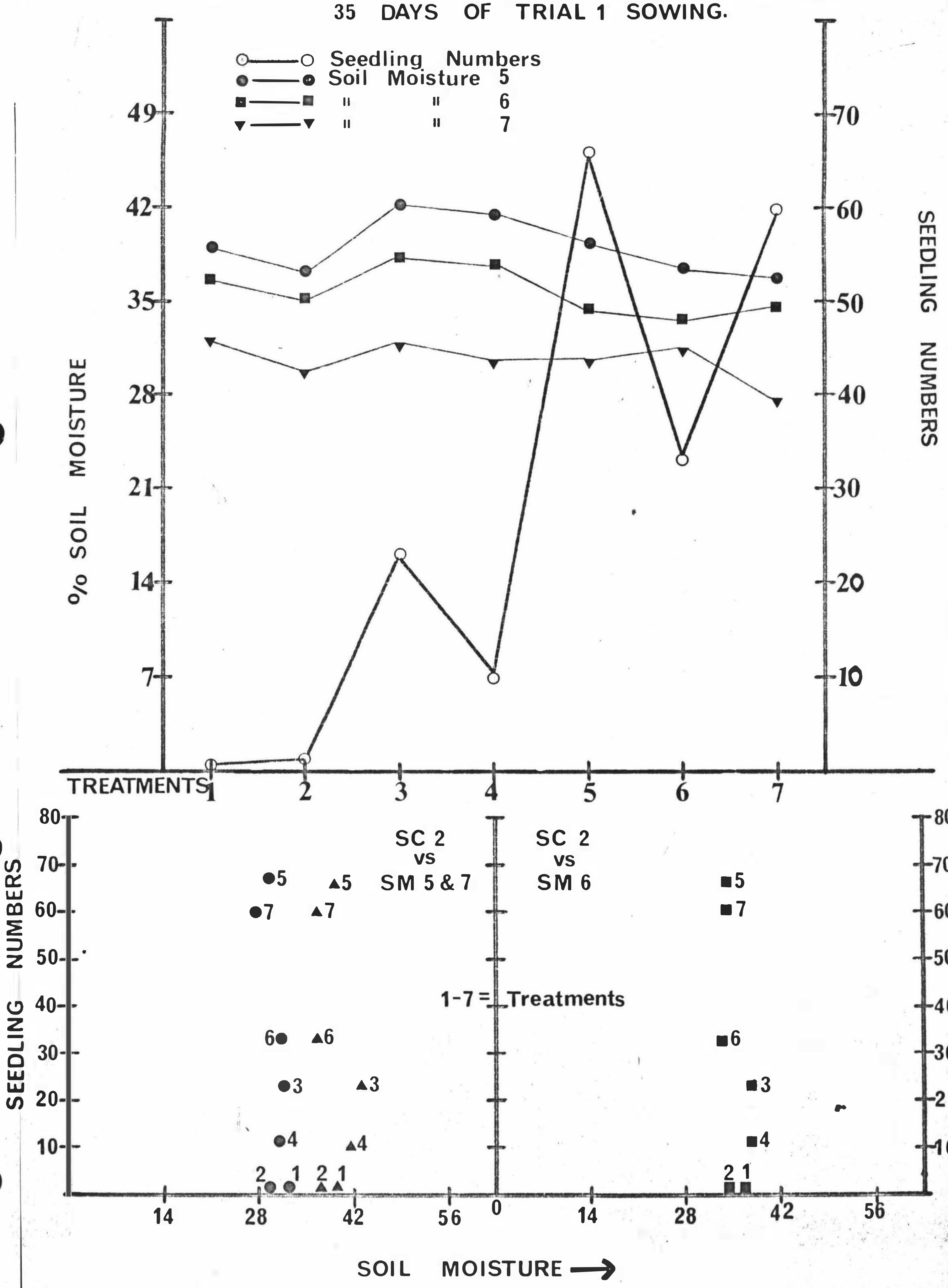


FIG. 6: RELATIONSHIPS BETWEEN SEEDLING COUNT 2 AND SOIL MOISTURES 5, 6 & 7 WITHIN 35 DAYS OF TRIAL 1 SOWING.



4.1.5 Lucerne Growth at Conclusion of Experiment 96 days (14 weeks) After Sowing.

4.1.5.1 Botanical composition by dissection and visual Assessment.

Table 10 gives the mean percentage lucerne per plot as obtained from dissection of cut herbage (2 x 1000 cm^2 quadrats per plot) and by visual assessment. The percentages are related to the final mean plant numbers per plot and to the total dry matter of herbage cut and dissected.

Table 10: Effects of cover treatments on final percentage lucerne in herbage.

Ground Cover Treatments	Mean Lucerne Numbers Per Plot	Mean Total DM of Herbage Dissected (G.M.)	Percentage Lucerne			
			Dissection		Visual Assessment	
			Actual	Transformed	Actual	Transformed
1 Long Cover Control	0	93.1a	0	0.71cD	0	0.71cC
2 Short Cover Control	0	75.1b	0	0.71cD	0.3	0.82cC
3 Long Cover + Paraquat 1*	20	86.6ab	11	2.73bBC	18	3.41abAB
4 Long Cover + Paraquat 2*	8	81.6ab	0.3	0.84cD	0.9	1.02cC
5 Short Cover + Paraquat 1	63	75.2b	22	4.60aA	27	4.96aA
6 Short Cover + Paraquat 2	30	73.4b	3	1.73bcCD	5	2.11bcBC
7 Paraquat + Burning	53	72.7b	17	4.01aAB	21	4.44aA
L S D (.05)		14.0		1.06		1.47
L S D (.01)		18.7		1.41		1.97
Standard Error		6.9		0.52		0.73
Coeff of Variation		17.4		47.8		58.3

* Paraquat 1 = Long term paraquat treatment

* Paraquat 2 = Short term paraquat treatment

The data in the table indicates that lucerne only made a significant contribution towards the final total dry matter of the herbage on the plots treated with long term paraquat (treatments 3 and 5) and on the burnt plots (treatment 7). Again it is shown here that where regrowth of ground cover commenced early, the lucerne percentage was low both by weight and visual assessments. For example, long cover + long term paraquat treatment (slower regrowth) and short cover + short term paraquat treatment (rapid regrowth) had averages of 20 and 30 lucerne plants per plot respectively and yet the herbage on the former had 11% lucerne and on the latter only 3% lucerne by weight. Here a function of individual plant size and weight is indicated (see table 12). The lucerne percentage assessed both by dissection and visually showed the same trend although the visual estimations were slightly higher than the figures obtained by dissection.

Figure 7 gives a general summary of the percentages of lucerne, grass, clover and weeds in each treatment. Where lucerne and weed percentages are relatively higher, percentage grass is low and vice versa; again treatment 3, 5 and 7 show this relationship quite clearly. Plate 13 and 14 also show a clear difference in the weed population between paraquat treated plots and controls. The table in Appendix 5A shows the levels of significance of the differences between treatments in the proportions of lucerne, grass, clover and weeds.

The lucerne sowing rate used in this trial was equivalent to approximately 3 kg/ha, based on the figure of 450,000 seeds/kg estimated by Halse and Francis (1974). In normal farming practice sowing rates of 9 - 11 kg/ha are recommended (Langer, 1973) so that the contribution made by lucerne towards the total dry matter of the herbage in the present trial would be expected to be lower than in a commercial crop.

FIGURE 7: Botanical Composition – dissection(d) & visual assessment(v).

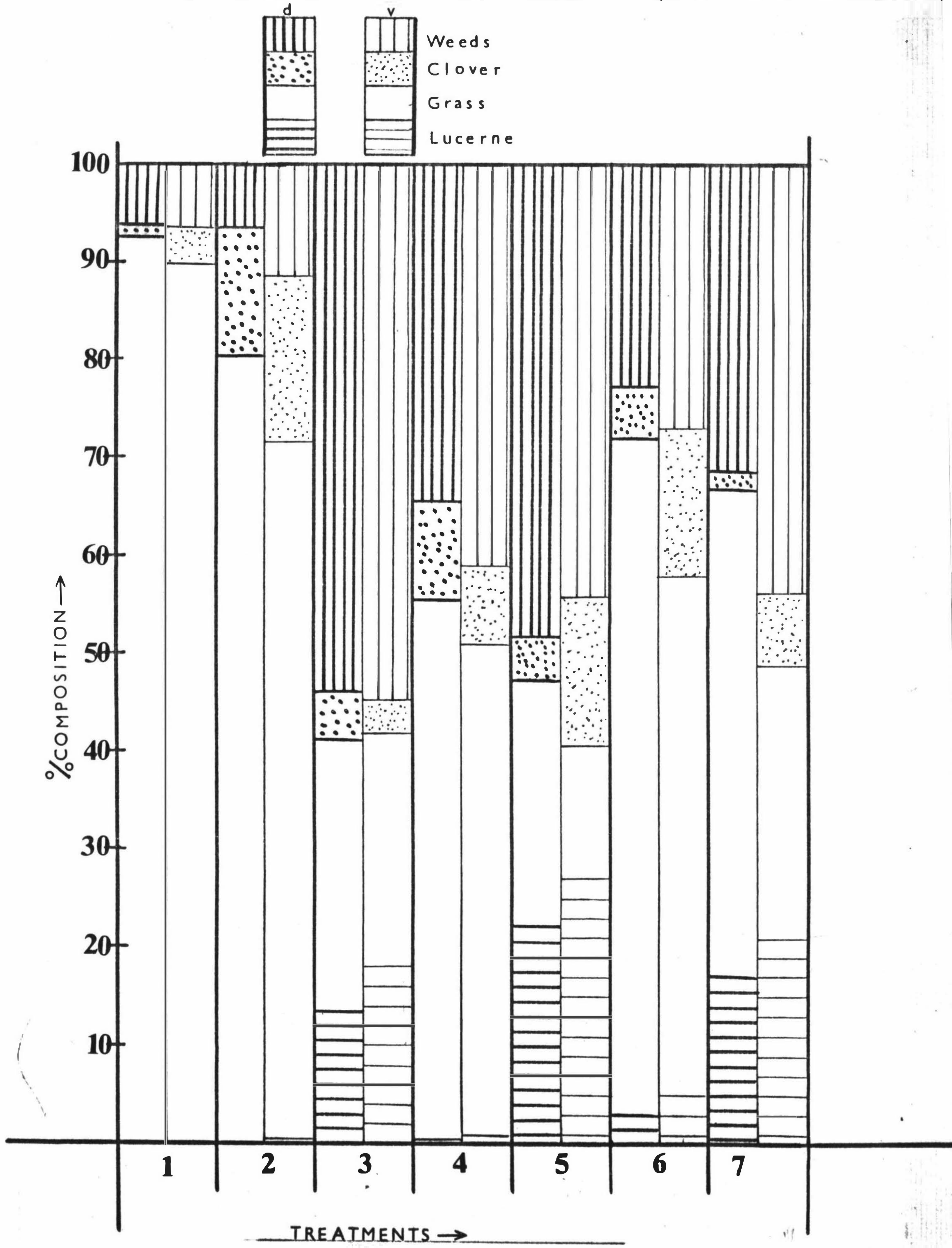


Plate 13: Short cover control plot at the end of Trial 1. Note the sparse weed population. (15/3/1976).

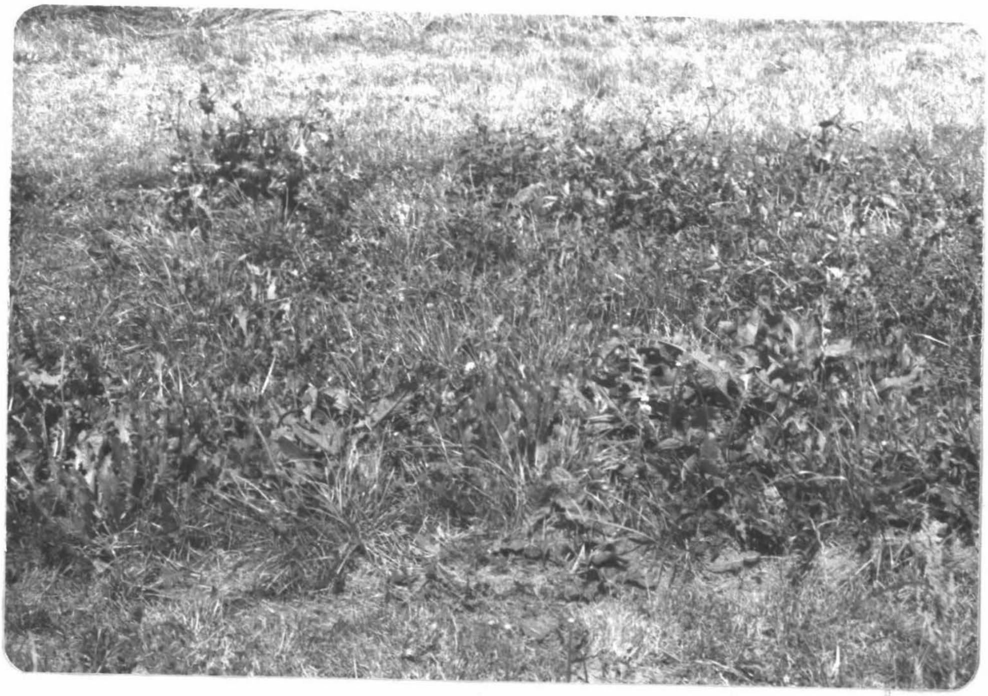


Plate 14: Long cover + paraquat 1 plot at the end of Trial 1. Note the dense population of weeds mainly *Taraxacum officinale*, *Sorchus oleraceus* and *Rumex obtusifolium* (15/3/1976).

4.1.5.2 Individual plant weights (total of shoot and root), nodule numbers and top/root ratios.

In table 11, the relationships between individual plant weight, nodule numbers per plant and the shoot/root ratio are shown. Treatments 1 and 2 (controls) are omitted because there were no plants to sample at the conclusion of the experiment. The differences between bare and coated seed are also examined in this table.

Table 11: Effects of cover and seed treatment on lucerne dry weights and nodule numbers.

Ground Cover Treatments	Individual plant dry Weights - total of root + shoot (gm)			Nodule Numbers per plant			Shoot/Root ratios		
	Bare Seed	Coated Seed	Mean	Bare Seed	Coated Seed	Mean	Bare Seed	Coated Seed	Mean
	***		**	***		**	***		**
3. Long Cover + Para 1*	6.20aA	6.60aA	6.45aA	3.60aA	3.50aA	3.55bB	1.30a	1.57a	1.44a
4. Long Cover + Para 2*	1.17aA	1.23aA	1.20cC	6.40aA	1.30bB	3.85bAB	0.97a	0.86a	0.92a
5. Short Cover + Para 1	7.28aA	3.34bB	5.31aAB	10.60aA	3.10bB	6.85aA	1.71a	0.77a	1.24a
6. Short Cover + Para 2	1.38bB	3.20aA	2.29bcC	7.40aA	2.70bB	5.05abAB	1.12a	1.08a	1.10a
7. Paraquat + Burning	2.92aA	3.47aA	3.20bBC	9.20aA	4.20bB	6.70aAB	0.84a	1.01a	0.93a
Means for Seed Type	**** 3.81a	3.57a		**** 7.44aA	2.96bB		**** 1.19a	1.06a	
LSD (0.05)			1.72			2.30			0.62 NS
LSD (0.01)			2.33			3.10			0.83
STD ERROR			0.84			1.12			0.66
COEFF. VAR.			45.5			13.6			36.3

* Para 1 = Long term paraquat treatment and para 2 = Short term paraquat treatment

** Compares treatment means down the column

*** Compares means for interactions

**** Compares means for seed type.

In Table 11, it is shown that, where regeneration of the resident species and weeds was rapid, final lucerne plant dry weight was reduced significantly. Thus the mean lucerne dry weight from long cover + short term paraquat treatment was significantly lower than that of long cover + long term paraquat treatment ($P < 0.01$). Table 12 also shows the relationship between final individual plant dry weight and the ground cover dry matter during the first 35 days after sowing.

For nodule numbers per plant, there was a significant difference between bare seed and coated seed ($P < 0.01$) and also significant interactions in the case of the short cover paraquat treatments, 5 and 6 ($P < 0.01$). The shoot/root ratios indicate that, they were very variable and the differences were non significant. It is also indicated, from Table 11, that there was no clear relationship between lucerne dry weights and nodule numbers but observations during nodule counting suggested that larger plants tended to have larger nodules.

In Table 12, the influence of ground cover dry matter during the first 35 days after sowing on the individual plant dry weight at the end of the trial is shown. Again in this table, treatments 1 and 2 (Long cover and Short cover Controls) are omitted because no plants survived with these treatments.

Table 12: Influence of ground cover during the first 35 days of lucerne germination and establishment on individual plant dry weight (gm) at the end of trial 1.

Ground Cover Treatment	Mean Lucerne Individual Plant Dry Weights (gm)	Ground Cover			
		Cut I	Cut 2	Cut 3	%
		Kg/ha	kg/ha	kg/ha	Growth of Cover
1 Long Cover Control	-	4677	4614	5466	17%
2 Short Cover Control	-	2188	2771	2636	20%
3 Long Cover + Paraquat 1*	6.45	3360	3091	3419	2%
4 Long Cover + Paraquat 2*	1.20	3511	3099	3803	8%
5 Short Cover + Paraquat 1	5.31	1658	1993	1888	14%
6 Short Cover + Paraquat 2	2.29	2200	2277	3318	51%
7 Paraquat + Burning	3.20	1260	1432	2640	110%

* Paraquat 1 = Long term paraquat treatment; Paraquat 2 = Short term paraquat treatment.

From the table it is evident that, where the cover was live and regrowth started early, the lucerne seedlings developed into etiolated plants and in treatments 1 and 2, 100% seedling loss occurred. Weak seedlings or plants contributed little to the total dry matter of the herbage at the end of the trial (see Table 10). It is interesting to compare the lucerne growth on Treatment 4 (long cover + short term paraquat) with that on the burnt plots (Treatment 7). On the latter, although there was much regrowth of cover during the first 40 days, this had relatively little effect on the lucerne plants compared with the small amount of regrowth on the former treatment. This suggests that although the cover on treatment 4 was mainly composed of dead matter it still exerted a considerable effect on the growth of the lucerne seedlings.

4.2 Trial 2

4.2.1 Germination and Establishment

The first three assessments of lucerne seedling numbers are summarised in Table 13. These assessments were discontinued at 5 weeks after sowing because of a 100% seedling loss which was mainly attributed to slug damage.

Table 13: Germination and establishment of lucerne 16, 25 and 35 days after sowing on 16 - 18/4/1976

Seedling Counts	1			2			3
Dates	3/5/1976			11/5/1976			21/5/1976
Days from Sowing	16 (2.3 weeks)			25 (3.6 weeks)			35 (5 weeks)
	Number of seedlings	% Germination		Number of Seedlings	% Seed Sown		Number of Seedlings
		Actual	Transformed		Actual	Transformed	
1 Long cover control	0	0	0.71cC	0	0	0.71cC	0
2 Short cover control	0	0	0.71cC	0	0	0.71cC	0
3 Long cover + glyphosate*	4	1.7	1.36bBC	3	1.4	1.25abAB	0
4 Long cover + paraquat*	3	1.3	1.32bBC	2	0.9	1.10bABC	0
5 Short cover + glyphosate	4	1.5	1.30bBC	1	0.5	0.94bcBC	0
6 Short cover + paraquat	6	2.2	1.55bB	1	0.6	1.00bcABC	0
7 Paraquat + burning	32	12.5	3.50aA	5	1.9	1.46aA	0
LSD (0.05)			0.47			0.34	
LSD (0.01)			0.63			0.46	
Std. Error			0.23			0.17	
Coeff. Var.			31.5			32.9	

* Glyphosate = long term herbicide treatment

* Paraquat = short term herbicide treatment

At the count done 16 days after sowing most seedlings were in the cotyledon stage and a few had reached the primary leaf stage. This count was taken to represent germination although it is possible that a few seedlings could have germinated and died by this time without being noted. It is evident that the highest germination occurred on the burnt plots, that very much smaller numbers germinated on the other sprayed plots (treatments 3 - 6) and that no seedlings appeared on the controls. The second count was taken 8 days later, by which time there had been a drastic reduction in seedling numbers. For example on the burnt plots there was an 84% loss of enlarged seedlings and an average of 59% loss on the other plots. By the time the third count was made, 5 weeks after sowing, all emerged seedlings had disappeared and no further emergence was noted. Under the very wet autumn conditions, many slug tracks were observed and this loss of seedlings was attributed mainly to slug damage (see section 4.2.5).

4.2.2 Ground Cover Dry Matter

Ground cover assessments are summarised in Table 14 and illustrated graphically in Figure 8. The figures again show the smallest amounts of dry matter on the burnt plots corresponding with the best germination and establishment. The table also shows a drop in dry matter with time in the herbicide treated plots resulting partly from earthworm activity and partly from slower regrowth of the cover due to the lateness of the season. By the third cut, some regrowth was recorded, on the sprayed plots, in the form of weed and grass germination together with slow regrowth of the original desiccated cover. In the control plots, regrowth from the cut stubble was noted from the 2nd cut onwards but was retarded by low temperatures.

Table 14: Ground cover dry matter (kg/ha assessments at sowing and at various times afterwards in Trial 2.

Harvests (cuts)	1	2	3	4
Dates	18/4/1976	4/5/1976	10/5/1976	27/5/1976
1 Long cover control	3240aA	3166aA	3430aA	3576aA
2 Short cover control	2516cAB	2520cdAB	2810bAB	2386bB
3 Long cover + glyphosate*	3176aA	3096abA	2606bB	1590cC
4 Long cover + paraquat*	2730abAB	2666bcAB	2310bB	790dDE
5 Short cover + glyphosate	2186cdBC	2110deBC	1145cC	1040dD
6 Short cover + paraquat	1750dC	1716eC	1516cdCD	820dDE
7 Paraquat + burning	946eD	956fD	640dD	460eE
LSD(.05)	517	453	528	330
LSD(.01)	692	607	706	441
Standard Error	256	224	261	163
Coefficient of Variation	21.7	19.7	19.4	21.4

* Glyphosate = Long term herbicide treatment

* Paraquat = Short term herbicide treatment

Reference to the last column in the table shows that paraquat desiccated vegetation appears to be more prone to breakdown by earthworms and other soil organisms than that desiccated by glyphosate. The effect is most evident on the long cover plots. With treatment 4 (paraquat), for example, the dry matter dropped by 66% between the 10th and 27th of May, 1976, while with treatment 3 (glyphosate) the reduction was only 39%. On the short cover plots the reduction over the same period was 46% and 9% for the paraquat and glyphosate treatments respectively, though in this case the difference was not significant.

FIG. 8: GROUND COVER DRY MATTER (kg/ha) AT SOWING AND REGROWTH

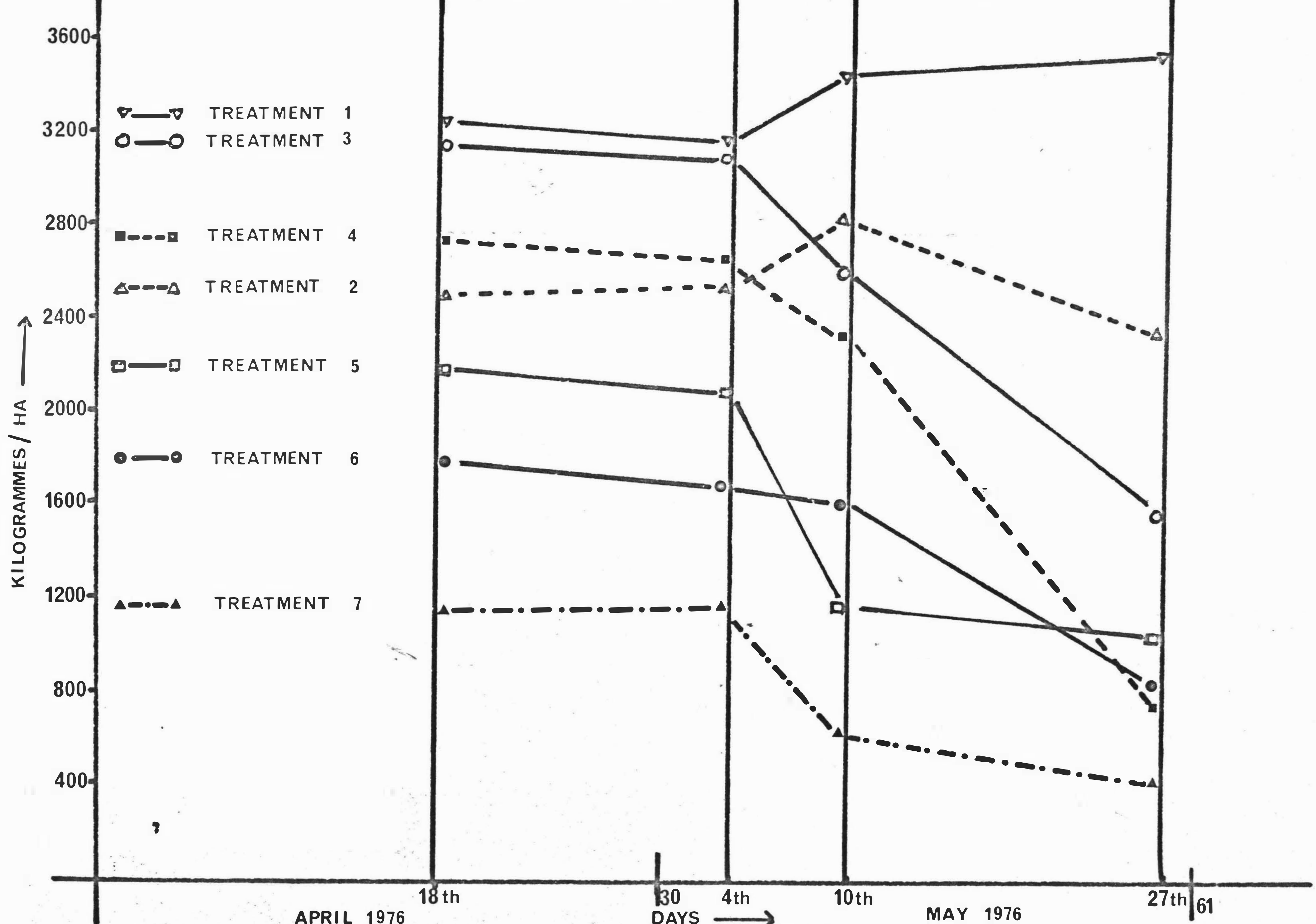
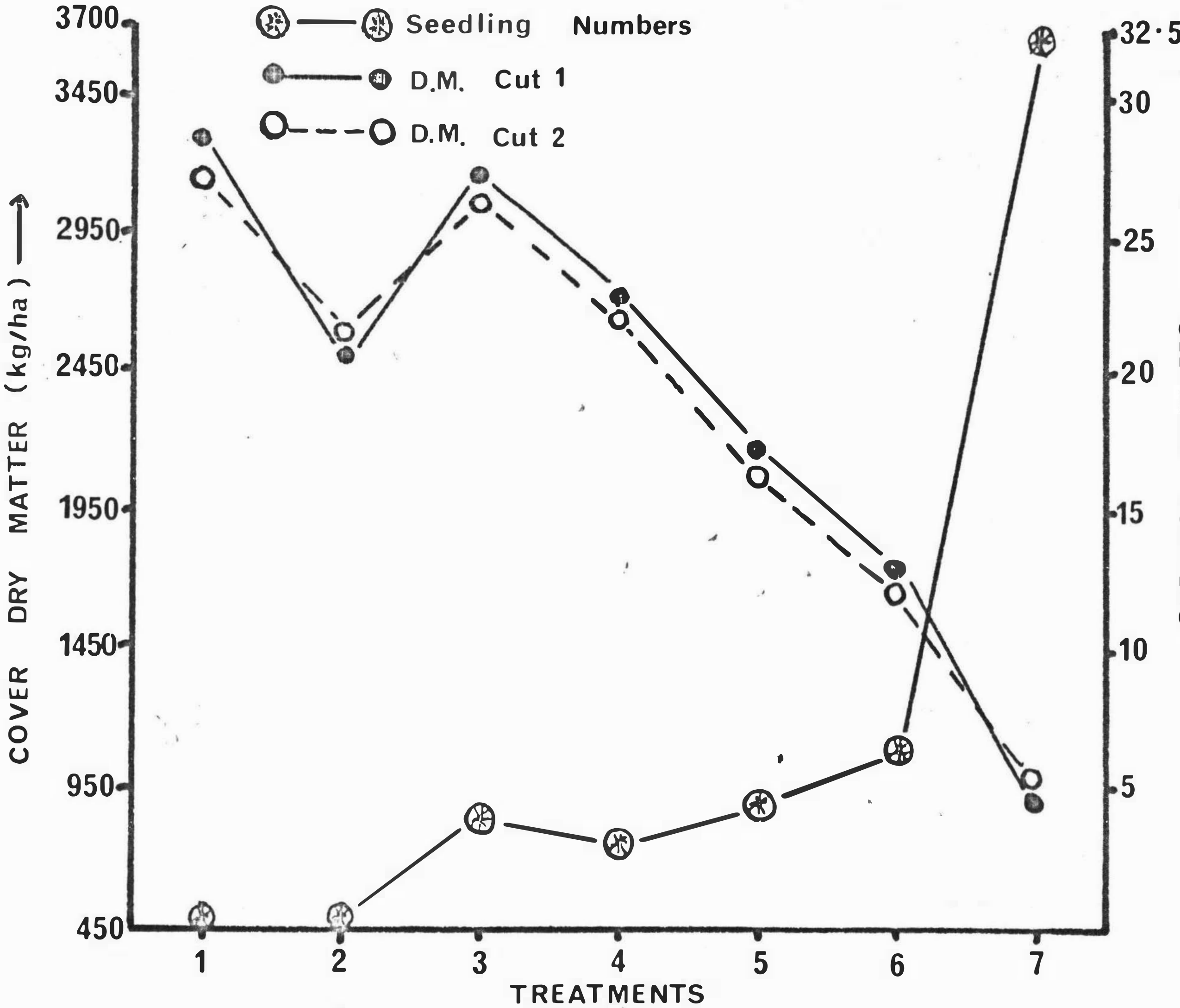


FIG. 9: SEEDLING COUNT 1 AND D.M. OF CUTS 1 & 2



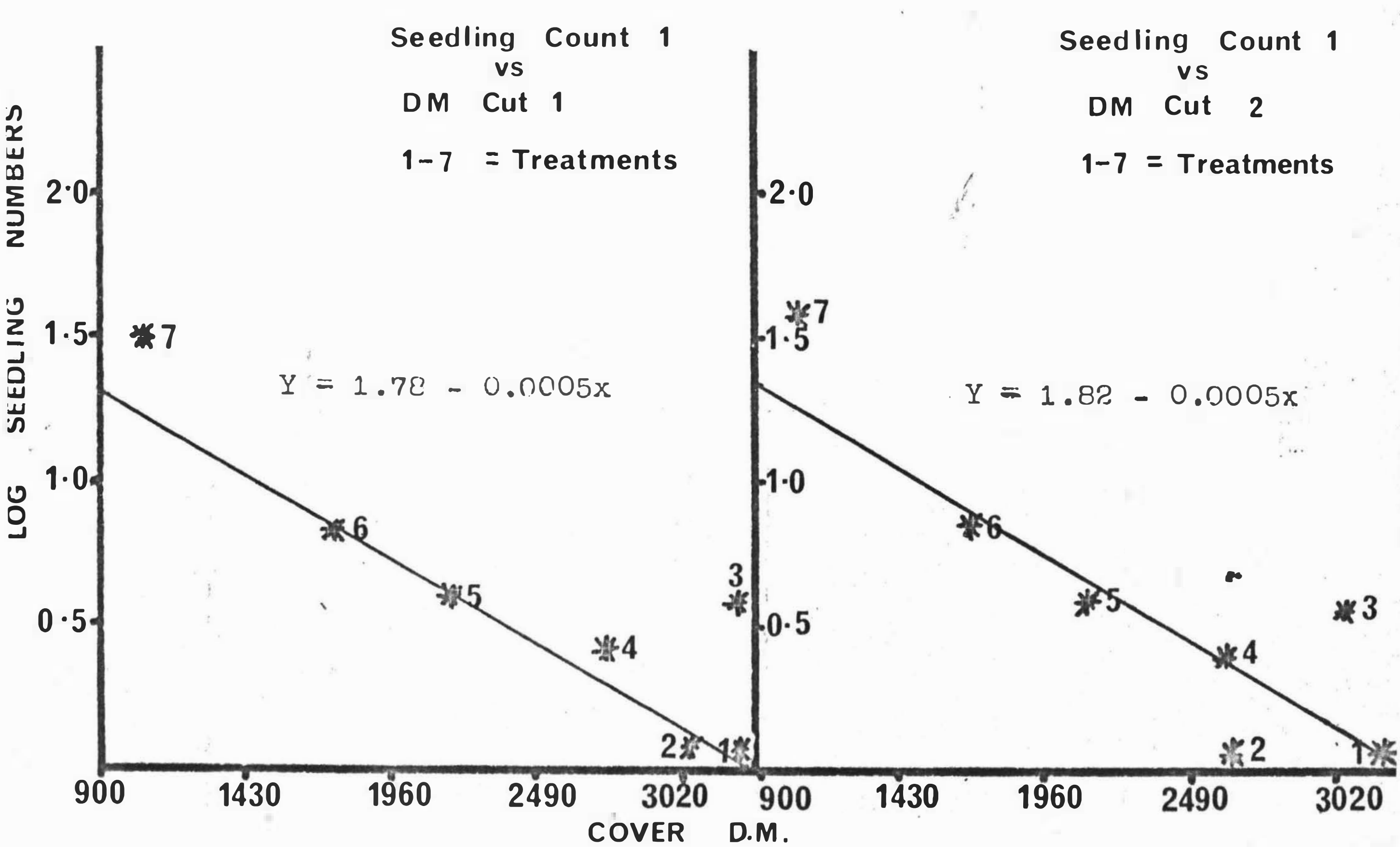
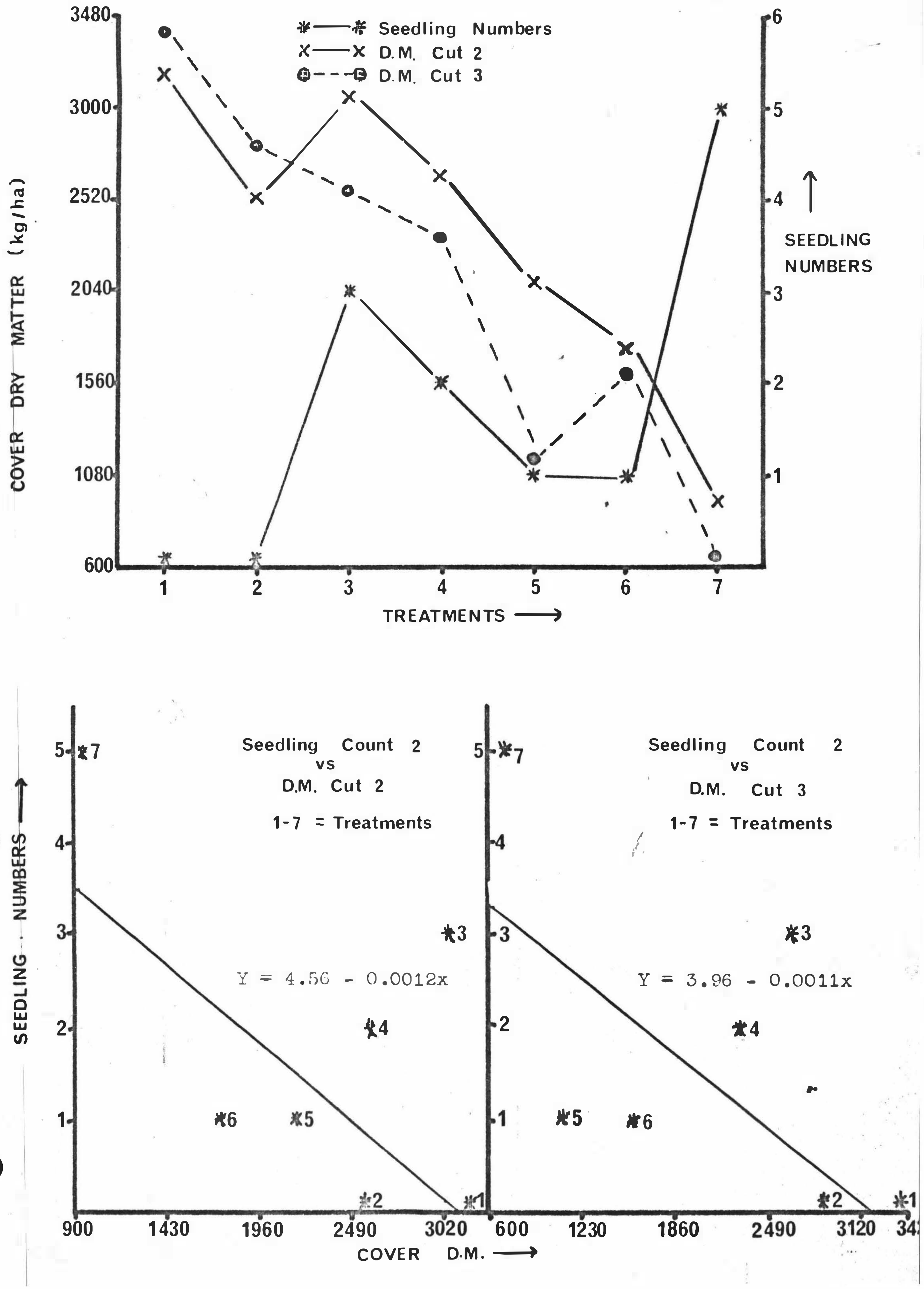


FIG. 10: SEEDLING COUNT 2 AND D.M. OF CUTS 2 & 3



4.2.2.1 Relationships between seedling numbers and ground cover dry matter.

In figures 9 and 10, the relationships between ground cover dry matter are presented graphically. Figure 9 examines the relationships between seedling numbers of count 1 and ground cover dry matter of cuts 1 and 2 while figure 10 shows the relationships between seedling numbers of count 2 and cover dry matter of cuts 3 and 4. The figures again show a negative correlation ($r = -0.84$) between seedling numbers and ground cover dry matter which is significant ($P < 0.05$) but this relationship is less close than that observed in trial 1. In this autumn trial, it is probable that the effects of cover on germination and establishment were masked to a varying extent by the effects of slugs, the slug effects being particularly marked on the plots with the least cover. See also section 4.2.4.

4.2.3 Soil Moisture and Rainfall

Soil moisture content, expressed as a percentage of oven dried soil, was high from the second sampling, taken on the 24/4/1976, onwards. Throughout the sampling period, soil moisture is shown to correspond with incidence of rainfall. For example, the low overall soil moisture level recorded on the 18/4/1976 corresponds with 8 days without rain. Table 15, 16 and Figure 11 summarise this relationship of soil moisture and rainfall. As a whole, this period was also abnormally wet as shown by comparing the weekly mean rainfall for 1971 - 1975 with that for 1976 over the months of April, May and June. Appendix 6 gives this comparison graphically.

Table 15: Soil Moisture Content (% in top 5.1cm layer)

Samples	1	2	3	4	5	6	7
Sampling Dates	18/4/76	24/4/76	29/4/76	4/5/76	10/5/76	18/5/76	27/5/76
1 Long Cover Control	14.6bB	28.8dC	28.6cC	39.6bAB	42.3a	43.0a	44.6abA
2 Short Cover Control	12.6dC	30.6cdC	30.3bBC	39.8bAB	42.4a	42.8a	44.2abA
3 Long Cover + Glyphosate*	17.5aA	38.1aA	35.6aA	42.3aA	41.8a	43.7a	44.6abA
4 Long Cover + Paraquat*	15.0bB	34.4bB	32.5bAB	40.3abAB	42.2a	43.0a	46.2aA
5 Short Cover + Glyphosate	17.7aA	37.6aA	35.3	40.8aAB	42.4a	42.9a	44.1abA
6 Short Cover + Paraquat	13.1cdBC	36.3abAB	32.5bAB	40.4abAB	40.6a	41.3a	42.8bB
7 Paraquat + Burning	14.0bcBC	31.3cC	30.8bBC	38.1bB	40.7a	42.6a	43.4abA
LSD (0.05)	1.3	2.2	2.4	2.4	3.5(NS)	2.5(NS)	2.2
LSD (0.01)	1.7	2.9	3.3	3.2	4.6	3.3	3.0
Std. Error	0.6	1.1	1.2	1.2	1.7	1.2	1.1
Coeff. Var.	8.4	6.3	7.5	6.0	8.2	5.8	5.0

* Glyphosate = Long term herbicide treatment

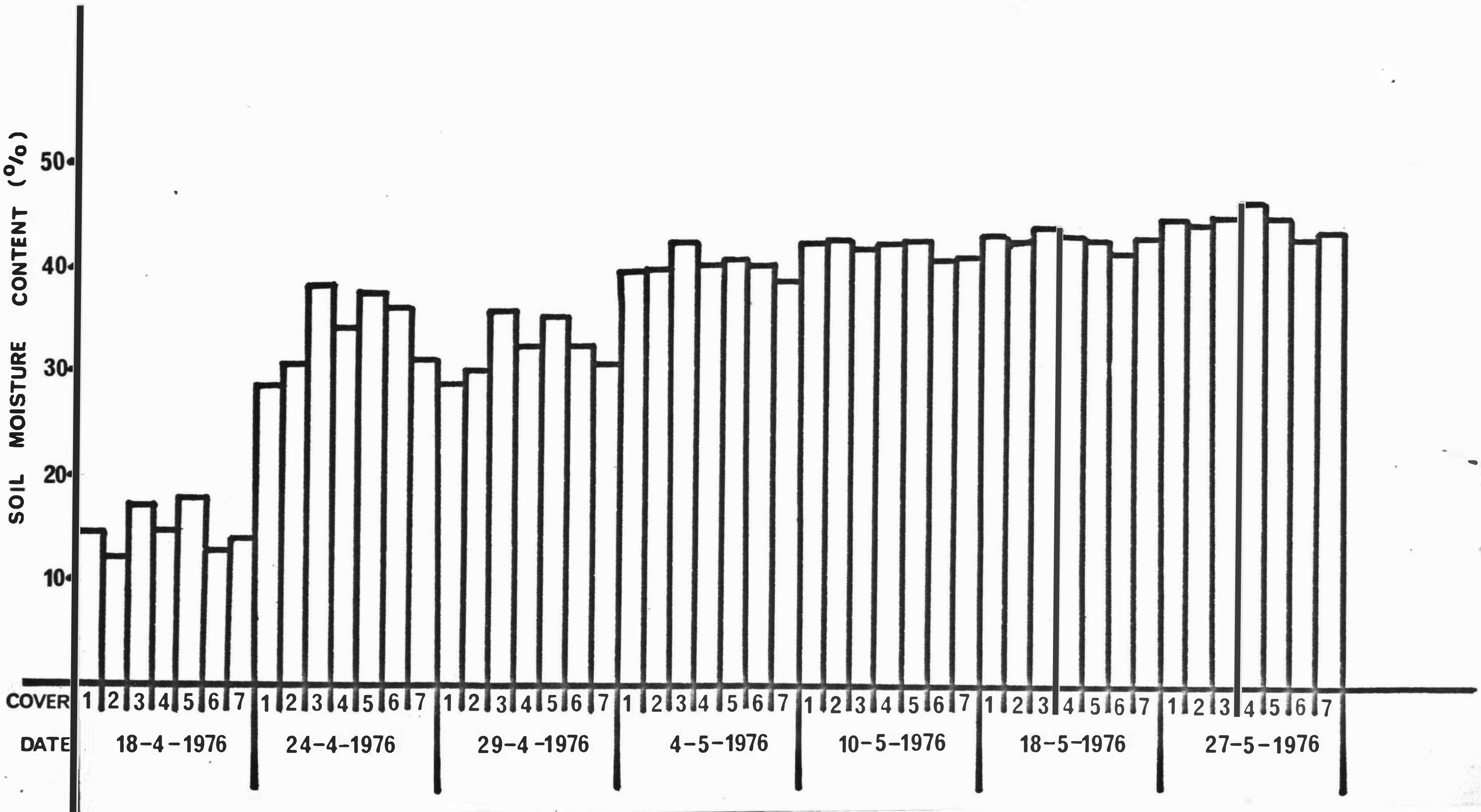
* Paraquat = Short term herbicide treatment

Table 15 shows that significant differences in soil moisture levels occurred on various sampling dates (samples 1, 2, 3, 4 and 7) but that, with the exception of the first date (18/4/1976), the levels were unlikely to have limited lucerne germination and growth. At the first sampling date the levels were so low that little germination took place until surface conditions became moister on the 23rd April, 1976. Germination was therefore slower than in Trial 1 and took longer than 7 days.

Table 16: Daily Rainfall (mm) During Trial 2

Date	Rainfall in Millimeters			
	April 1976	May 1976	June 1976	
1	0.0	5.5	1.0	
2	0.0	0.0	0.5	
3	0.0	0.0	14.2	
4	1.5	0.4	7.8	
5	0.0	0.1	11.3	
6	0.0	19.2	0.0	
7	0.0	0.1	0.0	
8	1.9	6.5	0.3	
9	1.4	7.7	4.1	
10	0.0	0.0	9.0	
11	0.0	0.0	0.0	
12	0.0	30.5	0.0	
13	0.0	0.0	0.0	
14	0.0	0.2	1.0	
15	0.0	0.0	1.4	
16	0.0	0.0	0.3	
17	0.0	0.4	26.5	
18	0.6	0.0	8.7	
19	0.3	12.7	5.7	
20	0.0	7.9	12.8	
21	0.4	0.0	0.2	
22	0.0	0.0	0.0	
23	3.8	0.0	0.0	
24	0.0	0.0	1.1	
25	0.0	10.9	0.0	
26	0.0	1.5	0.0	
27	0.0	0.0	0.2	
28	0.0	0.0	95.5	
29	21.1	0.8	5.2	
30	20.6	0.0	3.3	
31		0.0		
Total	51.6	104.4	210.1	366.1

FIG. 11: SOIL MOISTURE CONTENT (FROM SOWING TO FINAL SEEDLING COUNT)



4.2.4 Relationships Between Lucerne Germination and Establishment, Ground Cover Dry Matter and Soil Moisture.

The relationship between seedling number and cover dry matter was a negative correlation (r = -0.83) significant at the 5% level. As in the first trial, the observations in trial 2 showed no obvious relationship between lucerne germination and soil moisture (correlation r = 0.27). The correlation between soil moisture and ground cover was positive (r = 0.47) but not significant. Again it appears that soil moisture was not a limiting factor; though the high level of slug damage was probably related to the unusually wet conditions at the end of April and the first half of May 1976, when the lucerne seedlings were at a particularly susceptible stage of growth. (See Tables 13 and 15 and Appendix 6).

4.2.5 Slug Activity

Within 5 weeks of sowing, there was a 100% loss of lucerne seedlings attributed mainly to slug damage (see section 2.3.4.4). Estimations of slug population per plot by the use of a slug bait pellet (metaldehyde) yielded the figures given in Table 17. The figures cannot be regarded as giving accurate estimates of slug population because migration of slugs from plot to plot could have taken place, particularly at night when slugs are most active (Symonds, 1975). Although of limited value, however, the figures do suggest that dense cover was associated with high slug activity.

Table 17: Slug estimates from the different cover treatments (Totals of 3 counts over period 12/6/76 to 14/6/1976).

Cover	1. Long Cover Control	2. Short Cover Control	3. Long Cover + Glyphosate*	4. Long Cover + Paraquat*	5. Short Cover + Glyphosate	6. Short Cover + Paraquat	7. Paraquat + Burning	LSD(0.05)	LSD(0.01)	STD ERROR	COEFF. VAR
Slug Numbers	23aA	18bB	10cC	10cC	11cC	12cC	13cC	3.6	4.8	1.8	25.5

* Glyphosate = Long term herbicide treatment

* Paraquat = Short term herbicide treatment

4.2.6 Survival of Oversown Lucerne

Although no lucerne plants remained after 5 weeks, the botanical composition of the plots was assessed by cut herbage dissection into grass, weeds, clover and dead matter at the end of the experiment. Table 18 summarises the results of these observations.

Table 18: Botanical composition by dissection of herbage cut on the 11/6/1976, 65 days from second herbicide application. (Quadrat size = 1000 cm^2)

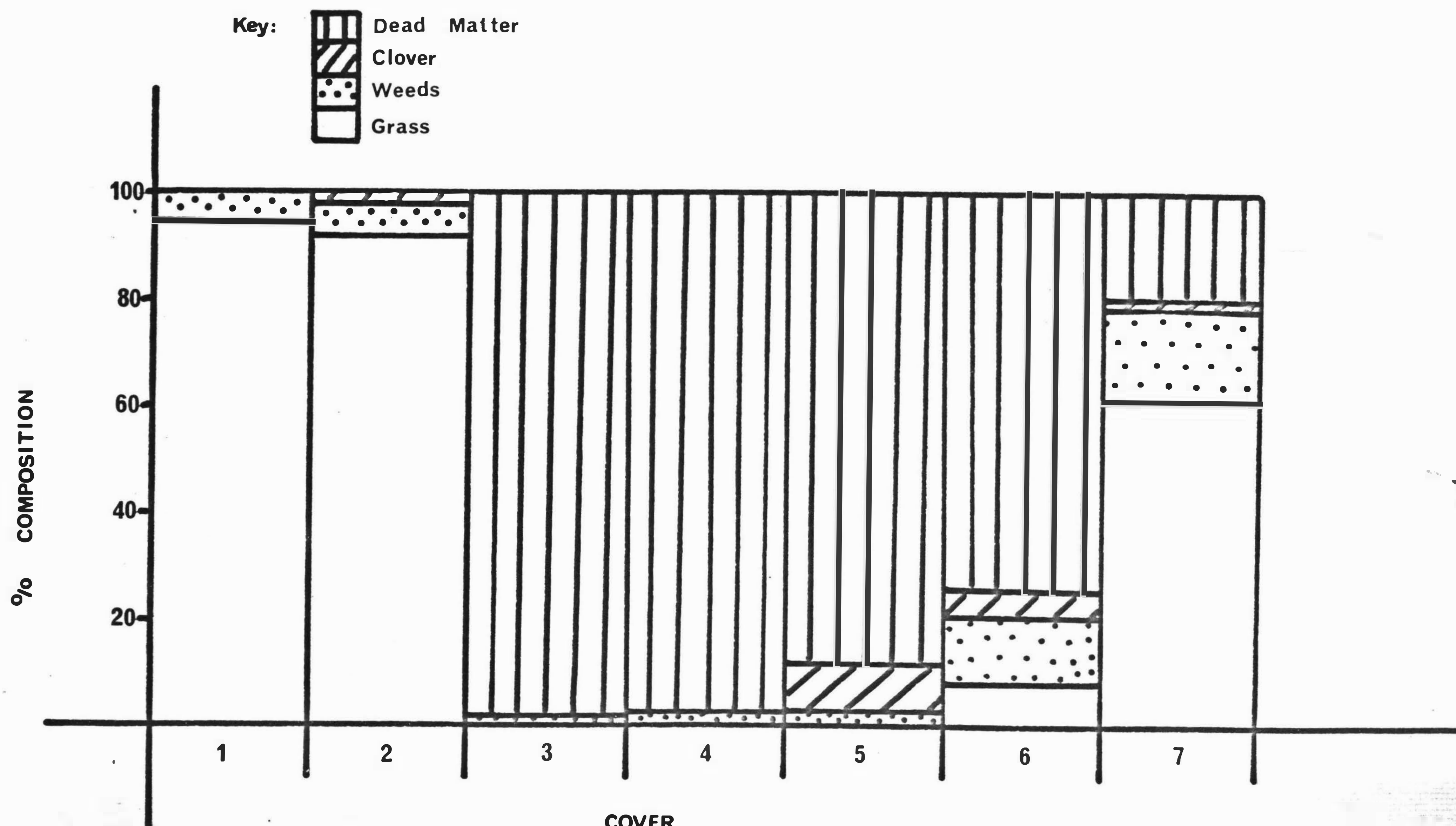
Cover Treatment	Total Dry Matter (gm) of dissected herbage	Botanical Composition (% Total Dry Matter)							
		% Grass		% Weeds		% Clover		%Dead Matter	
		Actual	Transformed	Actual	Transformed	Actual	Transformed	Actual	Transformed
1 Long Cover Control	26.8aA	95.0	9.77aA	5.0	2.21bc ABC	0	0.71a	0	0.71dC
2 Short Cover Control	20.8bB	93.0	9.66aA	5.8	2.14bc ABC	1.2	1.01a	0	0.71dC
3 Long Cover + Glyphosate*	7.6cC	0.9	0.98cdC	0	0.71cC	0	0.71a	99.1	9.98aA
4 Long Cover + Paraquat*	3.6dC	0	0.71dC	1.8	1.10cBC	0	0.71a	98.2	9.93aA
5 Short Cover + Glyphosate	4.1dC	0.3	0.84dC	0.4	0.86cC	10.9	2.19a	88.4	9.35abA
6 Short Cover + Paraquat	3.8dC	7.2	1.93cC	12.7	3.03ab AB	5.5	1.69a	74.6	8.48bA
7 Paraquat + Burning	6.1cdC	61.8	7.79bB	16.9	3.79aA	1.7	1.19a	19.6	4.01cB
LSD (0.05)	2.8		1.05		1.44		1.42 (NS)		1.31
LSD (0.01)	3.8		1.41		1.93		1.91		1.75
Std. Error	1.4		0.52		0.71		0.70		0.65
Coeff. Var.	26.8		23.0		72.3		121.1		21.0

* Glypohosate = Long term herbicide treatment

* Paraquat = Short term herbicide treatment.

The table shows that on the control plots (treatments 1 and 2) nearly all the herbage was grass with a few weeds and hardly any clover.

FIG. 12: BOTANICAL COMPOSITION (DISSECTION) 65 DAYS AFTER TREATMENT APPLICATION.



Thus a high level of lucerne survival would not have been expected with these treatments even if there had been no slug effect (cf also Trial 1). Weeds did best on treatments 6 and 7 and lucerne might have been expected to grow better here as it was observed in Trial 1 that, where lucerne did well, so did the weeds (see figure 7). Glyphosate (Long term herbicide treatment) produced almost 100% control of weeds for 65 days after spraying and this effect was complemented by a dead matter mulching effect as shown in treatment 3 (long cover, long lasting herbicide treatment). On all the sprayed and unburnt plots there were large amounts of dead matter which formed a mulch and possibly helped to encourage slugs. It may be that the lower amount of dead matter on treatment 7 (burnt plots) is the reason why lucerne seedlings lasted somewhat longer here than on the unburnt plots. (See also figure 12). The weed species dominant on the various treatments were identified and are tabulated in appendix 7 . As a whole, the control plots (treatments 1 and 2) contained fewer weed species and the herbicide treated and burnt plots contained a wider variety of weed species.

4.3 Trial 3

4.3.1 Germination and Establishment

The results of the trial on the effects of the live, dead and burnt cover on lucerne germination and establishment under two moisture regimes in the glasshouse are summarised in Table 19. The number of seeds sown in each box was 54 and the table gives both the actual seedling numbers and the percentages of the number of seeds sown.

Table 19: The effects of various cover treatments on lucerne germination and establishment in box trial under glasshouse conditions. Sowing date: 24/6/1976

Counts	1			2			3			4		
Dates	1/7/1976			9/7/1976			16/3/1976			31/7/1976		
Days from Sowing	7 (1 week)			15 (2.1weeks)			22 (3.1 weeks)			37 (5.3 weeks)		
	N	A	T	N	A	T	N	A	T	N	A	C
1 Live Cover Moist	40	74	8.66 abAB	38	71	8.45	30	55	7.47	17	31	5.64bBC
2 Live Cover Drying	30	57	7.53 cB	27	50	7.04	26	49	7.02	7	13	3.55cC
3 Dead Cover Moist	41	75	8.67 abAB	35	64	7.45	27	50	7.02	26	49	6.91abAB
4 Dead Cover Drying	36	66	8.15 bcAB	36	66	8.11	37	68	8.20	35	64	8.13aA
5 Burnt Cover Moist	45	83	9.14 aA	35	64	8.02	32	59	7.73	33	62	7.64aAB
6 Burnt Cover Drying	36	67	8.18 bcAB	28	52	7.22	28	52	7.27	27	50	7.17abAB
LSD (0.05)			0.84			NS			NS			1.58
LSD (0.01)			1.16			NS			NS			2.19
STD. ERROR			0.39			0.77			0.67			0.74
COEFF VAR.			6.7			14.2			12.7			16.2

N = Seedling numbers (mean of 4 boxes)

A = Seedlings as % of seed sown

T = Transformed Percentages ($\sqrt{A + \frac{1}{2}}$)

It is evident from Table 19 that seedling number did not differ significantly between treatments except in the first and fourth counts. This occurred probably as a result of differential seedling losses amongst treatments between the 1st and 2nd count; this then led to the levelling up of the treatment difference observed in the first count. For example, treatment 5 (burnt cover, moist) lost 10 seedlings during this period compared to 8, 6, 3, 2 and 0 seedlings in treatments 6, 3, 2, 1 and 4 respectively. This was probably more a result of slug damage than of treatment effects.

In Table 19a the means for cover and moisture regimes are compared. The interaction means are included in Table 19.

Table 19a: Seedling numbers (% of seed sown) in relation to cover and moisture regimes.

Counts		1	2	3	4
Covers	1. Live	8.10b	7.74a	7.24a	4.60B
	2. Dead	8.41ab	7.78a	7.61a	7.52A
	3. Burnt	8.66a	7.62a	7.50a	7.40A
Moisture Regimes	1. Moist	8.82A	7.97a	7.41a	6.73a
	2. Drying	7.95B	7.46b	7.50a	6.28b

The table shows that at Count 1, mean seedling numbers differed significantly between live and burnt cover ($P < 0.05$). The moisture regime effect was also significant at the 1% level. Interactions between cover and moisture regime were significant in the live and burnt cover ($P < 0.01$). In the subsequent counts, significant differences were not observed until the final count. Seedling numbers, declined at different rates in different boxes within each treatment, but by the time of the final count had stabilised at a lower level. At count 4, the mean seedling numbers again differed significantly between live and burnt or dead cover ($P < 0.01$). Moisture regime effects were also significant at the 5% level as were interactions between cover and moisture regime. The significant difference between moisture regimes in the dead cover boxes was not due to a direct effect of moisture (see table 21) but more likely could be atrributed to slug damage.

The vigour of seedlings was also found to be influenced by cover treatments. For example, the live covers (treatment 1 and 2) retarded growth and produced etiolated seedlings, some of which were still in the cotyledon - first true leaf stage 5 weeks after sowing (see plate 20).

4.3.1.1 Lucerne establishment and slug activity

Slug bait pellets were applied during the second week of sowing after slug damage was observed during seedling count 1. Slug damage was not uniform hence the high coefficient of variation (62.0%). Table 20 summaries the slug counts per box made over the 16 day period that slug baits were being used. By the end of this period slug activity had apparently ceased. The slug counts and corresponding counts of seedlings are also shown graphically in figure 13.

Table 20: Slug numbers estimations in relation to covers and moisture regimes.

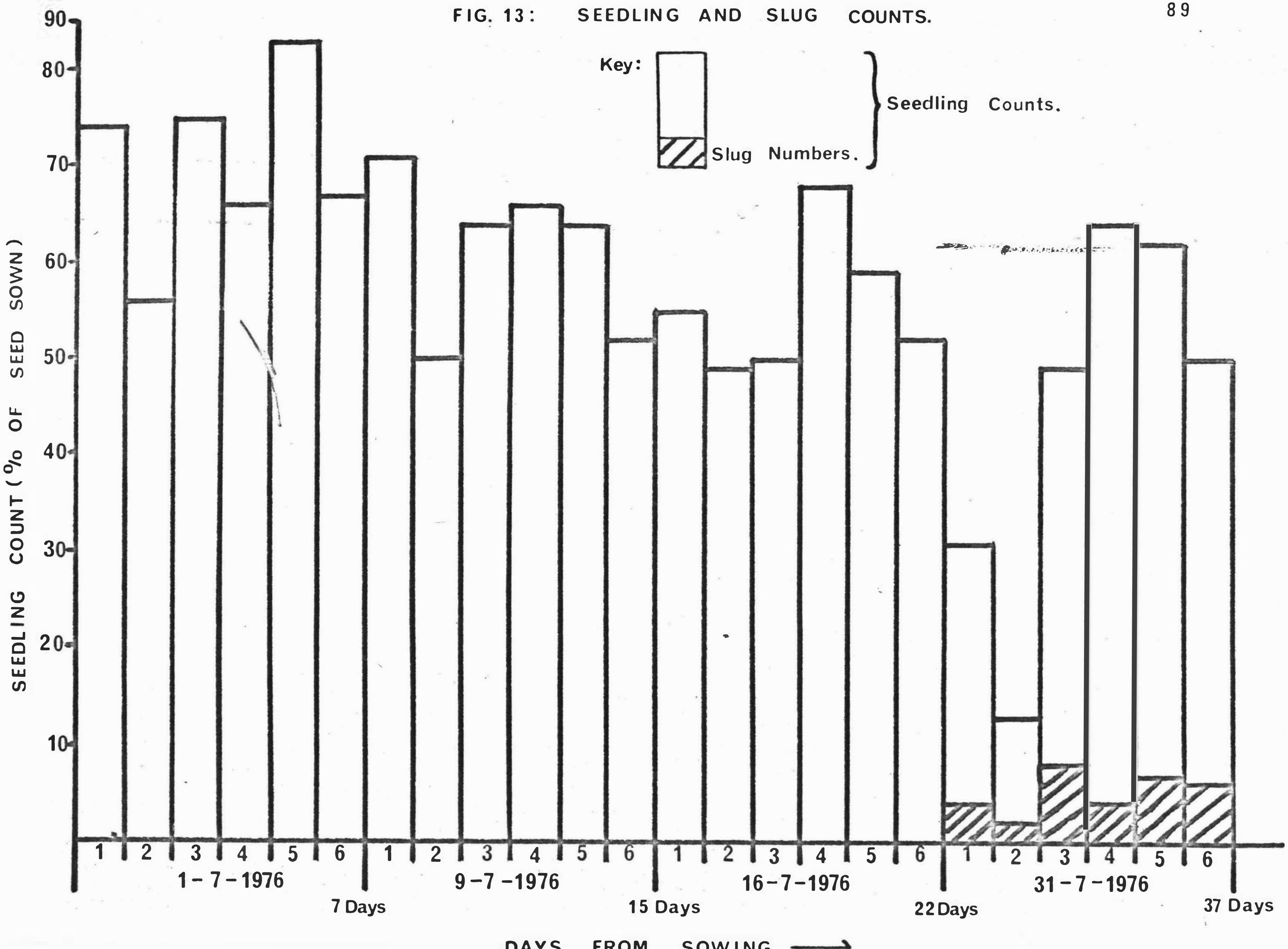
Cover	Moisture Regimes		Mean
	Moist	Drying	
Live	4ab	2b	3.0b
Dead	8a	4ab	6.0a
Burnt	7ab	6ab	6.5a
Mean	6.3a	4.0b	

Std. Error = 2
Coeff. Var. = 62%

Slug numbers, as indicated in Table 20, differed significantly between live and dead or burnt cover and also between the moist and drying moisture regimes ($P < 0.05$).

A significant interaction was found suggesting that moisture differences had less effect on slug numbers where cover had been burnt. It is clear from the table that dry conditions discouraged slug activity possibly because of a reduction in egg hatching and also because slugs appear to be able to recover more from the effects of metaldehyde bait under moist than under dry conditions (Symonds, 1975). The smallest number of slugs were recorded on treatment 2 (live cover, drying conditions). Figure 13 shows no clear cut connection between final seedling numbers and slug counts although it is probable that slug activity had some influence on the effects of the treatments.

FIG. 13: SEEDLING AND SLUG COUNTS.



4.3.2 Soil Moisture

In the first week after sowing the moist condition boxes were watered twice daily and the drying condition boxes were watered once every second day. After this period the watering frequency was reduced to 2 day intervals for the moist conditions and weekly intervals for the drying conditions.

The effects of the various covers and watering regimes on the moisture content of the 0 - 5.1 cm layer of soil are shown in Table 21 and Figure 14.

Table 21: Moisture content of top 5.1cm soil layer (% of oven dried soil) - Means of 4 replicates.

Watering Regime	Frequent (Wetter)	Less Frequent (Drier)
Period	24/6/76 - 1/7/76	2/7/76 onwards
Dates	28/6/1976	8/7/1976
1 Live cover, moist	41.9aA	40.1bA
2 Live cover, drying	24.4c	12.6eC
3 Dead cover, moist	43.5aA	42.6abA
4 Dead cover, drying	36.2bB	34.4cB
5 Burnt cover, moist	44.4aA	44.2aA
6 Burnt cover, drying	22.3cC	16.6dC
LSD (0.05)	2.5	3.6
LSD (0.01)	3.4	5.0
Std. Error	1.2	1.7
Coeff. Var.	4.7	7.5

* Footnote The soil moisture figures are typical of the levels of moisture for each period.

In the table, under the more frequent watering regime of the first week, it is evident that there were no significant differences in soil moisture between the moist cover treatments. Under the drying conditions, as would be expected, the moisture contents were considerably lower and differed significantly between covers, live and burnt cover boxes being drier than dead cover. Under the latter, less frequent watering regime, the effects were accentuated, with little difference between the moist covers (treatment 1, 3 and 5) and further large reductions under the drier live and burnt covers (treatments 2 and 6). Thus during the stages of lucerne establishment, after the first week in the drier boxes the driest conditions occurred under live cover and slightly less dry conditions under burnt cover. Under dead cover, however (treatment 4), the soil was considerably wetter, with a moisture content only 8.2% below that of the moist boxes, an effect presumably due to the mulching action of the dead grass.

FIGURE 14: SOIL MOISTURE CONTENT (%) AS AT 28/6/76 & 8/7/76

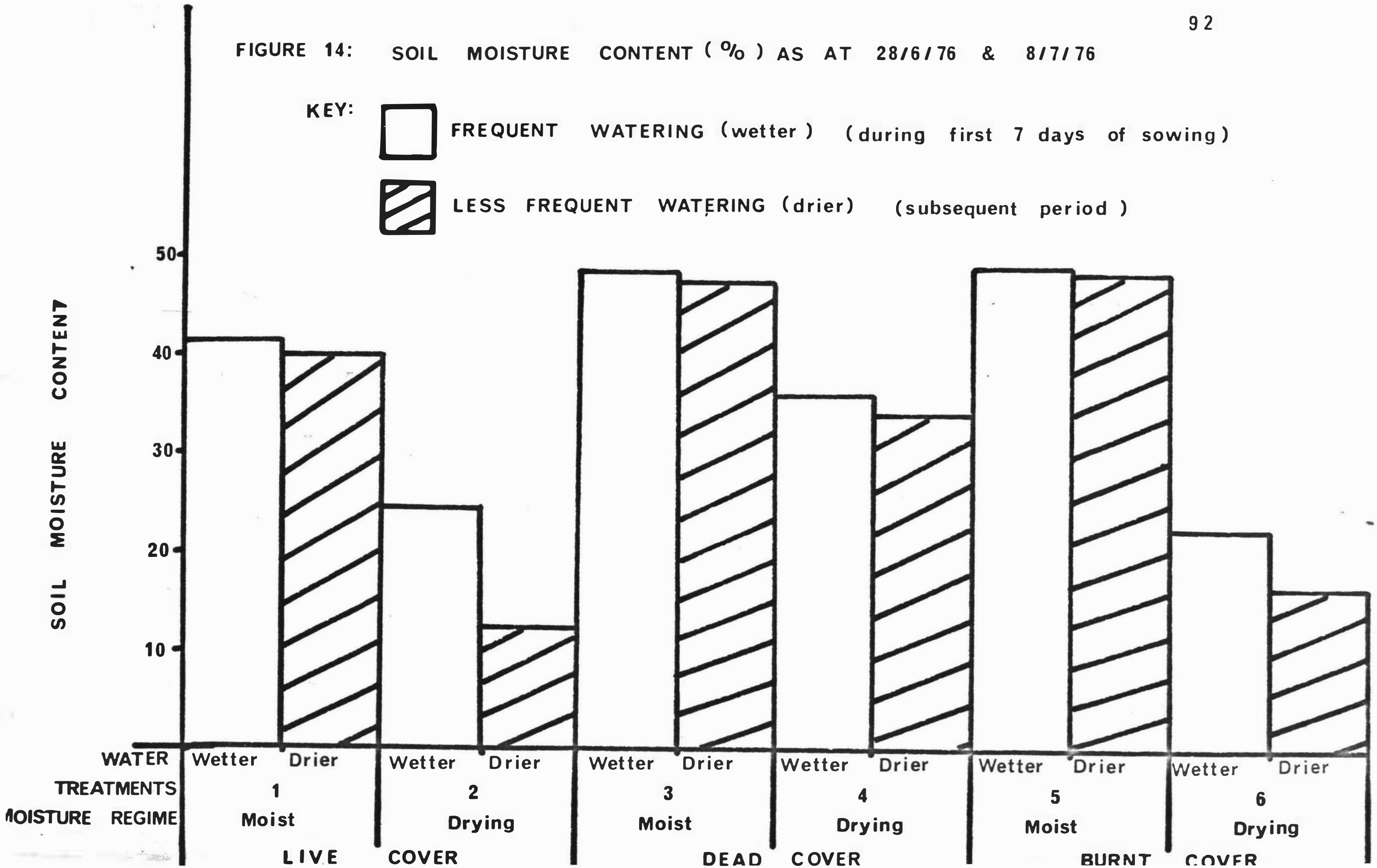
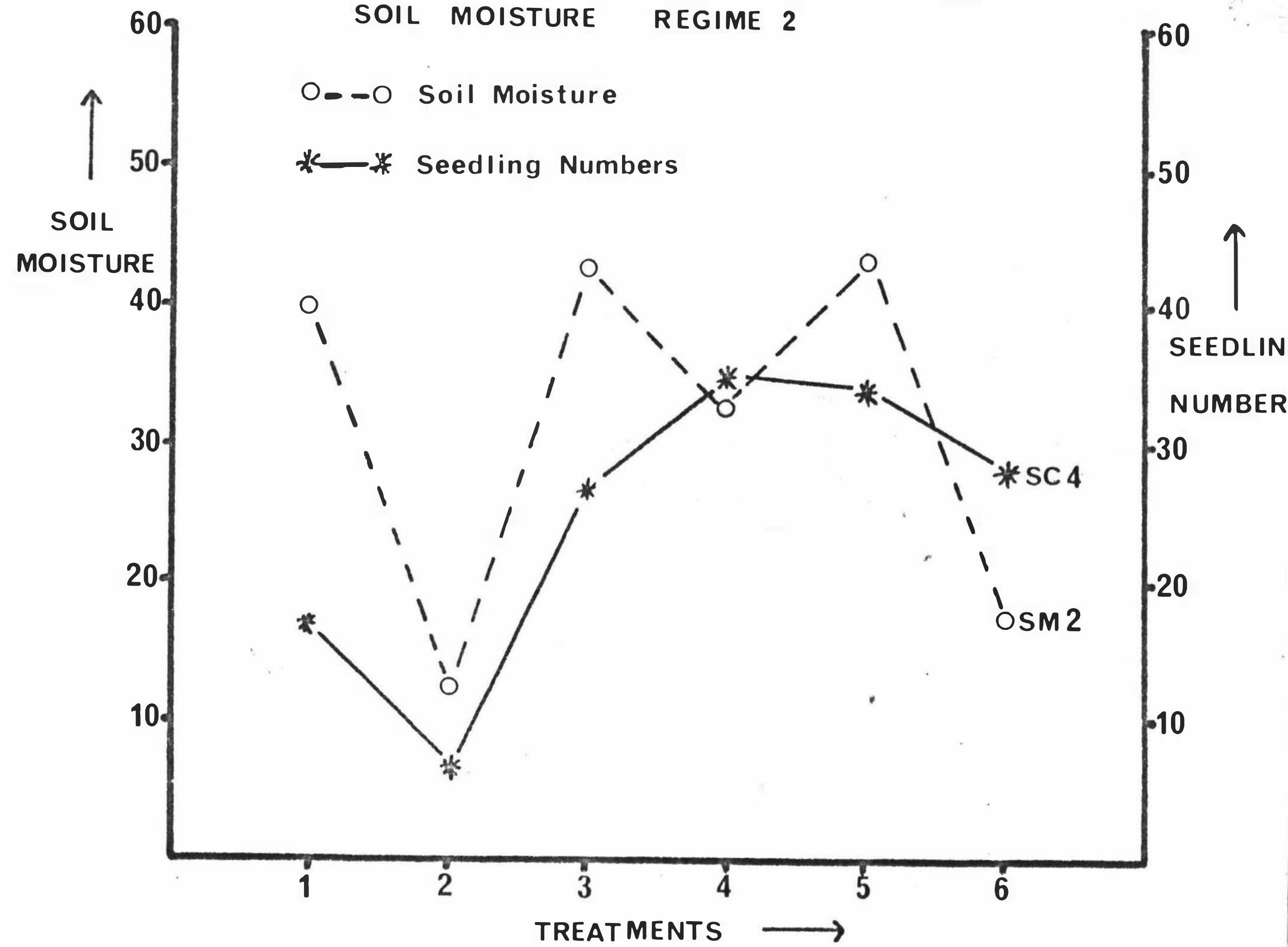
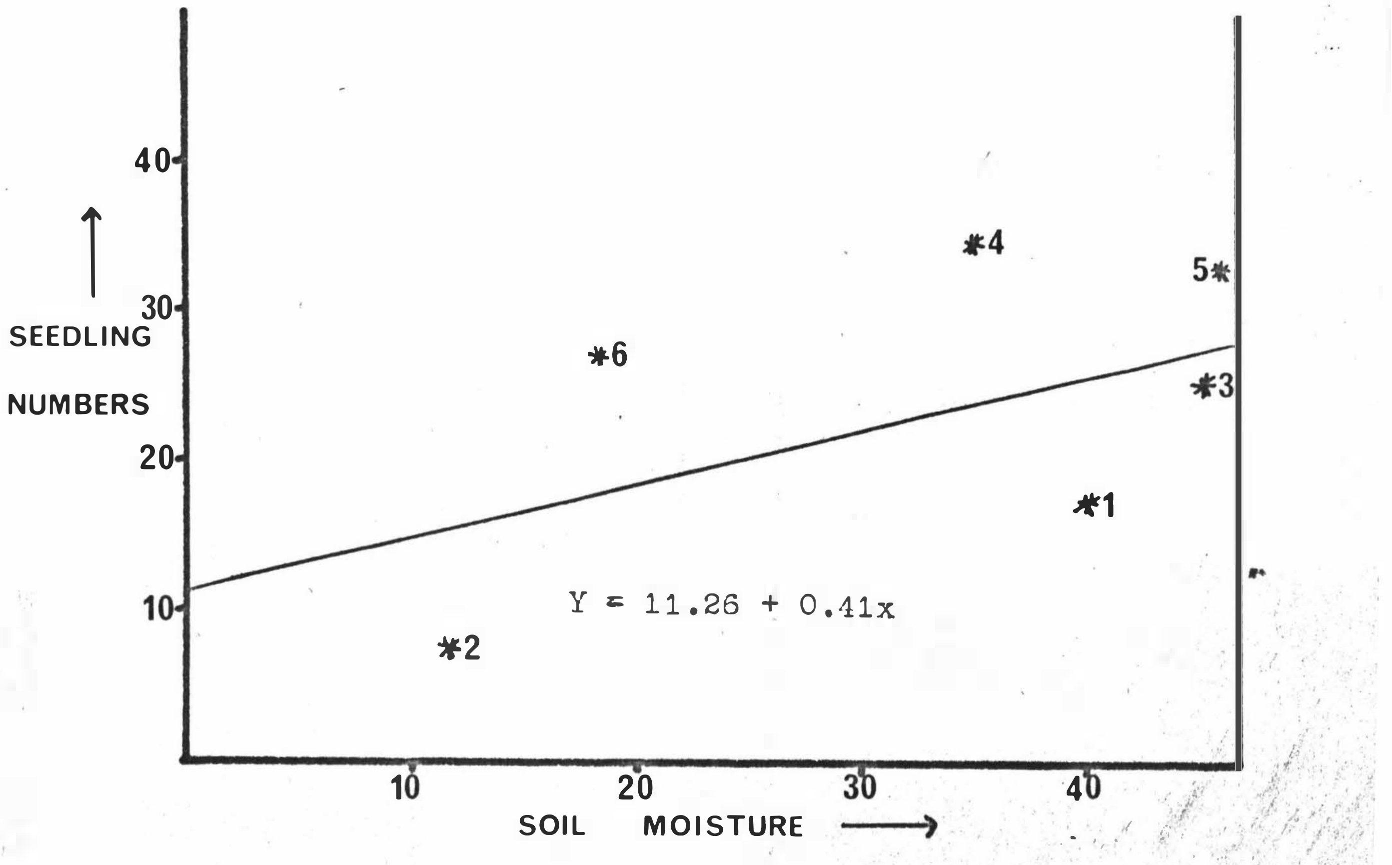


FIG. 15: SEEDLING NUMBERS OF COUNT 4 AND SOIL MOISTURE REGIME 2





4.3.3 Relationship between final seedling numbers and soil moisture levels of the less frequent watering regime.

Figure 15 summarises the relationship between the final seedling numbers and the soil moisture levels under the three drying treatments. A positive correlation was calculated ($r = 0.67$) significant at the 10% level. The main contribution towards the correlation is made by the low moisture content and small seedling number in treatment 2 (live cover, drying conditions), suggesting that conditions in these boxes were too dry for successful lucerne establishment.

4.3.4 Survival of Oversown Lucerne under Glasshouse Conditions

4.3.4.1 Botanical composition (dissection of cut herbage) at the conclusion of trial 3, 39 days after sowing.

Table 22 summarises the final botanical composition of the boxes expressed as the percentages of total dry matter contributed by lucerne, grasses, weeds, clover and dead matter. Figure 16 also gives the same expressed graphically. In general, lucerne seedling survival after the initial germination was found to be influenced both by cover treatment and soil moisture, with slug damage probably masking these effects slightly.

Table 22: Botanical Composition by Dissection of Herbage cut from 250cm^2 Quadrat per Box, 39 Days after Sowing.

Treatments	Total Dry Matter (GM)	Botanical Composition (% of total dry matter of dissected herbage)									
		% Lucerne		% Grass		% Weeds		% Clover		% Dead Matter	
		Actual	Transformed	Actual	Transformed	Actual	Transformed	Actual	Transformed	Actual	Transformed
1. Live Cover and Moist	9.2aA	0.1	0.76cC	99.8	10.02aA	0.1	0.74cB	0	0.71a	0	0.71cC
2. Live Cover and Drying	8.6aA	0	0.71cC	100.0	10.03aA	0	0.71cB	0	0.71a	0	0.71cC
3. Dead Cover and Moist	3.9bB	2.2	1.59cBC	0	0.71cC	0.2	0.84cB	0	0.71a	97.6	9.90aA
4. Dead Cover and Drying	4.9bB	2.1	1.49cC	0	0.71cC	1.5	1.27bcB	0.2	0.83a	96.2	9.83aA
5. Burnt Cover and Moist	0.4cC	35.6	5.75aA	9.3	2.98bB	6.8	2.48bB	3.2	1.68a	45.1	6.51bB
6. Burnt Cover and Drying	0.5cC	14.1	3.40bAB	9.4	2.54bBC	19.7	4.35aA	3.5	1.48a	53.3	7.18bB
LSD (0.05)	1.5		1.77		1.48		1.32		(NS) 1.24		1.48
LSD (0.01)	2.1		2.45		2.04		1.83		1.71		2.04
STD ERROR	0.7		0.83		0.69		0.62		0.58		0.69
COEFF. VAR.	22.2		51.5		21.8		50.6		80.5		16.9

FIG. 16: BOTANICAL COMPOSITION (DISSECTION)

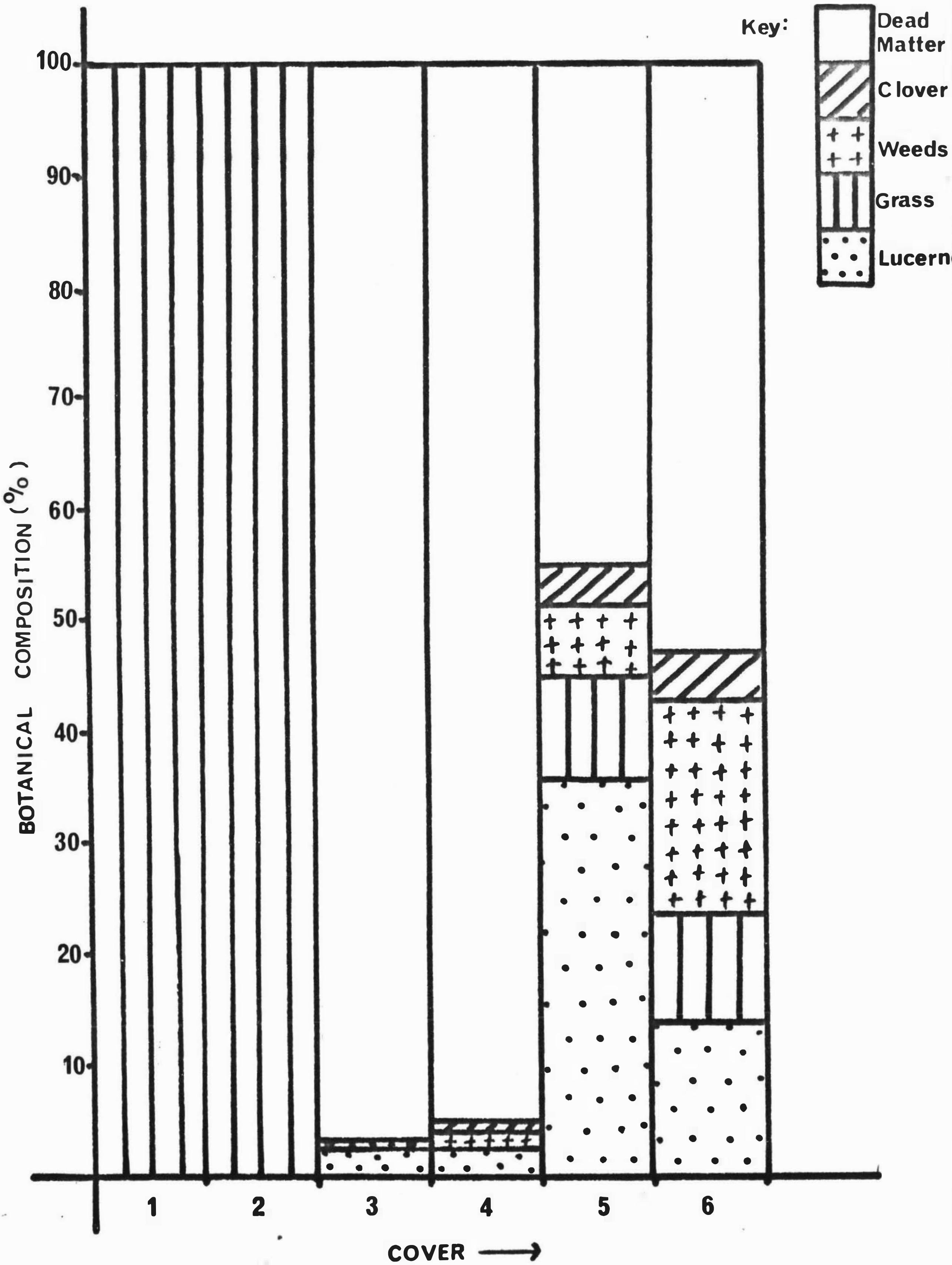


Plate 15: Sowing implement used in Trial 3 resting on treatment 5 (Burnt cover and moist conditions) box. Heavy slug damage is shown, compare with plate 18.

Plate 16: Live cover and drying conditions.

FIG. 16: BOTANICAL COMPOSITION (DISSECTION)

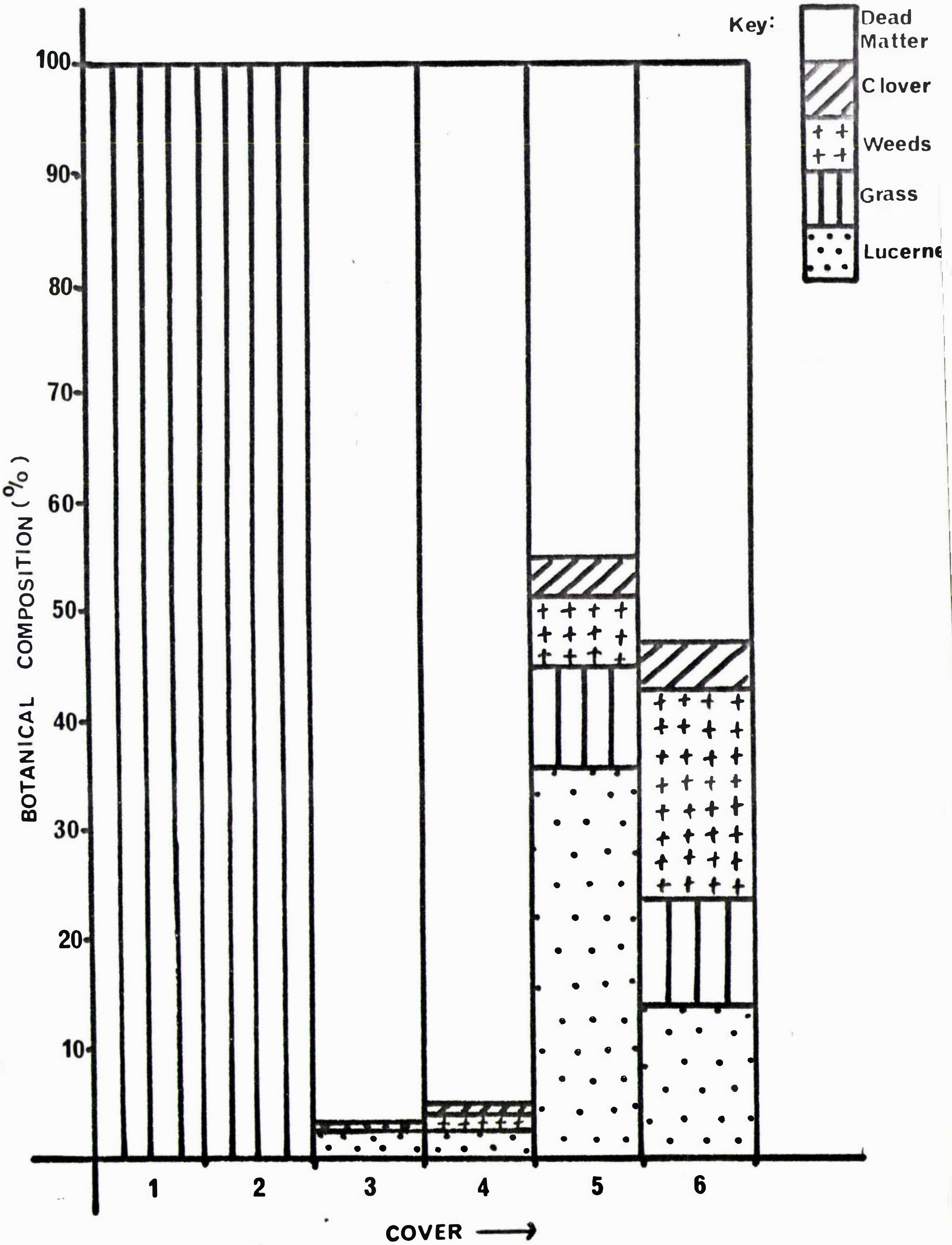


Plate 17: Dead cover and moist conditions at the end of Trial 3. Note the good strike of lucerne, no slug damage.

Plate 18: Burnt cover and moist conditions at the end of Trial 3. Note the good strike of lucerne, negligible slug damage.

Plate 19: Burnt cover and drying conditions at the end of Trial 3, slug damage was negligible.

Plate 20: Stages of growth of lucerne seedlings at the end of Trial 3, 39 days after sowing. Seedlings on the left were mostly found on burnt and dead cover treatments while the two weak seedlings on the right came from the live cover treatments.

The table shows that total dry matter was highest on treatments 1 and 2 (live cover), medium on treatments 3 and 4 (dead cover) and least on treatments 5 and 6 (burnt cover). The live cover consisted almost entirely of grass with very little of anything else. The dead cover contained no live grass but consisted mostly of dead matter with small amounts of lucerne and weeds. In these boxes lucerne establishment appeared to be good but the dry matter contribution of the lucerne seedlings was small in relation to the amounts of dead cover present (see plate 17). In the burnt cover boxes some grass remained, there was a medium amount of dead matter and relatively large amounts of lucerne and weeds, with a little clover. Because of the lack of ground cover with these treatments the lucerne, weeds and clover made substantial contributions towards the total dry matter. (See plates 18 and 19). On examining the relationship between percentage lucerne and total dry matter a negative correlation ($r = -0.84$) significant at the 0.05 level was found. The figures thus suggest that where grass was live and dominant lucerne growth was suppressed and that weed growth reacted to competition from grass in a similar manner.

4.3.4.2 Lucerne Growth by Conclusion of Trial

The mean plant dry weights 6 weeks after sowing are given in Table 23 together with the shoot/root ratios and the average numbers of nodules per plant for lucerne growing under the different treatments.

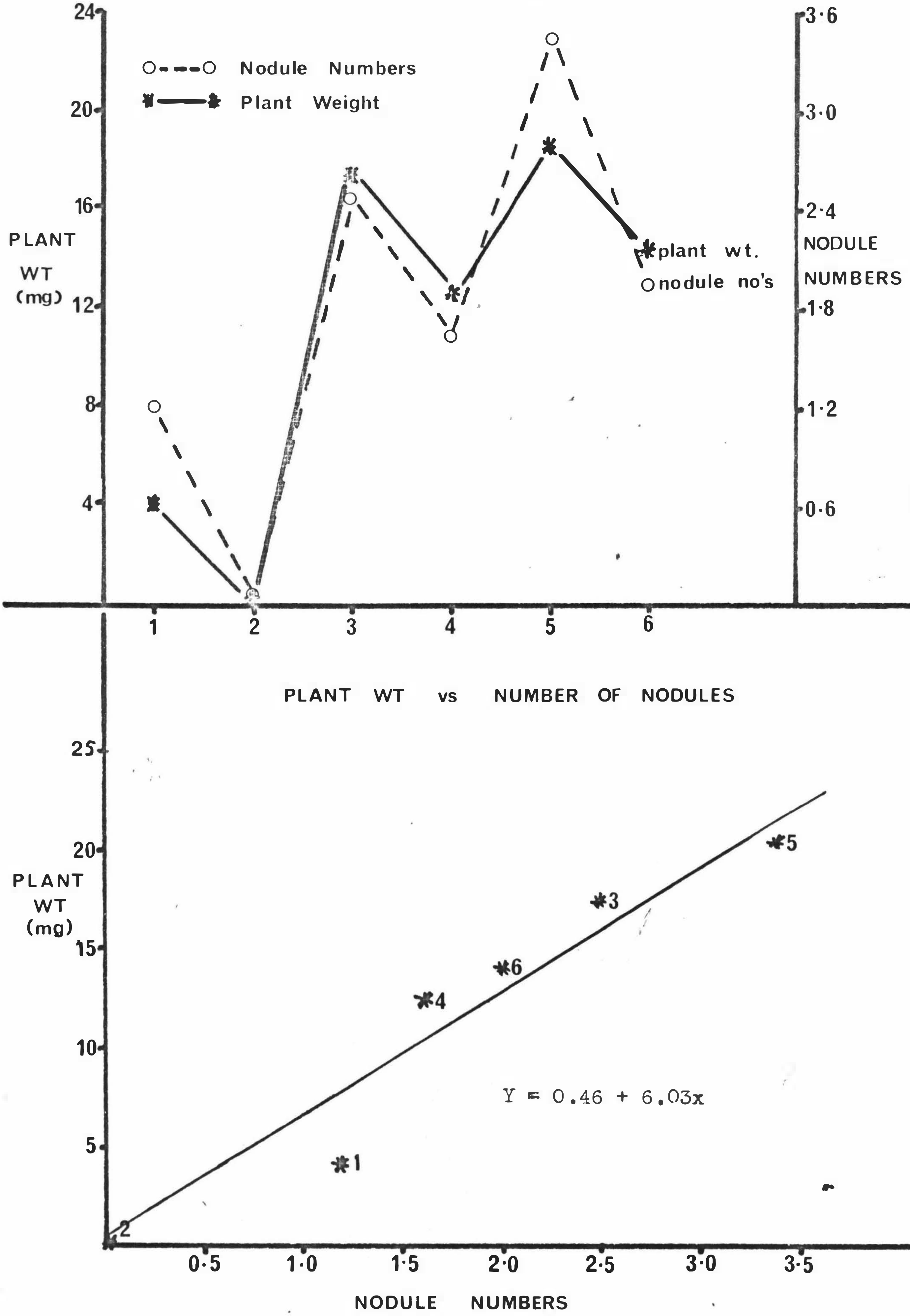
Table 23: Final plant dry weights (shoot + root), nodule numbers and shoot/root ratios

Treatments	Plant dry weights (shoot + root) mg	Nodule Numbers	Shoot/root Ratio
1. Live Cover + Moist	3.9bA	1.2bB	1.8a
2. Live Cover + Drying	-	-	-
3. Dead Cover + Moist	17.4aA	2.5aA	3.7a
4. Dead Cover + Drying	12.5aA	1.6bAB	3.1a
5. Burnt Cover + Moist	18.8aA	3.4aA	3.9a
6. Burnt Cover + Drying	14.2aA	2.0abA	2.9a
			NS
LSD (0.05)	10.83	1.36	2.30
LSD (0.01)	14.98	1.89	3.19
STD. ERROR	5.08	0.64	1.08
COEFF. VAR.	64.5	50.5	59.8

In spite of the very high variability, the figures show that plants surviving under the live cover treatment made considerably less growth than those in boxes with dead or burnt cover and they also developed fewer nodules. The differences between the four sprayed or burnt treatments were not significant but it may be worth noting that the plants with the highest final dry weights grew under the moist, burnt cover conditions (Treatment 5) and that these plants also had the greatest numbers of nodules.

Differences between the shoot/root ratios were not significant, showing, as would be expected, that plants with the largest shoots and nodule numbers also had the largest root systems (See plate 20). This relationship is further emphasised in Figure 17 which indicates a strong positive correlation ($r = 0.92$) between final plant weight and nodule number over the whole range of treatments significant at the 1% level.

FIG. 17: PLANT WT (mg) RELATIONSHIPS WITH NODULE NUMBERS 39 DAYS AFTER SOWING



5. DISCUSSION

For the purpose of this discussion, oversowing or surface sowing will be taken to represent the act of sowing seed on the surface of uncultivated land; germination will be defined as the sequence of steps which causes a quiescent seed with a low water content to show a rise in general metabolic activity and to initiate the formation of a seedling from the embryo (Mayer and Poljakoff-Mayer, 1963). Establishment will be taken to represent the subsequent seedling growth and survival the number of the plants remaining at the conclusion of the experiment compared with the number of seedlings germinating.

5.1 Seedbed Preparation Methods - Their Effects on Cover

5.1.1 Herbicides

Paraquat at 1.5 kg a.i./ha was used in both of the herbicide treatments in Trial 1, namely the long term paraquat treatment (Paraquat 1) and the short term treatment (Paraquat 2). With the long term treatment, paraquat was applied as a split application 0.5 kg a.i./ha at the first spraying and 1.0 kg a.i./ha 15 days later when some recovery of the cover was noticed. With the short term treatment, paraquat at 1.5 kg a.i./ha was applied as a single application.

The relative effects of the two treatments on the resident vegetation is shown in Figure 1. and it is clear that with the long-term treatment, the lucerne seedlings had a longer period to establish during their most vulnerable stage of growth. (Nixon, 1971). However, when weed ingress finally occurred, this treatment encouraged a more vigorous growth of weeds because growth of grass remained poor. Where lucerne did well so did the weeds, suggesting that lucerne and weeds responded in a similar manner to the influence of ground cover. (See Figures 7, 12 and 16). The short term treatment had less effect on the recovery of the grass cover and invasion of weeds occurred earlier during lucerne establishment so that competition led to poor establishment and survival of the oversown lucerne.

In Trial 2, glyphosate was used as the longer term herbicide treatment, (see appendix IB) and gave a remarkably persistent control of the existing cover. About 65 days after spraying plots receiving this treatment had virtually no weeds and negligible grass regrowth. This feature was accentuated on the long cover plots suggesting that the long cover exerted a shading effect so that light intensity was below the optimum for growth of lucerne or weed seedlings (Dowling, et al, 1

The short term herbicide treatment based on paraquat in Trial 2 suppressed cover regrowth and weed infestation much less than the glyphosate treatment so that 65 days after spraying the weeds and grass made an appreciable contribution to total dry matter. With this treatment also regrowth was particularly marked on the short cover plots, again pointing to the shading effects of the dead long cover. Dead cover on the paraquat treated plots appeared to decompose faster than that on plots sprayed with glyphosate. Thus in situations where maintenance of cover was important (e.g. under limiting soil moisture conditions) more benefits might be expected from dead covers killed with glyphosate because of their persistenc

With all herbicide treatments, however, a wider variety of weed species eventually became established than on the controls and suppression of grass growth clearly encouraged weed infestation (See plates 13 and 14). Under short cover, the effects of the herbicides appeared to result in the production of more favourable microsites for the germination and establishment of oversown lucerne seeds under the conditions prevailing in the present field trials.

On paraquat treated swards in boxes in the glasshouse trial both weeds and grass were completely suppressed for at least 39 days after spraying. Weights of dead matter were higher in these boxes than in the field, suggesting that breakdown of dead plant material was slower under glasshouse conditions.

5.1.2 Burning

Because of the greenness of the sward at the time of seedbed preparation (see plate 1) paraquat spraying was necessary to desiccate the cover before burning. The same procedure was used to achieve a burn in all three trials. The burning technique used resulted in a total destruction of cover and Figures 4, 11 and 14 indicate that as a result of absence of cover burnt plots (boxes) were prone to surface drying. In the two field trials however, soil moisture appeared to be sufficiently high that the germination and establishment of lucerne sown on the surface was not affected by the burning off of the cover. In the glasshouse trial, burnt plots under moist conditions gave the best germination, though in the establishment phase the numbers declined. The fastest cover regrowth and weed invasion also occurred with the burning treatment in all the trial so that by the conclusion of Trial 1, there was as much ground cover dry matter as on the long cover control plots. One reason for this rapid growth was presumably the lack of vegetation to compete with grass and weed regrowth. Another factor involved may have been the stimulation of regrowth by burning reported by various workers such as Adegbola and Onayinka, (1976), Coldrake and Russell, (1969), Tothill, (1971a, 1971b) and West, (1965).

5.1.3 Controls

5.1.3.1 Short cover (Simulating grazing)

This treatment was successful in providing initial conditions that were favourable to lucerne germination. Cutting was done only once before sowing and regrowth was vigorous so that by 35 days after sowing the lucerne seedlings were smothered. This emphasizes the need of keeping regrowth in check particularly regrowth from live cover, by some such process as controlled grazing, which checks competition and reduces shading as recommended by Suckling (1951, 1959, 1975). In Suckling's 1951 oversowing trial it was reported that under live short cover, smothering took place within 3-4 weeks after sowing.

5.1.3.2 Long cover

Under this treatment the grass was dense and long and probably provided the best characteristics required to increase soil surface humidity and thus favour germination. In the field trials this feature is supported by the soil moisture data recorded during the drier periods which indicate that long cover led to increased levels of soil moisture both in the 0 - 1.3cm and 0 - 5.1 cm layers. However, in the glasshouse, the benefit of a long, live cover in increasing humidity was limited under the low moisture regime in that the maximum soil surface drying occurred as a result of evapo-transpiration. Shading and intense competition for moisture and light led to the smothering of lucerne seedlings. These results are in accordance with Suckling's (1951) finding that long, live cover smothered oversown lucerne seedlings within 2 weeks. From the results obtained in both the field and glasshouse trials it appears that the long-lasting paraquat or glyphosate treatments on short cover produced the most suitable conditions for the establishment of oversown lucerne under adequate moisture levels. Long dead cover increased moisture at the soil surface but the reduced light intensity near the soil surface was unfavourable for plant growth (Dowling et al. 1971).

Under the tropical conditions of East Africa, oversowing of a hard grazed standing hay sward at the end of a dry season could be regarded as simulating to some extent the short-cover short term herbicide treatment.

Thus for successful oversowing, a supplementary weed control programme would probably be required to check regrowth during the early establishment of the oversown species. Under tropical conditions, burning would not normally require any preliminary desiccation by herbicides as conditions suitable for effective burning can be expected at the end of a dry season (West, 1965). Campbell (1969) recommends a 'wet' burn which scorches the cover without totally destroying it and leaves a protective layer. This type of burn involves burning at the start of the rains when the fuel is damp and results in a cooler fire which scorches but does not consume vegetation.

In all treatments designed to reduce cover there appears to be a need for the introduction of an early regrowth and weed control programme, to remove competition from the young establishing oversown species. Such programmes might involve controlled grazing and/or the use of selective herbicides.

5.2. Treatment Effects

5.2.1 Effects of pelleting (coating)

Bare and coated seeds alike gave very similar germination and establishment of oversown lucerne. Under the soil moisture conditions of the field trials, the supposedly beneficial effects of coating were not shown. In Trial 1 lucerne plants surviving at the conclusion of the experiment did not differ significantly in weight between the two seed treatments. Pelleting thus had no apparent effect on the germination, establishment or growth of lucerne.

In spite of the lack of difference between bare and coated seed in germination and establishment however, the degree of nodulation differed significantly, plants from bare seed having a greater number of nodules than those from coated seed ($P < 0.01$). This suggests differences in inoculum load and number of viable rhizobia per seed. The bare seed was inoculated liberally and sown only a few hours later so that the inoculum load and the number of viable rhizobia per seed was very high. There was thus a good chance for some rhizobia to survive until nodules were formed. In contrast the commercially inoculated and coated seed had been stored longer than the recommended 6 weeks before sowing. Another factor is that the minimum number of viable rhizobia per seed for Government seed coating tenders is only 150 bacteria (Hill, 1977-personal comm.) compared with the number of 10,000 regarded as necessary with oversowing (Date, 1970).

Hill (Loc. Cit.) has also found an average of 100-1000 rhizobia per seed on commercially pelleted seed. The combination of low inoculum load, small numbers of viable rhizobia and long storage period was presumably responsible for the poorer nodulation of plants growing from coated seed noted in Trial 1. This fact, however, did not appear to affect plant growth or vigour suggesting that the nitrogen status of the soil was high enough not to be limiting. Urea was applied as a top-dressing before commencement of the trials to boost grass growth. A vigorous grass/clover sward was also present, before the clover was killed off with dicamba and this also presumably helped to maintain a relatively high nitrogen status. In Trial 3, bare seed alone was used because of the evidence obtained in Trials 1 and 2.

5.2.2 <u>Soil Moisture</u>

The results reported in Chapter 4 show that for most of the duration of the field trials soil moisture was not a limiting factor for the germination and establishment of surface sown lucerne. In Trial 2 the moisture levels at and shortly after sowing were low due to lack of rain so that germination was delayed for a few days until further rain fell. Correlation coefficients between seedling number and soil moisture levels at various stages of lucerne growth were not significant, suggesting that no serious shortages of water occurred. Ground cover dry matter and soil moisture levels were positively correlated however, particularly under the denser dead cover of treatments 3 and 4 (long cover + long and short term herbicide treatments) as shown in figures 4 and 11.

It should be emphasised at this stage that the differences between treatments in lucerne germination and establishment appeared to be mainly due to shading and to such factors as the failure of radicles to penetrate the soil before the seedling dried up. Pests were an additional factor whose impact was minimal in Trial 1, severe in Trial 2 and moderate in Trial 3. The results of the glasshouse trial supported the view that, where moisture was not limiting, surface sowing of lucerne succeeded best under conditions of burnt or short desiccated cover. This trial also supported the results of the field trials in showing that cover, particularly live cover was not beneficial to the germination and establishment of the oversown species. Live cover and drying conditions gave the poorest results under glasshouse conditions, resulting in severe competition for moisture and light between the grass and the lucerne seedlings, so that seedlings were smothered within 39 days.

5.2.3 Effects of covers on germination and early establishment

The three trials agreed in showing that under the prevailing conditions an absence of ground cover at the time of oversowing encouraged both germination and early establishment of lucerne. In the field trials soil moisture was not limiting so that the mulching effect of the cover had no beneficial influence on lucerne growth. In the glasshouse trial, where soil moisture conditions were drier (e.g. dead cover, drying conditions) the presence of cover certainly encouraged lucerne growth but had no effect under moist conditions. In the summer field trial it was noted that the first 35 days of lucerne growth were the most important, in that later assessments showed no significant changes after the second count. This suggests that effective control of competition from resident vegetation for the first month after sowing can lead to satisfactory establishment of oversown lucerne.

5.2.3.1 Burnt Cover

In all trials, the largest seedling numbers at germination were recorded on the burnt plots. Seedling establishment numbers (i.e. from the second count onwards) did not differ significantly between burning and the short cover, long term paraquat treatment. In the autumn field trial the burnt plots remained superior to other treatments until slug damage occurred and the burning treatment also gave the best results in the box trial. Total destruction of existing vegetation and hence complete removal of competition during the germination and early growth stages appeared to be necessary for satisfactory lucerne establishment under moist conditions.

5.2.3.2 Herbicide treated cover

(a) Short cover

The long term herbicide treatment in Trial 1 gave the best establishment though the numbers germinating were lower than on the burnt plots. This effect can be attributed largely to the adequate moisture conditions during the trial period combined with the presence of a non-competing cover. The desiccated grass foliage provided a mulching effect and yet allowed adequate penetration of light to the lucerne seedlings at the soil surface. The long period of suppression of competing vegetation gave the lucerne seedling the opportunity to grow free from competition during the stage of growth at which they were most susceptible (Palmer & Wynn-Williams, 1972).

In Trial 2, germination and establishment were poor on the long-term herbicide (glyphosate) plots although regrowth of cover and weed invasion were suppressed for at least 65 days after spraying. Thus in this trial competition does not appear to have been the limiting factor but the effects of pest and slug damage was most important in causing the loss of seedlings.

(b) Long cover

In the first trial, long term herbicide treatment (Paraquat) resulted in half as much germination as on the short cover plots and only one third of the establishment. Although cover regrowth was suppressed for a long time, the desiccated foliage was dense so that light penetration to the surface was limited (Campbell and Swain 1973b); Dowling, et al. 1971). The results therefore suggest that long, dense cover, although dead, was detrimental to the germination and early establishment of oversown lucerne under conditions of high soil moisture. In the second trial, cover effects were masked by the extremely high moisture levels and slug activity so that there was no difference in lucerne germination or establishment between the herbicide treatments.

The slug estimates suggested that dense cover favoured a build up of these pests which were the main reason for the small seedling numbers recorded 16 days after sowing. It might also be expected that the shading effects of the long cover would have accentuated the loss of seedlings. In Trial 2, the two herbicide treatments did not differ significantly. In Trial 1, however, the treatments did differ and the long-term paraquat treatment resulted in 60% higher establishment than short-term paraquat at the final count 13 weeks after sowing. The improved establishment was probably because the long-term paraquat treatment provided the lucerne seedlings with a competition-free environment during their most vulnerable stage of growth. The box trial in the glasshouse revealed that cover favoured lucerne germination where conditions were not too dry. With increasing dryness however, the characteristics of the cover became more significant, e.g.. dead cover was preferable to live cover because it competed less for moisture. Paraquat treated cover therefore resulted in the best establishment of lucerne, though not significantly superior to the burnt cover treatment (see Table 19a).

From the above discussion it appears that the use of herbicide to suppress cover regrowth and weed invasion offers a possible method for oversowing lucerne in pasture as long as the cover is not too long (e.g. in this case 8cm). Split application of paraquat at a total of 1.5 kg a.i./ha, the second dose applied when regrowth started, gave much better control than the same dose sprayed as a single application. Glyphosate appeared to control grass regrowth and weeds better than the long-term paraquat treatment. However either treatment would appear suitable for producing the desired degree of vegetation control required for successful lucerne oversowing, provided that other limiting factors (e.g. moisture) were adequately supplied.

On the other hand the use of herbicides in the tropical pasture situation of East Africa remains questionable because of the high cost, the lack of appropriate spraying machinery and the inaccessibility of many natural grassland areas. Timely burning and seeding so as to ensure adequate moisture availability over the crucial establishment period would appear to be the most practical method of introducing legumes into natural grasslands in these areas.

5.2.3.3 Controls (Live cover)

In the first trial, short cover control plots supported a significantly higher number of lucerne seedlings than the long cover controls at the first count but 35 days after sowing there was almost complete loss of seedlings with both covers. This loss of seedlings is most likely to have been due to the effects of shading. Suckling (1951) also noted that oversown legume seedlings were smothered within 2 weeks or 3-4 weeks of sowing under long and short live covers respectively.

With both long and short live cover plots in the second trial, no live seedlings remained by the time of the first count 16 days after sowing. This helps to confirm the suggestion that live cover offers too much competition to young seedlings of the oversown species. However, it is possible that in both field trials, germination under the live covers, particularly long cover, might have been high because of increased surface humidity (Evans and Young, 1970). By the time the first assessments were made however, the seedlings had been smothered.
The trial in the glasshouse also supports this theory for, under moist conditions, germination under the long, live cover was high and did not differ significantly from that in boxes with burnt or dead cover.
On the other hand under drying conditions, seedling numbers in boxes with

live cover were significantly lower than with other treatments. These results suggest that the beneficial effect of live cover in increasing humidity at the surface and hence germination, was masked by the severe competition for moisture below the surface. By 39 days after sowing, seedlings surviving in the live cover boxes were significantly smaller than those in the burnt or dead cover boxes. This again indicates that even though germination may be high under live cover, the heavy shading effect produced by the cover discourages later establishment. The rapid loss of seedlings under live cover treatments in the field can be explained on the same basis.

From the above discussion, it has been established that burnt cover or short cover treated with herbicides encouraged germination and early establishment of oversown lucerne under non-limiting moisture conditions. Under contrasting conditions in South Island, Janson (1970) in a lucerne oversowing trial showed that cover was of advantage to germination under moist conditions and essential under dry conditions. A dead cover was recommended as it increased the humidity of the soil surface and buffered the fluctuations of the environment. In numerous experiments by Campbell (1968, 1969, 1972, 1973, 1974a, 1974b, 1976); Campbell and Swain (1973a, 1973b); Cullen (1971); Dowling et al. (1970); Janson and White (1971); White (1970, 1973b) and Squires and Elliott (1975) it has been observed that dead ground cover acts as a buffer to soil moisture fluctuations near the surface. However, the quantity of cover desirable was shown to have an upper limit, in that too long and dense covers caused excessive shading and sub optimal light intensities for the establishing of oversown species (Dowling et al. 1971; Evans and Young 1970). Campbell and Swain (1973b) have also noted a detrimental effect of too much cover.

Destruction of cover by burning as a seedbed preparation technique before oversowing has yielded poor results under many field conditions, though it has been more successful in wetter regions of the world such as New Zealand (Levy, 1970; Semple, 1972). In Australia Campbell (1969), successfully oversowed subterannean clover after wet burning during a season of adequate moisture conditions. Burning, therefore, can lead to successful oversowing of lucerne as long as soil moisture is adequate at and after sowing. This conclusion suggests that soil moisture was probably the major factor limiting the success of oversowing in the trials by Campbell (1968), Janson (1970) and Musgrave (1976). Suckling (1951) observed that, after the destruction of cover, although some seedlings died of desiccation, many survived under wetter conditions. The removal of competition was more important here than the provision of a protective layer of cover, especially if it was long and dense enough to cause shading of the growing seedlings. The importance of the sheer physical impedance caused by a thick cover is also stressed by Squires and Elliott (1975).

Provision of live cover as a measure to facilitate oversowing has been found of limited value. Cullen (1971), for example, found that a dense grass sward had to be sprayed with paraquat to facilitate successful oversowing of legumes. Campbell (1969) also reported that competition for moisture limited the growth of oversown species under a live cover. He observed that with a relatively sparse cover, competition for moisture was the main limiting factor, while with dense cover competition for light became more important. Though germination under a dense live cover may be high because of the relatively high humidity at the soil surface, early establishment is poor because intense shading leads to smothering of the seedlings. In a series of papers, Suckling (1951, 1959, 1966 and 1975) suggests the use of grazing to reduce competition and shading effects from cover so as to give young seedlings of the oversown species a chance to develop. Campbell (1973), Campbell and Swain (1973b), Janson and White (1971), Nixon (1971), Palmer and Wynn-Williams (1972) and Suckling (1975) all point out the importance of removing or reducing competition from existing vegetation by the use of herbicides, especially where the cover is dense and capable of growing vigorously.

In the oversowing of legumes for pasture improvement it appears from numerous reports that such moisture improving techniques as the provision of cover are insufficient to improve germination and establishment under conditions of severe moisture stress. Campbell and Swain (1973b) for example report that adequate soil moisture was the major factor determining the successful establishment of oversown species in Australia. In New Zealand the most favourable moisture conditions for oversowing appear to occur between late winter and early spring, when it is moist and cool (Musgrave 1976). In Australia, on the other hand, autumn appears to be the time when the most suitable moisture conditions can be expected (Campbell 1969). Under New Zealand conditions, Charlton (1977 personal comm.) has observed that autumn over-sowing would be likely to coincide with the build-up of maximum slug populations which can be a major cause of legume seedling mortality.

Under tropical conditions oversowing to coincide with adequate soil moisture would appear most likely to occur at the onset of a rainy season (either short or long rains). Growth of all types of vegetation would normally be vigorous at this time but carefully controlled grazing could be employed to reduce competition. Several authors have found that, although some seedlings may be lost during grazing, the overall benefit is greater than not grazing at all (Suckling 1959; Cullen 1970, 1971).

5.2.4 Effects on Subsequent Growth

5.2.4.1 Botanical Composition

The final botanical composition of the plots, as determined by dissection of herbage samples, again showed that large amounts of live cover (as on the control plots) severely reduced lucerne survival and also prevented the ingress of weeds. Proportions of lucerne were only high on plots with burnt or dead cover (especially the short cover).

In Trial 1, the largest contribution of lucerne dry matter to the total occurred on the short cover plots receiving the long term herbicide treatments (22% lucerne - see Fig 7). With the sowing rate of 3 kg/ha used in the trial, it is possible that the final stand of lucerne was less dense than would have been the case if the conventional seed rate of 9-11 kg/ha had been used. However, Langer (1973) showed that, although plant numbers increased with sowing rate, rates of 1-2 kg/ha could yield stands as productive as much heavier rates provided there was neither extreme summer drought nor major infestations of perennial weeds. He also suggested that, if competition from weeds was likely to be appreciable, seed rates should not be too light. Suckling (1966) suggested the use of a high seed rate with oversowing in order to simulate the natural seeding of spelled swards. On the other hand, Palmer and Wynn-Williams (1972) observed that in establishing lucerne, competition between plants at higher seed rates was apparently more likely to cause death of lucerne plants than competition between lucerne and other species. In this investigation, a slightly higher seed rate would possibly have led to the survival of larger numbers of plants but the number sown was dictated by the spacing of the grid used.

In Trial 2, all lucerne seedlings had disappeared 5 weeks after sowing and this loss was attributed primarily to slug damage. The possibility of 100% loss of seedlings from slug damage was referred to by Suckling (1959). Janson (1970) also noticed slug damage with oversown lucerne and Charlton (1977, personal comm.) suggests that slug damage may be the main cause of loss of oversown legume seedlings apart from severe weather changes.

The field trials showed that burnt and herbicide treated plots eventually supported the widest variety of weed species which further emphasises the need for weed control in establishing oversown species. Suckling (1959) and White (1973a) recommend the "hoof and tooth" treatment for controlling weeds. Campbell and Swain (1973b) suggest the use of selective herbicides while McWilliam and Dowling (1970) suggest leaving enough dead cover to suppress weeds without hindering the establishment of the oversown species. In the present work it was observed in Trial 2 that, dead, long cover suppressed weeds though the effect on lucerne could not be determined because of slug damage. It is suggested that in practice it may be difficult to provide just enough dead cover to control weeds without affecting the oversown species.

In the glasshouse trial, where cover was dense and live, the final lucerne dry matter production was very small. This was also the case with dead cover although the lucerne had established well with these treatments. In the burnt cover boxes, lucerne made up the highest proportion of the total dry matter largely because of the absence of cover dry matter. This trial further emphasized the points that removal of competition was necessary for successful oversowing of lucerne and that where moisture conditions were favourable, provision of ground cover had limited benefits. Weeds also grew well on the burnt cover boxes which further stressed the need for early weed control.

5.2.4.2 Lucerne growth and development

(a) Individual lucerne plant dry weights

The final dry weight of individual lucerne plants was negatively correlated with ground cover dry matter recorded at the earliest stage of growth. Where cover was dense as on the control and long cover sprayed plots, many lucerne seedlings were killed and surviving plants were small. The correlation suggests that when the growth of lucerne is checked by competition in the early stages, subsequent growth is also likely to be poor. It should be noted that where there was little competition for the first month, as on the short cover long-term herbicide plots there was little effect on lucerne growth even though a heavy growth of weeds developed later on. These observations support the findings of Palmer and Wynn-Williams (1972), Nixon (1971) and Suckling (1975) who also stress the importance of early weed control for successful oversowing.

(b) Shoot/root ratios

The final harvest showed no significant differences between the various treatments in the shoot/root ratio of the lucerne plants. This suggests that the growth of roots was in direct proportion to that of the shoots. In general, it has been found that soil moisture influenced the shoot/root ratio of lucerne, in that under moisture stress conditions, shoot growth was reduced more than root growth (Kramer, 1969; Peters and Runkles, 1967; and Slatyer, 1967). In the present work, soil moisture does not appear to have been a limiting factor so that low ratios of shoot to root were not anticipated.

5.3 Complications due to pests

During this study, particularly in trials 2 and 3 slugs appeared to be the major cause of seedling damage and loss. During the first trial in summer, this problem was not encountered. Because of this and the fact that the literature on slug damage was not noted until later, the damage that influenced the results of Trial 2 was not anticipated and no control measures were taken.

The slug and insect larva problem with oversowing under New Zealand conditions is cited by Suckling (1951), Janson (1970), Charlton (1977) and Sims (1977 personal comm.) In Australia, Campbell (1973) and Campbell & Swain (1973b) have also observed that slugs and larvae were active in winter and that legume seedlings were apparently eaten in preference to grasses. In Britain, Haggar et al. (1976) report the possibility of soil borne pests (especially slugs) being a limiting factor with oversown species.

In the autumn field trial all seedlings were lost within 5 weeks of sowing and in the box trial a few boxes were severely affected by slug activity. The metaldehyde bait used did not control slugs at once, particularly under the more frequent watering regime, where conditions were conducive to egg hatching and recovery from the effects of the bait (Symonds 1975). It was observed that in the boxes where high numbers of slugs were seen, greater damage occurred. Lucerne seedlings eaten off at the cotyledon or the first true leaf stage did not recover. The first 4 weeks after sowing represented the critical stage of growth, as far as slug damage was concerned. After this stage, seedlings appeared better able to recover from damage. No other pest was noticed to affect lucerne establishment.

The large difference in slug activity noted between the summer and autumn field trials confirms observations by other workers that activity is lowest in summer, starts building up in autumn and reaches its peak in spring (Charlton 1977 personal comm.). Suckling (1951) reported a loss of up to 100% of oversown legumes (clover) from slug damage under wet conditions and Charlton (Loc. cit.) has reached the following conclusions concerning slug damage to oversown legumes.

(i) slugs are the main cause of seedling loss following oversowing on North Island hill country pastures, apart from extreme changes of weather.

(ii) slugs have a preference for oversown legume seeds soon after they start to germinate.

(iii) Under normal conditions most damage is done during the first 4 weeks after sowing.

(iv) if legume seedlings are attached in the cotyledon, or first-true-leaf stages, they are generally killed. Older seedlings seem capable of growing on despite some grazing by slugs.

(v) Control of slugs is very difficult for periods longer than a few days. Coating seed with methiocarb molluscicide appears to provide some protection and allows significantly higher numbers of seedlings to establish than when no coating is used. Alternatively methiocarb prills may be mixed with the seed prior to sowing . Sims (1977 personal comm.) has suggested that the unusually wet summer and autumn of 1975/76 accentuated the slug problem because many slugs are killed in a dry summer, leading to a relatively slug free autumn. With oversowing or overdrilling the application of slug bait pellets at the time of seeding normally appears to solve the problem and facilitates the successful use of this short cut to pasture or crop establishment.

Apart from the problem of slugs, it has been reported that ants can be a serious problem with oversowing in tropical areas. In Australia, Campbell (1973), Campbell and Swain (1973b), Russel et al. (1967) have reported that termites and ants may remove large numbers of oversown seeds. This harvesting of seed varied with season and seed size, lighter seeds being preferred to heavier ones. Seed harvesting was also observed to increase if oversowing was followed by dry conditions. It is thought that under East African conditions the effects of ants and termites on the survival of oversown seed would probably be more important than the effects of slugs.

It would appear that loss of seed through theft by ants and loss of seedlings through slug damage can be important factors in oversowing and effective measures to prevent these losses need to be developed. Proper timing of sowing so that germination occurs rapidly (i.e. under wet conditions) appears to be the most effective way to counter the effects of ants because soon after germination ant harvesting ceases. (Campbell and Swain, 1973b). Possible solutions to slug damage may involve the use of higher seed rates, sowing at a time which avoids peak slug activity and, where necessary, the use of slug baits.

6. GENERAL CONCLUSIONS

This study has shown that oversowing of lucerne for improvement of pasture can be successful where soil moisture is plentiful. The establishment and survival results obtained in Trial 1 demonstrated that lucerne can be established successfully by surface sowing techniques under warm, moist conditions. Suitable conditions would be expected to occur in many of the wetter regions of the world. The use of some treatment to eliminate competition from existing vegetation proved to be essential. Two types of herbicide treatment have been shown to give the right degree of control of cover and burning offered a good alternative for situations where the use of herbicides might be impractical or too costly. Sowing of lucerne without killing back the cover was unsuccessful whether the cover was long or short due to severe competition and shading leading to the rapid smothering of the oversown species.

The results of oversowing lucerne could probably be improved by the following measures:-

(i) Complete control of the resident vegetation and prevention of weed invasion during the susceptible early stages of seedling growth. Under the conditions of the present trials this appeared to be the first 35 days after sowing.

(ii) Control of the subsequent ingress of weeds and grass by mob grazing or the use of selective herbicides (e.g. 2,4DB for broad-leaved weeds).

(iii) Where slugs are liable to be a problem, sowing the seed together with slug bait pellets. In this situation the seed rate should also be increased so as to compensate for the loss of any seedlings killed by slugs that escape the bait.

(iv) A general increase in seed rate is also advisable to boost germination and establishment.

(v) Provision of some form of mulch in the form of dead cover (herbicide desiccated or fire scorched vegetation) appears to be beneficial to oversown species. Too dense a cover may be detrimental however, in that it lowers the light intensity at the soil surface, causing etiolation or death of young oversown seedlings. Care should be taken not to exceed the upper limit of the density and length of cover found to be most suitable.

Under tropical conditions it is suggested that oversowing would have the best chances of success if carried out just before the onset of a rainy season, after burning or hard grazing of the resident vegetation. As the rains start, germination of the oversown species and growth of the existing vegetation would normally take place at the same time so that a carefully planned controlled grazing would be needed to reduce competition and give the desired species a chance to establish. The use of herbicide for pasture improvement purposes in developing countries as a means of removing competition to an oversown legume appears, at present, to be costly and impractical. However, where machinery is available and land accessible, strip spraying of herbicides and oversowing on these strips could be a way of cutting down the cost of chemicals.

In summary the following concluding comments have been drawn from the study:-

(a) Oversowing should be carried out when soil moisture conditions are likely to be adequate both at and after sowing and preferably throughout the first growth season.

(b) Killing off the resident vegetation which competes for available moisture with the oversown species is essential.

(c) The provision of some form of protective dead vegetative cover to reduce the evaporative loss of water and provide a more favourable moisture environment in the vicinity of the seed is recommended as long as it is not too long or dense.

(d) It is necessary to provide an early weed control measure to check regrowth of cover and prevent weed invasion during the early establishment period of the oversown species. This may be possible by controlled grazing.

(e) More work is needed to find more suitable legume species and to select them in order to improve their adaptation for oversowing purposes.

(f) Where pest problems are anticipated, control measures should be applied at the time of oversowing.

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8 APPENDICES

APPENDIX I: EXPERIMENTAL LAYOUT FOR TRIALS 1 AND 2

Replicate (Block)	Plots			
I	1 3C	2 6C	3 1B	4 2B
	5 7B	6 4C	7 1C	8 5B
	9 7C	10 3B	11	12 6B
	13 2C	14	15 4B	16 5C
II	17	18 1B	19 4C	20 3B
	21 6C	22 1C	23 2C	24 4B
	25 3C	26 7C	27 6B	28 7B
	29 5B	30 5C	31	32 2B
III	33 3B	34 1C	35	36 6C
	37 2B	38 1B	39 4C	40 5B
	41	42 7B	43 4B	44 5C
	45 3C	46 6B	47 7C	48 2C
IV	49	50 4B	51 6C	52 7B
	53 1B	54 1C	55 3B	56 2B
	57 5B	58 4C	59 7C	60 3C
	61	62 6B	63 5C	64 2C

Key: 1....64 Plot numbers
1B...7B Ground cover treatments sown with bare seed
1C...7C Ground cover treatments sown with coated seed.

APPENDIX IA: DESCRIPTION OF TREATMENTS IN TRIAL 1

Seed Type	Ground cover Treatment Number	Description
Bare Seed	1	Long cover control (15cm)
	2	Short cover control (8cm)
	3	Long cover + long Lasting Herbicide (Paraquat 1). Rate:0.5 kg a.i./ha followed by 1.0 kg a.i./ha 15 days later
	4	Long cover + short term herbicide (paraquat 2). Rate:1.5 kg a.i./ha applied once.
	5	Short cover + long lasting herbicide (Paraquat 1)
	6	Short cover + short term herbicide (Paraquat 2).
	7	Paraquat 2 + Burning.
Coated (Pelleted) Seed	1	Long cover control (15cm)
	2	Short cover control (8cm)
	3	Long cover + Paraquat 1 - As above
	4	Long cover + Paraquat 2 - As above
	5	Short cover + Paraquat 1 - As above
	6	Short cover + Paraquat 2 - As above
	7	Paraquat 2 + burning

APPENDIX IB: DESCRIPTION OF TREATMENTS IN TRIAL 2

Seed Type	Ground cover treatment Number	Description
Bare Seed	1	Long cover control (15 cm)
	2	Short cover control (8cm)
	3	Long cover + long lasting herbicide glyphosate). Rate: 2kg/ha Glyphosate. Then 0.5 kg a.i./ha paraquat and 1.0 kg/ha carbetamide sprayed 12 days after glyphosate.
	4	Long cover + short term herbicide (Paraquat). Rate: 1.0 kg a.i./ha paraquat and then paraquat at 0.5 kg a.i./ha 12 days later.
	5	Short cover + Glyphosate (as in 3 above).
	6	Short cover + Paraquat (as in 4 above).
	7	Paraquat (as in 4 above) + burning.
Coated Seed	1	Long cover control (15 cm).
	2	Short cover control (8cm).
	3	Long cover + glyphosate (as in 3 above).
	4	Long cover + paraquat (as in 4 above).
	5	Short cover + Glyphosate (as in 3 above).
	6	Short cover + Paraquat (as in 4 above).
	7	Paraquat (as in 4 above) + burning.

APPENDIX 2: EXPERIMENTAL LAYOUT FOR TRIAL 3

Replicate (Block)	I	II	III	IV
PLOTS	1 3*	7 2*	13 4*	19 5*
	2 2*	8 4*	14 5*	20 2*
	3 1*	9 3*	15 6*	21 6*
	4 4*	10 6*	16 3*	22 1*
	5 5*	11 5*	17 1*	23 4*
	6 6*	12 1*	18 2*	24 3*

Key: 1........24 Plot numbers

1* ..... 6* Treatments

APPENDIX 2A: DESCRIPTION OF TREATMENTS IN TRIAL 3

Seed Type	Cover Treatment Number	Description
Bare Seed	1	Live (green) cover and moist.
	2	Live (green) cover and drying.
	3	Dead cover (Paraquat sprayed at 1.0 kg a.i./ha) and moist.
	4	Dead cover (as in 3 above) and drying
	5	Paraquat (1.0 kg a.i./ha) + burning and moist.
	6	Paraquat (as in 5 above + burning and drying.

APPENDIX 3: GLOSSARY OF HERBICIDES CITED IN THE TEXT

Common Name	Trade Name	Chemical Name
1. Amitrole	Weedazol T.L.	3-amino-1,2,4-triazole
2. Carbetamide	Carbetamex	D-N-ethyl-2-(phenylcarbamoyloxy propronamide.
3. 2,2-DPA	Dalapon	2,2-Dichloropropionic acid
4. Dicamba	Shell Dicamba 2	Dichloro-2-methoxybenzoic acid
5. Diquat	Reglone	9, 10-dihydro-8a, 10-diazonia phenanthrene.
6. Glyphosate	Roundup	N-phosphonomethyl glycine.
7. Paraquat	Gramoxone	1,1-dimethyl-4, 4-bipyridilium.

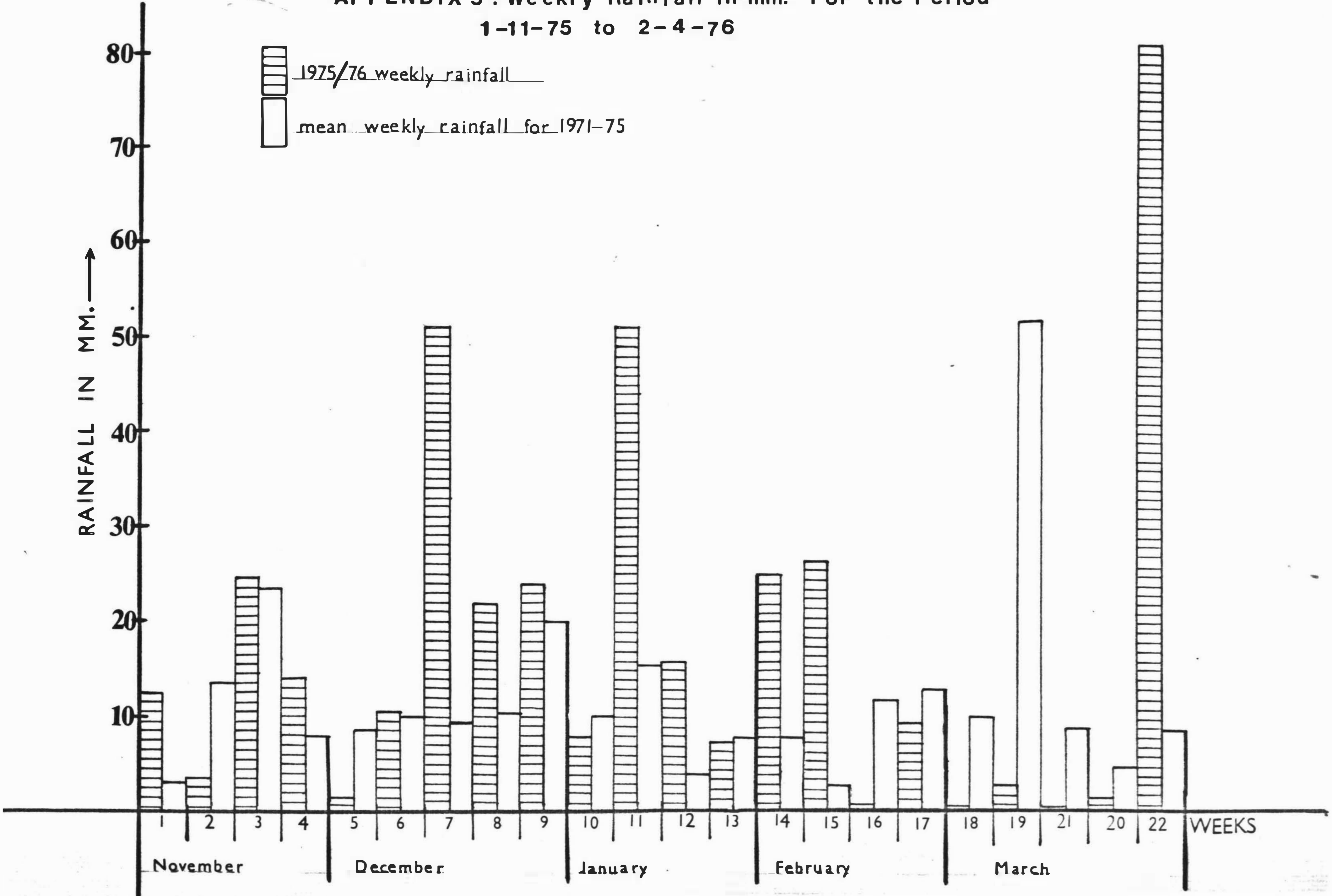
APPENDIX 4: Effects of ground cover treatments on lucerne germination and survival during 91 days of growth in Trial 1.

Sowing Date 10-13/12/1975

Counts	1			2			3			4			5		
Dates	26-29/12/1975			16-17/1/1976			6-10/2/1976			20-22/2/1976			12-13/3/1976		
Days From Sowing	15			35			58			70			91		
Treatments	Seedling Numbers	% Germination		Seedling Numbers	% of Seed Sown		Seedling Numbers	% of Seed Sown		Seedling Numbers	% of Seed Sown		Seedling Numbers	% of Seed Sown	
		A**	T***		A	T		A	T		A	T		A	T
1 Long Cover Control	5	2	1.13dC	0	0	0.71dD	0	0	0.71dD	0	0	0.71dD	0	0	0.71dD
2 Short Cover Control	40	16	3.81bc AB	1	0.2	0.77dD	0	0	0.71dD	0	0	0.71dD	0	0	0.71dD
3 Long Cover + Para 1*	33	13	3.07cBC	23	9	2.67bc BC	20	8	2.67bB	20	8	2.62bB	20	8	2.61bB
4 Long Cover + Para 2*	30	12	3.17cBC	10	4	1.97cC	8	3	1.80cC	8	3	1.82cC	8	3	1.82cC
5 Short Cover + Para 1	71	28	5.28ab AB	66	26	5.07aA	66	26	5.04aA	63	25	5.06aA	63	25	5.05aA
6 Short Cover + Para 2	60	23	4.60abc AB	33	13	3.45bB	30	12	3.26bB	30	12	3.30bB	30	12	3.30bB
7 Para + Burn	78	31	5.52aA	60	23	4.77aA	55	22	4.70aA	55	22	4.63aA	53	21	4.64aA
LSD (0.05)			1.53			0.79			0.76			0.73			0.72
LSD (0.01)			2.04			1.05			1.02			0.98			0.91
Std. Error			0.76			0.39			0.38			0.36			0.36
Coeff. Var.			39.8			28.0			27.9			26.9			26.5

* Para 1 = Long term paraquat treatment, Para 2 = Short term paraquat treatment A** = Actual % T*** = Transformed %

APPENDIX 5 : Weekly Rainfall in mm. For the Period
1-11-75 to 2-4-76



APPENDIX 5A: BOTANICAL COMPOSITION (DISSECTION)

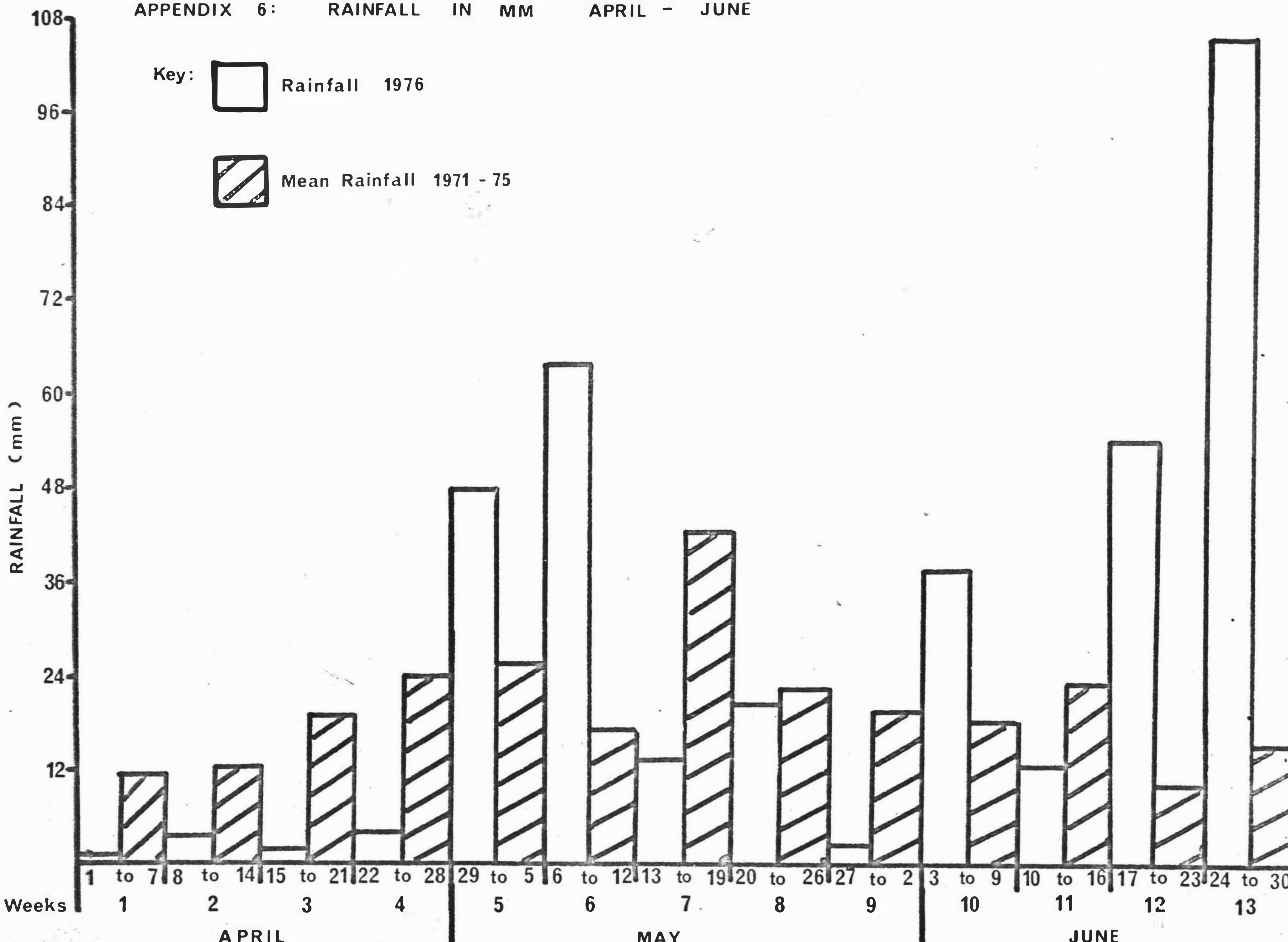
TRIAL 1

Treatments	Total Dry Matter (gm)	Botanical Composition (% Total DM)							
		% Lucerne		% Grass		% Clover		% Weeds	
		A*	T**	A	T	A	T	A	T
1	93.1	0	0.71	92.6	9.65	1.1	1.13	6.3	2.42
2	75.1	0	0.71	80.3	8.96	13.2	3.03	6.5	2.53
3	86.6	11	2.73	30.2	5.44	5.1	1.82	539	7.32
4	81.6	0.3	0.84	55.3	7.21	9.9	2.23	34.6	5.60
5	75.2	22	4.60	25.7	4.67	3.9	1.58	48.3	6.81
6	73.4	3	1.73	68.8	8.27	5.5	2.04	22.5	4.60
7	72.7	17	4.01	49.7	6.99	2.0	1.41	31.3	5.51
LSD (0.05)	14.00		1.06		1.52		1.53		1.34
LSD (0.01)	18.70		1.41		2.03		2.04		1.79
Std. Error	6.90		0.52		0.75		0.76		0.66
Coeff. Var.	17.38		47.78		20.52		79.93		26.72

*A = Actual %

**T = Transformed %

APPENDIX 6: RAINFALL IN MM APRIL - JUNE



APPENDIX 7 : WEED SPECIES FOUND UNDER DIFFERENT GROUND COVER TREATMENTS IN TRIAL 2, 112 DAYS (16 WEEKS) AFTER THE SECOND HERBICIDE APPLICATION.

Ground cover treatments	WEED SPECIES
1. Long cover control	Rumex spp. (dock); Taraxacum officinale (dandelion); Plantago spp. (Plantain); Cirsium vulgare (scotch thistle).
2. Short cover control	Taraxacum officinale; Rumex spp.; Plantago spp.
3. Long cover + glyphosate	Taraxacum officinale; Sonchus oleraceus (sow thistle); Senecio vulgaris (groundsel); Cirsium vulgare; Carduus tenuiflorus (winged thistle); Picris echioides (prickly oxtongue); Rumex spp.; Coronopus didymus (twin cress); Veronica persica (scrambling speedwell); Ranunculus spp. (buttercup).
4. Long cover + Paraquat	Conium maculatum (Hemlock); Rumex spp; Taraxacum officinale; Plantago spp.; Senecio vulgaris; Ranunculus spp.; Galium mollugo (Hedge bedstraw); Sonchus oleraceus; Cirsium vulgare; Veronica persica.
5. Short cover + glyphosate	Taraxacum officinale; Coronopus didymus; Senecia vulgaris; Veronica persica; Rumex spp.; Sonchus oleraceus; Cirsium vulgare; Galium mollugo; Carduus tenuiflorus.
6. Short cover + Paraquat	Rumex spp.; Taraxacum officinale; Sonchus oleraceus; Coronopus didymus; Cirsium vulgare; Cerastium spp. (Chickweed); Ranunculus spp.
7. Paraquat + burn	Sonchus oleraceus; Taraxacum officinale; Rumex spp.; Cirsium vulgare; Ranunculus spp; Carduus tenuiflorus; Cerastium spp.; Veronica persica; Coronopus didymus.

8A

MASSEY UNIVERSITY

OVERSOWING TRIAL I M.KUSEKWA AGRONOMY

ANALYSIS OF VARIANCE S.COUNT 1 NUMBER 2

SOURCE	DF	SS	MS	F CAL	F REQ		STD ERROR	LSD 1PC	LSD 5PC
REPLICATE	3.	4.6076	1.5359	0.672	4.31	2.84			
TREATMENT A	1.	0.7317	0.7317	0.320	7.31	4.08	0.4041	1.0928	0.8168
TREATMENT B	6.	110.9701	18.4950	8.089	3.29	2.34	0.7561	2.0444	1.5280
A*B INTERACTION	6.	6.3675	1.0613	0.464	3.29	2.34	1.0692	2.8912	2.1609
ERROR	39.	89.1748	2.2865						

COEFF VAR = 39.82

MEANS FOR A*B INTERACTION

1.547	0.708	1.127
4.381	3.236	3.809
2.930	3.208	3.069
2.908	3.438	3.173
4.997	5.570	5.283
5.060	4.143	4.601
5.561	5.479	5.520

MEANS FOR A 3.912 3.683

FACTOR A IS SEED TYPE, FACTOR B IS COVER

8B

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OVERSOWING TRIAL 2 M.KUSEKWA AGRONOMY

ANALYSIS OF VARIANCE S.COUNT.1 [illegible] NUMBER 2

SOURCE	DF	SS	MS	F CAL	F REQ		STD ERROR	LSD 1PC	LSD 5PC
REPLICATE	3.	1.1856	0.3952	1.794	4.31	2.84			
TREATMENT A	1.	0.4319	0.4319	1.960	7.31	4.08	0.1255	0.3392	0.2535
TREATMENT B	6.	42.6797	7.1133	32.285	3.29	2.34	0.2347	0.6346	0.4743
A*B INTERACTION	6.	1.5688	0.2615	1.187	3.29	2.34	0.3319	0.8975	0.6708
ERROR	39.	8.5929	0.2203						
COEFF VAR =	31.48								

MEANS FOR A*B INTERACTION

0.708	0.708	0.708
0.708	0.708	0.708
1.419	1.301	1.360
1.281	1.351	1.316
1.582	1.018	1.300
1.462	1.639	1.550
3.894	3.099	3.496

MEANS FOR A 1.579 1.403

FACTOR A IS SEED TYPE, FACTOR B IS COVER

8 C

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OVERSOWING TRIAL 3 M.KUSEKWA AGRONOMY

ANALYSIS OF VARIANCE S.COUNT 1 HARVEST 6

SOURCE	DF	SS	MS	F CAL	F REQ	
BLOCK	3.	1.5550	0.5183	1.665	5.42	3.29
TREATMENT	5.	6.1601	1.2320	3.958	4.56	2.90
ERROR	15.	4.6688	0.3113			

COEFF VAR = 6.65

8.6320	8.8610	8.8610	8.2770	8.6578
6.9650	7.1070	8.0940	7.9700	7.5340
7.7150	8.9730	8.8610	9.1390	8.6720
7.3830	7.5840	8.2770	9.3550	8.1498
9.4610	8.8610	9.2480	8.9730	9.1358
7.8430	8.8610	7.5180	8.5160	8.1845

BLOCK MEANS 7.9998 8.3745 8.4765 8.7050

STD ERROR 0.3945 LSD 1PC 1.1626 LSD 5PC 0.8407

OVERSOWING TRIAL 3 M.KUSEKWA AGRONOMY

ANALYSIS OF VARIANCE S.COUNT 2 HARVEST 6

SOURCE	DF	SS	MS	F CAL	F REQ	
BLOCK	3.	1.1336	0.3779	0.316	5.42	3.29
TREATMENT	5.	6.3070	1.2614	1.054	4.56	2.90
ERROR	15.	17.9491	1.1966			

COEFF VAR = 14.18

8.6320	8.2770	8.2770	8.6320	8.4545
7.5840	7.5180	7.5180	5.5240	7.0360
5.5840	9.4610	6.1250	8.6320	7.4505
8.4800	6.9650	7.9700	9.0290	8.1110
9.3550	7.9700	7.5180	7.2470	8.0225
7.3830	7.5180	6.8200	7.1490	7.2175

BLOCK MEANS 7.8363 7.9515 7.3713 7.7022

8D

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**********************************************************************************
*                                                                                *
*      ***          SOWING TRIAL 2  1976, CORRELATIONS               ***         *
*                                                                                *
**********************************************************************************
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NUMBER OF CHARACTERS = 10   NUMBER OF OBSERVATIONS = 56   NUMBER OF ANALYSES = 1   ANALYSIS OPTION =

INPUT FORMAT WAS :'(5X,F6.3,F6.3,F5.1,F5.1,F5.1,8X,F5.1,F5.1,F5.1,F5.1,F5.1)'

INPUT DATA WERE OBSERVATIONS

CHARACTERS ARE :

1	SEEDLING COUNT 1 (%EMERGED)	0
2	SEEDLING COUNT 2 (%EMERGED)	0
3	GROUND COVER 1 (GM/250SQ CM)	0
4	GROUND COVER 2 (GM/250SQ CM)	0
5	GROUND COVER 3 (GM/250SQ CM)	0
6	SOIL MOISTURE 1 (%)	0
7	SOIL MOISTURE 2 (%)	0
8	SOIL MOISTURE 3 (%)	0
9	SOIL MOISTURE 4 (%)	0
10	SOIL MOISTURE 5 (%)	0

SIMPLE CORRELATIONS

I	J	ESTIMATE	SIGNIF	LOWER 5% LMT	UPPER 5% LMT	R Z-TRNSFM
1	2	0.658	****	0.478	0.785	0.789
1	3	0.000	NS	-0.263	0.263	0.000
1	4	-0.579	****	-0.731	-0.373	-0.661
1	5	-0.653	****	-0.782	-0.471	-0.780
1	6	-0.019	NS	-0.281	0.245	-0.020
1	7	-0.010	NS	-0.273	0.253	-0.010
1	8	0.057	NS	-0.209	0.315	0.057
1	9	-0.259	(NS)	-0.488	0.004	-0.265
1	10	-0.221	(NS)	-0.457	0.045	-0.224
2	3	-0.579	****	-0.731	-0.373	-0.661
2	4	-0.170	NS	-0.414	0.097	-0.171
2	5	0.000	NS	-0.263	0.263	0.000
2	6	0.152	NS	-0.116	0.399	0.153
2	7	0.169	NS	-0.098	0.414	0.171
2	8	0.015	NS	-0.249	0.276	0.015
2	9	-0.069	NS	-0.326	0.198	-0.069
2	10	-0.136	NS	-0.385	0.132	-0.136
3	4	0.931	****	0.885	0.959	1.666
3	5	-0.010	NS	-0.273	0.253	-0.010
3	6	0.270	*	0.008	0.498	0.277
3	7	-0.034	NS	-0.294	0.231	-0.034
3	8	-0.037	NS	-0.297	0.228	-0.037
3	9	0.194	NS	-0.073	0.434	0.196
3	10	0.039	NS	-0.226	0.299	0.039
4	5	0.169	NS	-0.098	0.414	0.171
4	6	0.241	(NS)	-0.024	0.474	0.246
4	7	-0.071	NS	-0.328	0.196	-0.071
4	8	-0.016	NS	-0.278	0.248	-0.016
4	9	0.124	NS	-0.143	0.375	0.125
4	10	0.106	NS	-0.161	0.359	0.107
5	6	-0.040	NS	-0.300	0.225	-0.040
5	7	-0.267	*	-0.495	-0.005	-0.274
5	8	-0.171	NS	-0.415	0.096	-0.173
5	9	0.107	NS	-0.161	0.359	0.107
5	10	-0.064	NS	-0.321	0.203	-0.064
6	7	0.340	*	0.084	0.553	0.354
6	8	0.355	**	0.101	0.565	0.371
6	9	0.151	NS	-0.116	0.399	0.153
6	10	0.122	NS	-0.146	0.373	0.122
7	8	0.569	****	0.360	0.724	0.646
7	9	0.483	****	0.252	0.662	0.527
7	10	0.035	NS	-0.230	0.295	0.035
8	9	0.168	NS	-0.099	0.413	0.170
8	10	0.072	NS	-0.194	0.329	0.073
9	10	-0.040	NS	-0.300	0.225	-0.040