THE INTRODUCTION AND SPREAD OF WEEDS

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This treatment of what might be termed the initial phases of the alien weed problem in New Zealand will, I trust, help towards a better perspective of the problem as a whole, and prove complementary to the subsequent papers and discussions of this Conference dealing with the ultimate phase of the problem—control and eradication.

I. Development of an Alien Weed Flora:

The known introduction of alien plants commenced with Captain Cook's first voyage in 1769, while the first record of an apparently wild alien was that by Forster (1786:7) of a canary grass (*Phalaris canariensis* L.) (probably *P. minor* Retz.). That introduction of weeds might have commenced in the pre-Pakeha period as was conjectured by Allan (1937:27) is pertinent in the light of present day knowledge of means of weed introduction, and it might be that we owe the beginnings of our alien weed population to the intrepid voyageurs of the early Maori migrations (circa 1100 to 1350 A.D.).

Published accounts show a steady accession of alien weeds from 1786 to the present time, such that this flora now numbers over 1200 species, of which some 500 species are widely distributed and thoroughly established, the remainder being more local in distribution and less abundant.

The accompanying graph (Healy, 1949:161) shows the rate of ingress of alien weed species over the period 1786 to 1946, and gives a visual concept of the build-up of our alien weed flora.

II. Introduction of Weeds to New Zealand:

The known modes of introduction of weeds into New Zealand are many and varied and beside those discussed below there are undoubtedly others of which we are not cognizant. While it will be appreciated that two of

the modes of introduction treated account for the majority of our weeds, the other modes lose no significance by comparison since they have been responsible for introduction of weeds no less serious than those by the two main methods.

(a) **As Impurities in Commercial Seeds:**

Until recent years when seed-cleaning technique reached a reasonable standard of efficiency, many weeds reached New Zealand as impurities in grass-seed mixtures etc., and with the oversowing of ever-increasing areas of cleared forest country and tussock grassland, many species achieved a wide distribution by multiple introductions. It is probable that about two-thirds of our alien weeds came by this means.

Agricultural crop seeds have accounted for introduction of a number of weeds, of which might be mentioned the small-flowered clover (*Trifolium cernuum* Brot.) with field carrot seed, a parasitic weed, dodder (*Cuscuta campestris* Yuncker) with sugar-beet seed, and a group of weeds—gold of pleasure (*Camelina sativa* (L.) Crantz), flax-field ryegrass (*Lolium remotum* Schrank), cress (*Lepidium sativum* L.) and dissected mustard (*Sinapis dissecta* Lag.)—normally associated with linen flax crops overseas, appeared with that crop here during the recent war period. As recently as February of this year, I was able to examine another such instance—an infestation of ball mustard (*Neslia paniculata* (L.) Desv.) which appeared as an impurity in a crop of green feed at Wallaceville.

The importation of grain (wheat and oats) from Australia has accounted for the sporadic occurrence of the saffron thistle (*Carthamus lanatus* L.) and Mexican poppy (*Argemone mexicana* L.), usually in the vicinity of seed-cleaning plants or poultry runs.

That flower seeds are not immune to carriage of such stowaways was indicated by Guthrie-Smith (1926:xii, 258) who reported a pink (*Dianthus cinnabarinus* Sprun.) in seeds from Geneva, and a catchfly (*Silene* sp.) in mignonette seed.

(b) **As Escapes from Horticulture or of Allied Origin:**

Introduction of aliens for horticultural purposes and their subsequent escape from cultivation has accounted for more than one quarter of our alien weeds.

The vegetable garden has contributed such well-known escapes as the wild carrot (*Daucus carota* L.), garden mints (*Mentha* spp.), wild parsley (*Petroselinum crispum* (Mill.) Airey-Shaw), and wild parsnip (*Pastinaca sativa* L.).

Herbaceous flowering plants are represented by the Californian poppy or eschscholtzia (*Eschscholtzia californica* Cham.), now so common on Canterbury river-beds, the beautiful but poisonous Cape tulip (*Homeria collina* (Thunb.) Vent.) at the French Pass, Portland Island near Mahia Peninsula, and Woolley's Bay, north of Whangarei, and the spectacular but troublesome water hyacinth (*Eichhornia crassipes* (Mart.) Solms.) of the North Auckland region.

Ornamental climbers have given the climbing dock (*Rumex sagittatus* Thunb.) with its troublesome tubers, the persistent everlasting pea (*Lathyrus latifolius* L.) and the Japanese honeysuckle (*Lonicera japonica* Thunb.) of bush remnants, waste places and hedgerows.

Succulent-fruited plants are represented by the forms of blackberry (*Rubus* spp.), dew-berry (*Rubus phoenicolasius* Maxim.), and Cape gooseberry (*Physalis peruviana* L.), and gooseberry (*Ribes grossularia* L.).

Ornamental shrubs have contributed Darwin's barberry (*Berberis darwinii* Hook.), flowering currant (*Ribes glutinosum* Benth.), the several heaths (*Erica* spp.), Himalayan honeysuckle (*Leycesteria formosa* Wallr.), and the suspected toxic Jerusalem cherry (*Solanum pseudocapsicum* L.).

Hedge escapes are now prominent in many districts, and include common barberry (*Berberis vulgaris* L.), gorse (*Ulex europaeus* L.), hawthorn (*Crataegus monogyna* Jacq.), hakea (*Hakea* spp.), prickly wattle (*Acacia armata* R. Br.), and privet (*Ligustrum* spp.).

(c) Attached to Imported Farm Animals:

It is probable that a number of weeds reached New Zealand attached or clinging to wool or hair of imported animals, and Cockayne (1926:25) records burr clovers (*Medicago* spp.) and Bathurst burr (*Xanthium spinosum* L.) as being introduced on imported Merino rams, while the introduction of nassella tussock (*Nassella trichotoma* (Nees) Hack.) has been ascribed to this means.

(d) In Fodder or Crate Material used for Imported Stock:

Which weeds arrived by this means is not known, but indirect evidence points to it having been operative in the early days of stock importation. The pattern of infestation of kangaroo grass (*Themeda triandra* Forsk.) in the Wairau Valley, Marlborough, and the associated Australian weed species indicate that this was the likely means of introduction.

(e) In Ballast:

In the light of available records, this means must have accounted for a number of new weeds as well as providing additional introductions of weeds already in the country. Thomas Kirk's classical paper (1896:501-7) lists a total of 105 species which arrived in a single load of ballast of South American origin, 20 of which were new for New Zealand. Allan (1924:314) notes the establishment of a number of such ballast introductions about Oamaru Harbour in 1912, and the writer (1945:10) noted some 40 species introduced in ballast from the River Mersey, England, in 1940, including such undesirables as a parasitic broomrape (*Orobanche amethystea* Thuill.) and the poisonous henbane (*Hyoscyamus niger* L.).

(f) Attached to or in Packing Material of Imported Merchandise:

The use of hay and straw as packing materials indicates the possibilities of weed introduction by this means. The introduction of the well-known horned poppy (*Glaucium flavum* Crantz.) of Wellington beaches was suggested by Kirk (1878:369) as having come in packing about machinery for the Patent Slip, Wellington, and I recall in 1943, finding legume fruits attached to bundles of jute woolpacks from India.

(g) Due to Military Operations:

Large scale military operations during the recent war, with attendant lack of inspections and care against possible introductions, resulted in weed introductions to many countries, and there is in New Zealand instance of a European brome grass (*Bromus rubens* L.) naturalized in the United States arriving per medium of the United States Marine Corp and its equipment (Healy, 1946:403). The return of equipment of New Zealand's Third Division from the Pacific theatre resulted in large quantities of tropical grass and weed fruits being introduced on tenting and other materials, while the mud on frames, trays and wheels of vehicles yielded its quota of seeds and fruits, later successfully grown under supervision.

The salvage of derelict war material and its subsequent importation into New Zealand in 1949 provided further evidence of weed introduction—tropical weeds were actually growing and fruiting on dirt on trucks and graders when landed here, and over twenty species were later grown from the seeds and fruits contained in such dirt.

While there is no evidence to show that aeroplanes have been responsible for accidental introduction of weeds to New Zealand, there are a number of reported instances of introduction of spiny-fruited weeds per medium of aeroplane tyres during the recent war in the Pacific region when use of dirt aerodromes was necessary. It is, nevertheless, a means which could become operative at any time.

(h) In Dirt about Roots of Imported Plants:

The number of weeds using this means of entry is not known, but the possibility was there, as Guthrie-Smith (1926:275) indicated the probable introduction of a speedwell (*Veronica agrestis* L.) to "Tutira" in soil around the roots of moss-roses.

(i) Intentional Introductions for Specific Purposes:

The introduction of gorse (*Ulex europaeus* L.) and sowing for sheep forage was responsible for several infestations in Marlborough, and the use of lupin (*Lupinus arboreus* Sims) for sand reclamation provided a source of seed for weed infestations elsewhere. The troublesome heather (*Calluna vulgaris* (L.) Hull), was introduced, according to Marshall (1944:xiv) "... without the authority of the [Tongariro National Park] Board, by the then warden of the Park, with the intention of liberating grouse for sporting purposes.", hemlock (*Conium maculatum* L.) for herbal culture purposes in Canterbury in 1865 (Armstrong, 1872:286).

(j) In Bird-seed Mixtures:

The well-known bird-seed mixtures have been and still are responsible for limited introductions, including the true hemp (*Cannabis sativa* L.), broom-corn millet (*Panicum miliaceum* L.), and niger (*Guizotia abyssinica* Cass.).

The above means of weed introduction reveal, as it were, gaps in our agriculture's armour, and attempts to seal some of these are made by legal enactments which make provision for destroying imported packing and crate materials on arrival, prevent importation of soil, and guard against intentional importation of potentially troublesome plants under the provisions of the Importation of Plants Act, 1927.

It must be realized, however, that legal deterrents in themselves will not prevent weed introductions, and that ceaseless vigilance is necessary, and despite this, accidental introductions by some means or other are liable to occur. There is always the heedless but enthusiastic tourist who brings back in his pocket the few seeds of that plant which impressed him overseas, and which, when sown, may leave to posterity a legacy of weed infestation.

The fruits, seeds, bulbs or rhizomes of the weeds having reached the country, their fate is uncertain, and might be appropriately described in the words of St. Luke " . . . some fell by the wayside, . . . and the fowls of the air devoured it. And other some fell on rock; and soon as it was sprung up, it withered away because it had no moisture. And other some fell amongst thorns, and the thorns growing up with it choked it. And other some fell upon good ground, and sprung up, and yielded fruit a hundredfold."

III. Spread of Weeds Within New Zealand

Several factors are concerned in the spread of weeds, including (1) availability of suitable sites for establishment, (2) ability of the plant to reproduce sexually or asexually, and (3) availability of agents to effect the dispersal of fruits and seeds from the parent plants to new areas.

With the exception of bare waste land, fallow land and the like, the soil is clothed with a vegetative cover of varying density (forest, shrub communities, grassland or crop); successful invasion of any such vegetative cover by weeds requires the operation, either alone or in combination, of certain natural or artificial influences. The degree of weed establishment is then an expression of the competitive ability of the initial vegetation when influenced by natural or artificial modifying factors.

These modifying factors which influence natural vegetation in the direction of diminished density and reduced competition effect merit brief consideration.

(a) **Natural Factors:**

(i) **Soil:** In the main, weeds have a wide tolerance of conditions, and in New Zealand from the viewpoint of chemical composition it is only soils with a high salt (NaCl) content that markedly restrict the weed species which will successfully establish on an area. Weeds of saline soils tend to be only those with a high salt tolerance, as buck's-horn plantain (*Plantago coronopus* L.), etc.

Soils of low fertility, due either to type of parent material or decrease of nutrients due to over-cropping or erosion etc., dispose to a low density vegetation permitting easier weed invasion and establishment. Since many weeds tolerate a wide range of soil fertility, the composition of the weed flora of such areas can be correspondingly wide.

(ii) **Aspect and Slope:** The aspect, whether sunny or shady, is reflected in the type and composition of the vegetation of a particular area, the sunny aspect being drier by virtue of exposure to the sun, often drying effect of prevailing warm wind and effect of degree of slope. The combination of sunny aspect and operation of such artificial factors as burning and over-grazing generally results in reduction of density of the natural vegetation with availability of bare ground of reduced moisture content due to desiccating effect of wind and sun. Such a condition of reduced competition effect is a prelude to weed invasion and establishment. Illustration can be drawn from modified tussock-grassland—the native tussocks have been largely eliminated by continued firing, the associated useful grasses and clovers have suffered severe mortality due to grazing, firing and absence of shelter, and a volunteer vegetation of more hardy, but less useful species, including weeds, has arisen. Under rigorous conditions the vegetation is restricted to species which can tolerate xerophytic habitats—short-lived annual weedy species as the annual clovers (*Trifolium* spp.) and hair grasses (*Aira caryophyllea* L. and *Vulpia* spp.) and perennials with the necessary adaptations to survive under such conditions, sheep's sorrel (*Rumex acetosella* L.), Nassella tussock (*Nassella trichotoma* (Nees) Hack.) and scabweeds (*Raoulia* spp.).

(iii) **Rainfall:** Rainfall, apart from influencing the type of natural or induced vegetation, can, by marked fluctuations, influence weed establishment.

Drought periods can cause mortality of moisture-loving plants, in the case of pastures opening the sward to weed invasion. Conversely, excessive rainfall can also cause reduction of density of vegetation, which, coupled with poaching of a pasture, allows invasion of such high-moisture-tolerant weeds as rushes (*Juncus* spp.) and buttercups (*Ranunculus* spp.). Excessive moisture can result in rivers and streams depositing silt over existing vegetation, producing conditions favourable for weed invasion, and can cause mass movement of soil, slips, slumps, etc.) which provide competition-lacking areas for volunteer occupation.

(iv.) **Temperature:** The effect of the temperature factor is reflected in the marked differences in the competition of the weed floras of North Auckland and Southland, the weeds of tropical and sub-tropical origin being restricted to the warmer areas.

(v) **Wind:** This factor acts in conjunction with other climatic factors and slope and aspect in influencing vegetation. In coastal localities where the winds become salt-laden, it occasionally assists in preventing successful establishment of weeds whose leaves and flowers have a low salt tolerance, and can also prevent establishment of useful plants, resulting in lack of competition against weed invasion. Strong winds, by exercising a mechanical effect coupled with an excessive loss of moisture from the plant, can influence the well-being of vegetation and facilitate weed invasion.

(b) Artificial or Man-induced Factors:

(i) **Cultivation:** Cultivation is in essence a process which results in partial or total replacement of an existing vegetation, (giving bare ground and lack of competition) with the intention of clothing the area subsequently with some desired type of vegetation—crop, grassland or trees. Unless the replacement of cover is wholly successful, then bare ground and lack of competition favour weed invasion and establishment—compare the weed population of say land under a dense crop of green feed oats with that of land under a wide row crop.

The use of cultivation to destroy an existing plant cover under extremes of climate and slope often results in subsequent failure to establish a stable vegetation, and offers an invitation to volunteer plants, frequently weeds.

Most of you will have little difficulty in recalling examples of local weed problems attendant on cultivation of thin soils on steep slopes of sunny aspect.

(ii) **Grazing:** Good pasture management aims at establishing a balance such that the amount of grazing causes no weakening of the sward, while over-grazing results in a weakening of the sward, exposure of bare ground to effects of sun and wind, and reduction in the competition effect against invaders. Alone, or with periodic firing, this factor has a marked influence in pre-disposing hill country pastures to weed invasion, and few will have any difficulty in thinking of examples of weed infestation due in large measure to operation of this factor.

(iii) **Firing:** Firing of vegetation may result in the elimination of the non-fire tolerant elements of the cover or in the cover being completely destroyed, giving in both instances suitable conditions for weed invasion. As a means of inducing mortality of desirable plants, particularly the better grasses and clovers, it is very efficient, since few species can tolerate repeated firings, and, under such conditions, few species other than weeds can thrive. The combination of firing and over-grazing, as noted earlier, is lethal to many types of plant cover.

(iv) **Activities of Vermin:** Rabbits by their excessively close grazing modify grassland swards and permit weed invasion, while their scratching and burrowing provide mechanical aid to depletion. Similarly, rooting by wild pigs disturbs the cover, giving suitable conditions for spot infestation of weeds which serve as reservoirs of infection for adjacent areas.

Road and railway construction and similar public works activities all tend to disturb existing plant cover and provide suitable areas for weed invasion.

It will be apparent then that the factors outlined above acting alone or in combination tend to a depletion of the vegetative cover, with attendant reduction of competition effect, exposure of bare ground, in short, suitable conditions for weed invasion and establishment.

We can now logically consider the question of migration of weeds to such sites as indicated above, with particular reference to the agents responsible for the dispersal of weeds within New Zealand.

(b) Agents Effecting Dispersal of Weeds Within New Zealand:

(i) **Wind:** Dispersal by wind is usually associated with some modification of the plant itself, the fruiting head, the fruit or the seed to ensure such dispersal. Wind dispersal may be effective over a varying distance, as within a short radius of the parent plant, or up to a distance of several miles.

Dispersal of the whole plant at maturity is seen in a variety of saltwort (*Salsola kali* L.) found on some North Island coastal sands, the dried, mature plant rolling before the wind in "tumble-weed" fashion.

Nassella tussock (*Nassella trichotoma* (Nees) Hack.) of modified tussock-grassland in North Canterbury and Marlborough, provides a good example of dispersal of the whole fruiting head at maturity. The heads, each with 30 to 120 fruits, are detached from the parent tussocks by the wind, this being made possible by a weakening of the lower portion of the stem of the head. The heads are then wind-borne for distances of up to six miles.

The dispersal of individual fruits is best seen in weeds of the daisy family (Compositae), the ever-present "thistle-down" of the summer air being a constant reminder of this means of dispersal. In fruits adapted for such dispersal, the necessary buoyancy is attained from the parachute-like arrangement of long hairs at the summit of the fruit. Well-known species which use this means of dispersal are ragwort (*Senecio jacobaea* L.), catsear (*Hypochaeris radicata* L.), dandelion (*Taraxacum officinale* Weber) and hawkweed (*Crepis capillaris* (L.) Wallr.).

Fruits and seeds of species without special adaptations are often moved short distances by wind, while small, dust-like seeds of such weeds as broomrape (*Orobanche minor* Sm.), heaths (*Erica* spp.), tarweed (*Parentucellia viscosa* (L.) Caruel), and rushes (*Juncus* spp.), are carried for varying distances by this means.

Seeds with parachute-like structures for ensuring wind dispersal are exemplified in the moth-catching plant (*Araujia sericifera* Brot.) which occurs in the warmer areas of the North Island.

(ii) **Water:** Water may act as a single agent, or as complementary to wind dispersal. As with wind, water may be responsible for dispersal over varying distances, ranging from short distances from the parent plant in run-off down slopes, to long distances down streams and rivers.

The whole or portions of plants of aquatic weeds are carried by streams and rivers, examples being pondweed (*Elodea canadensis* Michx.), reed sweetgrass (*Glyceria maxima* (Hartm.) Holmb.), watercress (*Nasturtium* spp.), water buttercup (*Ranunculus fluitans* Lam.), water hyacinth (*Eichhornia crassipes* (Mart.) Solms.), and willows (*Salix* spp.). The dispersal of portions of non-aquatic plants is instanced in the many reports in the early days of the century of the spread of Californian thistle (*Cirsium arvense* (L.) Scop.) down rivers, and in recent years the spread of kikuyu grass (*Pennisetum clandestinum* Hochst.) from hillsides to fertile flats per medium of ditches and streams will be known to many of you.

The fruits and seeds of many weeds are carried down drains, streams and rivers, and the abundance and variety of weeds found on waste land adjacent to waterways affords an explanation of the variety of weeds which appear on land subsequent to flooding.

Water often acts as complementary to wind in the dispersal of fruits and seeds. Poole and Cairns (1940:35) record fruits of ragwort (*Senecio jacobaea* L.) as being carried by water, and there is little doubt that the greater proportion of them had been initially wind-borne. From personal observations can be cited the deposition of seed heads of nassella tussock on rivers and streams by wind—the water surface of some streams was found to be covered by masses of such wind-borne heads.

(iii) **Animals: Birds:** Weeds with succulent fruits owe their spread, in the main, to bird activity. The fruits being eaten, the seeds pass unharmed through the digestive tract and are voided in the faeces. Blackberry (*Rubus* spp.) seedlings growing on top of fence posts illustrate this means of dispersal, while other common examples of weeds so spread are barberry (*Berberis vulgaris* L.), inkweed (*Phytolacca octandra* L.), black nightshade (*Solanum nigrum* L.), sweet briar (*Rosa eglantaria* L.), tutsan (*Hypericum androsaemum* L.), and wild currant (*Ribes glutinosum* Benth.).

The common introduced birds of field and wayside are also responsible for the dispersal of fruits with hooks or hairs, these attaching to the down and feathers; recent observations on a burned-over site at Upper Hutt indicate the probable arrival of 19 weed species by this means.

The probable role of game birds (ducks, swans, etc.), has been discussed by Cockayne (1926:28), and I suggest that such birds were responsible for an infestation of tiger weed (*Bidens vulgata* Greene) at a bird sanctuary near Cheviot, North Canterbury.

Farm Livestock and Other Introduced Animals: Farm livestock, especially sheep, are responsible for carriage of fruits and seeds of many weeds, the distance being variable.

Ingestion of fruits and seeds with subsequent voiding in a viable condition has aided in the wide distribution of the annual clovers (*Trifolium* spp.), visual evidence being available in a photograph by Lamont (1939:154) which shows clover seedlings established in faeces; the spread of subterranean clover (*Trifolium subterraneum* L.) on many properties is due to this means.

The writer has demonstrated experimentally (Healy, 1940:40) that nassella tussock could be, and probably is, dispersed by this means, and noted a time lag of up to three days between ingestion and voiding; it is indicative that this particular phase of animal dispersal could operate over a considerable distance.

Weeds with hairy or bristly fruits are commonly carried by livestock, the hairs or bristles becoming entangled in the wool or hair. The classical work of Hayward and Druce (1919) on the seed and fruit content of wool processed at wool treatment plants at Tweedside, England, indicated the export of alien weed fruits in New Zealand wool, and the recent Canterbury Chamber of Commerce Bulletin by Henderson and Iversen (1948:1-8) treats presence of weed fruits in local wools, both revealing the reality of this method of dispersal. Examples of weeds dispersed by this means are many weed grasses, burr clovers (*Medicago* spp.), docks (*Rumex* spp.), horehound (*Marrubium vulgare* L.), nassella tussock (*Nassella trichotoma* (Nees) Hack.), burdock (*Arctium* spp.), and many will recall the spread of the viper's bugloss (*Echium vulgare* L.) [the so-called blue borage or cornflower of parts of Marlborough and Canterbury] along the major stock routes between Marlborough and Canterbury.

A group of weeds with small, dust-like seeds are also carried by stock, examples being broomrape (*Orobanche minor* Sm.), foxglove (*Digitalis purpurea* L.), heaths (*Erica* spp.), St. John's wort (*Hypericum perforatum* L.), and woolly mullein or flannel leaf (*Verbascum thapsus* L.).

The penetration of the animal's pelt ensures a more tenuous hold of the passive carrier, and necessitates the use of greater force to secure dislodgement. Weeds using this method are barren brome (*Bromus gussonii* Parl.) [the spear grass of many farmers], barley grass¹ (*Hordeum murinum* L.), and the true spear or needle grass (*Stipa* spp.).

The mud in animals' hooves is a significant vector of dispersal, and I feel sure that part of the blame for dispersal of the Cape tulip (*Homeria collina* (Thunb.) Vent.) in the French Pass locality can be attributed to this means. Examination of mud from hooves in any locality generally shows some "hitch-hikers."

Apart from farm livestock, it is probable that vermin (pigs, rabbits and deer, etc.), assist in weed dispersal in the same manner as farm livestock, although I am unable to present any definite evidence on this aspect.

It is evident that animal carriage of weed fruits and seeds has considerable economic significance, and that the phenomenon is commonly not recognised as such, but rather as a matter of seedy or burry wool in the

case of sheep—the manipulation of shearing date is a tacit admission by the pastoralist of the efficacy of this means of dispersal. Bought-in stock, particularly sheep, can and do play the role of weed introducers to properties, and with present day rapid transport of stock over long distances, weed introduction from another district is only a matter of an hour or so.

(iv) **Human Agency and Activity:** The multifarious activities of man provide many suitable means for weed dispersal, of which some of the more apparent are treated below.

A. Farm Produce: Weed-seed-infested agricultural seeds have played an important role in the dispersal of weeds in New Zealand, and while present day impurities are few by comparison with those listed by Cockayne (1912:440), Levy (1918:165-8) and Foy (1924:392-8) earlier in the century, the method is still operative.

Hay (and straw), depending on the stage at which harvested and the weed flora of the particular area, often contains weed seeds, which, from the nature of the commodity, may be spread to other districts. The finding of *nassella* tussock heads in Canterbury hay when opened over on the West Coast serves to illustrate the point.

The decline of the horse and consequent diminution of chaff used has materially lessened the significance of this commodity as an agent of weed spread. In earlier days with extensive use of horses on public works operations throughout the country, many weeds were carried by this means, and a local example was the introduction of the wild sage (*Salvia verbenaca* L.) to the upper reaches of the Hurunui River with construction of the Lake Sumner Road, while the introduction of Californian thistle (*Cirsium arvense* (L.) Scop.) to a number of districts has been ascribed by agricultural workers to this means.

The sale of farm manure, with its content of fruits and seeds, helps in the drift of weeds from country to town, whether it be from woolsheds, cowsheds, or material from under floors of sheep-trucks.

The sowing of the different grades of offal from seed cleaning operations has, unfortunately, given impetus to weed infestation in some localities, the underlying reason for use being that cheap seed in quantity would provide some cover on poor ground. I well recall an instance in the Manawatu where such material was sown on stony river flats, and resulted in infestation of the river bed for some miles below the sowings with weeds from the cleanings, this resulting in a number of new weeds establishing in the district.

Amongst odd means of dispersal of weeds by association with agricultural products, the instance cited by the Director-General of Agriculture (1941:150) of a ragwort plant found in a superphosphate bag returned from a works filling can be cited, and we might speculate the number and variety of weed seeds that have been dispersed per medium of sacks during the last decade of container shortages.

B. Farm Machinery: Examination of such machines as chaff-cutters, threshing machines and header harvesters shows weed fruits and seeds lodged on the frames and bodywork, and it is reasonable to suggest that contracting machines of this nature have facilitated weed spread from paddock to paddock, farm to farm and district to district, despite the legal requirements, more honoured in the breach than the observance, of cleaning after each stand. Contracting cultivation implements have, by means of bulbs in mud, been responsible in at least one district for spread of the bulbous wood sorrels (*Oxalis* spp.) from one nursery to another.

The common implements used on a farm are responsible for spread of fruits and seed, and in attached mud pieces of rhizomes of the several weeds rated as twitches or couch.

The increasing use of aeroplanes for topdressing and grass seed sowing, will, by reason of use of farm-paddock landings strips, probably assist in the spread of weeds in mud on the tyres. In view of the widespread oversowing of the back country by this means, it might be desirable, in the interest of preventing weed spread, to have deterrents to the use of other than high quality seed on such country, to alleviate the danger of weeds establishing in the back country and being carried down rivers to the flats.

C. Transport Vehicles: Fruits and seeds are carried in mud in tyre treads, lodged on bodies and frames of various types of transport vehicles. This means can act complementary to wind, as was observed with *nassella* tussock, when windborne heads were deposited in railway trucks and on trays of lorries, to be further carried by this means.

D. River Shingle: The weed vegetation of the metal verge and centre of country roads often bears a distinct resemblance to that of the river-bed from which the shingle was obtained; and on occasions such new introductions by shingle have permitted infestation of adjacent farm lands with additional weeds.

Shingle for railway ballast similarly assists spread of weeds, this being borne out by the occurrence of goats-rue (*Galega officinalis* L.) along the railway line both north and south of Palmerston North, indicating the source of the shingle as the Manawatu River or one of its tributaries.

Shingle brought to farms and elsewhere for such purpose as buildings and filling wet gateways has demonstrated itself a means of weed spread; the writer has noted introduction of gorse (*Ulex europaeus* L.), lupin (*Lupinus arboreus* Sims) and creeping yellow cress (*Rorippa sylvestris* (L.) Besser.) and haretail grass (*Lagurus ovatus* L.) in shingle at Upper Hutt.

The transference of earth and spoil by State Departments, local authorities and private individuals has been an important factor in the spread of weeds, e.g., bindweed (*Calystegia sepium* R.Br.), particularly about boroughs.

E. Horticultural Activities: The earth about roots of horticultural plants often contains weed seeds, and examples from personal experience can be cited—rhizomes of twitch (*Agropyron repens* (L.) Beauv.) in roots of rhubarb, oxalis bulbs in soil about roots of cabbage plants bought in a Wellington shop, seeds and seedlings of *nassella* tussock carried in dirt about strawberry plants in North Canterbury.

The dissemination of ornamental plants which show a tendency to escape from cultivation and establish as troublesome weeds has been, and still is, important. The culture and intentional spread by humans for aesthetic or sentimental reasons still aids and abets the spread of some very troublesome weeds—veil grass (*Pennisetum macrourum* Trin.) so troublesome near Kaikoura, and now established in localities in both North and South Island, owes its spread, according to my investigations, to its use in landscape gardening. The arrival of tutsan (*Hypericum androsaemum* L.) in some districts was due to its use as an horticultural plant, further dispersal being done by bird activity, and the thorough establishment of upright cinquefoil (*Potentilla recta* L.) [mistakenly called in this instance "Evening Primrose"] in parts of Wairau Valley, Marlborough, was due to its transference from garden to garden as a prized horticultural subject, followed by its subsequent escape.

F. Attached to Clothing: That fruit dispersal by clothing might be significant was indicated by the writer (1943:140), it being shown that five days' field work yielded about three-quarters of an ounce of seeds and fruits from "cuffs" of trousers and socks, 33 species being represented, of which 19 were grasses. The weed element included annual clovers (*Trifolium* spp.), Australian sheep's burr (*Acaena ovina* A. Cunn.), barley grass (*Hordeum murinum* L.), barren brome (*Bromus gussonii* Parl.), burr clovers (*Medicago* spp.), cleavers (*Galium aparine* L.), hair grass

(*Vulpia* sp.), hedgehog parsley (*Tarlis nodosa* (L.), Gaertn.), nassella tussock (*Nassella trichotoma* (Nees.) Hack.), rush (*Juncus* spp.), speargrass (*Stipa variabilis* Hughes), storksbill (*Erodium cicutarium* (L.) L'Herit.), sweet vernal (*Anthoxanthum odoratum* L.) and Yorkshire fog (*Holcus lanatus* L.). Thus a farm inspection, etc., by a farmer in a neighbouring district, and later turning out of seedy cuffs at home may be the means of introduction of a new weed or weeds to a district or farm. The now widespread occurrence of Jo Jo weed or Onehunga weed (*Soliva* spp.) in lawns and playing greens must surely acknowledge the debt to the shoes and clothing of bowlers and other users of playing greens.

G. Mud on Boots, etc.: The home gardener who slips over to his neighbour's garden for a chat often brings home more than the latest racing news—sometimes weed seeds, or rhizomes of bindweed *Calystegia sepium* R.Br.) or twitch (*Agropyron repens* (L.) Beauv.), or bulbs of *Oxalis*. The examination of mud from boots is often very interesting, and as a means of weed dispersal I have noted it operative over short distances.

It will be realised from the above account that weed invasion and establishment is no haphazard process, but is a consequence of the reaction of the various types of natural or artificially-induced vegetation to the operation of natural and/or man-induced influences, and it is, except with completely bared areas, a replacement phenomenon—replacement of desirable by undesirable plants.

By the same token, successful weed control is also a replacement phenomenon—replacement of undesirable by desirable plants—essentially of two phases, the removal or destructive phase effected by cultivation, fire, chemical or biological control, and the truly replacement phase of populating the partially or wholly bared soil with the desired plants.

It is often found in practice, however, that the interpretation of weed control is actually only that of the destructive phase, and after time, labour and materials have been expended, the equally important replacement phase is omitted, often resulting in a plant cover of the same or a different flora of weeds, for instance burning of a gorse infestation without resowing, application of fertiliser and appropriate stock management.

Finally, with reference to the replacement concept, it might be noted that a form of replacement control is practised in such instances as smothering, as of gorse or broom by fires or other trees, or Californian thistle by lucerne, by contrast with a strict definition of biological control which is essentially a host-parasite relationship, as with *Chrysomelid* beetle control of St. John's wort.

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DISCUSSION.

Q. What is the longest known distance seeds of plants have been distributed by wind in one step? Particularly the possibility of entry of weeds from Australia by the prevailing westerly winds.

A. Exact distances are not known accurately. The figure given for *Nassella tussock* is the most accurate. The revegetation of Krakatoa, where the heat of the volcanic eruption sterilized the land surface, must have been brought about by wind, water and bird transport from neighbouring islands.

Q. How far can ragwort be spread from an infestation in one step?

A. Poole and Cairns used seed trays to catch seed from individual plants and found that the bulk of seed fell within a few feet of the parent plant and only very few fell up to several chains. However, if the seeds have access to water the distances may be considerably increased.

Q. How did Manchurian rice grass get into New Zealand?

A. Cheeseman states that its arrival in ballast in North Wairoa was noted about the same time as another weed, *Telanthera*. A popular version suggests that it was introduced mistakenly as American wild rice—a non-rhizomatous species. Cheeseman is probably right.

Q. What is being done to prevent the sale of weed species with horticultural plants as indicated by Mr. Healy?

A. Helson: Nothing was done prior to four or five years ago. Now, however, all nurseries are regularly inspected and granted certificates providing the nurseries are not weedy. It is very difficult and practically impossible to prevent the spread of weed seeds in soil around the roots.

Q. Could Mr. Healy indicate any plants which appear to be in the early stages of establishment which could be guarded against? For example nodding thistle is spreading in Mid-Canterbury.

A. This thistle is well established, spreading as far as Marlborough. No more action necessary than with ordinary scotch thistle. There are a number of weeds in North Canterbury in small patches. It is better to take the offensive rather than wait and watch reaction.