Novel approaches to weed control

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SUMMARY

Some small scale novelties - a solar energy sunshade, a herbicide rogueing glove - are briefly described. Novel formulations for controlled release of herbicides or improved plant penetration are mentioned.

The main emphasis is on alternative energy sources for weed control. Ultra-high frequency (U.H.F.) irradiation is summarized in some detail since much investigation has been reported and prototype commercial units are under development. Some Russian work has been reported which indicates potential use of electric discharges for weed control. Useful aspects of water hyacinth are mentioned and also preliminary tests with CO_2 laser radiation for control.

The idea of herbicide protectants and antidotes is hardly novel but is mentioned to draw attention to a recent review of the subject. In conclusion, novelty in weed science may already be a practice in other disciplines. Progress in weed control can be aided by adapting from experiences of others.

INTRODUCTION

Tables of contents in "Weed Science" and "Weed Research" indicate little novelty in the main stream of research on weed control. However, buried in the mass of world literature in "Weed Abstracts" are some gems of novelty - of approaches away from the main stream.

Yet how novel are these approaches? Many are adaptations from other fields. Certainly a number of novelties to weed control have been considered, tested or used in other disciplines.

In today's world of energy crises looming, methods of weed control (and pest control generally) which use less energy or use energy in a more "acceptable" form warrant attention. This paper briefly reviews some investigations into alternative forms of energy as well as some "novel" ideas concerning old problems.

SOLAR ENERGY

Solar energy has been used to heat domestic water supplies in Mildura and elsewhere for a number of years. The idea has been adapted in Nigeria to power hand held sprayers of the Micron Herbi type. A device 33 cm square, utilizing 38 wafer-thin silicon photovoltaic cells connected in series provides more than 5 watts of power in average sunlight. This is more than sufficient to drive the motor and so allows for re-charging of nickel-cadmium cells. The power unit is harnessed to the body and carried over the head thus forming a sunshade. Total weight of harness and solar power unit is only 1.2 kg (Anon, 1977).

ROGUEING GLOVE

A rogueing glove has been invented (Bloomfield, 1976) which allows herbicide to be placed on weeds in sensitive crops. The glove consists of an industrial gauntlet with a foam pad in the palm. The pad is overlaid with a spot-welded PVC/nylon cover. The pad contains a bulb-type pump which, when pressed, forces herbicide mixture from a collapsible container worn from the waist. When weeds are gripped, 1 ml of herbicide mixture is forced through small holes in the pad. Glyphosate has been used successfully for control of perennial weeds (e.g. *Agropyron repens*) in places where hand weeding is the only option.

ROOT PLOUGH HERBICIDE TECHNIQUE

The stump-jump plough must be the forerunner for refinement of a root plough herbicide technique (Hollingsworth et al, 1973). Brush control (and therefore control of silver-leaf nightshade?) in low rainfall areas has been achieved by applying herbicide from nozzles on the trailing edge of a root plough (bean knife) blade. Herbicide is sprayed into the region of cut roots. A stump-jump-like mechanism would restrict sub-soil herbicide deposit by triggering nozzle flow only when a root is cut. This would limit distribution of herbicide to the immediate region of the cut roots, economize on herbicide and have minimal effect on the area as a whole.

NOISE

Noise has been used to protect (?) ripening crops from bird attack. The peace of the countryside is shattered by the staccato coughing of carbide scare guns. Birds (and humans) are at first put off by this regular monotonal banging but both soon get used to it.

An attempted improvement was to instal devices emitting very high frequency noise. This was effective in scaring birds (crop yields increased) but was intolerable to humans within half a kilometre (L. Campbell-Smith, personal communication).

ULTRA-HIGH FREQUENCY FIELDS

In 1972, at a Game and Fish Commissioners' conference in Texas, Champ and others (1973) reported that an ultra-high frequency (U.H.F.) field of 2450 ± 20 megahertz (MHz) was lethal to floating aquatic weeds. The median tolerance limit of the weeds was about 16.7 joules/ml (J/ml). However soil-banked test containers indicated higher energy levels would be necessary in the field.

Papers have followed every year since. Much of the work has been done at the Texas A. & M. University. The energy necessary to kill weed seeds or growing plants is expressed in the literature either as joules/cm^2 (J/cm^2) or as kilowatts (kW) for a certain time. Any confusion is resolved by the fact that

$$1 \text{ kW} = 1 \text{kJ/s}$$

An indication of what a megahertz is, is given by the fact that:-

$$1 \text{ Hz} = 1/10 \text{ sec.} = \text{sec}^{-1}$$

Thus 1 MHz = sec^{-6}. The frequency which appears to have been adopted as standard in U.H.F. work is 2450 MHz.

Plants vary in their susceptibility to U.H.F. as indicated in Table 1.

Table 1. Energy required for lethal dose of microwave (U.H.F.) to plant seeds

Seed	Energy flow	Reference
London rocket (*Sisimbrium irio*) sunflower (*Helianthus annuus*)	180 J/cm^2	Menges and Wayland (1974)
wheat (*Triticum*)	250 J/cm^2	Wayland et al (1973)
radish (*Raphanus sativus*)	250 J/cm^2 (65% kill)	
ridgseed spurge (*Euphorbia glyptosperma*) portulaca (*Portulaca oleracea*) red root pigweed (*Amaranthus retroflexus*) Japanese millet (*Echinochloa frumentacea*)	360 J/cm^2	Menges and Wayland (1974)

Much of the work reported is on seeds. However Wayland et al(1975) extended his research to include emerged weeds. Pre-emergence work indicated that energy levels above 70 J/cm^2 were required for consistent control in the field and there was no consistent selectivity between mono- and dicotyledonous weeds. Post-emergence tests indicated a need for higher energy levels and that broadleafed weeds were more susceptible than grasses. Further, established plants (surprisingly) were more susceptible than seedlings of the same species.

Phytotoxicity of U.H.F. fields is affected by soil and seed moisture, magnitude of the field (energy input), frequency and type of applicator (Whatley, 1974). Rice and Putman (1977) reporting investigations into factors affecting toxicity of U.H.F. energy state that weed seeds are more readily killed in moist muck and clay loam soils than in dry loamy sand. Seeds are easier to kill in moist soil than in absence of soil. However Menges and Wayland (1974) reported that the weeds listed in Table 1 were killed by 360 J/cm^2 regardless of seed or soil moisture. This statement seems at variance with other work.

The importance of seed moisture has been demonstrated for seed of Italian millet (*Setaria italica*), (Shafer and Smith, 1974). Dry and variously imbibed millet seed was exposed to varying periods of U.H.F. transmitted into a chamber at a net energy of 1kW. Time of exposure necessary to reach an LD50 of seed varied with the degree of imbibition from 30 minutes for dry seed down to 2 seconds for fully imbibed seed on wet filter paper. This is a 900 times variation in energy flow. Although this was laboratory work it must indicate that effective weed control by U.H.F. radiation, like conventional herbicides, will be most readily obtained and economic under moist conditions. If this is so, then the method in this respect offers no advance nor advantage over conventional weed control. Cultivation, herbicide application and irradiation must all be done after rain or irrigation.

However one advantage of U.H.F. weed control is that crops may be sown immediately after treatment. Heald et al (1974) treated soil infested with reniform nematode and portulaca (*Portulaca oleracea*) prior to planting southern peas (*Vigna unguiculata*). The soil fumigant telone killed nematodes but not portulaca. However when Telone was followed by U.H.F. energy (supplied by two 30 kW (again 2450 MHz) power packs) nematodes and portulaca were killed and the subsequent crop grew strongly. The U.H.F. energy used was 800 J/cm^2 and was considered effective to a depth of 10 cm. Strangely U.H.F. was not used on its own to determine any effect on nematodes yet the "dose" used was more than twice that necessary to kill portulaca (see Table 1). Menges and Wayland (1974) sowed cantaloupe and onions a few hours after U.H.F. doses ranging from 45 to 720 J/cm^2. Weeds (Table 1) were killed to 7.5 cm in irrigated soil and to 10 cm in non-irrigated. Crops grew normally and yielded better than when hand-weeded.

One may well ask what effect U.H.F. irradiation has on soil flora and fauna. Vela et al (1974) have studied this area. Radiation and thermal profiles show that heterotrophic bacteria, spores, fungi and actinomycetes were not affected by total microwave radiations over the range of 0 to 80 seconds at 1 kW intensity. Nitrogen fixing and nitrifying bacteria were also unaffected. If my conversion factors are correct, this means that many soil micro-organisms are unaffected by up to 80 J/cm^2. However as energy input increases to 480 J/cm^2 the effect on micro-organisms increases. Soil apparently offers considerable protection against radiation as pure cultures are readily killed. Soil moisture (while affecting speed of kill of seeds) does not affect micro-wave radiation resistance. The authors consider their data to imply that treatment of paddocks for weed control would have no effect on soil micro-organisms.

So far, we have considered a number of factors in U.H.F. weed control; soil and seed moisture, soil type, energy requirements, effect on micro-organisms. Soil temperature has been examined and energy requirements decrease as soil temperature rises from -20 to +18°C. These temperatures seem academic to us except in the range from about 0 to 18°C.

The obvious final question at this stage is: "What progress has been made towards practical weed control on a commercial scale"?

An article in the New Zealand Journal of Agriculture by F.S. Davis (1975) states that proprietry and development rights to the discovery at Texas A. & M. University on the effect of microwaves (U.H.F.) in plants have been purchased by a U.S. company. Davis was one of the team which pioneered the U.H.F. method and having joined the development company we find reference to the effect of U.H.F. on organisms other than weed seeds.

"Zapper" I, the prototype commercial machine, showed that microwaves could be injected safely into soil in sufficient strength to kill weed seeds and also nematodes, certain fungi and soil borne insect pests. A later version of the "Zapper" is claimed to have advantages over chemical and hand weed control. It kills all weed seeds, does not affect the environment and is competitive in cost. Experiments have shown effects greater than whole body heating (thermal effects had been considered the main lethal factor), probably involving disruption of cell membranes. In practice so far "Zapper" machines are slow, treating only 0.5 to 2 ha/day.

If the photo-voltaic celled sunshade mentioned earlier produces sufficient power for driving a spinning disc hand held herbicide applicator, what chance has solar energy as a power source for U.H.F. weed control? It has been calculated that the "sunshade" generates sufficient power to kill London rocket seed if resultant U.H.F. micro waves are applied for 36 seconds per cm^2, assuming 100% efficiency in energy conversion. Although this is too low a dose for practical purposes it does conjure up the picture of a solar energy converter powering an U.H.F. machine for band treatment pre-sowing of row crops such as tomatoes.

ELECTRICITY

Electricity has been tested as a means for weed control. This work has been reported by workers in the U.S.S.R. (Slesarev, 1972; Vasilenko and Sakalo, 1971; Baev and Savchuk, 1974). On the accepted premise that repeated cultivation of fallow land degrades soil structure and reduces moisture content, weed control by electrical discharge has been proposed as an alternative. A benefit claimed (in addition to avoiding repeated cultivation of the soil) is that artificial lightning increases availability of nitrate N and K.

Electrical discharges of 30 to 50 kV for a duration of 10^{-6} seconds killed all weeds tested in 4 to 6 days, apparently by shattering cell walls. Preliminary work suggested that fallow land could be effectively treated with 10 to 15 kWh of electrical energy per ha. Cost was estimated to be about one tenth that for tractor cultivation.

An experimental device has been field tested which delivered 3000 impulses per second, killing target plants but not affecting non-target neighbouring plants. Other work has shown that the lethal agent is the spark current flowing through plant tissue. When the effect of lightning on large trees is considered then this method of directed and controlled "lightning" would appear to have promise.

OTHERS

Water hyacinth (*Eichhornia crassipes*) is regarded as a really cursed weed. As well as being declared noxious (since 1901 in Victoria) it has numerous obnoxious properties (Parsons 1973). Yet N.A.S.A. in a series of Technical Memoranda points to water hyacinth as a source of methane gas (when harvested), and while growing in waters can reduce pollution levels of heavy metals (Ni, Cd, Ag, Co, Sr) phenols, and in sewage effluent reduces suspended solids, bio-chemical oxygen demanding substances, and other chemical parameters to levels below standards set by state pollution control agencies

(Wolverton, 1975). Thus water hyacinth is not all bad but has potential as a useful tool - in places.

Even so, methods of control are necessary and the U.S. Army has experimented with yet another form of energy - CO_2 laser irradiation. Energy inputs from 0.2 to 100 J/cm^2 were tested. Laser irradiation caused significant decrease in growth rates as energy input increased, but plants gradually recovered. It would seem that the techniques are capable of being improved (Long and Smith, 1975).

Before concluding this review a few novelties or perhaps novel ideas warrant brief mention.

Herbicide formulations have been developed with what might be considered novel properties. "Solubilized" formulations of paraquat, amitrole and glyphosate have been made in oil and water by using suitable surfactants as co-solvents. This increases penetration through bark and in the case of glyphosate considerably enhances leaf uptake (Turner and Loader, 1974).

Others (Mehltretter et al, 1974 and Frederick, 1976) have experimented with controlled release formulations to provide prolonged herbicide effect where this is desirable.

Herbicide protectants and antidotes have recently been subject to a review by Blair, Parker and Kasasian in PANS (1976). Since they draw from papers going back 30 years (activated charcoal for protection of sweet potatoes from 2,4-D injury) it is difficult to claim novelty. However the paper is worthy of our notice as there are recent developments which allow control of shatter cane (*Sorghum bicolor*) in maize with EPTC and wild oats (*Avena fatua*) can now be taken out of oats and wild rice (*Oryza punctata*) out of rice.

In conclusion, novelty in weed science may already be an established practice in other fields. Should we be permanently wedded to 100 to 200 ℓ/ha as the volume of spray necessary for weed control from ground spraying rigs? Likewise we seem wedded to 20 to 30 ℓ per ha by aerial application. Yet aphids have been effectively controlled in lucerne 30 cm high with insecticide plus heavy aromatic naptha at a total volume of only 1.5 ℓ/ha from the air (Ward, 1977).

It is very easy, when immersed in a particular discipline, to become blinkered, to be so set on a certain pathway that valuable and pertinent experience in another field is ignored, or not sighted or, because of blinkerism, considered irrelevant. Novelty and its attendant excitement requires blinkers to be removed so that eyes and mind seize every opportunity.

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