IDRC-126e

Food Legume Improvement and Development

Proceedings of a workshop held at The University of Aleppo, Syria, 2-7 May 1978

Geoffrey C. Hawtin and George J. Chancellor, Editors

CANADA

Published by The International Center for Agricultural Research in the Dry Areas and International Development Research Centre

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IDRC–126e

Food legume improvement and development: proceedings of a workshop held at the University of Aleppo, Aleppo, Syria, 2–7 May 1978. Ottawa, Ont., IDRC, 1979. 216 p.:ill.

/IDRC publication/. Compilation of workshop papers on /legume/ /food production/ in the /Middle East/ and /North Africa/ — discusses agro/bioclimatology/ and /cultivation system/s, /nutrition/al value and /food composition/; /plant production/ (particularly of /chickpea/s, /lentil/s, and /faba bean/s), /agricultural research/, /cultivation practice/s for /plant protection/; /plant disease/s, /insect/ /pest/s, /disease resistance/, /weed control/ problems (use of /herbicide/s in /arid zone/s); /plant breeding/ and /genetic improvement/. /IDRC mentioned/, /list of participants/.

UDC: 633.3 ISBN: 0-88936-202-5

Microfiche edition available

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International Development Research Centre

Contents

Accentuation of Weed Control Problems in the Dry Areas with Relevance to Herbicides in Food Legumes

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Over a large part of the subtropical, semi-arid zone, both highland and lowland, a cereal–fallow rotation system has traditionally been practiced. The main weed control methods in such a system have involved grazing during the fallow period and cultivation prior to planting the cereal crop. For economic reasons the largest possible area is maintained under cereals each year and as a result grazing has often been reduced to the off-season or in some cases completely abandoned. This has allowed the proliferation of many winter weeds, which infest autumn-sown cereal and legume crops, because by the time that grazing occurs these weeds have already, to a large extent, shed their seeds. With this increasing tendency toward intensification of cropping systems, curative weed control is becoming imperative to the maintenance of high levels of productivity.

Constraints of Curative Weed Control in Dry Areas

Water availability is the major factor affecting the productivity of crops in the dry areas. Even in good years the productivity of field crops in these areas is suboptimal and the profitability is generally low and variable. Farmers thus attempt to minimize the cost of their inputs and avoid as far as is possible the relatively costly fertilizers and pesticides that are applied early in the cropping season and that would thus be wasted in the event of crop failure due to insufficient rainfall.

At present the feasible curative weed control methods available are threefold:

Firstly, there is manual weeding, which can be through hand pulling in broadcast crops and where weeds are well established, or with tools if the crop is row planted or the weeds are not too far developed. Farmers often use hand-pulled weeds as animal fodder but although this may at first sight seem a very useful practice, to be suitable for fodder the weeds must have reached a certain size and will have already exerted a considerable yield-reducing effect on the crop by the time they are removed. Manual weeding is very labour intensive and according to recent studies at ICARDA requires at least 60 man-days per hectare for the minimal two weedings that are necessary. The advantage of this control method, however, is that it can be foregone in the event of crop failure due to drought.

Mechanical weeding is the second available control practice and involves the use of animal or tractor power. It can only be carried out in row-planted crops and where the rows are sufficiently spaced to allow for the passage of the machine without causing severe crop damage. This method is ineffective for the control of in-row weeds; requires a relatively level soil surface; can cause considerable soil compaction and loss of soil moisture; and is not possible when the land is wet. However, considerable savings in labour can be made over manual weeding, although investment in machinery may be high and increases with decreasing between-row spacing, meaning that fewer plants can be grown on a given area unless investment is considerable. These requirements and disadvantages have tended to hamper the widespread introduction of mechanical methods in the relatively poor marginal areas.

Finally there is chemical weed control. This requires some skill and accuracy to apply the right herbicide at the right dosage at the right time and again considerable investment in equipment. Results can be excellent when the chemicals are used in the correct way but lack of operator skill and variable environmental conditions can result in total wastage of the investment or even destruction of the crop being treated. In addition, the use of herbicides can considerably reduce moisture loss as no soil disturbance is generally required and as water-consuming weeds are effectively eliminated. However, despite the cost of chemical control in most of the countries of the dryland region being far below that of correspondingly effective manual methods, the relatively high risks involved in their use and the high costs of the chemicals, which are largely imported, have so far inhibited the large-scale use of herbicides, especially by the small farmers.

A better understanding of the actions of these chemicals under dryland conditions will perhaps enable us to evolve recommendations and procedures that will reduce the risks and costs of this more effective and economic means of weed control and as a result increase its popularity with the farming community.

Selectivity Mechanisms of Soil Herbicides

Phytotoxic chemicals have a very wide range of modes of action. Amongst the soil herbicides these include retarding root growth, inhibiting photosynthesis, interfering in cell meiosis, and affecting the uptake of minerals and water, to name but a few. Irrespective of their modes of action all chemicals must first be absorbed by the plant and translocated to their place of action before they can begin to be effective. In considering herbicides we would do well to remember Paracelsus' assertion of 500 years ago, that all substances are poisonous to living organisms at a certain quantity. The critical factor to be considered is thus the quantity of the herbicide that reaches its specific site of action. The variation in this determines the selectivity of the chemical (i.e., which plants will be killed by a certain dosage of herbicide under certain conditions and which plants under the same conditions will survive). Selectivity is of tantamount importance in the use of herbicides and it may be achieved by a number of different mechanisms. These mechanisms include physical placement of the chemical; ease of penetration of the root epidermis; metabolism to harmless derivatives within the plant; and ease of transport within the plant. In hydroponic culture the explanation would stop here, but in agriculture the soil, which is the link between the application of the chemical and its absorption by the plant, plays a very important role in determining the action of herbicides, most of which are soil applied. The soil represents a very complex system but certain important factors, such as quantity of water in the soil, adsorption of herbicides on soil particles, and movement of herbicides in the soil, that affect selectivity can be identified.

Quantity of Water in the Soil

Herbicides are translocated within the soil from their site of placement to their site of uptake either in solution with water or in a gaseous state. Chemicals commonly absorbed in solution include the groups of substituted ureas, uracils, triazines, diphenylethers, acetamides, and thiocarbamates, which are mainly applied to the soil surface. Gas-transported chemicals are largely of the group of nitroanilines generally incorporated in the soil prior to planting due to their high vapour pressure.

With solution-absorbed herbicides, uptake by the plant depends to a large extent on the water solubility of the chemical, which is in turn affected by the temperature and pH of the soil water and the rate of plant water uptake. In this context, the amount of available soil water is very important, as with less water to dissolve a given quantity of chemical the resulting solution will be more concentrated and the amount of chemical taken up by the plant over a fixed time will thus be greater. Thus it appears that, providing a chemical dissolves readily in water, its action will be considerably more vigorous under dry soil conditions than when the soil is wet. Comparison of the quantity of water required to dissolve a given quantity of various chemicals could thus be used as a good guide to the chemicals likely to act more aggressively under dry land conditions.

Chemical	Solubility in water	Amt water to dissolve 1 kg	mm rain required to dissolve 1 kg	End effect
A	1000 ppm	1 m^3	0.1	Increased
B	100 ppm	10 m^3	1.0	Increased
C	10 ppm	100 m^3	10.0	Increased
D	1 ppm	1000 m^3	100.0	Normal
E	0.1 ppm	10000 m^3	1000.0	Ineffective

The application of high dosages of herbicides with very low solubilities (e.g., E) is a waste of resources under dry conditions because much of the chemical will remain immobilized in the soil due to insufficient water. However, above the level of 1 ppm solubility (A, B, and C), the total quantity of chemical can be dissolved in increasingly less soil water, the concentration of chemical in solution is increased, and, as the degree of interplant selectivity is not altered, the effect on the crop is considerably enhanced (Table 1).

In general those herbicides that are translocated and absorbed by plants in their gaseous state have a very low solubility in water. This fact largely prevents the absorption of these chemicals through the soil-water solution and movement to the plant is thus mainly by means of the soil-air system. The moisture condition of the soil is also a crucial factor in influencing the action of these herbicides, because the rate of diffusion depends largely on the available airspace in the soil. When the soil is in a dry condition a larger proportion of the soil pores are air-filled, as opposed to water filled, and the soil airspace is thus greater. Greater airspace means more rapid diffusion of the chemicals in the soil and enhanced absorption by the plant. Thus herbicides taken up by plants in their gaseous state are also more aggressive under dryland conditions.

Adsorption of Herbicides on Soil Particles

A further factor bearing on the action of herbicides is the degree to which they are adsorbed onto soil particles. The amount of adsorption depends on a number of factors related to the nature of the soil and of the specific chemical. This phenomenon significantly reduces and balances the quantity of herbicides available to the plants and thus considerably affects their activity.

It has been shown that within a group of herbicides (which therefore have a similar means of bonding) the amount of adsorption is positively correlated to the chemical's solubility in water (Table 2). This therefore balances to some degree the increased aggressiveness shown by highly soluble chemicals under dryland conditions.

The physical and chemical properties of the soil play a very important role in determining the degree of herbicide adsorption. Soil particle size is particularly significant in this respect, in that small particles offer a larger surface area for adsorption per unit area of soil. Thus the degree of adsorption increases with decreasing soil particle size. This effect, however, is modified by the relative reactivity of the particle surface, expressed in the cation exchange capacity. Because the soils of the arid zones are usually low in soil constituents with a high cation exchange capacity, such as organic matter, vermiculite, montmorillonite, and illite (Table 2), the amount of herbicide adsorbed is relatively low

TABLE 1. Solubility and selective rates of some herbicides (from various sources).

Herbicide	Solubility in water (*ppm*)	Selective rates recommended (*kg active ingredient/ha*)
Fluorodifen	2	2.0–4.0
Simazine	5	0.25–1.0
Prometryne	48	1.0–2.0
Methabenzthiazuron	59	2.0–4.0
Linuron	75	0.5–1.0
Alachlor	240	1.0–2.0
Metolachlor	530	1.0–2.0
Metribuzin	1200	0.5–1.0

TABLE 2. Magnitude of adsorption on Na-montmorillonite of selected herbicides with different solubilities in water expressed with Freundlich "k" and "n" values.[a]

Adsorbate	Water solubility (*ppm*)	"k" value	"n" value
Simetone	3200	2200	3.23
Atratone	1800	400	2.08
Prometone	750	150	1.56
Trietazine	20	58	1.00
Propazine	8	18	0.89
Atrazine	70	15	1.18

[a] Source: Bailey, G. W. et al. 1968. Adsorption of organic herbicides by montmorillonite soil. Sci. Soc. Amer. Proc. 32: 222.

and its availability to plants correspondingly high. This means that the effect of the herbicide will be greater than in more highly adsorptive soils.

High soil pH reduces the degree of adsorption especially with herbicides that depend on an acid-charged particle surface or on the weak positivity of their radicals (nitrogen in the case of anilines, ureas, and carbamates) for adsorption. Most soils found in the arid lands have a pH of greater than or equal to 8 and thus tend to adsorb chemicals much less readily than the majority of soils.

Environmental conditions such as temperature also have a considerable effect on the adsorption properties of soils. As high temperatures tend to decrease adsorption, particular attention must be paid to treating summer- or autumn-sown crops in the dry areas.

Movement of Herbicides in the Soil

The direction and amount of a herbicide transported in the soil, or the ability of it to diffuse from one place to another, depends largely on the amount and frequency of water infiltration into the soil and the degree of adsorption by the soil particles. When precipitation and infiltration are high, the chemical tends to be leached downward and diluted within a large quantity of soil. This increases the degree of adsorption and further reduces the effect of the herbicide by reducing its concentration in the root zone where it must remain to be effective. In contrast to this, under dryland conditions the dilution of the chemical is less, as a result of less water infiltrating into the soil and so the effect of the herbicide is enhanced. This is further exacerbated by reconcentration of the herbicide near the soil surface as a result of upward soil water movement during spells of dry weather.

It can be seen that the factors underlying the behaviour and efficacy of soil herbicides are of a very complex nature. Much work needs to be carried out to evolve recommendations for herbicide use suited to the specific situation of the arid zones. However, with the knowledge that soil herbicides act more aggressively under dryland conditions, weed control methods can now be developed involving smaller quantities of chemicals. This will reduce the cost of treatments to a level that will better suit the low-cost input requirements of the agricultural systems of the Middle East and North Africa.