DECISION MAKING ON INPUT USE UNDER WEATHER UNCERTAINTY
Herbicide Application in Tunisia

Ali Ben Zaid Salmi*

A large number of Northern Tunisian weed species are known to seriously compete with wheat for the use of factor inputs, particularly moisture and fertilizers. The overall loss in wheat yields due to weeds has been estimated to be around 50 percent of the yield potential (1). Hence, in the general effort of increasing wheat production in Tunisia, weed control would be no less important than the genetic improvement of wheat materials or any other technological advances designed to extract higher yields of wheat.

Various technological packages of herbicide treatment have been defined for weed control in the wheat belt of Northern Tunisia. However, the effectiveness of such treatment is related to weather conditions that remain impredictable. The Dosanex treatment, for instance, resulted in 1.3 additional quintals of wheat per hectar in 1971-72, 6.9 additional quintals in 1972-73 and 3.9 in 1973-74 (2). Since the short run decision of the user is largely related to profit making weather uncertainty will inhibit rational decision making on the use of herbicides.

The objective of this paper is to suggest an analytical framework which could integrate weather conditions into the decision making on the use of herbicides. The procedure is based essentially on game theory (3). Weather conditions are expressed as states of nature, with a given probability distribution; herbicide treatments, including the option of no treatment would be the possible strategies, the decision maker could adopt in his "game against nature." Such a framework would also help with policy making on price fixing and subsidies, once the expected outcomes are estimated for the different states of nature.

---

*Assistant Professor of Agricultural Economics at the Institut National Agronomique de Tunis, Tunisia. Thanks are expressed to Mr. Torrey Lyons (CIMMYT/Projet Ble, Tunis) and Messrs. Piero Bronzi and Werner Kiene (Ford Foundation, Tunis) for their contributions and useful suggestions to this paper. A detailed report on this research was presented at the 3rd Regional Wheat Workshop, Tunis, April 28 - May 2, 1975.

(1) The Annual Report of the "Projet Ble" for 1973-74, Office de Cereales, Republic of Tunisia.

(2) The Annual Reports of the "Projet Ble" for 1971-72, 1972-73, 1973-74, Office de Cereales, Republic of Tunisia

(3) Details on game theory may be found for instance in: "Economic Theory and Operations Analysis," Second edition of 1965, by W.J. Baumol, Prince-Hall, Inc., Englewood Cliffs, New Jersey.

Actually, the investigation about weather conditions affecting the outcome of various herbicide treatments may include such factors as temperature, winds and rainfall. The last factor, however, seems to be the most important, and it is a reasonable simplification to focus the present analysis on rainfall only.

With regard to the biological growth of wheat and weeds, the effect of rainfall should be explained not only by the annual total quantity of rain, but also by the distribution pattern of rainfall over the critical phases. Three periods of the growing season have been chosen to represent such a distribution and for each period the critical quantity of rainfall has been defined on the basis of agronomic research and expert opinion. The early period (E) corresponds to wheat and weed establishment, and determines the weed infestation potential. The sufficient quantity of rain during this period would be 50 to 100 mm between September and November. During the middle period (M) wheat and grass weeds complete their vegetative cycles, while broad leaf weeds go into their reproductive cycle. Rainfall would be sufficient over the range of 200 to 400 mm from December to March. The late period (L) covers the reproductive cycle of wheat and grass weeds. The range of sufficient rainfall for this period would be around 50 to 150 mm between April and June.

Considering that rainfall may be either sufficient (=), insufficient (-) or excessive (+) for each period, the combination of the three periods of a given year would be one of 27 possible states of nature. The frequency distribution of those rainfall states of nature has then been estimated from records of the last 73 years. Those frequencies are presented in table 1, for six meteorological stations. The overall average of the six stations is also given in that table and should be representative for the wheat belt in Northern Tunisia.

Actual outcomes from herbicide treatments have been documented only over the last four years, and do not cover all types of rainfall patterns. However, each of the four observed years has a different rainfall pattern so as to explain the yearly variation in outcomes and to provide a basis for extrapolation as well. Hence using the actually observed outcomes as a basis, and with the assistance of knowledgeable agronomists, estimates were obtained for the rest of possible outcomes. The results are summarized in table II interpreting the effect of rainfall on outcomes from herbicide treatments.

Given the probability distribution of rainfall patterns on one hand, and the corresponding estimates of the outcomes on the other hand, it is possible to compute the expected values of increase in wheat yields due to each treatment for each station as well as for the total region (see table III).

Table III shows a large variation among treatments, while for the same treatment the variation among stations is relatively limited. With prices prevailing in 1974, all treatments seem to be profitable at the regional level (4). The net profit varies from half a quintal of wheat per hectar from the first treatment (T_1) to around 6 quintals from the last treatment (T_6). Similarly, most treatments seem to be profitable at the station level. Only T_3 turns out to be inefficient in most locations.

In 1975 the price of wheat went up by around 17 percent while herbicide prices became subsidized by 50 percent. It appears from the present analysis that the purpose of such a subsidy was not to compensate for an expected loss from herbicide use, but rather to encourage expanded application of herbicides in order to improve national wheat production.

Comparing the stations one may notice that Maktar in most cases shows the lowest expected outcomes, while Bizerte shows the highest ones. The difference is mainly due to the specific distribution of rainfall patterns which seem to characterize each station. Bizerte for instance, is characterized by excessive rain in the middle period (72 percent of the years) and insufficient rain in the late period (about 50 percent of the years). On the contrary, in Maktar rainfall is often insufficient in the middle period (around 50 percent of the years) and excessive in the late period (63 percent of the years). In the first case, the excess of water in the middle period would be favorable to weeds that are more tolerate to soil saturation, and would decrease the competitive capacity of wheat by keeping its root system near the surface. When moisture stress becomes critical in the last period, weeds would be most

(4) Net profits may be calculated from table III by subtracting the treatment cost from the corresponding expected additional yield. Costs of treatment under 1974 prices are as follows: The equivalent of 3.5 quintals of wheat for T_1 and T_2; 2.9 for T_3 and T_4; and 3.5 for T_5 and T_6. (For more details see Annual Report, Projet Ble, 1973-74.)

damaging and inversely, herbicides would be most efficient as noticed above for Bizerte. The damage from weeds is less important when the middle period is dryer, forcing wheat to develop roots deeper in the soil, as seems to be the case in Maktar and the Kef. Consequently, the behavior of the user of herbicides would not be necessarily the same in all parts of the region.

Hence, given the location at which the decision maker is operating, he will be faced with various possibilities of outcomes, each being weighted by a known probability of occurrence. The strategy he will adopt will finally depend on his own attitudes towards risk taking.

In conclusion, this analysis shows an example of dealing with weather uncertainty, both for decision making at the micro-level and for policy making. To improve the practical usefulness and reliability of the presented framework, more field data results need to be obtained in order to replace the estimated outcomes used in the present analysis. Furthermore, a detailed investigation of weather records should be continued in order to determine the sequence of rainfall patterns, and other conditions of weather that are critical to agricultural practices.

Finally, it may be suggested that the same framework be used in dealing with other factors and weather conditions that are critical to agricultural production. The timing and profitability of fertilizer use and seed bed preparation, as well as the effect of temperature variations and wind patterns could be foremost candidates for such an analysis.

TABLE I

Relative Frequencies of Rainfall Patterns for Different Stations In Northern Tunisia (1901 - 1973) +

Rainfall Pattern		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Period	E	-	=	+	-	=	+	-	=	+	-	=	+	-	=	+	-	=	+	-	=	+	-	=	+	-	=	+
	M	-	-	-	-	-	-	-	-	-	=	=	=	=	=	=	=	=	=	+	+	+	+	+	+	+	+	+
Stations	L	-	-	-	=	=	=	+	+	+	-	-	-	=	=	=	+	+	+	-	-	-	=	=	=	+	+	+
Bizerte		0	1.53	0	0	1.53	3.07	0	0	1.53	0	1.53	4.61	0	6.15	0	0	4.61	3.07	4.61	23.07	7.69	0	9.23	9.23	0	10.76	7.69
Medjez		3.5	17.54	0	0	15.78	1.75	3.50	3.50	0	0	8.77	5.26	7.01	5.26	0	5.26	7.01	1.75	3.50	3.50	0	0	1.75	0	3.50	1.75	0
Beja		0	0	0	0	0	0	1.47	1.47	0	0	4.41	1.47	1.47	7.35	0	1.47	11.76	8.45	4.41	14.70	1.47	0	9.85	7.04	5.63	9.85	5.63
Bouslama		2.89	13.55	0	0	7.24	1.44	1.44	8.69	0	1.44	8.69	1.44	2.89	10.14	0	7.24	11.59	2.89	2.89	4.34	0	1.44	5.79	1.44	0	4.34	0
Le Kef		1.44	2.89	1.44	0	4.34	1.44	1.44	13.04	2.89	4.34	4.34	2.89	1.44	13.04	0	10.14	13.04	4.34	1.44	0	0	0	5.79	1.44	4.34	1.44	2.89
Maktar		1.40	2.81	1.40	2.81	8.45	1.40	7.04	14.08	8.45	0	2.81	1.40	5.63	2.81	0	5.63	14.08	4.22	2.81	0	0	1.40	1.40	0	7.04	1.40	1.40
Overall Average ++		0	0	2.73	0	4.10	2.73	0	9.58	0	0	12.32	1.36	1.36	17.80	0	1.36	13.69	4.10	4.10	4.10	2.73	1.36	6.84	0	0	9.58	0

\+ The rainfall pattern is defined by a combination of the three periods, early (E), middle (M) and late (L). The sign corresponding to each period, in a given pattern, indicates whether the quantity of rain received in that period is sufficient (=), insufficient (-) or excessive (+).

- During the period E, rain is sufficient if it is between 50 and 100 mm over the months of September through November.
- The period M covers the months of December through March, and the corresponding sufficient range of rain is between 200 and 400 mm.
- Period L covers the months of April through June. The corresponding sufficient quantity of rain is estimated at 50 to 150 mm.

++ Corresponds to the overall Northern Region of Tunisia, represented by the average of the six stations.

TABLE II

Potential Additional Yields of Wheat from Various Herbicide Treatments in Different Rainfall Patterns + (in quintals/ha)

Type of Weeds	Infestation +	Herbicide Treatment +	Rainfall Pattern 1	2	3	4	5‡	6	7	8	9	10	11	12	13	14‡	15	16	17	18	19‡	20‡	21	22	23	24	25	26	27
			-	=	+	-	=	+	-	=	+	-	=	+	-	=	+	-	=	+	-	=	+	-	=	+	-	=	+
			-	-	-	-	-	-	-	-	-	=	=	=	=	=	=	=	=	=	+	+	+	+	+	+	+	+	+
			-	-	-	=	=	=	+	+	+	-	-	-	=	=	=	+	+	+	-	-	-	=	=	=	+	+	+
Broad Leaves	Average	T_1 2-4D	0.8	1.0	1.2	0.6	0.9	1.1	0.7	0.8	1.0	1.8	1.7	2.0	0.5	0.5	0.7	0.5	0.5	0.7	1.7	1.5	1.8	0.7	0.6	0.9	0.6	0.5	0.7
Broad Leaves	High	T_2 2-4D	2.4	2.5	2.7	1.3	1.6	1.9	1.3	1.5	1.8	3.1	3.0	3.2	1.0	0.9	1.1	0.9	0.8	1.0	3.4	3.0	3.7	1.1	1.0	1.2	0 9	0.8	1.0
Wild Oats	Average	T_3 Suffix	2.3	2.3	3.0	1.5	1./5	2.0	1.5	1.5	2.0	4.7	4.1	5.0	2.3	2.0	2.5	2.1	1.9	2.2	7.1	5.8	7.1	4.0	3.5	3.8	3.8	3.4	3.5
Wild Oats	High	T_4 Suffix	6.9	6.9	5.9	4.6	4.6	5.9	4.6	4.6	5.9	10.6	8.2	9.1	5.3	4.1	4.6	5.3	4.1	4.6	14.3	9.5	12.3	8.0	7.0	7 6	8.0	7.0	7.6
Most Weeds +++	Average	T_5 DOS+TOK	5.5	6.0	7.9	4.5	5.0	6.6	4.3	4.8	6.4	6.6	6.4	9.0	3.3	3.2	4.7	3.3	3.2	4.5	9.8	8.1	11.3	5.0	4.2	5.7	4.8	4.0	5.5
Most Weeds +++	High	T_6 DOS+TOK	10.9	13.1	17.2	9.1	10.9	14.3	8.8	10.6	14.0	14.2	13.7	15.6	7.9	7.6	8.7	7.9	7.6	8.4	17.1	12.8	17.9	8.8	6.6	9.0	8.6	6.4	8.8

+ The additional yield estimates of this table hold for the Soltane variety and require a good seed-bed preparation. Details about the doses and timing of the treatments, as well as the definitions of high and average degreee of infestation are given in the Annual Report Projet Blé, 1973-74.

++ The outcomes in columns 5, 14, 19 and 20 were actually observed and have been reported by the Projet Blé for the corresponding years of 1973-74, 1971-72, 1970-71 and 1972-73 respectively. Those outcomes have been used as a basis for estimating the rest of this table.

+++ Including canary grass and ryegrass.

TABLE III

Expected additional yield of wheat from various herbicide treatments (in quintals/ha) +

Herbicide Treatments ++	Stations						
	Bizerte	Medjez	Beja	Bousalem	Le Kef	Maktar	Regional Average
T_1	1.08	0.95	0.86	0.89	0.80	0.78	0.89
T_2	1.96	1.86	1.50	1.71	1.44	1.42	1.61
T_3	4.24	2.73	3.54	2.78	2.56	2.33	3.02
T_4	8.05	6.39	6.95	6.33	5.85	5.66	6.28
T_5	6.42	5.31	5.29	5.05	4.67	4.79	5.03
T_6	10.94	10.97	9.30	10.41	9.77	10.07	10.07

+ Expected values as obtained from multiplying the outcomes in table II by the corresponding probabilities in table I.

++ The same as in table II.