THE ECO-ECONOMIC THRESHOLD PERIOD FOR CONTROLLING BARNYARD GRASS IN SUMMER SOYBEANS

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Summary. A term of "Eco-economic Threshold Period for Weed Control" was proposed and field experiments were conducted in the Beijing region of China to study the functional relationship between the summer soybeans (*Glycine max.* L.) yield and the relative weedy and weed free days by barnyard grass (*Echinochloa crus-galli* (L.) Beauv.). Models for calculating the eco-economic threshold period for the weed control in the crop were then developed. Results calculated using these models showed that the eco-economic threshold period for controlling barnyard grass in summer soybeans was 16.8-26.0% days of the total crop growth season after emergence. This is the critical period for avoiding the weed damage whilst maximizing the use of the weed in reducing soil erosion and the loss of light interception and soil nutrients caused by insufficient plant covering during the early growth phase.

INTRODUCTION

Weeds not only have harmful aspects on crop productivity but also useful in the agro-ecosystem in preventing soil erosion (2-7). Therefore, the principle of weed control should be to avoid their negative effects, utilize their positive effects and optimize the socio-economic ecosystems (4).

Soybeans are usually sown in row spacings of more than 45 cm. Their vegetative growth and increase in leaf area develop slowly in the beginning of the growth season so that most parts of the field are bare for a long period after planting. As a result, the soil erosion and the loss of light interception without weed mulching in the field during this period is quite heavy, especially in sloping fields. Early chemical weed control will not only aggravate this situation but also may increase the environmental pollution and the cost of weed control.

The objectives of this work were to develop models for calculating the eco-economic threshold period which might serve as a guide for efficiently controlling barnyard grass in summer soybeans.

METHODS

Experiments were conducted in three fields with a large natural seed bank of barnyard grass in the Beijing region during 1984 and 1985. Soybeans was seeded in 7x45 cm row spacing to give a final density of 21 plants/m^2 in 1984 and in 6x45 cm row spacing to give a final density of 24 plants/m^2 in 1985. After seeding the fields were immediately irrigated to improve the emergence of the weed and crop. The plot size of each experiment was 12-15 m^2 containing 6 rows of soybeans. All weeds except barnyard grass in the experimental plots were removed during soybean growth season by hand weeding. All treatments were accomplished with 3 replications.

In 1984, barnyard grasses were allowed to emerge together with soybean and grow for 0, 21, 42, 63, and 84 days after crop emergence and for the entire growth season at the density of 6.7, 33, 73, and 147 barnyard grass plants/m^2, while for 0, 14, 28, 38, and 42 days and for the entire growth season at the density of 6.7, 33, 73, and 147 plants/m^2 in 1985. After the termination of each weedy duration these plots were then kept weed free by hand weeding until soybean maturity. In an other experiment in 1985, plots were kept weed free for 0, 21, 35, 49, 63, and 77 days after soybean emergence and for the entire season. After the terminating of the weed free duration barnyard grasses were allowed to emerge and grow until soybean maturity.

The eco-economic threshold period for weed control in this paper was defined as "A weed free period which can economically and ecologically avoid the damage caused by the growth of weeds emerging before and during crop growth season". The onset of the threshold period was defined as the maximal percent weedy days after crop emergence before the crop relative yield was over 97% of the weed free treatment. The end of the threshold period was defined as the percentage of the least weed free days after crop emergence after which the growth of the emerging weeds did not reduce crop yield by more than 3%.

The functional relationships between soybean relative yield and the relative weedy and weed free days after crop emergence were fitted by means of computer software PlotIT.

RESULTS AND DISCUSSION

1. Relationship between weedy days and soybean yield. As shown in Table 1, barnyard grass irrespective of plant density did not significantly reduce soybean yield when the relative weedy duration was kept within the first 23.9% days of the total crop growth season after emergence in 1984. However the relative weedy days by barnyard grass lasting longer than 47.7% days of the total crop growth season after emergence decreased the soybean relative yield significantly and reached the maximum after the first 95% relative days. There was a significant interaction effect between weed density and weedy duration on soybean yield. Soybean relative yield was reduced as increase of weed density and the lasting of the weedy duration. In 1985, barnyard grass interference resulted a less reduction in soybean yield and a delayed damage time because of its reduced density in this year (Table 2). The function fitting results indicated that there was a Weibull functional relationship with r= 0.98 shown as follows between the relative weedy duration (X_u) by barnyard grass at the highest interference density and the relative yield of soybean (Y_u) :

$$Y_u = 107.6(1-\exp(-(1.00376-0.000074X_u)^{334.1}) \qquad \text{<1>}$$

2. Relationship between weed free days and soybean yield. In 1985, only those barnyard grass which emerged together with soybean and was in interference with soybean for an entire growth season caused a significant reduction in soybean yield. However it did not reduce soybean yield when it emerged 21 days after soybean emergence or later because it hardly emerged and formed little biomass under strongly shading of soybean (Table 3). The function fitting results showed that there was a positioned exponential functional relationship with r= 0.99 shown as follows between the relative weedy free days of barnyard grass after crop emergence (X_d) and the soybean relative yield (Y_d):

$$Y_d = -63.4\exp(-0.1172X_d)+100.02 \qquad \text{<2>}$$

3. Establishment of models for calculating the eco-economic threshold period. According to the definition of the eco-economic threshold period for weed control and the above functions <1> and <2>, the functional relationships between the relative weedy and weed free days by barnyard grass and the soybean relative yield was fitted. The following models were derived:

$$X_u= 16.8\%T \qquad \text{<3>}$$
$$X_d= 26.0\%T \qquad \text{<4>}$$

where,

T= total crop growth days after emergence

X_u= onset of the eco-economic threshold period in percent days of the total crop growth season after emergence

X_d= end of the eco-economic threshold period in percent days of the total crop growth season after emergence

Table 1. Weedy duration by barnyard grass in relation to soybean yield in 1984

Weedy day after emergence		Density plants/m²	DM g/m²	Relative height x DM g/m²	Soybean relative yield %
days	%				
0	0.0	0.0	0.0	0.0	100.0
21	23.9	6.6	1.7	1.6	100.0
		33.0	7.0	6.5	100.0
		73.0	13.1	14.2	99.9
		147.0	23.5	32.0	97.8
42	47.7	6.7	15.3	24.3	99.9
		33.0	53.5	68.5	81.0
		73.0	99.6	116.9	75.3
		147.0	176.9	210.3	62.0
63	71.6	6.7	22.9	53.9	99.9
		33.0	103.2	192.0	68.9
		73.0	150.4	299.0	63.1
		147.0	240.6	462.0	42.3
84	95.5	6.7	38.4	82.9	89.7
		33.0	120.3	252.0	64.1
		73.0	165.5	363.0	52.6
		147.0	289.0	578.0	34.1
88	100.0	6.7	37.9	80.9	89.7
		33.0	115.9	247.0	63.5
(Entire season)		73.0	146.8	327.0	51.0
		147.0	276.4	555.0	33.5

By combining the model of <3> and <4> it can be seen that the eco-economic threshold period for controlling barnyard grass in summer soybeans lay in the first 16.8-26.0% days of the total crop growth season after emergence, namely around 14 to 22 days after soybean emergence in the Beijing region.

The boundaries of the "critical periods for weed control" in many studies were usually arbitrarily defined as the period during which the relative crop yield exceeds 95% (1,8). But in our study they were defined as the period during which keeping weed free can ensure the crop relative yield exceeds 97% of the weed free treatment. This is because in our other research it was found that the loss caused by weed growth from soybean emergence to crop maturity could be usually counteracted by the value provided by it in preventing soil and nutrients from washing away and providing the soil with organic matter (4,5 Table 1-3).

Table 2. Weedy duration by barnyard grass in relation to soybean yield in 1985

Weedy day after emergence		Density plants/m²	DM g/m²	Relative height x DM g/m²	Soybean relative yield %
days	%				
0	0.0	0.0	0.0	0.0	100.0
14	16.5	3.3			102.9
		6.7			107.7
		20.2			108.1
		33.7			107.9
28	32.9	3.3	4.2	5.4	107.6
		6.7	14.5	22.3	100.5
		20.2	60.9	100.1	88.5
		33.7	94.9	156.4	86.1
35	41.2	3.3	14.5	23.1	100.5
		6.7	32.2	46.3	90.9
		20.2	89.5	148.5	86.2
		33.7	311.2	554.0	79.0
42	49.4	3.3	38.6	69.6	95.7
		6.7	77.3	133.7	84.7
		20.2	196.5	327.9	79.9
		33.7	324.2	560.4	75.1
85	100.0	3.3	54.8	124.4	90.9
		6.7	124.0	220.9	79.9
		20.2	227.8	432.0	78.5
		33.7	356.4	608.3	76.6

Table 3. Weed free and emerging period by barnyard grass in relation to soybean yield in 1985

Weed free days after emergence		Density plants/m²	DM g/m²	Relative height x DM g/m²	Soybean relative yield %
days	%				
0	0.0	303	775.8	1081.0	36.3
21	24.7	22	9.3	4.5	98.6
35	41.2	18	11.1	6.4	99.7
49	57.6	15	4.5	2.5	100.0
63	74.1	12	3.9	1.0	99.3
77	90.6	3	0.6	0.0	99.5
85	100.0	0	0.0	0.0	100.0

You has simulated the nitrogen loss caused by leaching in soybeans under weedy and weed free conditions and found that the nitrogen loss caused by leaching in soybeans without weed growth was more heavy than that with weed growth during the first 17% days of the total growth season because of the little vegetative growth and the limited uptake of nitrogen from soil by soybean plants (5). Results obtained in this study showed that barnyard grass emerging after the first 24.7% days or later in soybean growth season no longer significantly reduced the yield of summer soybeans (Table 3). These results indicated that this kind of weed growth had used only those resources which soybean could not use. According to the definition of the eco-economic threshold period and the results shown in Table 1, 2 and 3 it can be seen further that keeping barnyard grass free in soybeans after the end of the threshold control period by weeding will only waste money, while killing the weed emerging together with soybean immediately after its emergence can surely avoid the potential weed damage in the late growth season, but it will be not favourable for utilizing the positive aspects of the weed. Only keeping weed free within the eco-economic threshold control period can, in one side, avoid all the weed interference damage to the crop during the whole growth season, and, in other side, fully utilize the positive aspects of weed growth in the field ecosystem and achieve a highest eco-economic benefit in weed control.

Weed density reaches only half of its maximum before the first 16.5% relative days while it does after the first 24.7% days (5). This is just the time within the eco-economic threshold period for controlling barnyard grass. Weed control with post-emergence herbicides to keep the weed free within the threshold control period can also avoid the shortcomings of less chemical control percentage with pre-emergence herbicides because of weed emerging afterwards.

Nowadays, barnyard grass control in summer soybeans in China is usually blindly accomplished outside its eco-economic threshold control period. Usually 1-2 times of pre-emergence herbicides applications and 1 to 3 times of mechanically weeding are normally needed to avoid the weed damage to soybeans. This weed control performance usually results a weed control cost as high as 85 to 150 yuan/ha. However, when barnyard grass is kept free subjectively only within its threshold control period found in this study weed control cost will be reduced to 51 to 58 yuan/ha which saves over 40% of the conventional weed control cost. This is achieved by applying post-emergence herbicides such as sethoxydim, fluazifop (methyl, butyl or p-butyl ester), or imazethapyr at the time around the first 16% days of the total soybean growth season (the onset of its threshold control period) and its efficacy is kept until to the first 26% days after emergence (the end of its threshold control period.

By comparing world research results in weed-crop competition (1), Heemst found that the "critical period for weed control" in soybeans averagely arranged in the first 12-30% days of the total soybean growth season worldwide, which is similar to the eco-economic threshold period for controlling barnyard grass by the first 16.8-26% days found in this research. This implies that using the relative weedy and weed free time and the relative crop yield to present the functional relationship between weed interference duration and crop yield reduction can estimate the effect of weed species, crop varieties, and environmental factors on the threshold period for weed control. Therefore, the eco-economic threshold period for controlling barnyard grass in spring soybeans in China may be similar to that in summer soybeans found in this study. This is to be studied in the future.

Moreover, the results achieved in this study means also that the herbicide efficacy for controlling barnyard grass inn summer soybeans should remain at least from the application day till to the first 26% days of the total crop growth season and for the post-emergence herbicides their eco-economical application date would be around the first 16% days.

ACKNOWLEDGEMENTS

This project was funded by the National Natural Science Foundation of China.

REFERENCES

1. Heemst, H.D.J.van. 1985. Agricultural Systems 18, 81-93.
2. Holzner, W. 1979. Die Bodenkultur (Wien) 30, 377-380.

3. Holzner, W. and Numata, M. 1982. Biology and Ecology of Weeds, edited by W. Holzner and M. Numata, Junk Publishers, 3-20.
4. You, Z.G. 1986. Master Sci. Dissert., Beijing Agri. Univ.
5. You, Z.G. 1993. Acta Phytophylacica Sinica 20 (2),37-41.
6. You, Z.G. and Kahnt, G. 1990. Z. PflKrankh. PflSchutz, Sonderh. XIII 285-291.
7. You, Z.G. 1992. Scientia Agricultura Sinica 25 (5), 58-64.
8. Zimdahl, R.L. 1980. Weed-Crop Competition, A Review, IPPC, Oregon State Univ.